William B. Geissler
Editor

Wrist and Elbow Arthroscopy

A Practical Surgical Guide to Techniques

Second Edition

SpringerImages

Springer

Wrist and Elbow Arthroscopy

William B. Geissler
Editor

Wrist and Elbow Arthroscopy

A Practical Surgical Guide to Techniques

Second Edition

Springer

Editor
William B. Geissler, MD
Alan E. Freeland Chair of Orthopedic Hand Surgery
Professor and Chief, Division of Hand and Upper Extremity Surgery
Chief, Section of Arthroscopic Surgery and Sports Medicine
Department of Orthopedic Surgery and Rehabilitation
University of Mississippi Medical Center
Jackson, MS, USA

Videos for this book can be accessed at http://www.springerimages.com/videos/978-1-4614-1595-4

ISBN 978-1-4614-1595-4 ISBN 978-1-4614-1596-1 (eBook)
DOI 10.1007/978-1-4614-1596-1
Springer New York Heidelberg Dordrecht London

Library of Congress Control Number: 2014951507

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Preface

It has been my pleasure to edit the second edition to *Wrist and Elbow Arthroscopy* textbook. Arthroscopic surgery has continued to revolutionize the practice of orthopedics by providing the technical ability to examine and treat intra-articular abnormalities under bright light and magnified conditions. Wrist arthroscopy has continued to significantly advance our knowledge and understanding of this complex joint with its multiple articulations and ligaments all within a 5 cm interval. Since the previous textbook, there has been continued considerable growth in the indications and techniques for wrist arthroscopy. As more surgeons are exposed to wrist arthroscopy, newer techniques continue to be developed, which helps our patients. This is evident by the growth of this textbook to 34 chapters compared to the previous edition.

As before, this is truly an international text. Recognized experts from around the world from four continents have contributed the latest techniques and advances in wrist arthroscopy. The goal for the authors was to describe their arthroscopic techniques in detail to include their tips and tricks to make the procedures easier for all of us to perform. There are many new topics and additions with the second edition. This includes multiple chapters on management of scapholunate instability, arthroscopic proximal row carpectomy, and arthroscopic staging management of Kienbock disease. In addition, dry arthroscopy has continued to grow in popularity. A chapter is dedicated specifically to these newer techniques. Small joint arthroscopy has continued to make several gains and multiple chapters are included describing these techniques and applications for the smaller joints of the hand.

Lastly, I am pleased that the second edition has been expanded to include the field of elbow arthroscopy, which continues to grow in popularity. This can be a very difficult joint for arthroscopic surgical techniques and leaders from around the world have contributed their techniques and pearls for this newest edition. Arthroscopic management of complex topics including elbow arthritis, contractures, and instability are included in this edition.

First, I want to acknowledge and thank the international group of experts who committed their time and expertise to author these chapters. Their tips and tricks are invaluable and they all have advanced the field of wrist and elbow arthroscopy.

I want to acknowledge my early mentors in hand surgery including Terry L. Whipple, M.D., who initially exposed me to the wonderful techniques of wrist arthroscopy. He particularly demonstrated to me how precise and delicate arthroscopic surgery is of the wrist to be well performed. I want to acknowledge and thank Alan E. Freeland, M.D., my mentor, friend, and colleague who instructed me in hand surgery and guided my career. I certainly want to acknowledge and thank my wife, Susan, and daughter, Rachel Leigh, who provided tireless support and understanding throughout my career.

I want to thank my nurses, Tracy Wall, R.N., and Janis Freeland, R.N., who work tirelessly behind the scenes, but really run the show. Finally, Sheila Steed, my administrative assistant, who has always been there and somehow always keeps me pointed in the right direction.

Jackson, MS, USA — William B. Geissler, MD

Contents

Contributors

Joshua M. Abzug, MD Department of Orthopaedics, University of Maryland School of Medicine, Timonium, MD, USA

Julie E. Adams, MD Department of Orthopaedic Surgery, University of Minnesota, Minneapolis, MN, USA

Laith Al-Shihabi, MD Department of Orthopaedic Surgery, Rush University Medical Center, Chicago, IL, USA

Andrea Atzei, MD Fenice HSRT Hand Surgery and Rehabilitation Team, Centro di Medicina, Treviso, Italy

Policlinico San Giorgio, Pordenone, Italy

Alejandro Badia, MD Badia Hand to Shoulder Center, Doral, FL, USA

Nicole Badur, MD Hand Surgery and Surgery of Peripheral Nerves, University Hospital Bern, Freibugstrasse, Bern, Switzerland

Gregory Ian Bain, MBBS, FRACS, FA (Orth) A, PhD Upper Limb Surgeon, Professor of Upper Limb and Research, Department of Orthopaedic Surgery, Flinders University of South Australia, Flinders Drive, South Austalia, Australia

Randy Bindra, MD Department of Orthopaedic Surgery, Griffith University and Gold Coast University Hospital, Southport, QLD, Australia

Jared L. Burkett, MD Alabama Orthopaedic Clinic, Mobile, AL, USA

Miguel Del Cerro, MD Hand Surgery Unit, Beata María Hospital, Madrid, Spain

Sonya M. Clark, DO Upstate Hand Center, Spartanburg, SC, USA

Tyson K. Cobb, MD Orthopaedic Specialists, Bettendorf, IA, USA

Mark Steven Cohen, MD Department of Orthopaedic Surgery, Rush University Medical Center, Chicago, IL, USA

Fernando Corella, PhD Section of Hand Surgery, Orthopaedic and Trauma Department, Infanta Leonor University Hospital and Beata María Hospital, Madrid, Spain

Gregory Couzens, MBBS, FRACS (Orth) Brisbane Hand and Upper Limb Research Institute, Brisbane, QLD, Australia

Randall W. Culp, MD, FACS Department of Orthopaedics, Thomas Jefferson University Hospital, The Philadelphia Hand Center, King of Prussia, PA, USA

Carlos Henrique Fernandes, MD Department of Orthopedic Surgery, Universidade Federal de São Paulo, São paulo, SP, Brazil

Larry D. Field, MD Upper Extremity, Mississippi Sports Medicine and Orthopaedic Center, Jackson, MS, USA

Alan E. Freeland, MD Department of Orthopaedic Surgery and Rehabilitation, University of Mississippi Medical Center, Brandon, MS, USA

Erich M. Gauger, MD Department of Orthopaedic Surgery, University of Minnesota, Minneapolis, MN, USA

William B. Geissler, MD Department of Orthopaedic Surgery, University of Mississippi Medical Center, Jackson, MS, USA

Michael R. Hausman, MD Department of Orthopaedic Surgery, Mount Sinai Medical Center, New York, NY, USA

Pak-cheong Ho, MBBS, FRCS, FHKCOS, FHKAM (Ortho) Department of Orthopaedic and Traumatology, Prince of Wales Hospital, Chinese University of Hong Kong, Hong Kong SAR, China

Steven M. Koehler, MD Department of Orthopaedic Surgery, Mount Sinai Medical Center, New York, NY, USA

Tommy Lindau, MD, PhD The Pulvertaft Hand Centre, Royal Derby Hospital, Derby, UK

Jeremy Loveridge, MD, MBBS, FRACS (Orth) Brisbane Hand and Upper Limb Research Institute, Brisbane, QLD, Australia

Riccardo Luchetti, MD Private Activity, Rimini Hand and Rehabilitation Center, Rimini, Italy

Michael L. Mangonon, DO Plancher Orthopaedics and Sports Medicine, New York, NY, USA

Noah C. Marks, MD Mississippi Sports Medicine and Orthopaedic Center, Jackson, MS, USA

Christophe L. Mathoulin, FMD, FMH Institut De La Main, Clinique Jouvenet, Paris, France

Duncan Thomas McGuire, MBCHB, FC (Orth) (SA), MMed Department of Orthopaedic Surgery, Groote Schuur Hospital, Cape Town, South Africa

Megan Anne Meislin, MD Department of Orthopaedics, Loyola Univesity Medical Center, Maywood, IL, USA

Cesar Dario Oliveira Miranda, MD Department of Hand Surgery, Hand Surgery Institute Salvador, Salvador, Bahia, Brazil

Michael J. Moskal, MD Orthopaedic Surgery Department, University of Louisville, Sellersburg, IN, USA

Daniel J. Nagle, MD, FAAOS, FACS Department of Orthopedics, Northwestern University Feinberg School of Medicine, Chicago, IL, USA

Michael J. O'Brien, MD Department of Orthopaedics, Tulane University School of Medicine, New Orleans, LA, USA

Montserrat Ocampos, MD Section of Hand Surgery, Orthopaedic and Trauma Department, Infanta Leonor University Hospital and Beata María Hospital, Madrid, Spain

Kerstin Oestreich, MD, MSc Department of Plastic Surgery, Birmingham Childrens Hospital, Birmingham, UK

A. Lee Osterman, MD The Philadelphia Hand Center, P.C., King of Prussia, PA, USA

Meredith N. Osterman, MD Department of Orthopedic Surgery, Thomas Jefferson University Hospital, Philadelphia, PA, USA

Enrique Pereira, MD Department of Hand Surgery, Penta Institute of Traumatology and Rehabilitation, Martinez, Buenos Aires, Argentina

Stephanie C. Petterson, MPT, PhD Research Department, Orthopaedic Foundation, Stamford, CT, USA

Francisco del Piñal, MD Unit of Hand-Wrist and Plastic Surgery, Private Practice and, Hospital Mutua Montañesa, Santander, Spain

Kevin D. Plancher, MD Plancher Orthopaedics and Sports Medicine, New York, NY, USA

Roger P. van Riet, MD, PhD Department of Orthopedics and Traumatology, Monica Hospital, Erasme University Hospital, Antwerp, Belgium

Mark Ross, MBBS, FRACS (Orth) Brisbane Hand and Upper Limb Research Institute, Brisbane, QLD, Australia

David S. Ruch, MD Duke University Medical Center, Durham, NC, USA

Felix H. Savoie III, MD Department of Orthopaedics, Tulane University School of Medicine, New Orleans, LA, USA

David J. Slutsky, MD The Hand and Wrist Institute, Torrance, CA, USA

John M. Stephenson, MD Department of Orthopaedic Surgery, University of Arkansas for Medical Sciences, Little Rock, AR, USA

Aaron H. Stern, BA Weiss Orthopaedics, Sonoma, CA, USA

John R. Talley, MD Division of Plastic Surgery, Department of Surgery, Stanford University Medical Center, Palo Alto, CA, USA

Steven M. Topper, MD Colorado Hand Center, Colorado Springs, CO, USA

Abhijeet L. Wahegaonkar, MD, FACS, MCh (Orth) Department of Hand and Microvascular Reconstructive Surgery, Brachial Plexus and Peripheral Nerve Surgery, Sancheti Institute for Orthopaedics and Rehabilitation, Pune, Maharashtra, India

Noah D. Weiss, MD Weiss Orthopaedics, Sonoma, CA, USA

Robert W. Wysocki, MD Department of Orthopedic Surgery, Rush University, Chicago, IL, USA

Jeffrey Yao, MD Department of Orthopedic Surgery, Stanford University Medical Center, Redwood City, CA, USA

1 Arthroscopic Wrist Anatomy and Setup

Nicole Badur, Riccardo Luchetti, and Andrea Atzei

Introduction

Arthroscopy, first described in 1918 in a cadaver knee joint and 1962 successfully as an operative procedure [1], has equipped the orthopedic surgeon with an excellent tool to assess and treat intra-articular pathologies. After successful application on large joints, the technique has been progressively extended onto smaller sized joints as the shoulder, the hip, the ankle, the elbow and the wrist. Wrist arthroscopy was reported first in 1979 for diagnostic purposes [2]. From the late 1980s through the 1990s arthroscopy has become an important means in the armory of a hand surgeon and wrist arthroscopy the so-called golden standard for diagnosing intra-articular lesions in the wrist. Since then it has continued to evolve not only as a diagnostic, but also therapeutic tool and indications have steadily grown. Iatrogenic complications from open wrist surgery as capsular fibrosis resulting in stiffness are reduced by arthroscopic surgery [3, 4]. Wrist arthroscopy is now an established procedure for treating many intra-articular wrist pathologies with chronic wrist pain and in acute wrist trauma [5].

The wide list of indications for wrist arthroscopy is continuously growing and includes basic treatment of soft tissue pathologies as synovitis, ganglia, fibrosis, stiffness, management of triangular fibrocartilage complex (TFCC) tears, scapholunate- and lunotriquetral ligament lesions and removal of loose bodies. Osseous procedures include partial bone resections in ulnocarpal- or ulnostyloid impaction syndrome and scaphotrapeziotrapezoid (STT) or triquetrohamate (TH) arthritis [6]. The method has also gained wider acceptance in more sophisticated procedures as assisting reduction of intra-articular distal radius fractures [7–13], or scaphoid fractures [14, 15] and in posttraumatic sequelae. Arthroscopically assisted osteotomy in intra-articular distal radius malunions [16, 17], treatment of scaphoid nonunions [15] and arthroscopic arthrolysis has been described [18]. Arthroscopic decompression of the lunate for Kienböck's disease [19], arthroscopic proximal row carpectomy [20] and arthroscopically assisted partial wrist fusions have been described [21].

Dedicated miniaturized instrumentation meeting the needs of a small joint, a thorough knowledge of wrist anatomy and the anatomic landmarks [22] as well as careful and skilled surgical technique are required to allow a safe and appropriate arthroscopic treatment of disorders in the wrist joint.

Setup and Equipment

Setup

Wrist arthroscopy requires standard arthroscopic equipment. An arm table, arthroscopy tower system with monitor, video recorder and printer, a scope with a camera attached, light source with fiber-optic cable, motorized shavers, radiofrequency ablators, an image intensifier and a traction system have become the standard of care. Digital systems allow data transfer to a USB stick.

The intervention is frequently carried out under regional anesthesia (axillary block) or general anesthesia under sterile

Electronic supplementary material: Supplementary material is available in the online version of this chapter at 10.1007/978-1-4614-1596-1_1. Videos can also be accessed at http://www.springerimages.com/videos/978-1-4614-1595-4.

N. Badur, M.D.
Hand Surgery and Surgery of Peripheral Nerves, University Hospital Bern, Freiburgstrasse, Bern 3010, Switzerland
e-mail: nicbadur@hotmail.com

R. Luchetti, M.D. (✉)
Private Activity, Rimini Hand & Rehabilitation Center, Via Pietro da Rimini 4, Rimini 47924, Italy
e-mail: rluc@adhoc.net

A. Atzei, M.D.
Fenice HSRT Hand Surgery and Rehabilitation Team, Centro di Medicina, Via Repubblica, 10/B Villorba, Treviso 31050, Italy

Policlinico San Giorgio, Via Gemelli 10, Pordenone 33170, Italy
e-mail: andreatzei@gmail.com

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*,
DOI 10.1007/978-1-4614-1596-1_1, © Springer Science+Business Media New York 2015

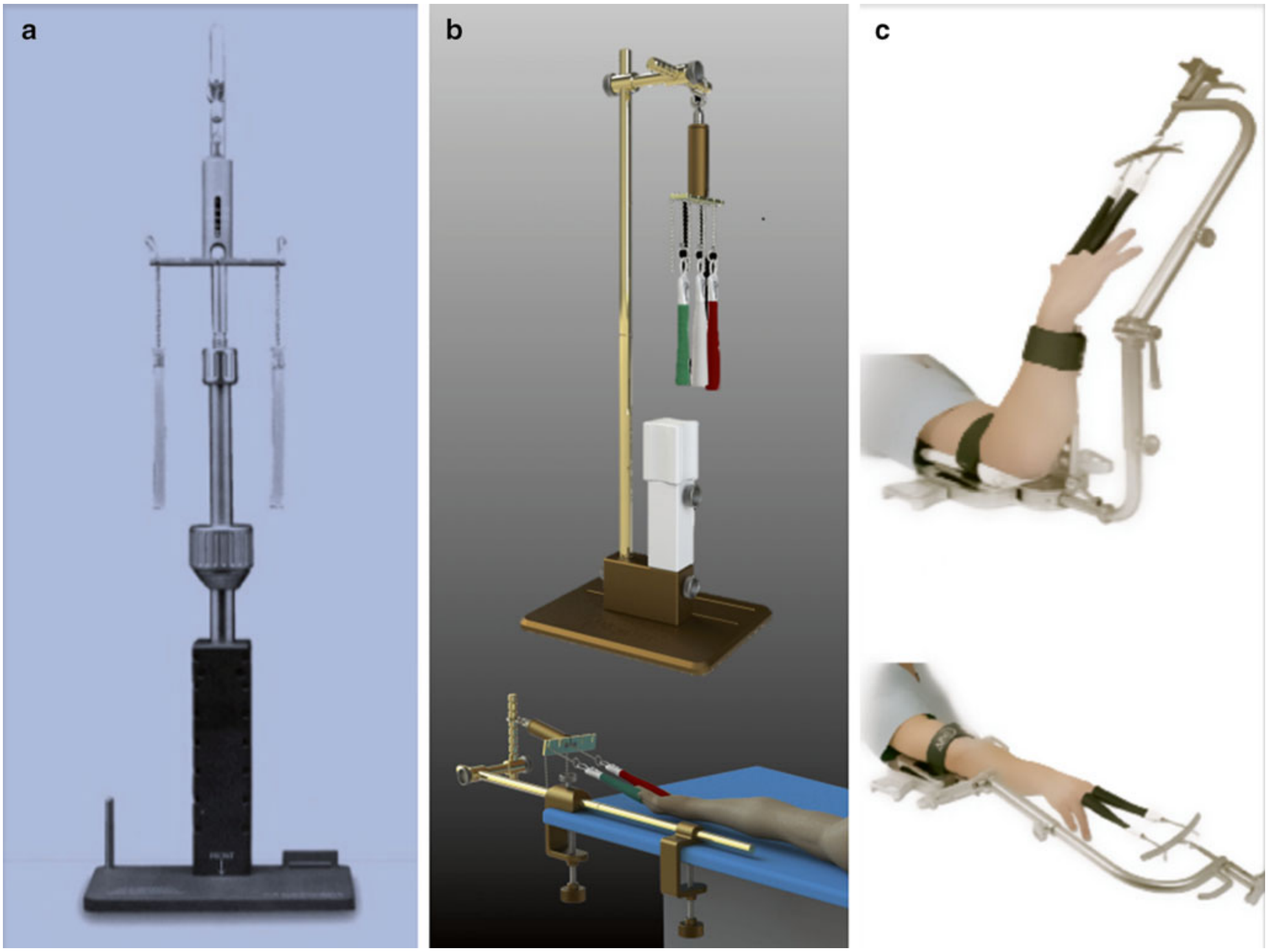


Fig. 1.1 Different traction systems. Vertical traction tower designed by Whipple (Linvatec®, Largo, FL, USA). Wrist positions can be adjusted through a ball-and-socket joint. The central rod position hinders intra-operative X-ray views (**a**). Traction tower designed by Borelli (Micai®, Genova, Italy), allowing free dorsal and volar approach to the wrist, rotation of the wrist and easy image intensifier access with the eccentric rod position. Vertical and horizontal position of the wrist is possible (**b**). Wrist tower designed by Geissler (Acumed®, Hillsboro, Oregon, USA) that can be modified allowing different angles in wrist position and vertical or horizontal traction positioning without interference with intraoperative X-ray (**c**)

conditions in an aseptic operation theater. Although wrist arthroscopy has also been described without exsanguination [15], the use of a pneumatic tourniquet placed at the upper arm is generally recommended.

The patient is positioned supine on the operation table with the affected arm on a hand table. The arm is abducted 90° and the elbow flexed 90° allowing a vertical position of the forearm, wrist and hand. In this position the wrist is kept in neutral prono-supination. Horizontal wrist arthroscopy has been described [23, 10], however, we prefer the vertical position to maintain a neutral rotation of the wrist and 360-degree access to the wrist. Traction is usually recommended to distend the wrist and improve intra-capsular vision [1]. Vertical traction across the wrist is preferably achieved using a traction tower. The arm and forearm need to be padded with towels, preventing direct skin contact with the metal of the tower, and are then stabilized to the tower. Different models of traction towers exist (Fig. 1.1).

Vertical traction is then applied by suspending the fingers with sterile finger traps and applying counter-traction through a gearing mechanism at the tower that allows precise modulation. To visualize the radiocarpal joint, the finger traps are preferably placed on the index- and middle-finger or the index-, middle- and ring finger. Other traction devises allowing traction to all fingers are also used (Fig. 1.2). The applied traction varies between 3.5 and 7 kg in patients. For visualization of the STT joint traction can be applied by suspending only the thumb.

Advantages of traction towers as the Whipple-, Borelli- or Geissler traction tower are that they provide good stability that can be crucial for certain interventions as arthroscopic assisted reduction of distal radius fractures. Further they can

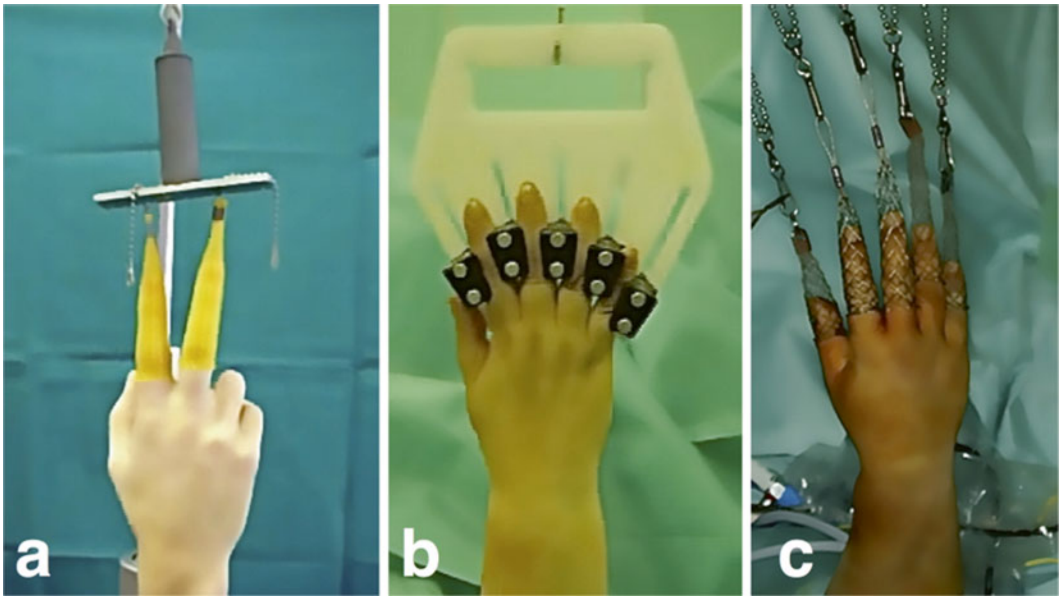


Fig. 1.2 Vertical traction is applied using Chinese finger traps at the index- and middle finger (**a**). Traction on all fingers, the thumb included if needed, can be applied by special traction hands (e.g., Arthrex®, Naples, FL, USA) (**b**) and standard suspension systems (**c**) [Modified from Atzei A, Luchetti R, Sgarbossa A, Carità E, Llusà M. Set-up, portals and normal exploration in wrist arthroscopy. Chir Main. 2006;25 Suppl 1:S131-44. French. With permission from Elsevier]

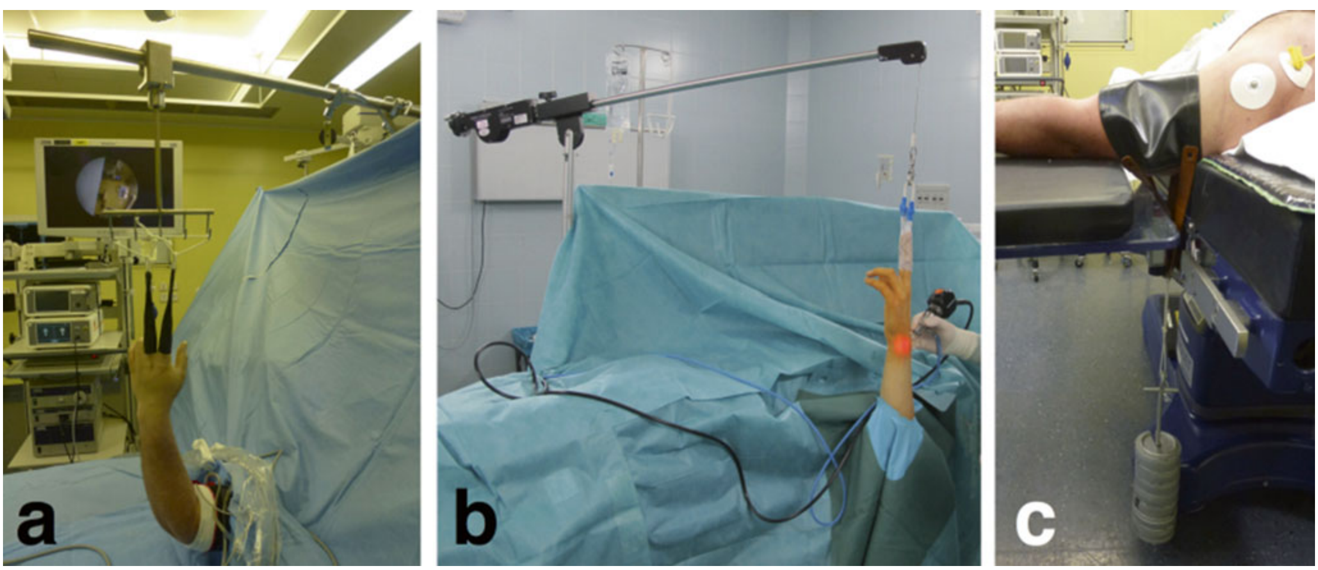


Fig. 1.3 Unconventional vertical overhead traction systems allowing rotation of the wrist and 360° access (**a** and **b**). A counter-traction band is placed around the arm proximal to the elbow. The tension can be adjusted by adding weights (**c**)

be sterilized. For some interventions, however, we need a free pronosupination as for arthroscopic stabilization of TFCC lesions and the stability provided by the tower can hinder. Also the central bar of some towers can interfere with the intraoperative use of an image intensifier. The fact that traction towers need to be sterilized can be a hassle if there is only one available and more wrist arthroscopies are performed within the same operating session.

If a traction tower is not available a simple traction method can be used: a shoulder traction holder can provide overhead suspension with a counter traction band around the arm proximal to the elbow. The tension can be adjusted by adding weights (Fig. 1.3). Those systems are easy to set up and allow undisturbed intra-operative X-ray access as well as more freedom of motion than a traction tower while providing less stability (Fig. 1.4).

Fig. 1.4 Undisturbed intra-operative X-rays access is possible by simple overhead suspension of the wrist while providing less stability

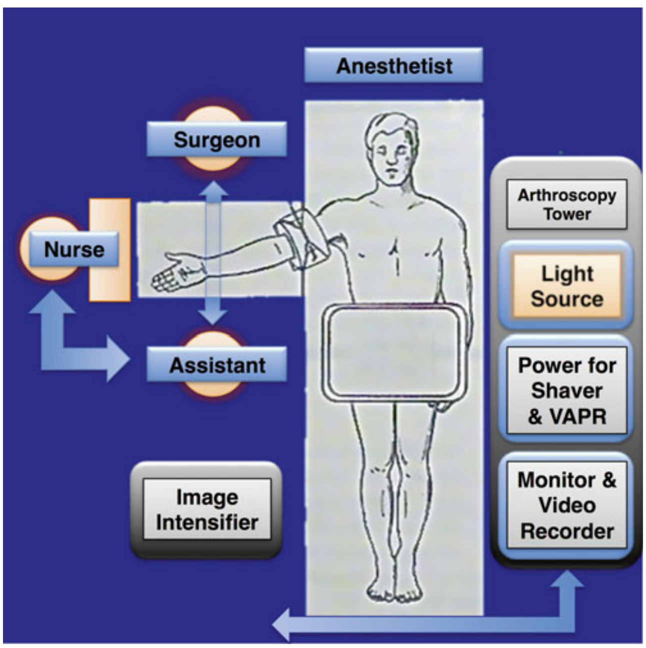


Fig. 1.5 Positioning of the patient, the surgical and anesthetic staff and the arthroscopic equipment

Anesthesia is positioned on the side of the uninvolved extremity or at the patient's head, the surgeon on the side that is awaiting surgery, at the patient's head. The arthroscopy tower and video monitor are placed at the patient's feet, usually on the opposite side of the patient. An image intensifier is positioned in the operating theater so that it is not in the way of the surgeon and rolled into the operating field as needed. The assistant and scrub nurse can position themselves depending on the intervention and the surgeon's needs which may differ in diagnostic and interventional wrist arthroscopies (Fig. 1.5).

Equipment

The most important instrument is the arthroscope (Fig. 1.6). Because of the size of the joint, arthroscopes for wrist arthroscopy are smaller in diameter than traditional arthroscopes. Different diameters of the optic are used in wrist arthroscopy, ranging from 1.9 to 2.7 mm, with either a 30-degree- or less common a 70-degree-viewing-angle to meet the needs of the different articulations in the wrist. The light source cable is also smaller in diameter. The smaller the diameter of the arthroscope, the higher is the risk of bending and damaging the fiber-optic in the cannula. Short cannulas (5–8 cm) and scopes (lever arm of 100 mm) are long enough and allow easier handling and control [24]. The 2.7 or 2.4 mm optic is ideal for the exploration of the radiocarpal- and midcarpal joint as the arthroscopic vision field is bigger, but too bulky for exploration of the distal radioulnar joint (DRUJ), the scaphotrapeziotrapezoid (STT) joint and in patients with a small wrist. In those cases the use of an arthroscope with a diameter of 1.9 mm or smaller is more appropriate.

A blunt trocar with a trocar sleeve is important to establish the viewing and working portals of the joints to be inspected without damaging the articular cartilage.

Numerous instruments, appropriate to meet the criteria of diagnosing and treating wrist pathologies have been developed. The probe is probably the simplest but most useful diagnostic tool in wrist arthroscopy, serving as an extension of the surgeon's finger [1]. For some interventions the use of a stronger probe as used in shoulder arthroscopy that does not bend is beneficial [16]. A variety of differently angled punches, baskets with or without the option of incorporating a suction mechanism and grasping forceps in various sizes are useful in removing loose bodies and excising pieces of soft tissue. Small arthroscopy knives with differently shaped and retrograde blades aid in excising unstable chondral portions of the carpal bones. A freer elevator, pins and a variety of small differently shaped osteotomes are useful tools in arthroscopically assisted correction of mal-united distal radius fractures [17].

Differently aggressive and sized motorized shavers and differently sized burrs ranging from 2.0 to 4.5 mm with integrated finger-controlled suction mechanism are powered instruments for debriding synovium or resecting bone, e.g., when performing a resection of the distal pole of the scaphoid for STT arthritis or a radial styloidectomy for beginning radiocarpal arthritis as in stage 1 of scaphoid nonunion advanced collapse (SNAC I). Shavers and burrs can be operated with a foot pedal or by finger control and allow continuous or oscillating cutting.

Radiofrequency probes allow efficient soft tissue debridement and ligament- or capsular shrinkage [25], but because of the risk of thermal injury adequate fluid control must be carefully managed [26].

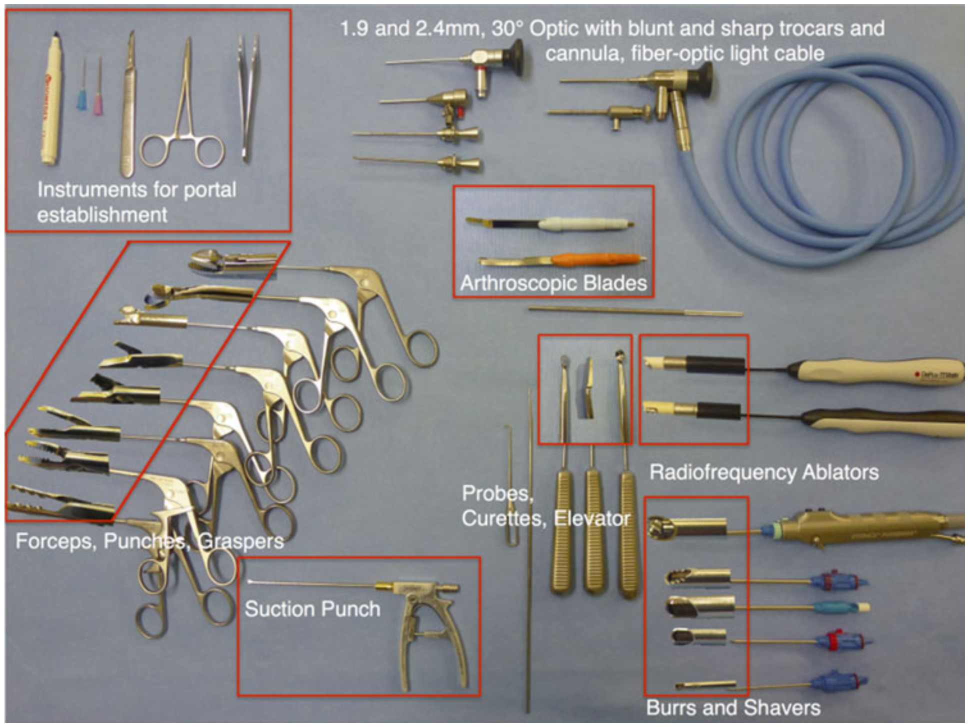


Fig. 1.6 Wrist arthroscopy equipment

Traditionally wrist arthroscopy has been carried out with constant joint irrigation for distension and improvement of intra-articular vision [27]. Lactated Ringer's solution is used for irrigation because it is rapidly reabsorbed from the soft tissues [8]. Electric fluid pumps that regulate fluid volume to avoid extravasation and decrease intraoperative bleeding may be used but pure gravitational force is generally sufficient for the irrigation of the wrist joint. Outflow is provided via the port of the cannula with the camera or a separate needle placed into the ulnar side of the wrist or the successively established portals. While the classic (wet) wrist arthroscopy bears the disadvantage of cumbersome extra-articular water leakage into the soft tissue and the risk of serious complications as development of compartment syndrome [7, 8, 28, 29], the wrist joint can easily be inspected without the use of water, referred to as "dry arthroscopy" [30]. Synovial villi or ruptured ligament parts do not interfere with the intra-articular vision as they do not float into the field of vision and remain at their origins. In the usual joint there is mucous fluid that does not impede vision. However, depending on the procedure to be performed, an initial washout of the joint may be useful, e.g., evacuation of hematoma in acute intra-articular distal radius fractures. Debris can be cleared by injecting 10–20 ml of saline through the side valve of the scope followed by aspirating with the shaver. The wrist joint can also be dried with small neurosurgical patties inserted with a grasper. Other helpful maneuvers to keep a clear vision in dry arthroscopy are to immerse the tip of the scope into warm water to prevent condensation (fog effect) due to temperature differences outside and inside the wrist and to avoid closeness of the scope and motorized instruments, thus preventing splashing. The arthroscope can be cleaned by rubbing its tip carefully at the local soft tissue [30].

However, dry arthroscopy also has its limits. For example when radiofrequency ablators are used, water is necessary as milieu conductor and to prevent temperature peaks and possible joint damage. Also when using a burr the aspiration may be blocked by small cartilage and bone fragments and water facilitates the aspiration.

The equipment is completed by different utensils for specified arthroscopic procedures as ligament repair, from simple needles or longer Tuohy needles [31] to more sophisticated, commercially available ligament repair kits [32].

Surgical Technique

Certain rules need to be respected in order to obtain a good intra-articular vision and to avoid complications. It is very important that all external anatomic landmarks and portals must be marked after the traction to the wrist is applied but before starting the arthroscopic procedure so that the relationship of surface landmarks are not altered [28]. The following landmarks can be palpated if the wrist is not too swollen (Fig. 1.7):

Osseous landmarks:

- *Dorsal*: Lister's tubercle, distal radial edge, dorsal ulnar head, index-, middle-, (ring-) and small metacarpals.

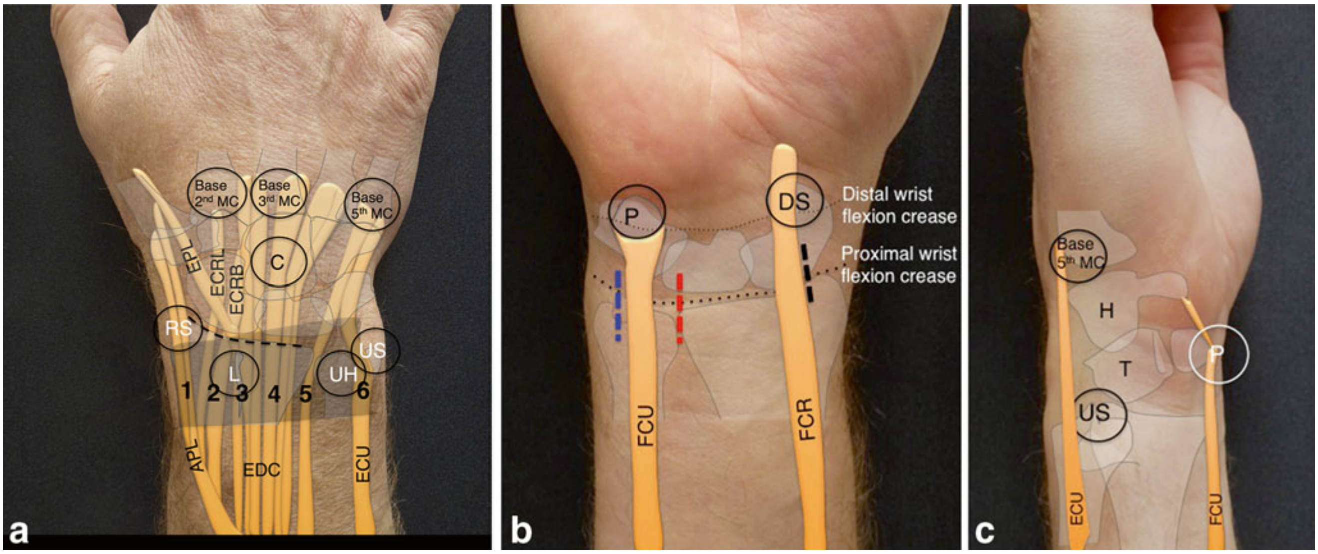


Fig. 1.7 Osseous and tendinous landmarks of the wrist from dorsal (**a**), volar (**b**) and ulnar (**c**). *RS* radial styloid, *L* Lister's tubercle, *UH* ulnar head, *US* ulnar styloid, *P* pisiform, *DS* distal pole of the scaphoid, *APL* abductor pollicis longus, *ECRL* extensor carpi radialis longus, *ECRB* extensor carpi radialis brevis, *EPL* extensor pollicis longus, *EDC* extensor digitorum communis, *ECU* extensor carpi ulnaris, *FCU* flexor carpi ulnaris, *FCR* flexor carpi radialis. The numbers 1–6 represent the extensor compartments. Volar incisions for the establishment of the VR and VM joint (*black line*), for the VU and V-DRUJ (*red line*) and for the 6-U and DF portal (*blue line*)

- *Radial*: radial styloid process, trapezium, base of the first metacarpal.
- *Ulnar*: ulnar styloid, triquetrum, base of the fifth metacarpal.
- *Volar*: pisiform and distal pole of the scaphoid.

Tendinous landmarks:

- *Dorsal*: extensor carpi radialis longus (ECRL) tendon, extensor pollicis longus (EPL) tendon, extensor digitorum communis (EDC) tendon, extensor carpi ulnaris (ECU) tendon.
- *Radial*: abductor pollicis longus (APL) tendon.
- *Ulnar*: extensor carpi ulnaris (ECU) tendon.
- *Volar*: flexor carpi radialis (FCR) tendon, flexor carpi ulnaris (FCU) tendon.

Not all palpable surface landmarks need to be drawn onto the skin as orientation for establishing the portals, we mark the key structures as needed for each intervention (Fig. 1.8). Standard wrist arthroscopy includes the assessment of the radiocarpal- and ulnocarpal joint, the midcarpal- and STT joint and the distal radioulnar joint (DRUJ). Numerous arthroscopic dorsal and palmar approaches have been described and are routinely used. The most commonly used dorsal radiocarpal portals are named relative to the extensor compartments between which they are located.

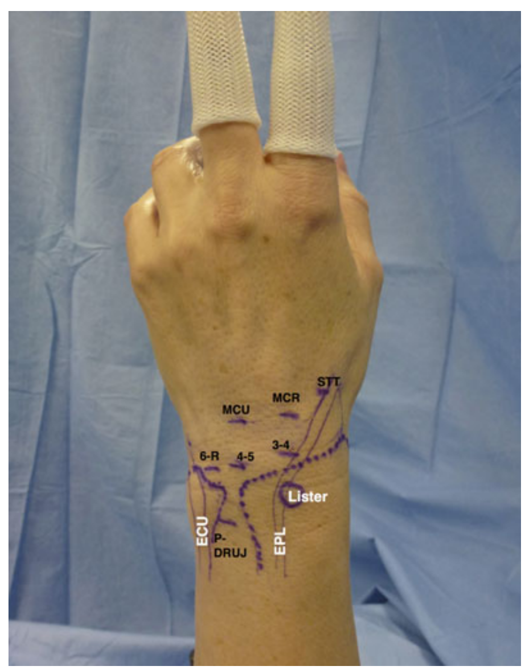


Fig. 1.8 Preoperative marking of the landmarks and dorsal portals for performing a standard wrist arthroscopy. Abbreviations are according to the previous figure

The first portal to be established in almost every wrist arthroscopy is the 3-4 radiocarpal portal. It can be identified by simple palpation of the "soft spot" just distal of the dorsal rim of the radius in a vertical line with Lister's tubercle. Two methods of localizing the entry point for the 3-4 portal are used. The first method is called the "3 circle method" (Fig. 1.9). A circle is drawn around Lister's tubercle. Two other circles of the same dimension are drawn just distal to the first one in a vertical line with Lister's tubercle. The third circle is located directly over the soft spot that is the entry point of the 3-4 portal [33]. The second method is called the "rolling thumb method" (Fig. 1.10). The thumb

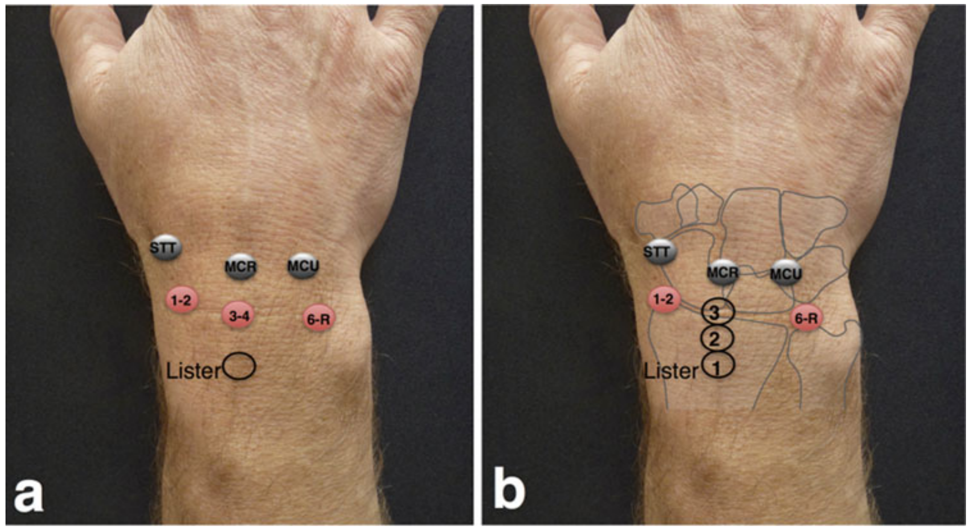


Fig. 1.9 Establishment of the 3-4 portal using the "three circles technique": a *circle* is drawn around the palpable Lister's tubercle (**a**). Two circles of the same size are then drawn distally to the first circle. The third and most distal circle lies at the level of the 3-4 portal (**b**)

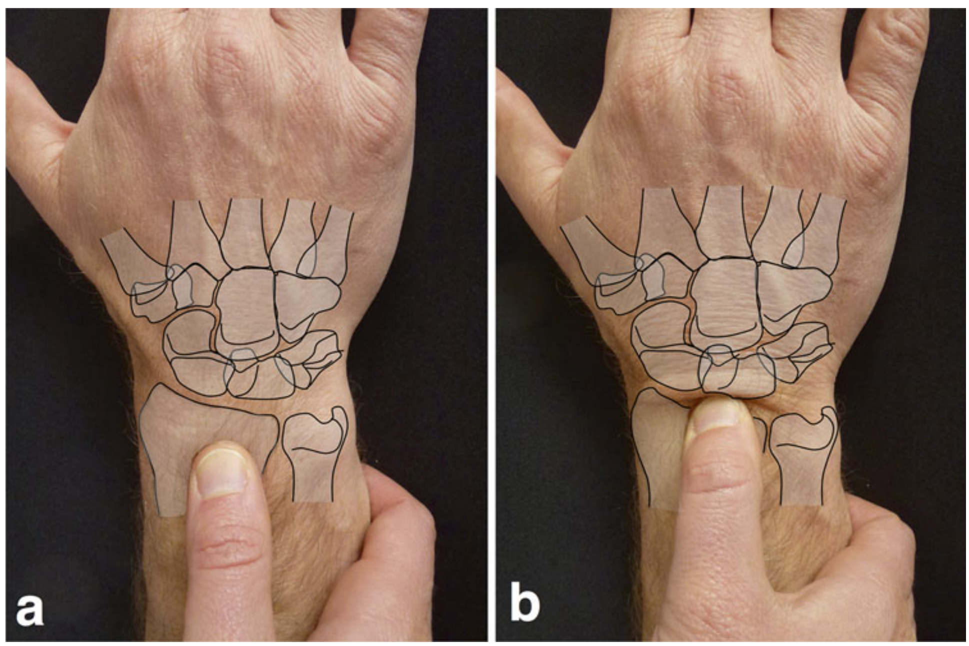


Fig. 1.10 Establishment of the 3-4 portal using the "rolling thumb technique": the thumb is placed on the palpable Lister's tubercle (**a**). The thumb is then rolled distally over the tubercle until the pulp of the surgeon's thumb feels the soft spot corresponding to the 3-4 portal (**b**)

pulp is placed on Lister's tubercle and is then rolled over the tubercle distally. The tip of the thumb is now exactly centered on the soft spot corresponding to the 3-4 portal. An 18- or 22-G needle is inserted at the soft depression into the radiocarpal joint, minding the normal inclination of the distal radius. Therefore the needle is pointing 20–30° proximally to parallel the articular curve of the distal radius to verify correct intra-articular placement (Fig. 1.11).

Injection of a saline solution through this needle to distend the radiocarpal joint has been described. A normal uninjured wrist can contain 2–5 ml of fluid, but in the case of TFCC lesions, or lesions of the intracarpal ligaments of the proximal carpal row, up to 10–15 ml can be injected and the adjacent joints (distal radioulnar- and midcarpal joint) are indirectly filled. As stated above our preferred method for wrist arthroscopy is the so-called dry technique. The traction often is sufficient for obtaining a quiet good intra-articular vision. After the needle has been placed correctly the skin is incised with a number 15 blade instead of using a number 11 blade as common for arthroscopy in other joints. Care must be taken to incise only the skin to prevent damage to superficial vessels, tendons, and cutaneous nerves. Depending on the portal to be established the nerves can be found in very close proximity to the portals and are at risk [34–36]. Longitudinal incisions are possible and favorable if the incision needs to be enlarged in a proximal-distal direction, for

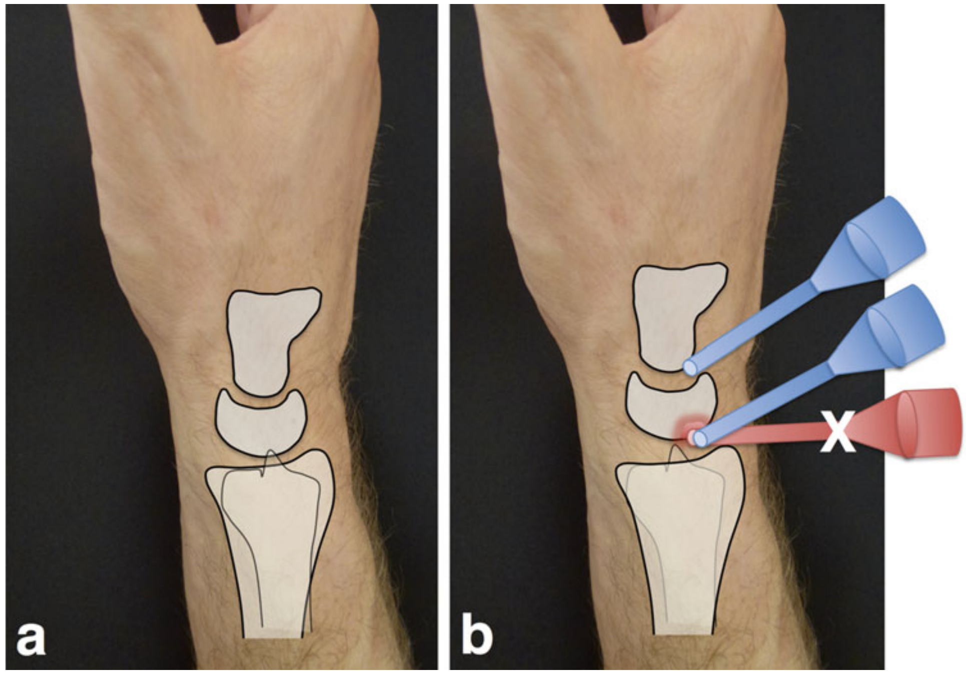


Fig. 1.11 Schematic lateral view of the wrist (**a**). External traction allows widening of the articular spaces. The arthroscope should be inserted into the radiocarpal- and midcarpal joint respectively, paralleling the dorsal articular slope of the joints. Horizontal introduction of the arthroscope may damage the articular cartilage of the carpal bones (**b**).

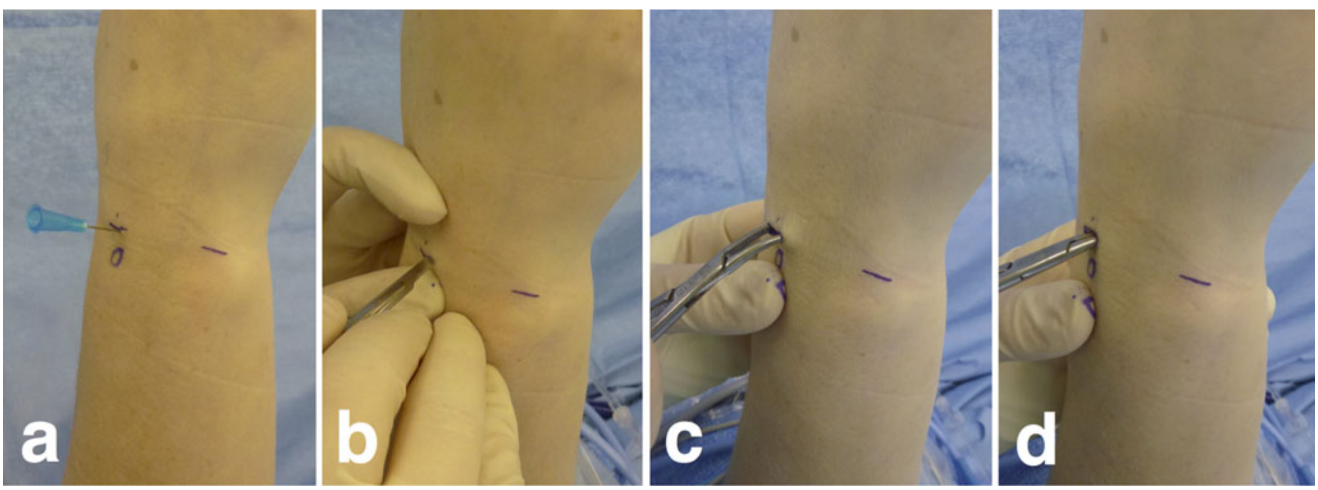


Fig. 1.12 Standard procedure for establishment of an arthroscopic wrist portal (3-4 portal), right wrist. Localization of the radiocarpal joint space with a 22-G needle (**a**). Horizontal skin incision (**b**). Spreading of the subcutaneous tissues with a blunt hemostat to the capsule (**c**). Piercing of the capsule with the closed tip of the hemostat (**d**)

example if conversion to an open intervention needs to be performed. However, we generally prefer horizontal skin incisions on the dorsal aspect of the wrist, in line with the skin lines, thus improving the esthetic appearance of the scar. A blunt hemostat is advanced through the subcutaneous tissue by carefully spreading the branches until there is contact with the joint capsule. The capsule is then pierced with the tip of the closed hemostat (Fig. 1.12). A blunt trocar is introduced through a cannula into the joint directed volar and proximal at an approximately 30° angle, aligning the cannula with the volar inclination of the distal radius. The trocar is removed and the arthroscope is introduced through the cannula. The radial midcarpal portal can be established following the same technique, following the 10° obliquity of the first carpal row (Fig. 1.11). For establishment of the other portals we recommend to insert the needle arthroscopically controlled.

Despite the revolutionary advances in wrist arthroscopy we have to remember that all indications to perform an arthroscopy should be based on a thorough clinical examination, aiming at detecting the origin of the intra-articular pathology and consequently avoiding inappropriate

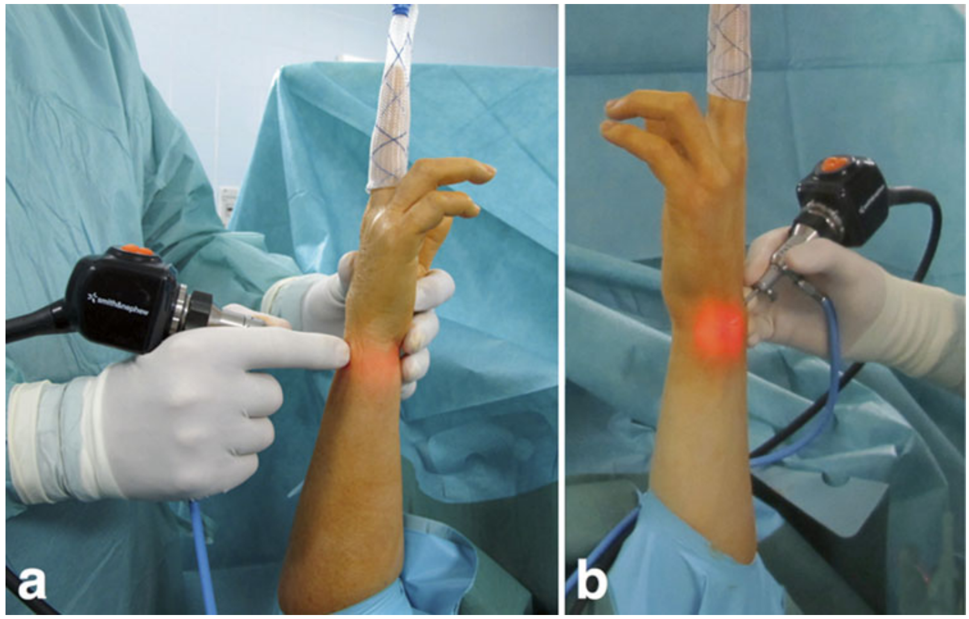


Fig. 1.13 Handling of the arthroscope. Control of minimal movements within the joint is achieved by constant finger contact to the patient's wrist with the index finger (**a**) or the middle- to small finger (**b**)

indications that would not address the true nature of the pathology [37].

The diagnostic evaluation always starts with the exploration of the radiocarpal joint, but the evaluation of the midcarpal joint should never be neglected and is considered a part of wrist arthroscopy. Arthroscopy of the DRUJ has only recently gained interest [38, 39]. It is performed in special indications and not conducted in every wrist arthroscopy.

A standardized, systematic arthroscopic examination with a routine circuit helps in visualizing all structures and not forgetting anything [4]. A few simple rules that should be followed are:

- Examination of the radial side before the ulnar side.
- Examination of the distal part of the articulation before the proximal part.
- Examination of the volar aspect before the dorsal aspect.
- Examination of the ligaments before the articular surfaces.
- Simple inspection before using a probe.

Rotation of the 30-degree-angle arthroscope allows the exploration of different regions of the articulation and switching the arthroscope and the instrument within the different portals can be limited. It is crucial to stabilize the arthroscope and control the small movements of the optic within the joint in order to prevent damage to the articular cartilage. Therefore the arthroscope should be held in a manner that allows constant contact to the skin of the wrist. The small optic is short enough to be grasped in a way that provides contact of the surgeon's index finger to the patient's wrist while larger arthroscopes need to be stabilized with the middle- and ring finger (Fig. 1.13).

Arthroscopic Portals: Approaches and Anatomy

Meticulous knowledge of the anatomy is essential for performing wrist arthroscopy (Fig. 1.14) [40]. The entry portals are numerous (Fig. 1.15) and need to be adapted to the pathology and the particular anatomy in this region [1, 28, 41]. The standard arthroscopic portals have been developed on the dorsal side of the wrist and their localizations and names are in direct relation to the six extensor compartments. In the space between two extensor compartments the arthroscopic portals can be established and instruments introduced without the risk of damaging the extensor tendons. On the dorsal side of the wrist there are not many neurovascular structures that could be damaged (Fig. 1.16a–c). Volar portals have been previously reported [42, 43] but lacked popularity for a long period because they seemed to jeopardize important neurovascular structures on the volar side of the wrist (Fig. 1.16d, e). Only recently the safety of volar portals to the wrist could be shown [44–48], and it is possible to have viewing and working portals that encircle the whole wrist joint. This is called the "box concept" (Fig. 1.17) [24].

The arthroscopic exploration of the wrist is divided into three parts: proximal, volar (dorsal when using a volar portal), and distal. Then the arthroscope can be rotated to the radial and the ulnar side. We generally proceed with the arthroscopic overview from proximal to distal and from radial to ulnar (Fig. 1.18).

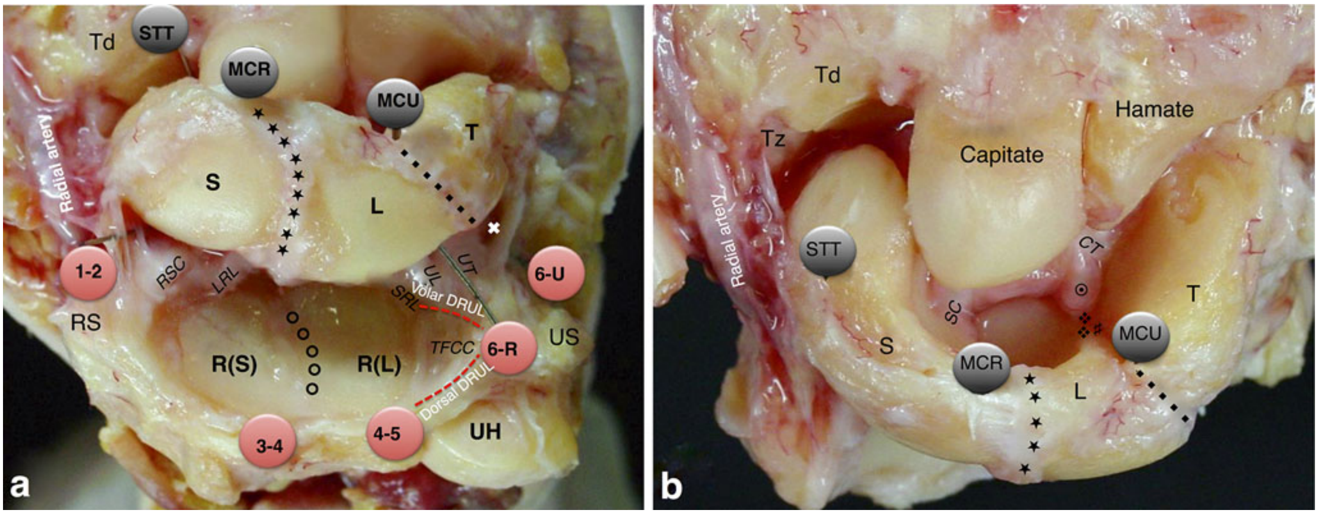


Fig. 1.14 Anatomic dissection of the radiocarpal- (**a**) and midcarpal joint (**b**). The radiocarpal portals are indicated with *red circles* and the midcarpal portals with *black circles*. The proximal articular part of the radiocarpal joint is comprised by the scaphoid- and lunate fossa of the radius (R(S) and R(L)), separated by the interfosseal ridge (O) and the TFCC with its volar- and dorsal distal radioulnar ligaments (DRUL). The volar radiocarpal ligaments are from radial to ulnar the radioscaphocapitate (RSC) ligament, the long radiolunate (LRL) ligament and the short radiolunate (SRL) ligament. The volar ulnocarpal ligaments are the ulnolunate (UL) and the ulnotriquetral (UT) ligament. Ulnar and distal to the UT ligament we find the entry to the pisotriquetral joint (×). The distal part of the radiocarpal joint is formed by the proximal articular surfaces of the scaphoid (S), the lunate (L) and the triquetrum (T). The scapholunate ligament (★) and the lunotriquetral ligament (◆) separate the carpal bones of the first carpal row, respectively. The proximal part of the midcarpal joint is formed by the distal articular surfaces of the scaphoid, lunate and triquetrum. The distal pole of the scaphoid and the proximal articular surfaces of the trapezium (Tz) and the trapezoid (Td) form the scaphotrapeziotrapezoid (STT) joint as a part of the midcarpal joint. The scaphoid body articulates with the capitate. The lunate, triquetrum, capitate and hamate form the 4-bone-corner. The lunate may have two distal articular facets, a major one for the capitate and a smaller one for the hamate (♯), which are separated by a longitudinal crest (❖). The volar midcarpal ligaments are radially the scaphocapitate (SC) ligament as the distal portion of the RSC ligament and ulnarly the capitotriquetral (CT) ligament, that is usually covered by a fibroadipose structure (◉). *UH* ulnar head, *US* ulnar styloid. [Modified from Atzei A, Luchetti R, Sgarbossa A, Carità E, Llusà M. Set-up, portals and normal exploration in wrist arthroscopy. Chir Main. 2006;25 Suppl 1:S131-44. French. With permission from Elsevier]

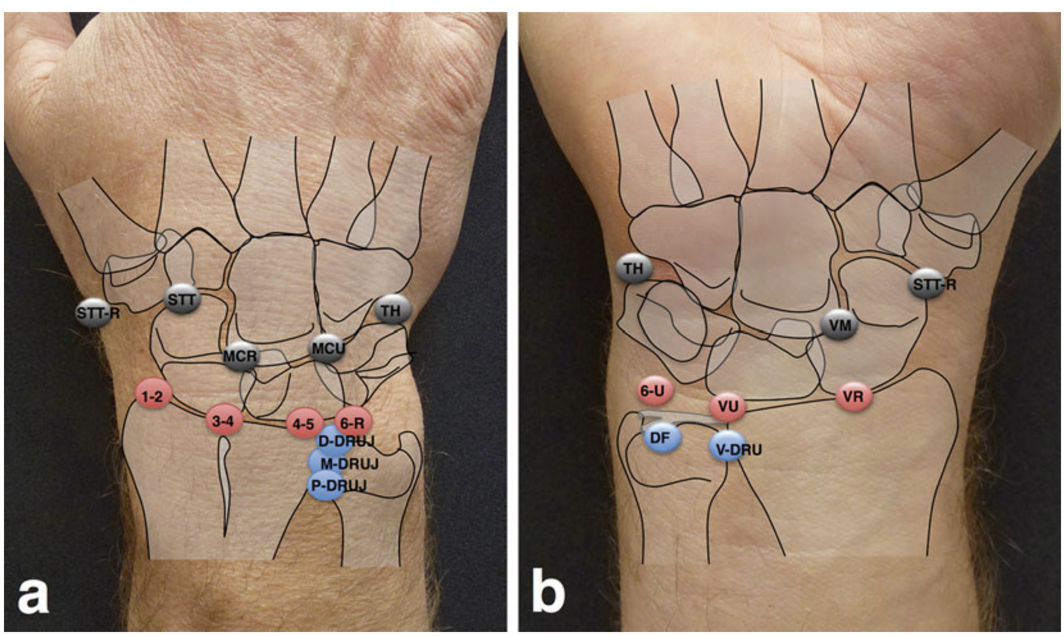


Fig. 1.15 Overview of the dorsal (**a**) and volar (**b**) portals used in wrist arthroscopy. Portals to the radiocarpal joint are marked in *red*, portals to the midcarpal joint are marked in *black* and portals to the DRUJ are marked in *blue*

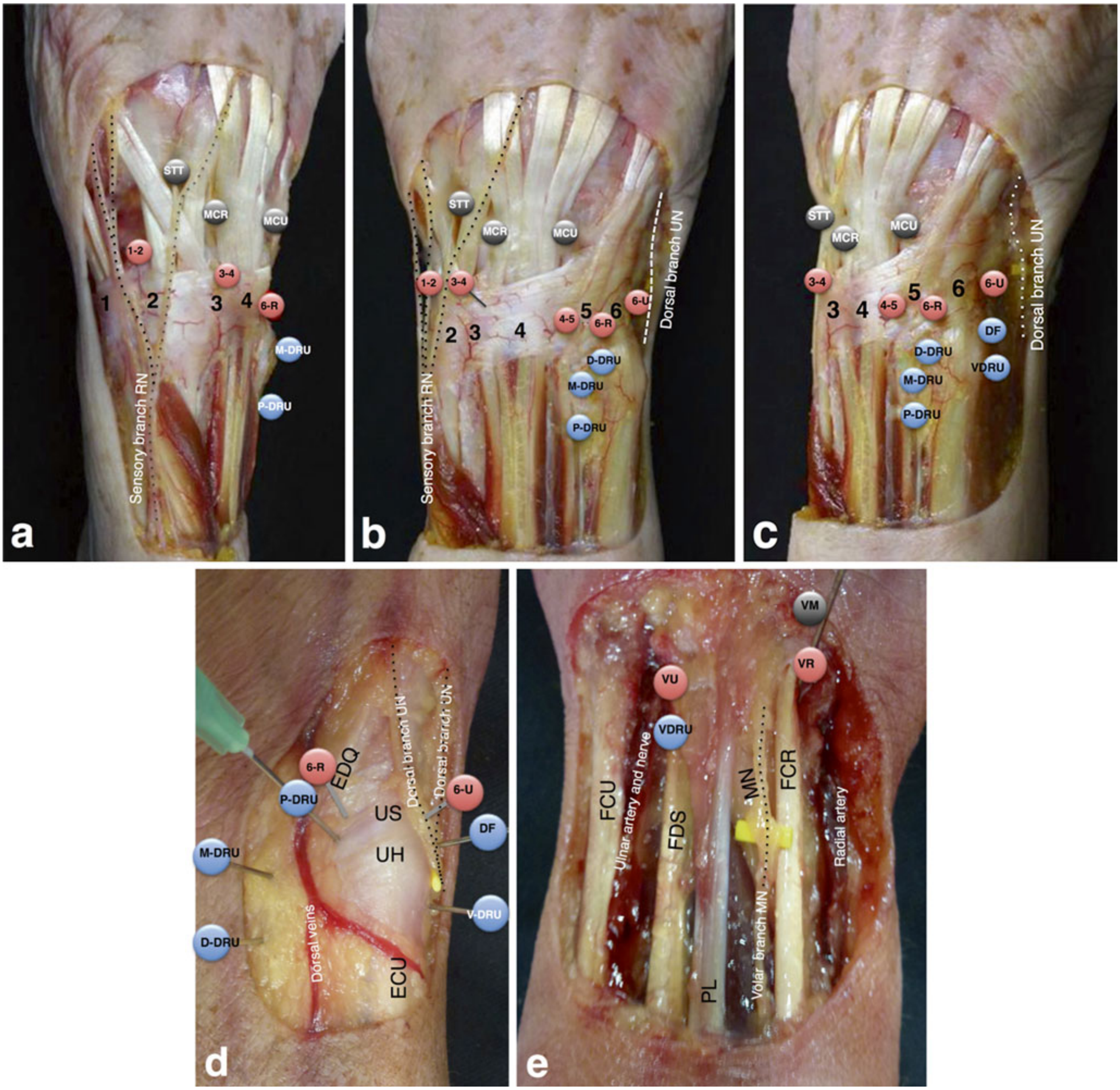


Fig. 1.16 Anatomic dissection of the wrist from dorso-radial (**a**), dorsal (**b**), dorso-ulnar (**c**), ulnar (**d**) and volar (**e**). (**1**) First compartment: containing the abductor pollicis longus (APL) tendon and the extensor pollicis brevis (EPB) tendon. (**2**) Second compartment: containing the extensor carpi radialis longus and -brevis (ECRL and ECRB) tendons. (**3**) Third compartment: containing the extensor pollicis longus (EPL) tendon. (**4**) Fourth compartment: containing the extensor digitorum communis (EDC) tendons and the extensor indicis proprius (EIP) tendon. (**5**) Fifth extensor compartment: containing the extensor digiti quinti (EDQ) tendon. (**6**) Sixth extensor compartment: containing the extensor carpi ulnaris (ECU) tendon. On the radial side of the wrist the sensitive branches of the superficial radial nerve can be visualized and on the ulnar side the terminal branches of the sensitive dorsal branch of the ulnar nerve. Entry portals to the radiocarpal joint and the midcarpal joint are marked in *red* or *black*, respectively. Entry portals to the DRUJ joint are marked in *blue* [**a–c**: Modified from Atzei A, Luchetti R, Sgarbossa A, Carità E, Llusà M. Set-up, portals and normal exploration in wrist arthroscopy. Chir Main. 2006;25 Suppl 1:S131-44. French. With permission from Elsevier]

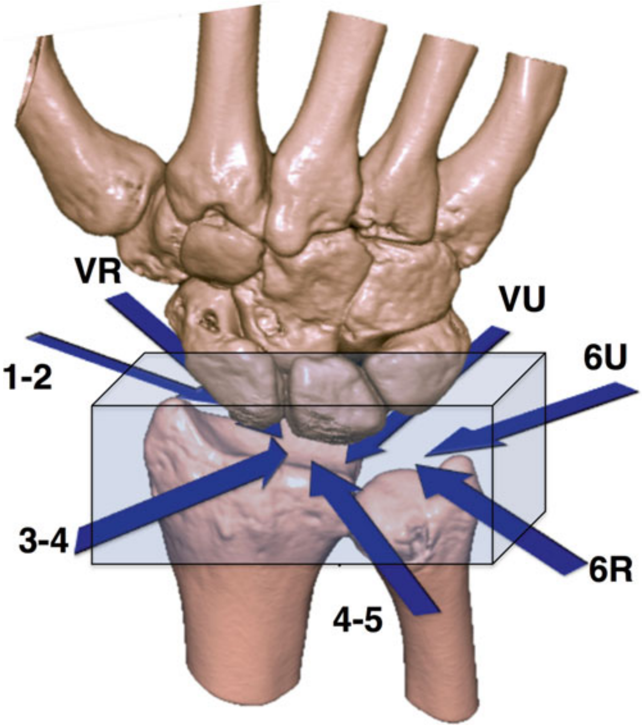


Fig. 1.17 "Box concept" of the wrist. The wrist can be thought of as a box, which can be visualized from almost every perspective. Through a combination of arthroscopic portals it is possible to have viewing and working portals that encircle the wrist. This enables the arthroscopic surgeon to see and instrument from all directions [Modified from Bain GI, Munt J, Turner PC. New advances in wrist arthroscopy. Arthroscopy. 2008;24:355-67. With permission from Elsevier]

Dorsal Portals of the Radiocarpal Joint

Five standard dorsal portals of the radiocarpal joint are routinely used [35].

1-2 Portal

The 1-2 portal is situated between the first extensor compartment, containing the abductor pollicis longus (APL) tendon and the extensor pollicis brevis (EPB) tendon, and the second extensor compartment, containing the extensor carpi radialis longus and -brevis (ECRL and ECRB) tendons. Proximally it is bordered by the distal, radial end of the radius, the radial styloid, and distally by the scaphoid. Several important structures can be found in this interval and may be endangered when establishing the 1-2 portal (Fig. 1.19). Two branches of the sensory branch of the radial nerve (SBRN) were shown in proximity with a mean of 3 mm radial and 5 mm ulnar to the portal. The radial artery was located on average 3 mm radial to the portal [34]. In a different study the mean distance of the SBRN was only 1.8 mm [36]. Partial or complete overlap of the lateral antebrachial cutaneous nerve (LABCN) with the SBRN is reported in up to 75 % [49].

We recommend to carefully entry the joint capsule close to the tendons of the first extensor compartment and just distal to the radial styloid to avoid damage to the dorsal branch of the radial artery. Inserting the optic through this portal allows exploration of the entire dorsal capsule of the radiocarpal joint and the major part of the anterior capsule with

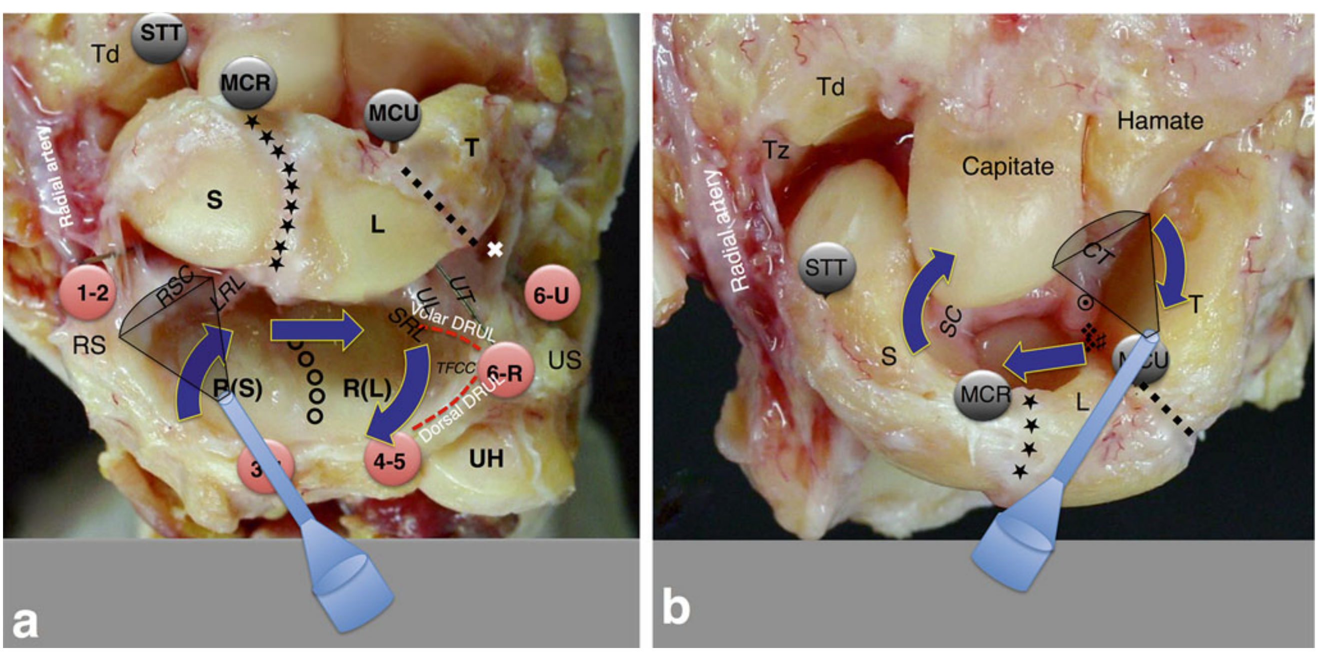


Fig. 1.18 Arthroscopic tour of the radiocarpal and midcarpal joint. For the radiocarpal joint the primary viewing portal is the 3-4 portal and we proceed from radial to ulnar, proximal to distal (**a**). For the midcarpal joint the MCU portal is the main viewing portal and we proceed with the arthroscopic tour from ulnar to radial (**b**). Abbreviations are according to Fig. 1.14

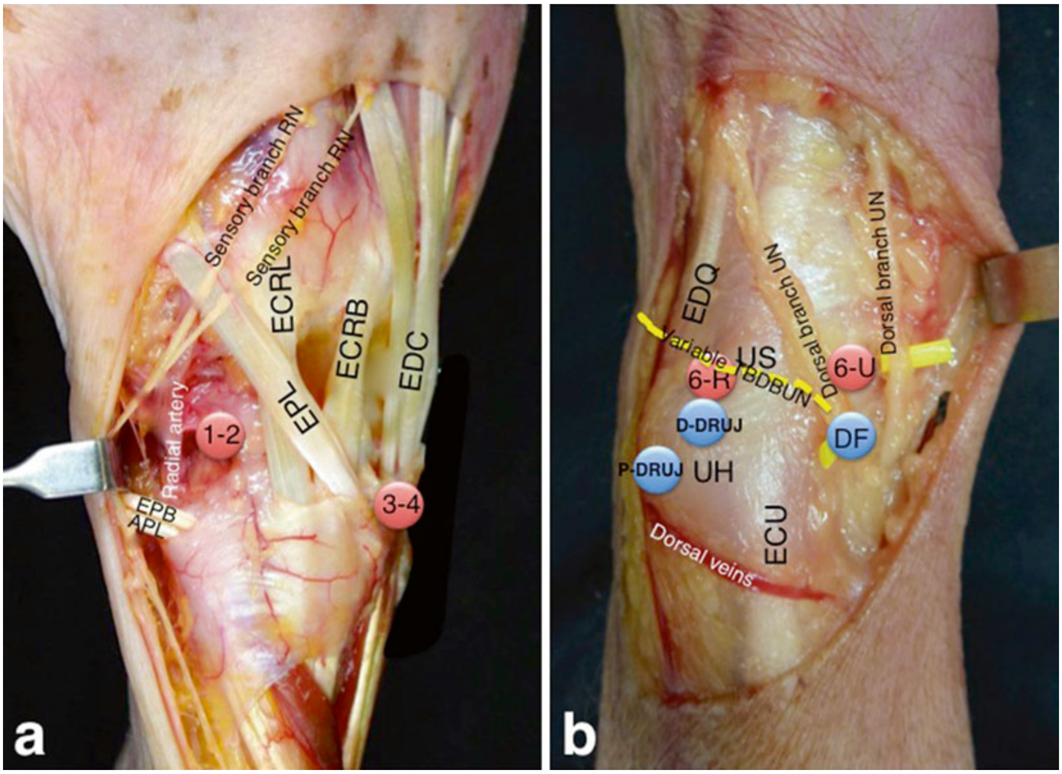


Fig. 1.19 Particular anatomy of the radial (**a**) and ulnar (**b**) aspect of the wrist. Branches of the sensitive branch of the radial nerve (SBRN) are moved radially by a retractor and the close relation of the dorsal branch of the radial artery to the 1-2 portal becomes evident. On the ulnar side the close relation of the two dorsal branches of the ulnar nerve (UN) to the 6-U portal and the direct foveal (DF) portal is demonstrated. The terminal branching of the dorsal branch of the ulnar nerve (DBUN) is variable and a transverse branch of the DBUN (TBDBUN) can be found in some cases [**a**: Modified from Atzei A, Luchetti R, Sgarbossa A, Carità E, Llusà M. Set-up, portals and normal exploration in wrist arthroscopy. Chir Main. 2006;25 Suppl 1:S131-44. French. With permission from Elsevier]

the extrinsic ligaments. Further the proximal pole and the body of the scaphoid, the proximal pole of the lunate, the articular surface of the radius, and the dorsal rim of the radius can be visualized. This portal is mainly used as portal for instrument placement in special surgical procedures as arthroscopic arthrolysis, resection of volar or dorsal ganglion cysts, or styloidectomy just to mention a few.

- *Proximal*: we can observe the radial styloid and the scaphoid fossa of the radius.
- *Volar*: we identify the radioscaphocapitate (RSC) ligament and the long radiolunate (LRL) ligament that originate from the anterior margin of the radius.
- *Distal*: the most proximal 2/3 of the scaphoid and the proximal surface of the lunate can be visualized.
- *Radial*: rotating the arthroscope to the radial side one is very close to the radial part of the radiolunate articulation and the vision is limited.
- *Ulnar*: pivoting to the ulnar side the anterior margin of the radius and the radioscapholunate (RSL) ligament (ligament of Testut) can be appreciated.
- *Dorsal*: rotating to the dorsal side we can see the entire dorsal part of the radiocarpal capsule with an oblique view of the dorsal radiocarpal ligament (DRCL).

3-4 Portal

The 3-4 portal is situated between the third extensor compartment, containing the extensor pollicis longus (EPL) tendon and the fourth extensor compartment with the common finger extensor (EDC) tendons and the extensor indicis proprius (EIP) tendon (Fig. 1.20, Video 1.1). Proximally it is boarded by the distal radius and distally by the scapholunate ligament. The entry is 1 cm proximal to Lister's tubercle. The portal is considered safe with a low risk of damaging neurovascular structures. The mean distance of the SBRN is reported between 4.85 mm [36] and 16 mm radial to the portal [34]. The main risk is damaging the EPL tendon itself. We recommend to routinely establish this portal as the first portal for placement of the arthroscope. It is the main radiocarpal viewing portal as almost the complete radiocarpal articulation can be visualized through this portal:

- *Proximal*: we can observe the distal radial epiphysis with the interfosseal ridge that separates the scaphoid fossa and the lunate fossa in a sagittal direction.
- *Volar*: in the center of the field of vision we see the RSL ligament that has the aspect of a fibro-fatty villus. It is considered to be more of a neurovascular connective tissue than a true ligament [50]. De facto it is the reference point

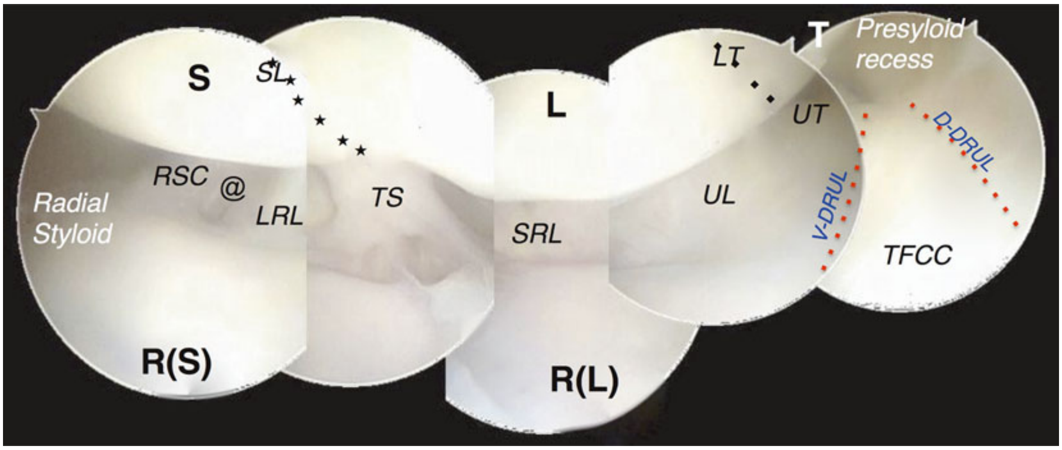


Fig. 1.20 Complete arthroscopic view of the radiocarpal joint through the 3-4 portal, from the radial styloid to the ulnar insertion of the TFCC in a right wrist. *S* scaphoid, *R(S)* scaphoid fossa of the radius, *L* lunate, *R(L)* lunate fossa of the radius, *T* triquetrum, *SL* (★-line) scapholunate ligament, *RSC* radioscaphocapitate ligament, *LRL* long radiolunate ligament, *TS* Testut (radioscapholunate) ligament, *SRL* short radiolunate ligament, *LT* (◆-line) lunotriquetral ligament, *UL* ulnolunate ligament, *UT* ulnotriquetral ligament, *V-DRUL* volar distal radioulnar ligament, *D-DRUL* dorsal distal radioulnar ligament, @ gap between RSC and LRL ligament [Modified from Atzei A, Luchetti R, Sgarbossa A, Carità E, Llusà M. Set-up, portals and normal exploration in wrist arthroscopy. Chir Main. 2006;25 Suppl 1:S131-44. French. With permission from Elsevier]

for the exploration of the radiocarpal articulation. The volar radiocarpal ligaments are examined next. From radial to ulnar we find the stout radioscaphocapitate (RSC) ligament, arising from the radial styloid, then inserting on the waist of the scaphoid and reaching the palmar part of the capitate. Ulnar to the RSC ligament we find the long radiolunate (LRL) ligament that is wider and its fibers are orientated more obliquely. Its insertion is mainly at the lunate while some fibers proceed to the triquetrum. The short radiolunate (SRL) ligament is the most ulnar ligament. The RSC and the LRL ligaments are separated by an interligamentous gap where volar wrist ganglions usually originate. The LRL ligament forms together with the SRL ligament a reversed V that comprises the radioscapholunate ligament. At the apex of the V one will find the anterior part of the scapholunate ligament.

- *Distal*: The articular surfaces of the scaphoid and the lunate and the scapholunate interosseous ligament (SLIL) between the two bones are visualized. It appears as an "indentation" and has a cartilage-like look [22]. The SLIL can be divided into a weak anterior part, a thin membranous proximal part and a strong dorsal part [51]. By slightly flexing and extending the wrist, the articular surfaces of the scaphoid and the lunate can be inspected more volarly and dorsally.
- *Radial*: rotating the arthroscope radially one can explore the radial compartment of the radiocarpal articulation. We can visualize the proximal pole and the body of the scaphoid, the radiocarpal ligament, the radial styloid, and the scaphoid fossa of the radius very nicely.
- *Ulnar*: rotating the optic to the ulnar side we can appreciate the lunate fossa of the radius and the triangular fibrocartilage complex (TFCC). Sometimes it can be difficult to see the separation between the radial margin of the TFCC and the articular surface of the lunate fossa of the radius. A probe will help in distinguishing between articular surface and TFCC. The TFCC is arranged in a three-dimensional manner into three components: the proximal triangular ligament, the distal hammock structure, and the ulnar collateral ligament (UCL) [52]. The volar and dorsal distal radioulnar ligaments (v-DRUL and d-DRUL) are thickenings of the periphery of the TFCC. They originate from the ulnar margin of the radius and insert as the proximal component of the TFCC at the ulna fovea (pc-TFCC) while the distal hammock structure and the UCL represent the distal component of the TFCC (dc-TFCC), attaching at the ulnar styloid and the ulnocarpal capsule. If the TFCC is intact only the superficial part of the ulnar attachment of the radioulnar ligaments can be seen. In traumatic or degenerative central TFCC lesions we can see onto the exposed ulnar head and the pc-TFCC at the fovea can be visualized. The ulnocarpal ligaments consist of the ulnolunate ligament (UL), the ulnocapitate (UC) and the ulnotriquetral ligament (UT) and originate at the anterior edge of the TFCC, the v-DRUL and the ulnar styloid and insert on the lunate and the triquetrum, respectively. It is also possible to visualize the prestyloid recess, a synovial pouch that is located volar to the ulnar styloid. The meniscus homologue, a synovial tissue distal to the prestyloid recess that physiologically covers the tip of the ulnar styloid, can sometimes present as an indurated structure that can lead to impingement between the ulnar styloid and the triquetrum [53]. Next we analyze the complete articular surface of the lunate and the triquetrum as well as the lunotriquetral ligament.

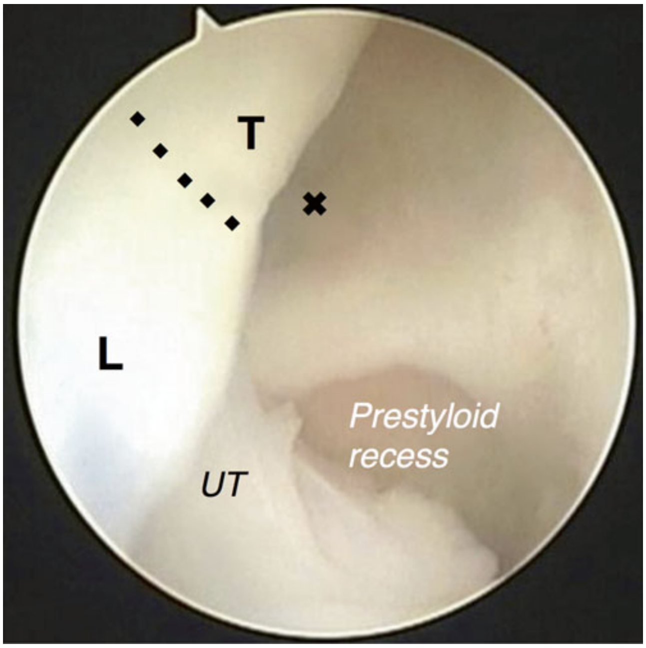


Fig. 1.21 Arthroscopic exploration of the ulnar compartment of the wrist from the 4-5 radiocarpal portal. Abbreviations and symbols are used according to the previous figure. ×: entry to the pisotriquetral joint. The opening is covered by a synovial membrane (right wrist) [Modified from Atzei A, Luchetti R, Sgarbossa A, Carità E, Llusà M. Set-up, portals and normal exploration in wrist arthroscopy. Chir Main. 2006;25 Suppl 1:S131-44. French. With permission from Elsevier]

4-5 Portal

This portal is situated between the fourth extensor compartment containing the above-mentioned tendons and the fifth extensor compartment with the extensor digiti quinti (EDQ) tendon. It is in line with the fourth metacarpal and slightly proximal to the 3-4 portal. Proximally it is bordered by the radius and distally by the lunate. Establishing the 4-5 portal does not put any particularly relevant structures at risk except from the EDC and EDQ tendons itself, dorsal sensory nerve branches are at a mean distance of 16.13 mm (range: 9.48–26.82 mm) [36]. The 4-5 portal has been the most frequently used portal for placement of the instruments, however, nowadays it is less frequently used than the 6-R portal. The 4-5 portal allows observation of the same structures as the 3-4 portal but with a more direct view onto the ulnar compartment of the wrist joint (Fig. 1.21). The possibility of exchanging the position of the arthroscope and the instruments with the 3-4 portal allows to accomplish surgical interventions in all parts of the radiocarpal articulation:

- *Proximal*: in the center of the field of vision we see the radial insertion of the TFCC that merges with the lunate fossa on the radial side.
- *Volar*: focusing on the ulnar side we encounter the LRL ligament and the SRL ligament, the UL ligament and the UT ligament.
- *Distal*: we recognize the proximal lunate and triquetrum, separated by the lunotriquetral interosseous ligament (LTIL).
- *Radial*: swinging the arthroscope to the radial side we can visualize the volar rim of the radius and the ulnar part of the scaphoid fossa, the RSC and the LRL ligaments as well as the dorsal capsule of the radiocarpal articulation. We can observe the dorsal surface of the lunate and the central, membranous part as well as the dorsal part of the scapholunate ligament and its distal attachment to the dorsal capsule.
- *Ulnar*: rotating the arthroscope to the ulnar side we can observe the most ulnar part of the TFCC up to the prestyloid recess and the pisotriquetral articulation. The pisotriquetral joint is part of the wrist joint. It is a diarthrosis and is enclosed in a small capsule. The pisotriquetral joint often communicates with the radiocarpal joint through a fenestration in the capsule [54].

6-R Portal

The 6-R portal is localized radial to the sixth extensor compartment that contains the extensor carpi ulnaris (ECU) tendon. Its radial border is the EDQ tendon. The portal is approximately 5 mm distal to the dorsal part of the TFCC, representing the proximal border. Distally the portal is bounded by the lunotriquetral interosseous ligament. The structure most at danger in establishing this portal is the TFCC. To avoid damage of the TFCC this portal is established by the use of a needle under direct vision of the arthroscope (Videos 1.2 and 1.3). The structure second most at risk is the dorsal sensory branch of the ulnar nerve (DBUN) (Fig. 1.19b). The mean distance of the DBUN to the 6-R portal has been found to be 8.2 mm [34]. A transverse branch of the DBUN (TBDBUN) has been found in 27 % of dissected cadavers [55] with a very variable course. If present it is encountered a mean of 2 mm proximal to the 6-R portal [34] (Fig. 1.22). Together with the 3-4 portal the 6-R portal is one of the two essential portals in wrist arthroscopy as they allow to examine and access the whole radiocarpal joint. Although the 6-R portal is the main working portal, instruments and the arthroscope can easily be switched between those two portals. The 6-R portal shows the ulnocarpal compartment and is particularly useful in repairing lesions of the TFCC, the lunotriquetral ligament or lesions of the lunate and the triquetrum (Video 1.4):

- *Proximal*: we can perfectly visualize the complete peripheral component of the TFCC up to the prestyloid recess and the opening into the pisotriquetral bursa.
- *Volar*: the ulnolunate and ulnotriquetral ligaments (ULL and UTL), supporting the TFCC volarly, and the depression corresponding to the pisotriquetral articulation are examined.
- *Distal*: The entire articular surface of the triquetrum and the central volar part of the LTIL can be analysed.

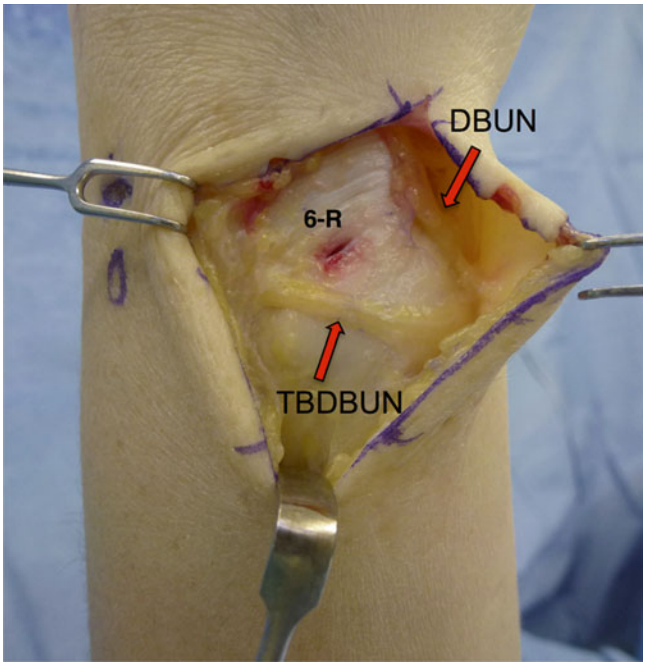


Fig. 1.22 Open approach to the DRUJ after wrist arthroscopy. Note the transverse branch of the dorsal branch of the ulnar nerve (TBDBUN) crossing 3 mm proximal to the 6-R portal

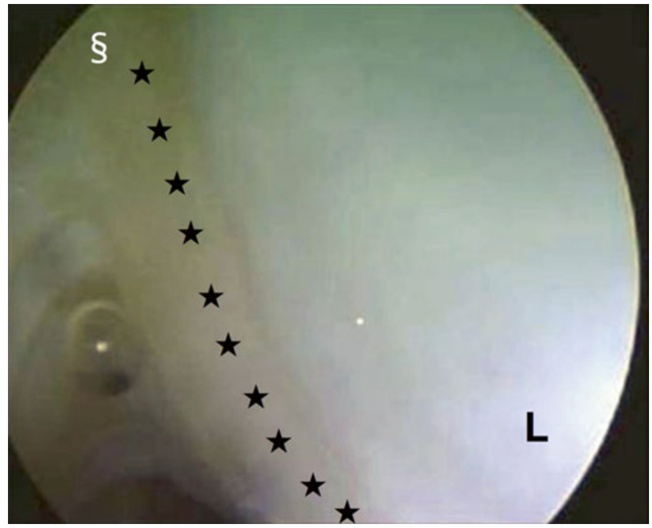


Fig. 1.23 Arthroscopic view onto the dorsal aspect of the radiocarpal joint from the 6-R portal. The dorsal, distal aspect of the lunate (L) and the scapholunate ligament (★-line) can be inspected up to the attachment of the SL ligament to the dorsal capsule (§), that separates the radiocarpal joint from the midcarpal joint (right wrist) [Modified from Atzei A, Luchetti R, Sgarbossa A, Carità E, Llusà M. Set-up, portals and normal exploration in wrist arthroscopy. Chir Main. 2006;25 Suppl 1:S131-44. French. With permission from Elsevier]

- *Radial*: sweeping the arthroscope radially we will find the TFCC, the lunate fossa of the radius and the short radiolunate ligament. We also can explore parts of the dorsal aspect of the radiocarpal articulation (Fig. 1.23, Video 1.5).
- *Ulnar*: rotating the arthroscope to the ulnar side it is possible to glide into the prestyloid recess and the pisotriquetral space if the opening is not covered by a thick synovial membrane as reported in 27 % [54].

6-U Portal

The 6-U portal is situated ulnar to the ECU tendon. Ulnarly it is bounded by the DBUN, proximally by the TFCC and distally by the triquetrum. Damaging the terminal branches of the DBUN that divides itself inconsistently about 1.5 cm distal to this portal is the highest risk when establishing the 6-U portal. The frequent anatomical variations of the terminal branching of the DBUN are an additional risk. The mean distance of the DBUN from the 6-U portal is 8.3 mm if there is only one terminal branch and 1.9 mm if two terminal branches are present. In cases where a TBDBUN is found the mean distance is 2.5 mm proximal to the portal. In some cases the branch is crossing directly over the portal [36]. Therefore the 6-U portal has been used for a long time predominantly as an outflow portal. Some authors however have shown that respecting certain rules and keeping the possible anatomic variations of the dorsal branch of the ulnar nerve in mind, the 6-U portal can be used advantageously in diagnostic wrist arthroscopy and in treating certain pathologies [56], especially those around the ulnocarpal complex as the visualization of the ulnocarpal compartment is excellent.

- *Proximal*: we can see the ulnar and dorsal border of the TFCC and the prestyloid recess.
- *Volar*: the ULL and the UTL can be inspected.
- *Dorsal*: the dorsal ulnotriquetral ligament on the dorsal aspect of the TCFF may be visualized if not covered with synovial tissue. The ECU subsheath is a further stabilizer on the dorsal aspect of the TFCC but not visible with an intact capsule.
- *Distal*: the triquetrum can be perfectly displayed, most notably the ulnar part as well as the depression between the triquetrum and the lunate corresponding to the lunotriquetral ligament. The lunotriquetral ligament is more difficult to detect than the scapholunate interosseous ligament and probing the ligament is the best way to localize it [57].

Volar Portals of the Radiocarpal Joint

Two volar portals to the radiocarpal joint are used. Especially the dorsal capsular structures, dorsal radiocarpal ligaments and volar subregions of the scapholunate interosseous ligament as well as the lunotriquetral interosseous ligament are better visualized from a volar perspective [44, 45].

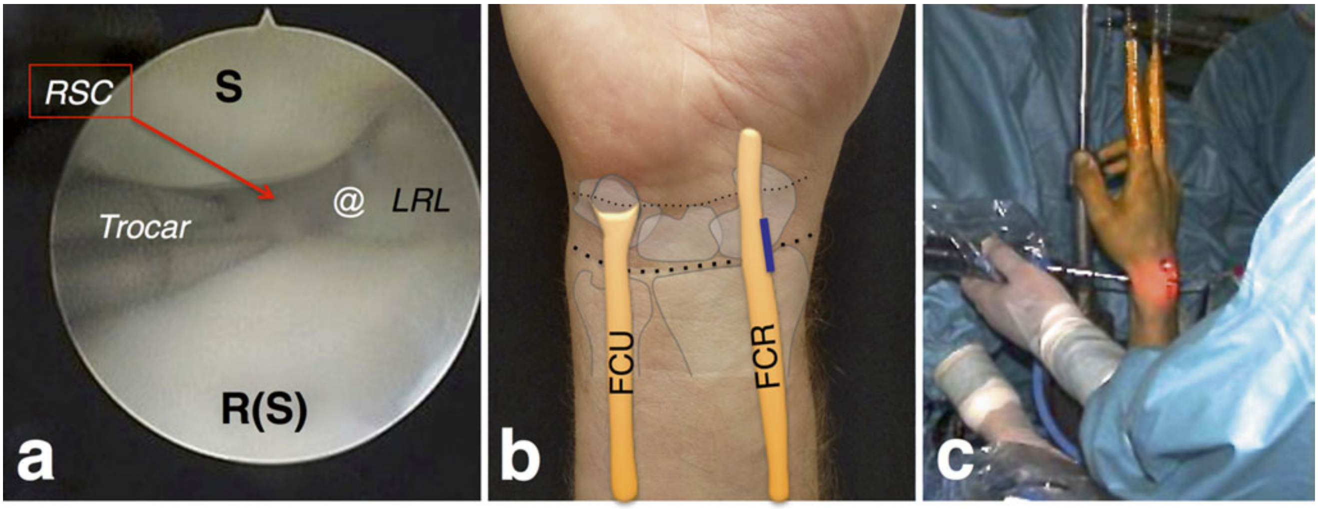


Fig. 1.24 Establishment of the volar radial radiocarpal portal with the "in-out" technique (right wrist). The optic is introduced via a dorsal ulnar portal (4-5 or 6-R): above the proximal pole of the scaphoid (S) is visualized and below we see the scaphoid fossa of the radius (R(S)); the trocar is introduced via the 3-4 portal and advanced through the gap (@) between the radioscaphocapitate (RSC) and the long radiolunate (LRL) ligaments and advanced volarly (**a**). On the volar radial side of the wrist the skin incision is made at the level of the proximal wrist crease (*blue line*), radial to the flexor carpi radialis (FCR) tendon, close to the radial artery (**b**). After the blunt tip of the trocar has been advanced volarly through the joint capsule, a trocar sleeve can be placed over the trocar from the volar side, the trocar removed from the dorsal side and the arthroscope is place into the trocar sleeve from volar (**c**) [Modified from Atzei A, Luchetti R, Sgarbossa A, Carità E, Llusà M. Set-up, portals and normal exploration in wrist arthroscopy. Chir Main. 2006;25 Suppl 1:S131-44. French. With permission from Elsevier]

Volar Radial Portal (VR)

Two ways of establishing this portal have been described and are considered safe. The first method is the so-called in-out technique, first described in cadavers (Fig. 1.24) [43]: the optic is placed in an ulnar portal (4-5 or 6-R), a blunt trocar is inserted into the 3-4 portal and pushed towards the anterior radiocarpal joint capsule. It is then pushed through the capsule between the RSC and LRL ligaments, exiting next to the flexor carpi radialis tendon where a small skin incision is made. A cannula can then be placed safely over the trocar and the arthroscope inserted from the volar side into the radiocarpal joint. The second method of establishing the volar radial portal has also been shown to be safe [44, 45]: a 1–2 cm longitudinal skin incision is made at the proximal wrist crease over the flexor carpi radialis (FCR) tendon, the tendon sheath is divided and the tendon retracted ulnarly. After identification of the radiocarpal joint space with an 18-G needle the volar capsule is penetrated with the tip of a blunt artery forceps between the RSC ligament and the LRL ligament. A blunt trocar is inserted with a cannula, the trocar removed and the arthroscope is introduced over the cannula. Structures at risk are the radial artery on the radial side and the volar cutaneous branch of the median nerve (VBMN) ulnarly (Fig. 1.16d). There is a safe zone of 3 mm in all directions with respect to the mentioned structures [47].

This portal allows visualization of the complete radiocarpal articulation, particularly the dorsal capsule, the dorsal radiocarpal ligament (DRCL), the volar aspect of the bones of the first carpal row and the volar subregions of the intercarpal ligaments. The TFCC can also be visualized (Fig. 1.25). A good surgical indication where the volar radial portal is beneficial is arthroscopic arthrolysis in cases in which complete dorsal capsulotomy for the treatment of flexion stiffness is needed:

- *Proximal*: the scaphoid and lunate fossae of the distal radius as well as the dorsal rim of the radius can be visualized.
- *Dorsal*: the dorsal capsule is inspected, the established dorsal 3-4 portal can be localized and the radiolunotriquetral ligament is seen.
- *Distal*: we can visualize the proximal pole of the scaphoid and the volar part of the SLIL.
- *Radial*: rotating the optic to the radial side it is possible to visualize the radial styloid and the external part of the articular capsule.
- *Ulnar*: swinging the optic to the ulnar side one can visualize the entire surface of the distal radius up to the TFCC and the prestyloid recess. It is also possible to visualize the anterior part of the lunate but the vision may be limited in cases where the radioscapholunate ligament is very voluminous.

Volar Ulnar Portal (VU)

The volar ulnar portal of the radiocarpal joint has been described by Slutsky [46]. Like the volar radial portal its clinical experience is still limited. The VU portal is bounded

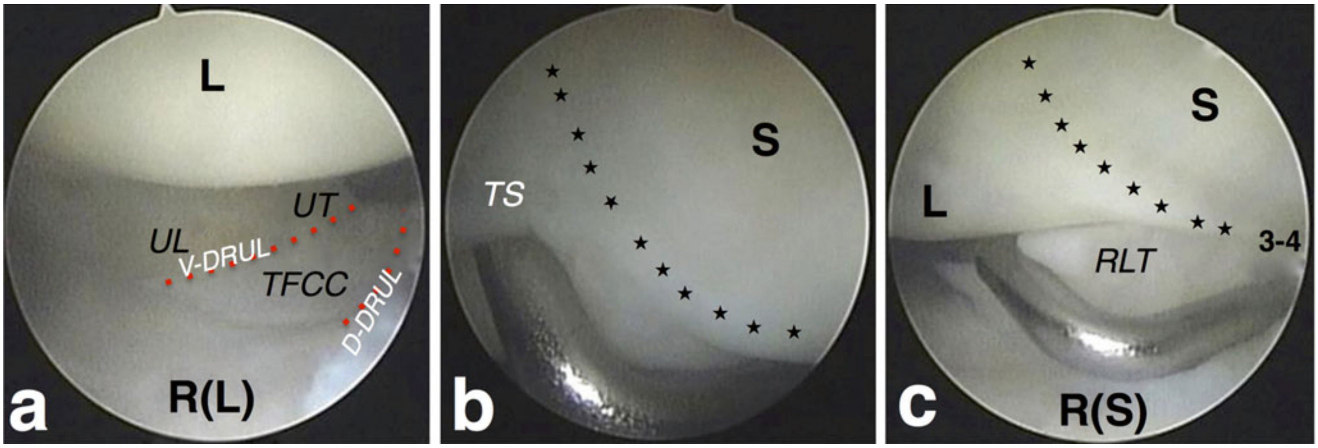


Fig. 1.25 Arthroscopic exploration of the radiocarpal joint from the volar radial portal (right wrist). Abbreviations and symbols are used according to the previous figures. Exploration of the ulnar part of the radiocarpal joint and the ulnocarpal joint: the articular surface of the lunate fossa of the radius can be examined and the corresponding proximal and volar aspect of the lunate. Further the radial insertion of the TFCC, the TFCC and the volar- and especially the dorsal distal radioulnar ligaments are visualized. On the volar aspect the UL and UT ligaments can also be seen (**a**). With the probe in the 3-4 portal the Testut ligament can be palpated. Especially the volar aspect of the scaphoid and the scapholunate ligament is visualized (**b**). The dorsal extrinsic radiolunotriquetral (RLT) ligament can be tested with a probe. The proximal aspect of the scaphoid, lunate and the scapholunate ligament are inspected (**c**) [Modified from Atzei A, Luchetti R, Sgarbossa A, Carità E, Llusà M. Set-up, portals and normal exploration in wrist arthroscopy. Chir Main. 2006;25 Suppl 1:S131-44. French. With permission from Elsevier]

proximally by the ulnar styloid, distally by the triquetrum, ulnarly by the FCU tendon and radially by the finger flexor tendons. A 2 cm longitudinal skin incision is centered over the proximal wrist crease along the ulnar edge of the common finger flexor tendons (Fig. 1.7b). The tendons are retracted radially and the volar radiocarpal joint capsule is pierced with an 18-G needle. The capsule is then pierced with the tip of a blunt hemostat, followed by the insertion of a cannula and a blunt trocar. The trocar is removed and the arthroscope is inserted. The portal penetrates the ulnolunate ligament adjacent to the radial insertion of the TFCC. As for the establishment of the volar radial portal the volar ulnar portal can also be created with the "in-out" technique with the arthroscope in the 3-4 portal. A blunt trocar is inserted into the 6-U portal and pushed towards the anterior ulnocarpal joint capsule. It is then pushed through the capsule between the UL and UT ligaments, exiting ulnar to the flexor tendons where a small skin incision is made.

Structures at risk are the flexor tendons, the ulnar artery and ulnar nerve; however, they have been generally found more than 5 mm ulnar to the trocar (Fig. 1.16d). The median nerve is protected by the flexor tendons. The volar cutaneous branch of the ulnar nerve is highly variable and its distal branch is at risk with a volar ulnar approach if present.

Like the VR portal the VU portal provides a view of the dorsal articular surface of the radius and the dorsal extrinsic ligaments. Ulnar-sided structures that are more easily seen from the ulnar volar side of the wrist include the volar subregion of the LTIL, the dorsal distal radioulnar ligament, and the dorsal ulnar wrist capsule, containing the ECU subsheath (ECUS) [46]. Like the scapholunate interosseous ligament (SLIL) the LTIL can be divided into three parts: the volar part, the central part and the dorsal part [58]. While the central part has more the structure of a thin membrane, the dorsal part of the SLIL and the volar part of the LTIL are the most important subregions contributing to stability. The VU portal is especially useful for the viewing and debridement of palmar tears of the lunotriquetral ligament [46] and in assisting in reduction of distal radius fractures [24].

Arthroscopy of the Midcarpal Joint

The midcarpal joint contributes together with the radiocarpal joint to flexion-extension and radio-ulnar deviation of the wrist (Fig. 1.14) and arthroscopy of the midcarpal joint should be routinely performed in every wrist arthroscopy.

Six portals to the midcarpal joint are used in wrist arthroscopy (Figs. 1.15 and 1.16). Next to the two standard dorsal midcarpal portals, one volar midcarpal portal [47], the standard ulnar STT portal, the radial STT portal [59] and the accessory triquetro-hamate (TH) portal [60] have been described. The midcarpal joint is comprised of three proximal bones: the scaphoid, lunate and triquetrum, and four distal bones: the trapezium, trapezoid, capitate and hamate. The depth of the midcarpal joint is less than half of that of the radiocarpal joint and the joint is tighter than the radiocarpal joint. The joint space of the scapholunate and lunotriquetral articulation can be inspected directly as there are no interosseous ligaments distally. The portal most

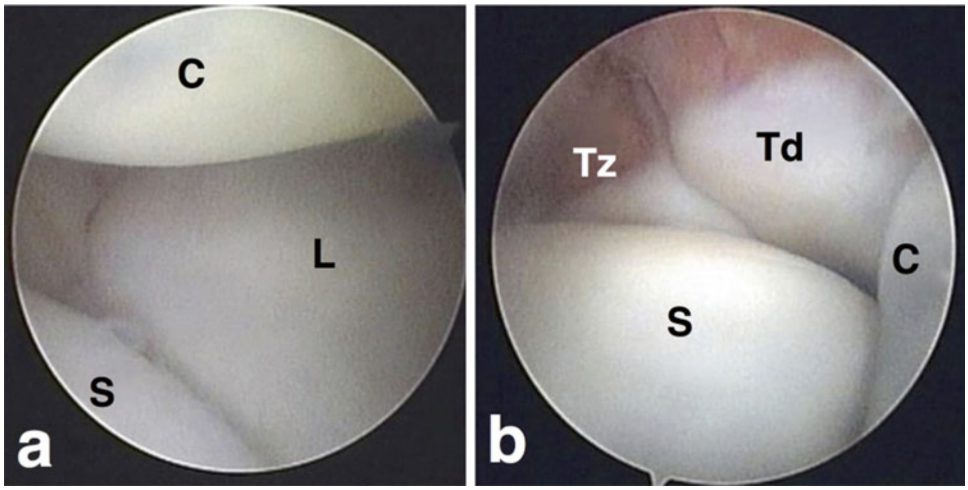


Fig. 1.26 Arthroscopic exploration of the midcarpal joint through the MCR portal (right wrist): below we see the concave surface of the scaphoid (S) and the lunate (L), separated by a narrow gap corresponding to the scapholunate articulation. Above the articular surface of the round head of the capitate (C) can be inspected (**a**). Exploration of the STT joint from the MCR portal (right wrist): the distal pole of the scaphoid (S), articulating with the trapezium (Tz) and the trapezoid (Td) can be assessed. Note that the trapezoid is encountered more dorsally than the trapezium and only the dorsal aspect of the trapezium can be visualized through this portal (**b**) [Modified from Atzei A, Luchetti R, Sgarbossa A, Carità E, Llusà M. Set-up, portals and normal exploration in wrist arthroscopy. Chir Main. 2006;25 Suppl 1:S131-44. French. With permission from Elsevier]

commonly used in midcarpal arthroscopy is the ulnar midcarpal (MCU) portal.

Radial Midcarpal Portal (MCR)

The MCR portal is situated 1 cm distal to the 3-4 portal and in line with the radial margin of the third metacarpal. It is bounded radially by the ECRB tendon, ulnarly by the fourth extensor compartment, proximally by the concave surface of the scaphoid and distally by the proximal pole of the capitate. The radial midcarpal portal is the principle midcarpal portal as it allows visualization of the complete midcarpal joint including the STT joint. Structures at risk while establishing this portal are the extensor tendons (Fig. 1.16a–c). The SBRN is found at a mean distance of 6.65 mm [36] to 15.8 mm radial to the portal and was found in one occasion 2 mm ulnar to the portal [34]. A small transverse skin incision is made over the palpable soft spot 1 cm distal to the 3-4 portal after the entry to the joint has been triangulated with an 18-G needle. The joint capsule is pierced with a blunt hemostat, then a trocar sleeve with a blunt trocar is inserted, orientated approximately 10° proximally to parallel the dorsal midcarpal joint axis, followed by a 1.9 mm 30-degree-angle arthroscope.

The complete midcarpal articulation can be visualized (Video 1.6), the distal surface of the lunate, the triquetrum and the scaphoid (Fig. 1.26a) and the proximal surface of the hamate and the capitate. Sweeping the arthroscope over the distal pole of the scaphoid, even the proximal surface of the trapezium and trapezoid can be evaluated (Fig. 1.26b) and resection of the distal pole of the scaphoid in STT arthritis is possible. As the joint is usually tight it is however not always possible to advance the arthroscope sufficiently volar to see the volar capsule and midcarpal ligaments [60]:

- *Proximal*: we see the concave surface of the lunate and the scaphoid, separated by a physiologic cleft corresponding to the scapholunate articulation. A fibrocartilaginous meniscus can be present in the joint, mainly at the volar aspect.
- *Volar*: when the joint is lax we can pass the arthroscope volarly enough to visualize the distal part of the RSC ligament that forms the radial limb of the arcuate ligament anterior to the capitate.
- *Distal*: the field of vision is completely filled by the convex head of the capitate.
- *Radial*: sweeping the arthroscope radially along the scaphoid, we can follow the complete scaphocapitate articulation area up to the STT joint distally. The trapezoid is found more dorsally than the trapezium, the two carpal bones are separated by a narrow groove corresponding to the trapeziotrapezoidal articulation. Sometimes the volar radial scaphotrapezial ligament can be seen, a strong structure that is reinforced by the FCR tendon sheath [60, 61].
- *Ulnar*: rotating the scope to the ulnar side we find the articulating corner of four carpal bones, forming a cross by the hamate, capitate, lunate and triquetrum. We inspect carefully the lunotriquetral joint and we can assess the distal alignment of the articulating surfaces of the two bones. A fibrocartilaginous meniscus can be present in the joint. The lunate can present with one concave, articulating

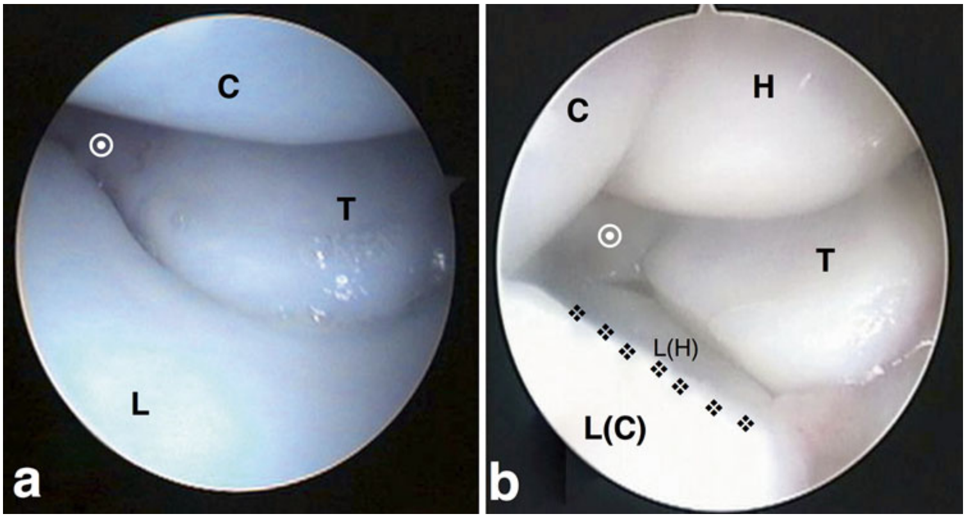


Fig. 1.27 Exploration of the corner of the four midcarpal bones (lunate, triquetrum, capitate and hamate) via the MCR portal. Lunate type I according to Viegas with one distal articular facet, articulating with the capitate. Note the step of the triquetrum to the lunate that is a physiological finding and not a sign for lunotriquetral instability. (◉) Fibroadipose tissue, covering the capitatotriquetral ligament (**a**). Lunate type II according to Viegas with a separate distal articular facet (L(H)), articulating with the hamate (H). The facet articulating with the capitate (L(C)) is bigger. The two facets of the lunate are separated by a longitudinal crest (❖) (**b**) [Modified from Atzei A, Luchetti R, Sgarbossa A, Carità E, Llusà M. Set-up, portals and normal exploration in wrist arthroscopy. Chir Main. 2006;25 Suppl 1:S131-44. French. With permission from Elsevier]

only with the capitate, or two concave facets for a common articulation with the capitate and hamate. In this case we find a longitudinal ridge at the lunate, separating the two articulation fossae to the hamate and the capitate, respectively. Viegas has classified the different types of the lunate into type I, if articulating only with the capitate, and type II, if an additional facet for the hamate is present [62] (Fig. 1.27).

Ulnar Midcarpal Portal (MCU)

The MCU portal is situated symmetrically to the above-mentioned portal in the soft depression of the four-corner intersection of the hamate, capitate, lunate and triquetrum, on the midaxial line of the fourth metacarpal where the soft sport is easily palpable making it to the preferred portal to be established first for arthroscopy of the midcarpal joint (Fig. 1.18b). The portal is situated approximately 1–1.5 cm distal to the 4-5 portal. It is bounded radially by the EDC tendons and ulnarly by the EDQ tendon. In type I lunates the proximal border is the lunotriquetral joint and the distal border is the capitohamate articulation. In type II lunates the proximal border remains the same but the distal border is the proximal pole of the hamate. The structure most at risk is the EDQ tendon. The SBRN is remote to this portal and the branches of the DBUN are found a mean of 15.1 mm ulnar to this portal (Fig. 1.16a–c). However, aberrant branches can run closer or directly over the portal [34]. In type II lunates the exploration of the ulnar component of the midcarpal joint is easier via the MCU portal (Fig. 1.28), however, the visualization of the radial aspect of the midcarpal joint is not as good as through the MCR portal, especially the exploration of the STT joint is not convenient from the MCU portal.

- *Proximal*: the distal lunate with the lunotriquetral articulation in the center and the scapholunate articulation can be visualized (Videos 1.7 and 1.8).
- *Volar*: one can identify the ulnar limb of the arcuate ligament, the continuation of the capitotriquetral ligament and the distal fibers of the ulnocapitate ligament.
- *Distal*: this portal allows visualization of the proximal aspect of the capitate, the apex of the hamate, and the capitohamate interosseous ligament (CHIL).
- *Radial*: sweeping the arthroscope radially we have a better view of the scapholunate articulation and the alignment of those two bones of the proximal carpal row can be assessed. It is also possible to visualize and test the scaphocapitate articulation with a probe inserted into the MCR portal (Video 1.9), but not the STT joint.
- *Ulnar*: looking ulnarly we see the distal surface of the triquetrum and it is possible to analyze the articulation between the hook-shaped tip of the hamate and the triquetrum. The saddle-shaped triquetrohamate (TH) joint is held tightly by the volar triquetrohamate and triquetrocapitate ligaments [60] and it is difficult to enter the TH articulation directly except in the setting of midcarpal instability.

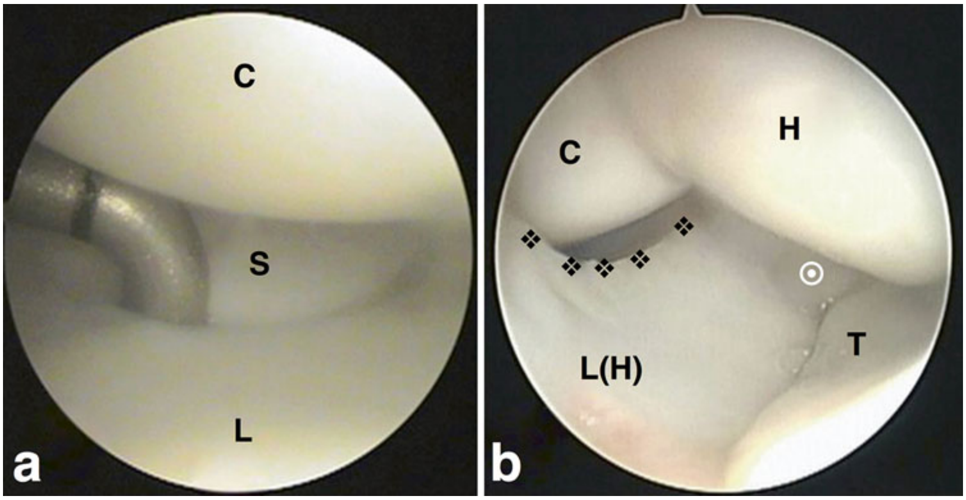


Fig. 1.28 Arthroscopic view of the midcarpal joint through the MCU portal. The scapholunate articulation is tested with a probe (**a**) and is intact as the probe cannot be protruded into the articulation. The articulation of the lunate, triquetrum, capitate and hamate is inspected, showing a lunate type Viegas II (**b**) [Modified from Atzei A, Luchetti R, Sgarbossa A, Carità E, Llusà M. Setup, portals and normal exploration in wrist arthroscopy. Chir Main. 2006;25 Suppl 1:S131-44. French. With permission from Elsevier]

Volar Midcarpal Portal (VM)

The volar midcarpal portal has been mentioned as an accessory midcarpal portal [47], however, it lacks widespread use and we do not have any clinical experience with this portal. The topographic landmarks and skin incision are the same as for the VR portal (Figs. 1.15b and 1.16d). The volar aspect of the midcarpal joint is identified with a 22-G needle on average 11 mm (range 7–12 mm) distal to the entry to the VR portal, and the joint entered with a cannula and a blunt trocar after piercing the joint capsule with a blunt artery forceps. The portal may be useful in assessing the palmar aspects of the capitate and the hamate in cases of avascular necrosis or osteochondral fractures and the capitohamate interosseous ligament that provides stability to the transverse carpal arch [63].

Scaphotrapeziotrapezoid Portal (STT)

The STT portal is found at the level of the STT joint in line with the radial margin of the index metacarpal just ulnar to the EPL tendon. The portal is bordered ulnarly by the ECRL tendon, proximally by the distal pole of the scaphoid and distally by the trapezium and the trapezoid and is localized approximately 1 cm distally to the 1-2 portal. Structures that can be jeopardized are the radial artery, the EPL tendon and small terminal branches of the SBRN (Figs. 1.16a, b and 1.19a). Establishing the portal on the ulnar side of the EPL tendon usually keeps the radial artery safe.

The joint is triangulated with an 18-G needle, and confirming correct placement of the needle in the STT joint under fluoroscopy can be convenient. Then a skin incision is made and the joint capsule pierced with a blunt artery forceps. A 1.9 mm 30-degree-angled arthroscope is inserted over a trocar sleeve after a blunt trocar has been introduced to the joint.

The STT joint can be inspected, however, the concavity of the distal pole of the scaphoid makes it difficult to explore the anterior part of this articulation. The portal is primarily utilized for instrumentation, particularly for arthroscopic resection of the distal pole of the scaphoid in STT arthritis.

Radial STT Portal (STT-R)

The radial STT portal is situated at the same level of the STT joint as the standard STT portal but radial to the APL tendon [59]. The radial artery is found at a mean distance of 8.8 mm radial to the portal. The terminal branches of the SBRN with individual arborization are in close vicinity of the portal and care must be taken when establishing the portal. The portal is created as described for the standard STT portal above. Together the two portals for the STT joint allow a working angle of 130° and the radial STT portal (sometimes also called volar STT portal) serves as a better working portal for removal of the distal pole of the scaphoid in STT arthritis.

Triquetrohamate Portal (TH)

For completeness we mention the TH portal that is an accessory portal on the ulnar aspect of the midcarpal joint. It is located between the ECU and FCU tendon and is bordered proximally by the triquetrum and distally by the base of the fifth metacarpal and the hamate. The portal has been described for an inflow or outflow cannula and can be used as an instrument portal in assessing the triquetrohamate joint and the proximal pole of the hamate [60]. However, we do not have any experience with this portal.

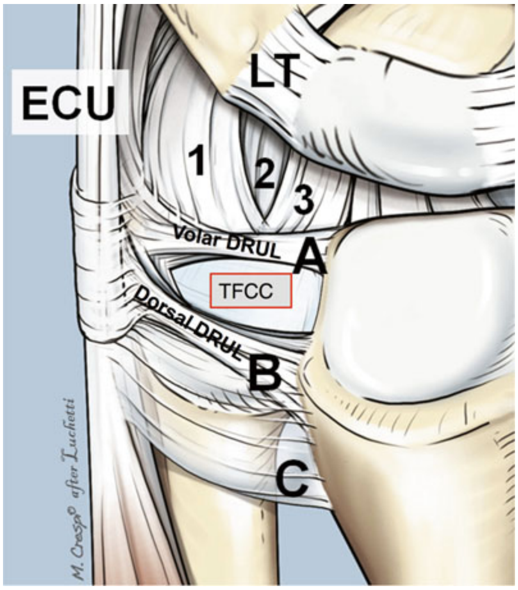


Fig. 1.29 Drawing of the DRUJ. *LT* lunotriquetral ligament, *ECU* extensor carpi ulnaris, 1, 2, 3: volar ulnocarpal ligaments (1: ulnotriquetral, 2: ulnocapitate, 3: ulnolunate); *A*: volar distal radioulnar ligament, *B*: dorsal distal radioulnar ligament, *C*: dorsal articular capsule

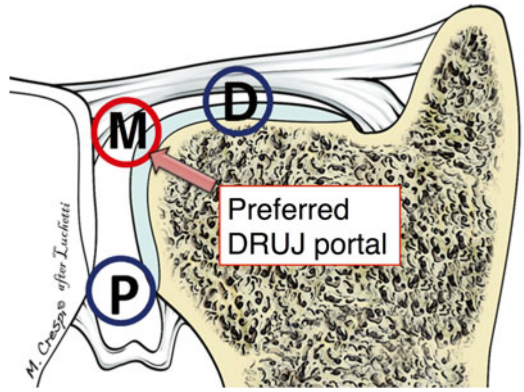


Fig. 1.30 Dorsal DRUJ portals: drawing of the dorsal portals. *D*: distal DRUJ portal, *P*: proximal DRUJ portal, *M*: mid–DRUJ portal (preferred dorsal portal)

Arthroscopy of the DRUJ

The DRUJ is the main articulation of the wrist allowing pronosupination. Arthroscopy of the DRUJ is the most recently introduced part in wrist arthroscopy and preserved for special indications. The anatomy of the DRUJ is complex. It is mostly described as a diarthrodial trochoid articulation composed of the medial articular facet of the distal radius, the radial notch and the distal end of the ulna. As the distal ulna not only articulates with the distal radius but also with the carpus by the ulnocarpal joint, arthroscopy of the DRUJ addresses the evaluation of pathologies of the DRUJ and the ulnocarpal articulation. In a normal wrist joint the TFCC with its volar and dorsal distal radioulnar ligaments, merging at the insertion at the fovea, supports the DRUJ. The volar branch of the DRUL merges also with the ulnocarpal (UC) ligaments, which also contribute stability to the ulnar side of the carpus (Fig. 1.29).

In a normal wrist the DRUJ is very narrow and hard to enter and explore, therefore the 1.9 mm arthroscope should be used. Traction should be reduced to 3–5 kg for DRUJ arthroscopy [5] to reduce the tension. As for the radiocarpal joint arthroscopy fluid distension is generally not necessary for DRUJ arthroscopy. If needed we use saline to flush out the synovial liquid in intense DRUJ synovitis, then the joint is dried with suction. DRUJ arthroscopy is useful in the assessment of soft tissue disorders and the articular cartilage of the sigmoid notch or ulnar head [64].

Four portals for the DRUJ have been described, two dorsal portals [65], one volar portal (V-DRUJ) [39] and the direct foveal portal (DF) [66] (Figs. 1.15 and 1.16).

The two dorsal portals, the proximal DRUJ portal (P-DRUJ) and the distal DRUJ portal (D-DRUJ) are the standard portals for exploration of the DRUJ and normally utilized for the assessment of the foveal insertion of the deep component of the distal RUL as the main stabilizer of the DRUJ or for arthrolysis of the DRUJ. However, we prefer to start the DRUJ exploration through a dorsal portal located at a midpoint between the traditional P-DRUJ and D-DRUJ portals, below the radial insertion of the TFCC, at the point where the distal profile of the ulnar head curves to parallel the sigmoid notch (Figs. 1.30 and 1.31). Through this portal we assess the surface of the ulnar head, the TFCC with its volar and dorsal distal RUL and its foveal insertion, and the sigmoid notch. As in the radiocarpal joint the dorsal und volar portals allow an omnidirectional evaluation of the DRUJ (Fig. 1.32).

Distal DRUJ Portal (D-DRUJ)

This portal is located in line with and about 5–8 mm proximal to the 6-R portal just under TFCC (Fig. 1.16). With the forearm in neutral rotation the TFCC has the least tension, however, because of the shape of the ulnar head wrist supination facilitates the establishment of the dorsal DRUJ portals (Fig. 1.33). The DRUJ is bordered radially by the EDQ and EDC tendons and ulnarly by the ECU tendon. Proximally it is bounded by the ulnar head and distally by the TFCC (Fig. 1.16e). The structure that can be jeopardized is the TFCC, while the only sensory nerve in proximity to the portal is the TBDBUN that has been found at a mean distance of 17.5 mm distally to the portal (Figs. 1.18b and 1.22) [34]. In the presence of a positive ulnar variance this portal should not be used [64]. After localizing the portal with a 22-G needle, a small longitudinal skin incision is made and the

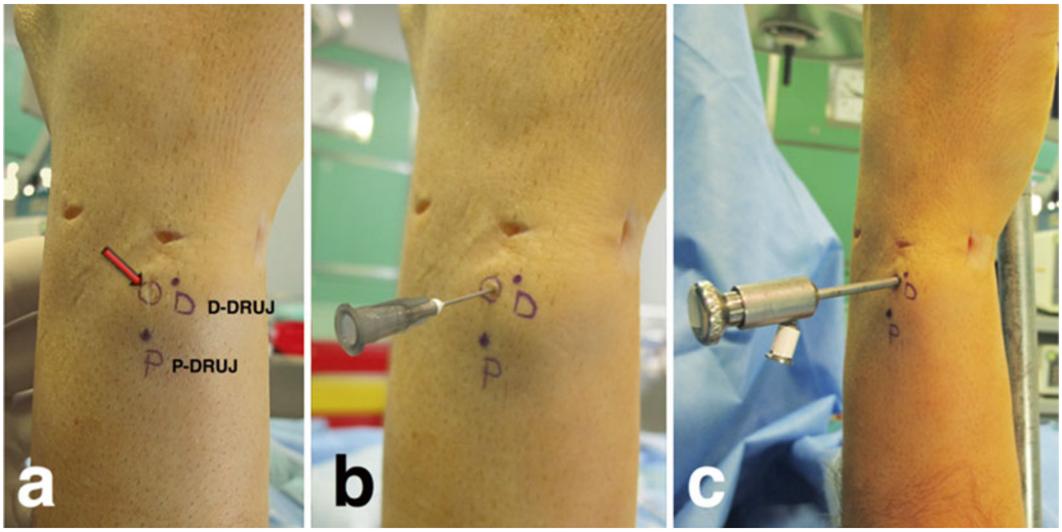


Fig. 1.31 Establishment of our preferred dorsal DRUJ portal. The *red arrow* is pointing at the entry portal and its relation to the classic proximal DRUJ portal (P-DRUJ) and distal DRUJ portal (D-DRUJ) (**a**). Verification of the correct entry point with introduction of a needle (**b**) and introduction of a blunt trocar over a trocar sleeve (**c**)

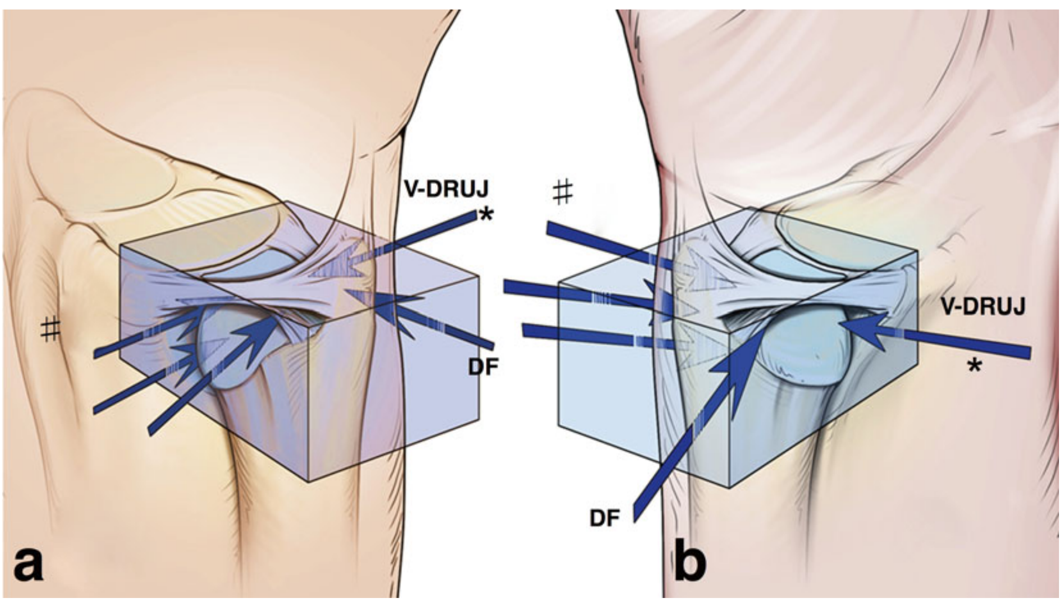


Fig. 1.32 Drawing of the "box concept" of the arthroscopic portals to the DRUJ: dorsal view (**a**) and volar view (**b**). There are three dorsal and two volar portals: (♯): preferred dorsal portal; (*): preferred volar portal

dorsal capsule is pierced with a blunt artery forceps. Then a cannula with trocar is inserted, followed by a 1.9 mm 30-degree-angle arthroscope. We recommend starting the joint exploration by rotating the scope (Fig. 1.34), rather than moving its tip inside the joint.

- *Proximal*: the whole surface of the ulnar head can be visualized.
- *Distal*: the undersurface of the TFCC is visible.
- *Radial*: rotating the scope radialwards the TFCC is visualized and its radial insertion at the sigmoid notch of the radius is shown (Fig. 1.35). The DRUJ capsule attaches to the volar and dorsal distal radioulnar ligaments, and the volar capsule of the DRUJ can be seen obliquely.
- *Ulnar*: turning the arthroscope to the ulnar side, the proximal insertion of the deep component of the distal radioulnar ligaments, merging at the ulnar fovea, can be seen. A 22-G needle, introduced from the area of the DF portal, may elevate the ligament to obtain a better vision of the ulnar part of the TFCC, inserting at the fovea (Fig. 1.36).

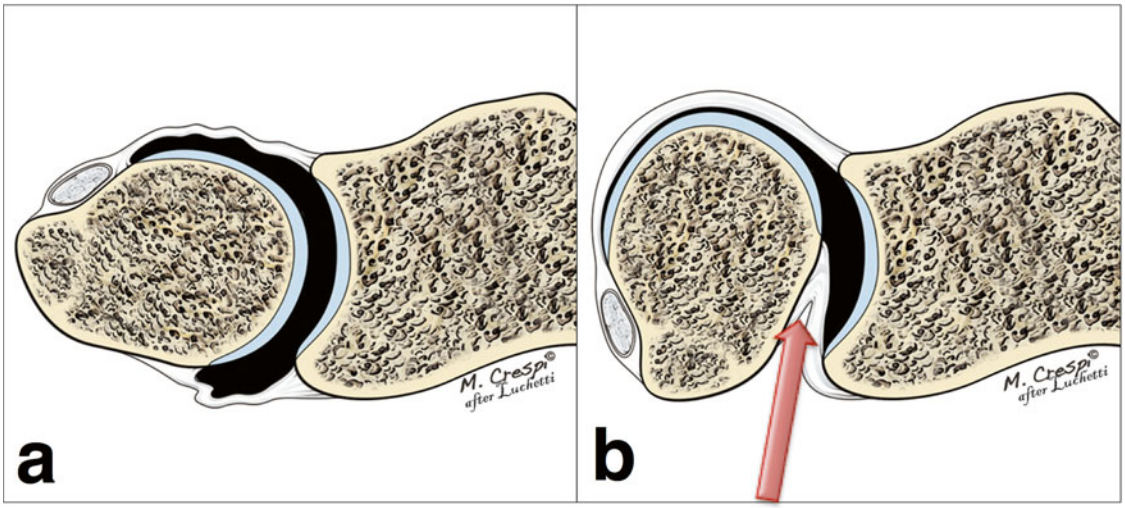


Fig. 1.33 Transverse drawing of the DRUJ in neutral rotation (**a**) and supination (**b**). Due to the osseous morphology of the ulnar head it becomes evident that introduction of the scope through a dorsal portal into the DRUJ (*red arrow*) is easier when the wrist is fully supinated (**b**)

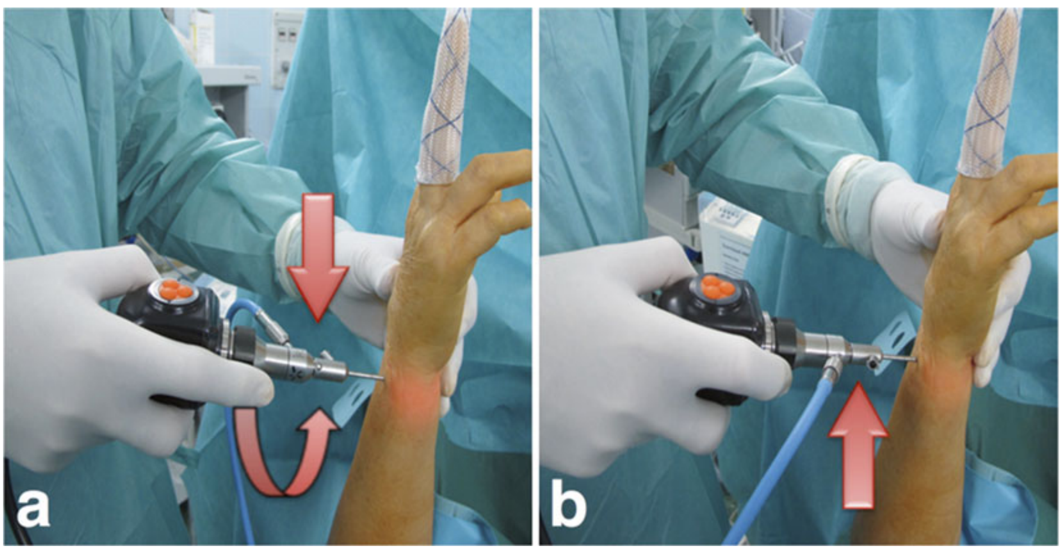


Fig. 1.34 Rotation of the scope for a better vision of the DRUJ (*red arrows*). The first position allows a better vision of the TFCC insertion (**a**); the second allows a better vision of the radial insertion of the TFCC and the sigmoid notch (**b**)

Proximal DRUJ Portal (P-DRUJ)

The P-DRUJ portal is situated 1 cm proximal to the distal DRUJ portal. It is located at the level of the proximal soft spot of the DRUJ, corresponding to the axilla of the joint, just proximal to the sigmoid notch of the radius and the flare of the ulnar metaphysis [64]. The portal is bordered radially by the EDQ tendon and the radial sigmoid notch, ulnarly by the ECU tendon and the neck of the ulna and distally by the TFCC. The structure most at risk is the EDQ tendon. The P-DRUJ portal is a very narrow portal. If preferred the joint can then be filled with saline but the capacity of distension of this articulation is limited. A small skin incision is made and the dorsal joint capsule is pierced with a blunt hemostat. A cannula with a blunt trocar is inserted, aiming slightly distally, then a 1.9 mm 30-degree wide-angle scope. On entry into the P-DRUJ we can first see the sigmoid notch of the radius and the articular surface of the neck of the ulna (Fig. 1.37). Systematically the following structures are inspected:

- *Proximal*: the palmar aspect of the capsule of the DRUJ can be visualized.
- *Distal*: the articular surface of the ulnar head can be seen on the ulnar side and the junction of the TFCC to the sigmoid notch of the radius is visible.

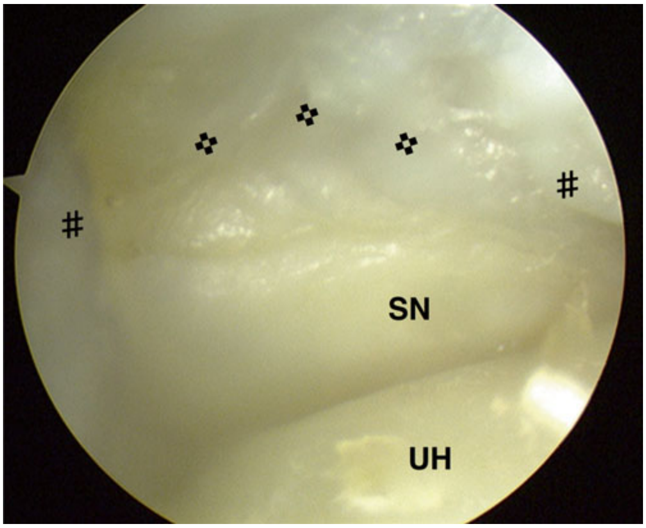


Fig. 1.35 Arthroscopic exploration of the DRUJ through the D-DRUJ portal. *SN* sigmoid notch, *UH* ulnar head, (❖): central insertion of the TFCC, (♯): radial insertion of the volar and dorsal branches of the TFCC

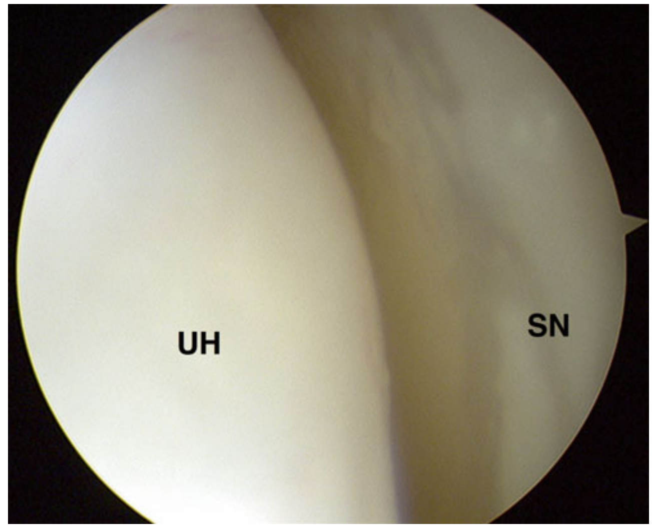


Fig. 1.37 Arthroscopic exploration of the DRUJ from the P-DRUJ portal. *UH* ulna head, *SN* sigmoid notch

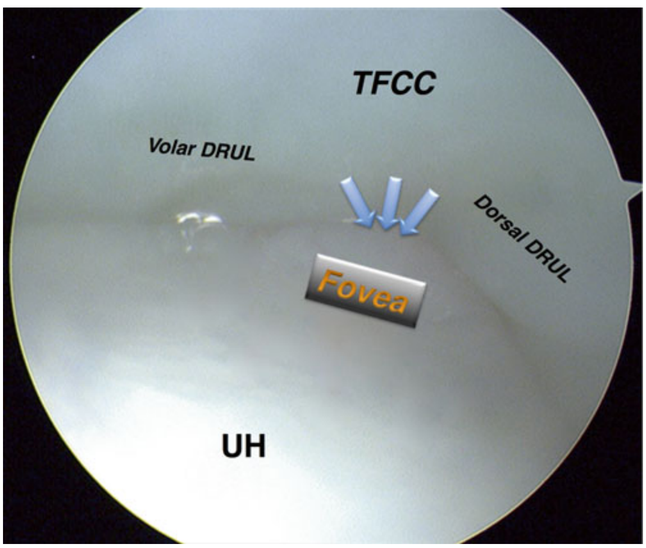


Fig. 1.36 Arthroscopic view of the undersurface of the TFCC with its volar and dorsal DRUL, merging at the insertion at the fovea (*blue arrows*)

- *Volar*: the volar capsule of the DRUJ can be seen and the course of the volar radioulnar ligament. The origin of the volar ulnocarpal ligaments more distally is difficult to see.
- *Radial*: the sigmoid notch of the radius can be inspected by rotating the arthroscope radially.
- *Ulnar*: the articular surface of the neck of the ulna can be visualized by turning the scope to the ulnar side.

Volar Distal Radioulnar Portal (V-DRUJ)

Two ways of establishing the V-DRUJ exist. The initial description of establishing the V-DRUJ portal uses the same landmarks as those of the VU portal (Figs. 1.7b and 1.15b, e) [39]. After the skin incision is made, the common flexor tendons retracted radially and the FCU tendon with the ulnar neurovascular bundle retracted ulnarly, the joint capsule is entered approximately 5–10 mm proximal to the entry to the VU radiocarpal portal. The DRUJ joint is located with a 22-G needle and the joint capsule pierced with a blunt artery forceps followed by insertion of a cannula and a blunt trocar, then the arthroscope. Our preferred method for creating the V-DRUJ portal uses a similar technique as described above for the establishment of the volar radial radiocarpal joint (Fig. 1.38). In our experience the ulnar neurovascular bundle has never been damaged performing this technique. For the introduction of the arthroscope through the V-DRUJ portal a switching rod can be used.

From a volar approach the course of the dorsal radioulnar ligament can be followed, which is not possible from the dorsal DRUJ portals, until it merges with the volar radioulnar ligament and inserts at the fovea. With the instruments placed through one of the dorsal DRUJ portals, arthroscopic procedures as the wafer partial ulnar head resection can be performed directly under the TFCC instead of through its lesion from above.

Direct Foveal Portal (DF)

The direct foveal (DF) portal as described by Atzei et al. [66], is located approximately 1 cm proximal to the 6-U portal (Figs. 1.15b, 1.16e, 1.39). For establishment of the DF portal the forearm is held in full supination. That way the portal is bounded by the ulnar styloid and the ECU tendon dorsally, the flexor carpi ulnaris (FCU) tendon volarly, the ulnar head proximally and the TFCC distally. The DBUN is at risk and is usually displaced dorsally to the portal if the

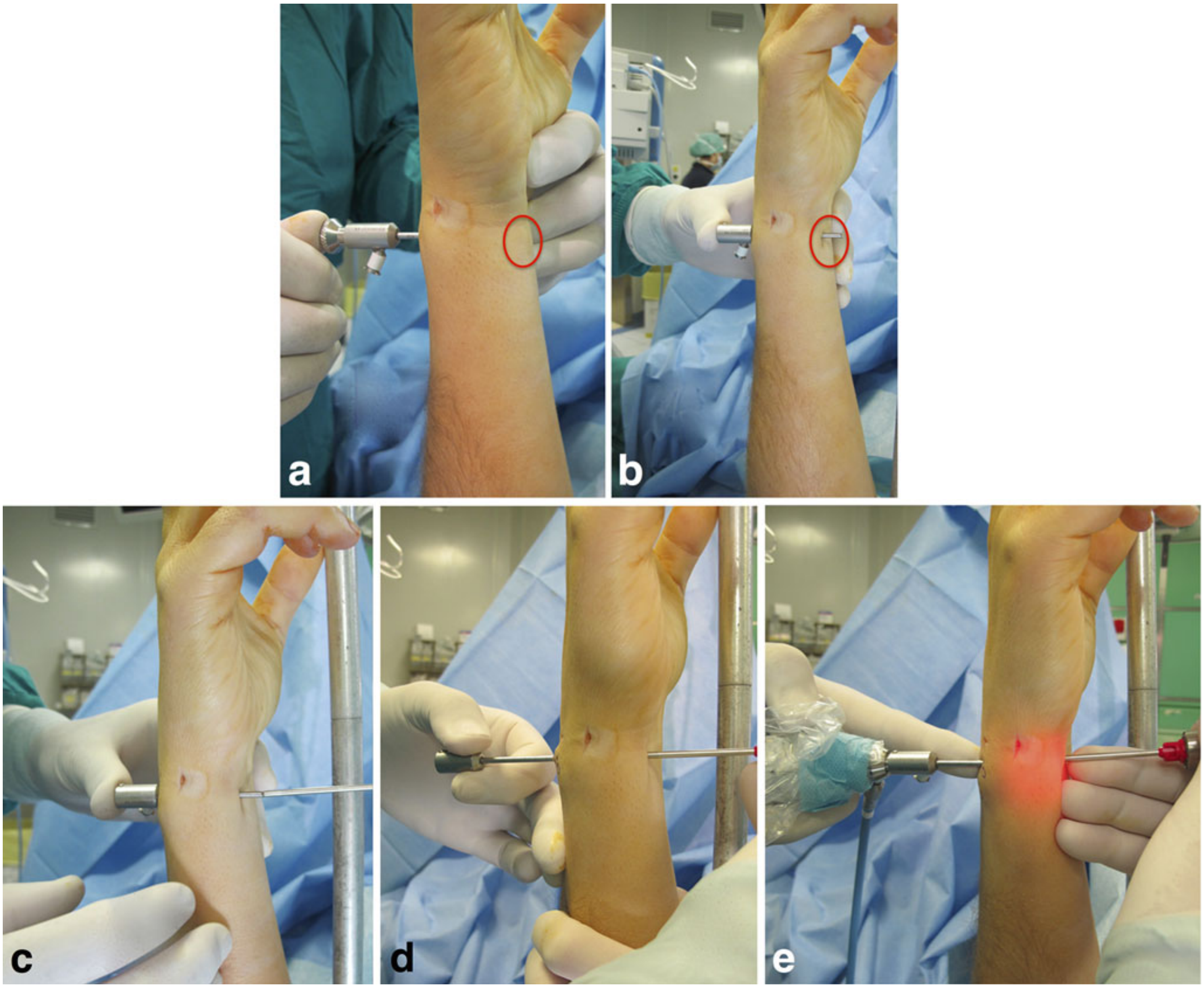
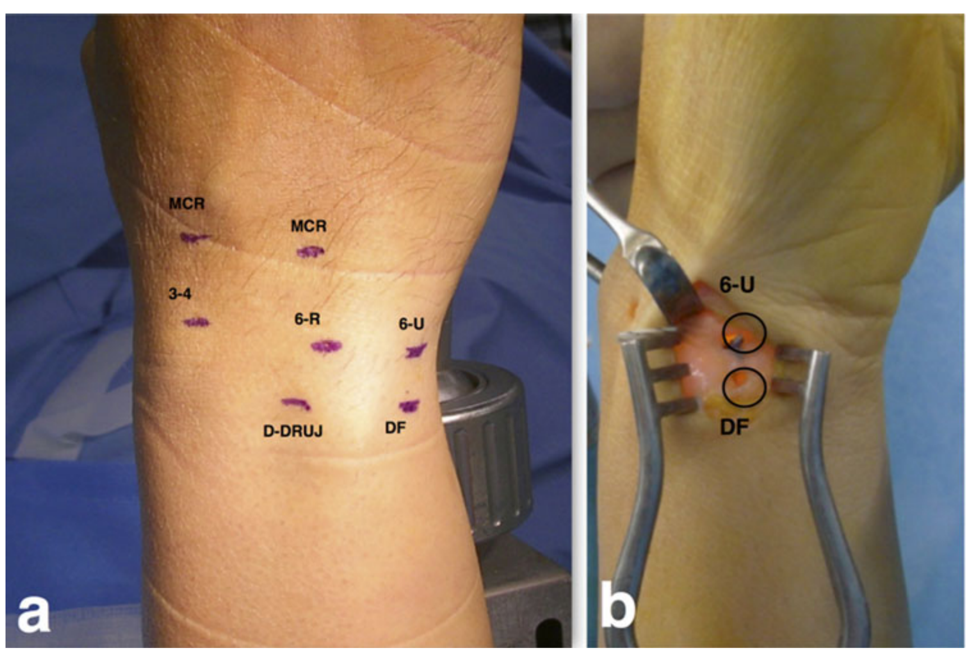


Fig. 1.38 Technical procedure to establish the volar DRUJ portal: A blunt trocar perforates the volar capsule and is pushed through the volar skin after a small skin incision is made (*red circle*) (**a** and **b**). The trocar is then used as a guide for the introduction of the shaver into the DRUJ, the trocar is pulled backwards and the shaver advanced into the DRUJ through the volar DRUJ portal (**c** and **d**). Handling of the arthroscope and shaver. The Surgeon should stay at the ulnar side of the wrist (**e**)

Fig. 1.39 Anatomic location of the DF portal (**a**). The DF portal is located 1 cm proximal to the 6-U portal and a skin incision can connect those two portals while leaving the retinaculum and capsule intact (**b**)



forearm is held in supination (Fig. 1.16e). A 22-G needle is inserted percutaneously just underneath the TFCC to verify the correct position. Then a small longitudinal skin incision is made between the ECU and FCU tendon. Next the extensor retinaculum is exposed and split along its fibers. The DRUJ capsule is incised longitudinally to reach the distal articular surface of the ulnar head under the TFCC.

When the surgeon is more experienced with establishing this portal and familiar with the anatomy, the DF portal can be created using the standard portal establishing technique without any clinically relevant disturbance to the DBUN.

The DF portal is used as a dedicated working portal for fixation of the TFCC to the ulnar fovea in proximal TFCC lesions. Small shavers or curettes are used to debride the torn or avulsed ligament back to healthy tissue, debride the fovea and prepare it for suture screw or anchor insertion while the arthroscope is in the distal DRUJ portal.

Conclusion

Wrist arthroscopy is a reasonable recently introduced technique but has continued to evolve rapidly. In its beginnings wrist arthroscopy was primarily used for diagnostic purposes. The introduction of smaller optics and miniaturized instruments however has allowed the development of more arthroscopically sophisticated surgical interventions. Nowadays it is impossible to ignore the impact of therapeutic wrist arthroscopy that limits the iatrogenic effect of open wrist procedures, e.g., as creating intra-articular fibrosis. It has been proved more reliable in assessing many wrist pathologies than even sophisticated MRI images. Step by step and adapting to the surgical needs, the portals for wrist arthroscopy have been developed. Starting with the four classic standard portals (3-4 radiocarpal, 4-5 radiocarpal, radial midcarpal and ulnar midcarpal), an increasingly number of new portals as well as volar portals have been established and proved to be safe. However, the learning curve takes its time and precise knowledge of the anatomy and the pathologies of the wrist is crucial in order to limit the risk of complications or true diagnostic or therapeutic failures. Earlier teaching of wrist arthroscopy has been performed under simple observing conditions. Nowadays the teaching is much more structured and numerous instructional courses are offered, allowing to study wrist arthroscopy and the handling of the arthroscope and instruments in cadavers. The European Wrist Arthroscopy Society (EWAS, www.wristarthroscopy.eu) has developed specific courses on fresh cadavers for a couple of years. Practicing on cadavers and examining the wrist joint from different portals and viewing angles helps in understanding the three-dimensional anatomy of the wrist. Once normal arthroscopic wrist anatomy is clear, pathologic problems can be more readily identified and treated. It is without doubt that the creativity of the surgeon and the introduction of adapted miniaturized instruments will allow for realization of precise performance and continuous development of more and more sophisticated arthroscopic techniques.

References

1. Ekman EF, Poehling GG. Principles of arthroscopy and wrist arthroscopic equipment. Hand Clin. 1994;10:557–66.
2. Chen YC. Arthroscopy of the wrist and finger joints. Orthop Clin North Am. 1979;10:723–33.
3. Fontès D. Wrist arthroscopy current indications and results. Chir Main. 2004;23:270–83. French.
4. Mathoulin C, Levadoux M, Martinache X. Intérêt thérapeutique de l'arthroscopie du poignet: à propos de 1000 cas. E-mémoires de l'Académie Nationale de Chirurgie. 2005;4:42–57. French.
5. Wolf JM, Dukas A, Pensak M. Advances in wrist arthroscopy. J Am Acad Orthop Surg. 2012;20:725–34.
6. Harley BJ, Werner FW, Boles SD, Palmer AK. Arthroscopic resection of arthrosis of the proximal hamate: a clinical and biomechanical study. J Hand Surg Am. 2004;29:661–7.
7. Doi K, Hattori Y, Otsuka K, Abe Y, Yamamoto H. Intra-articular fractures of the distal aspect of the radius: arthroscopically assisted reduction compared with open reduction and internal fixation. J Bone Joint Surg Am. 1999;81:1093–110.
8. Geissler WB. Arthroscopically assisted reduction of intra-articular fractures of the distal radius. Hand Clin. 1995;11:19–29.
9. Geissler WB, Freeland AE. Arthroscopically assisted reduction of intraarticular distal radial fractures. Clin Orthop Relat Res. 1996;327:125–34.
10. Lindau T. Wrist arthroscopy in distal radial fractures using a modified horizontal technique. Arthroscopy. 2001;17:E5.
11. Shih JT, Lee HM, Hou YT, Tan CM. Arthroscopically-assisted reduction of intra-articular fractures and soft tissue management of distal radius. Hand Surg. 2001;6:127–35.
12. Trumble TE, Culp RW, Hanel DP, Geissler WB, Berger RA. Intra-articular fractures of the distal aspect of the radius. Instr Course Lect. 1999;48:465–80.
13. Whipple TL. The role of arthroscopy in the treatment of intra-articular wrist fractures. Hand Clin. 1995;11:13–8.
14. Shih JT, Lee HM, Hou YT, Tan CM. Results of arthroscopic reduction and percutaneous fixation for acute displaced scaphoid fractures. Arthroscopy. 2005;21:620–6.
15. Wong WY, Ho PC. Minimal invasive management of scaphoid fractures: from fresh to nonunion. Hand Clin. 2011;27:291–307.
16. del Piñal F, García-Bernal FJ, Delgado J, Sanmartín M, Regalado J, Cerezal L. Correction of malunited intra-articular distal radius fractures with an inside-out osteotomy technique. J Hand Surg Am. 2006;31:1029–34.
17. del Piñal F, Cagigal L, García-Bernal FJ, Studer A, Regalado J, Thams C. Arthroscopically guided osteotomy for management of intra-articular distal radius malunions. J Hand Surg Am. 2010;35:392–7.
18. Luchetti R, Atzei A, Fairplay T. Arthroscopic wrist arthrolysis after wrist fracture. Arthroscopy. 2007;23:255–60.
19. Bain GI, Smith ML, Watts AC. Arthroscopic core decompression of the lunate in early stage Kienbock disease of the lunate. Tech Hand Up Extrem Surg. 2011;15:66–9.
20. Weiss ND, Molina RA, Gwin S. Arthroscopic proximal row carpectomy. J Hand Surg Am. 2011;36:577–82.
21. Ho PC. Arthroscopic partial wrist fusion. Tech Hand Up Extrem Surg. 2008;12:242–65.

22. Buterbaugh GA. Radiocarpal arthroscopy portals and normal anatomy. Hand Clin. 1994;10:567–76.
23. Huracek J, Troeger H. Wrist arthroscopy without distraction. A technique to visualise instability of the wrist after a ligamentous tear. J Bone Joint Surg Br. 2000;82:1011–2.
24. Bain GI, Munt J, Turner PC. New advances in wrist arthroscopy. Arthroscopy. 2008;24:355–67.
25. Lee JI, Nha KW, Lee GY, Kim BH, Kim JW, Park JW. Long-term outcomes of arthroscopic debridement and thermal shrinkage for isolated partial intercarpal ligament tears. Orthopedics. 2012;35:e1204–9.
26. Sotereanos DG, Darlis NA, Kokkalis ZT, Zanaros G, Altman GT, Miller MC. Effects of radiofrequency probe application on irrigation fluid temperature in the wrist joint. J Hand Surg Am. 2009;34:1832–7.
27. Botte MJ, Cooney WP, Linscheid RL. Arthroscopy of the wrist: anatomy and technique. J Hand Surg Am. 1989;14:313–6.
28. Geissler WB, Freeland AE, Weiss APC, Chow JC. Techniques of wrist arthroscopy. J Bone Joint Surg Am. 1999;81:1184–97.
29. Geissler WB. Intra-articular distal radius fractures: the role of arthroscopy? Hand Clin. 2005;21:407–16.
30. del Piñal F, García-Bernal FJ, Pisani D, Regalado J, Ayala H, Studer A. Dry arthroscopy of the wrist: surgical technique. J Hand Surg Am. 2007;32:119–23.
31. DeAraujo W, Poehling GG, Kuzma GR. New Tuohy needle technique for triangular fibrocartilage complex repair: preliminary studies. Arthroscopy. 1996;12:699–703.
32. Geissler WB. Arthroscopic knotless peripheral ulnar-sided TFCC repair. Hand Clin. 2011;27:273–9.
33. Atzei A, Luchetti R, Sgarbossa A, Carità E, Llusà M. Set-up, portals and normal exploration in wrist arthroscopy. Chir Main. 2006;25 Suppl 1:S131–44. French.
34. Abrams RA, Petersen M, Botte MJ. Arthroscopic portals of the wrist: an anatomic study. J Hand Surg Am. 1994;19:940–4.
35. Grechening W, Peicha G, Fellinger M, Seibert FJ, Weiglein AH. Anatomical and safety considerations in establishing portals used for wrist arthroscopy. Clin Anat. 1999;12:179–85.
36. Tryfonidis M, Charalambous CP, Jass GK, Jacob S, Hayton MJ, Stanley JK. Anatomic relation of dorsal wrist arthroscopy portals and superficial nerves: a cadaveric study. Arthroscopy. 2009;25:1387–90.
37. Atzei A, Luchetti R. Clinical approach to the painful wrist. In: Geissler WB, editor. Wrist arthroscopy. New York: Springer; 2005. p. 185–95.
38. Lawler EA, Adams BD. Arthroscopy of the distal radioulnar joint. In: Slutsky D, Nagle D, editors. Techniques in wrist and hand arthroscopy. Philadelphia: Churchill Livingstone Elsevier; 2007. p. 54–7.
39. Slutsky DJ. Distal radioulnar joint arthroscopy and the volar ulnar portal. Tech Hand Up Extrem Surg. 2007;11:38–44.
40. Berger RA. Arthroscopic anatomy of the wrist and distal radioulnar joint. Hand Clin. 1999;15:393–413.
41. Whipple TL, Marotta JJ, Powell 3rd JH. Techniques of wrist arthroscopy. Arthroscopy. 1986;2:244–52.
42. Levy HJ, Glickel SZ. Arthroscopic assisted internal fixation of volar intraarticular wrist fractures. Arthroscopy. 1993;9:122–4.
43. Tham S, Coleman S, Gilpin D. An anterior portal for wrist arthroscopy. Anatomical study and case reports. J Hand Surg Br. 1999;24:445–7.
44. Abe Y, Doi K, Hattori Y, Ikeda K, Dhawan V. A benefit of the volar approach for wrist arthroscopy. Arthroscopy. 2003;19:440–5.
45. Slutsky DJ. Wrist arthroscopy through a volar radial portal. Arthroscopy. 2002;18:624–30.
46. Slutsky DJ. The use of a volar ulnar portal in wrist arthroscopy. Arthroscopy. 2004;20:158–63.
47. Slutsky DJ. Clinical applications of volar portals in wrist arthroscopy. Tech Hand Up Extrem Surg. 2004;8:229–38.
48. Van Meir N, Degreef I, De Smet L. The volar portal in wrist arthroscopy. Acta Orthop Belg. 2011;77:290–3.
49. Mackinnon SE, Dellon AL. The overlap pattern of the lateral antebrachial cutaneous nerve and the superficial branch of the radial nerve. J Hand Surg Am. 1985;10:522–6.
50. Berger RA, Kauer JM, Landsmeer JM. Radioscapholunate ligament: a gross anatomic and histologic study of fetal and adult wrists. J Hand Surg Am. 1991;16:350–5.
51. Berger RA. The gross and histologic anatomy of the scapholunate interosseous ligament. J Hand Surg Am. 1996;21(2):170–8.
52. Nakamura T, Makita A. The proximal ligamentous component of the triangular fibrocartilage complex. J Hand Surg Br. 2000;25: 479–86.
53. Zahiri H, Zahiri CA, Ravari FK. Ulnar styloid impingement syndrome. Int Orthop. 2010;34:1233–7.
54. Arya AP, Kulshreshtha R, Kakarala GK, Singh R, Compson JP. Visualisation of the pisotriquetral joint through standard portals for arthroscopy of the wrist: a clinical and anatomical study. J Bone Joint Surg Br. 2007;89:202–5.
55. Ehlinger M, Rapp E, Cognet JM, Clavert P, Bonnomet F, Kahn JL, Kempf JF. Transverse radioulnar branch of the dorsal ulnar nerve: anatomic description and arthroscopic implications from 45 cadaveric dissections. Rev Chir Orthop Reparatrice Appar Mot. 2005; 91:208–14.
56. Luchetti R, Atzei A, Rocchi L. Incidence and causes of failures in wrist arthroscopic techniques. Chir Main. 2006;25:48–53. French.
57. Lee JH, Taylor NL, Beekman RA, Rosenwasser MP. Arthroscopic wrist anatomy. In: Geissler WB, editor. Wrist arthroscopy. New York: Springer; 2005. p. 7–14.
58. Ritt MJ, Bishop AT, Berger RA, Linscheid RL, Berglund LJ, An KN. Lunotriquetral ligament properties: a comparison of three anatomic subregions. J Hand Surg Am. 1998;23:425–31.
59. Carro LP, Golano P, Fariñas O, Cerezal L, Hidalgo C. The radial portal for scaphotrapeziotrapezoid arthroscopy. Arthroscopy. 2003;19:547–53.
60. Viegas SF. Midcarpal arthroscopy: anatomy and portals. Hand Clin. 1994;10:577–87.
61. Bettinger PC, Cooney III WP, Berger RA. Arthroscopic anatomy of the wrist. Orthop Clin North Am. 1995;26:707–19.
62. Viegas SF, Wagner K, Patterson R, Peterson P. Medial (hamate) facet of the lunate. J Hand Surg Am. 1990;15:564–71.
63. Garcia-Elias M, An KN, Cooney III WP, Linscheid RL, Chao EY. Stability of the transverse carpal arch: an experimental study. J Hand Surg Am. 1989;14:277–82.
64. Whipple TL. Arthroscopy of the distal radioulnar joint. Indications, portals, and anatomy. Hand Clin. 1994;10:589–92.
65. Bowers WHWT. Arthrosopic anatomy of the wrist. In: McGinty J, editor. Operative arthroscopy. New York: Raven Press; 1991. p. 613–23.
66. Atzei A, Rizzo A, Luchetti R, Fairplay T. Arthroscopic foveal repair of triangular fibrocartilage complex peripheral lesion with distal radioulnar joint instability. Tech Hand Up Extrem Surg. 2008; 12:226–35.

2 Evaluation of the Painful Wrist

Enrique Pereira

Introduction

The human wrist connects the forearm to the hand. Under healthy conditions, the wrist is capable of precise hand positioning in space due to a wide range of motion (flexion/extension, pronation/supination, and radio/ulnar deviation). Such freedom of wrist movement and position is necessary to perform highly complex and delicate movements of the thumb and fingers.

Following the notion that *function follows anatomy*, wrist's ample range of motion is the product of the complex interplay of a sophisticated arrangement of bony and ligamentous structures added to normal function of the five carpal joints (radioulnar, the radiocarpal, midcarpal, intercarpal, and carpometacarpal joints) [1, 2].

After evaluating 52 standardized tasks of activities of daily living, Palmer et al. [3] showed that the wrist *normal functional range of motion* allows 5° of flexion, 30° of extension, 10° of radial deviation, and 15° of ulnar deviation. On the other hand, according to the *ideal range of motion* for activities of daily living described by Ryu et al. [4] the wrist should reach 54° of flexion, 60° of extension, 17° of radial deviation and 40° of ulnar deviation.

The presence of wrist pain may lead to functional impairment of the entire upper extremity, and thus, greatly impacting the patient's quality of life. In view of the fact that there is a wide range of etiologies for wrist pain, the treating physician should keep a high index of suspicion during patient's history and physical examination. Collected findings during patient examination (along with auxiliary studies) are intended to generate the most likely diagnosis. As expected, further comprehension of the underlying anatomic abnormalities is pivotal for a precise diagnosis.

A brief discussion of some core anatomic concepts of the wrist is necessary though before addressing patient assessment. Considering that there are no muscles or tendons attached to the carpus, the stability of each carpal bone is only dependent on bone surface anatomy and ligament attachments.

There are two main ligament systems in the wrist:

1. Extrinsic system capsular (extraarticular) ligaments that extend from the radius or metacarpals to the carpal bones.
2. Intrinsic system: interosseous (intraarticular) ligaments that take origin from and insert on adjacent carpal bones.

The triangular fibrocartilage complex (TFCC) attaches the distal radius, the lunate, and the triquetrum to the distal ulna. This complex along with the bony architecture provides the stability for the distal radio ulnar joint (DRUJ). The vascular pattern and nerve distribution of the pain together with their pathophysiological correlation remain essential when facing a painful wrist. This complexity of the carpus and our incomplete understanding of carpal kinematics makes diagnosis of a painful wrist very difficult.

History

Obtaining a detailed history often helps narrow the differential diagnosis over a number of potential etiologies. Determining the diagnosis is usually a challenge in patients with wrist pain, to some extent due to the large number of structures found in the human wrist (bone, soft tissues, and extra-articular and intra-articular etiologies) as well as their complex biomechanical characteristics (Table 2.1). During the first step in history taking, the patient should be able to express any detail that judges related to the his/her symptomatoly. This step creates sympathy towards the patient and a suitable environment during the clinical encounter and enhances patient's compliance for future diagnostic and therapeutic steps. After that, the physician should direct the history in orderly sequence, collecting facts that have the greatest clinical relevance like pain characteristics, the presence of other symptoms and predisposing factors.

E. Pereira, M.D. (✉)
Department of Hand Surgery, Penta Institute of Traumatology and Rehabilitation, Ladislao Martinez 256 1° A, Martinez 1640, Buenos Aires, Argentina
e-mail: enriqueepereira@gmail.com

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*,
DOI 10.1007/978-1-4614-1596-1_2, © Springer Science+Business Media New York 2015

Table 2.1 Most common traumatic and atraumatic etiologies of wrist pain

Wrist pain: outline of most frequent etiologies
• *Bone* Fractures (distal radius, scaphoid, triquetral, hook of the hamate) Malunions (distal radius, scaphoid) Nonunions (scaphoid, hook of the hamate, ulnar styloid) Impingement (radiocarpal, ulnocarpal / stylocarpal impaction syndrome) Osteonecrosis (Kienböck disease, Preiser disease)
• *Joint* Synovitis Loose Bodies Chondral lesions Posttraumatic arthritis Degenerative arthritis (radiocarpal, radioulnar, midcarpal, intercarpal) Crystal arthritis (gout, pseudogout, lupus) Inflammatory arthritis (rheumatoid arthritis, psoriatic arthritis, Reiter's syndrome)
• *Ligament* Ligament tear/rupture (TFCC, SLIL, LTIL) Instability (scapholunate, lunotriquetral, DRUJ, midcarpal, capitolunate, pisotriquetral, STT)
• *Tendon* Tendonitis and tenosynovitis (De Quervain's) Tendon tear/subluxation (ECU) Tendon rupture
• *Nerve* Trauma/neuroma (superficial branch of radial or ulnar nerve) Compression (carpal tunnel syndrome, Wartenberg syndrome, Guyon's canal) Peripheral neuropathy (diabetes mellitus)
• *Vascular* Arterial occlusion Hypothenar hammer syndrome
• *Tumor* Soft Tissue (ganglion cyst, giant cell tumor, fibroma, synovial cell hemangioma) Bone tumors (primary, metastatic)
• *Infection* Bacterial arthritis (staphylococco, steptococco, Lyme disease, tuberculosis, gonorrhea) Viral arthritis
• *Other* Complex regional pain syndrome (CRPS)

TFCC Triangular Fibrocartilage Complex, *SLIL* Scapholunate Interosseous ligament, *LTIL* Lunotriquetral Interosseous ligament, *DRUJ* distal radio ulnar joint, *STT* Scaphotrapeziotrapezoid joint, *ECU* extensor carpi ulnaris

Pain

Several pain features are worth recording such as its quality (cramping, dull, aching, sharp, shooting, severe, or diffuse), frequency, duration, intensity, radiation, and movements in conjunction with the activities that may elicit pain. Nerve injury usually manifests as a sharp pain associated to a burning sensation. On the other hand, a deep, constant, boring pain mostly accompanies bone fractures. Pain from a ligamentous injury is often intermittent and elicited upon activity. In addition, location of symptoms can help guide diagnosis. The presence of localized pain may point towards ligamentous disruption, whereas nerve compression (due to carpal tunnel syndrome) is frequently associated with a more diffuse discomfort.

Predisposing Factors

Trauma

The patient should describe thoroughly any recent trauma, as its mechanism of injury may give up the diagnosis. For instance, a fall onto an outstretched hand during practice of contact sports is a common mechanism for fractures of the distal radius or scaphoid, whereas a direct palmar trauma from swinging a baseball bat or golf club could lead to a fracture of the hook of the hamate. Ligament tears may also occur, mainly at the TFCC, scapholunate and/or lunotriquetral ligaments. Depending on the kinetic energy of the trauma, these ligament injuries could either be partial or complete, isolated or associated with either distal radius fractures or scaphoid fractures. TFCC tears (with or without DRUJ instability) are often seen in gymnastic and racquet sports and may mimic extensor carpi ulnaris (ECU) pathology.

At times, trauma kinetics of a given wrist lesion remains elusive. In these situations, symptom duration may provide a temporal clue related to a vague history of trauma, while the patient refers spontaneous onset of the pain. Sometimes, the examiner faces such challenging scenario in patients with carpal bone nonunion or avascular necrosis, in whom symptoms may manifest several years after the index injury because of ongoing inflammation, leading to arthritis, swelling, pain, and loss of grip strength. The scaphoid is particularly prone to developing nonunions [5]. The latter is due to its vulnerable blood supply that can lead to complete vascular interruption of a bone fragment following wrist trauma. Idiopathic avascular necrosis generally occurs either at the lunate (Kienböck's disease) or at the scaphoid (Preiser's disease).

Patient Occupation or Recreational Activities

Several leisure or labor activities can affect wrist function. For example, long-standing history of typing that involves repetitive motion can trigger wrist pain, while knitting or sewing may lead to compressive neuropathy. Activities requiring forceful grasping with ulnar deviation or repetitive use of the thumb (e.g., caring for a newborn infant) can lead to De Quervain's tenosynovitis with pain and swelling along the first extensor compartment.

Specific details regarding sport activities can be very informative about the mechanism of injury: repetitive stress versus blunt trauma. Contact sports, such as American football or rugby, may lead to blunt trauma, while noncontact sports, such as golf, tennis, field hockey involve repetitive stress of the wrist.

The presence of a painful clunking on the ulnar side of the wrist during activities that involve active ulnar deviation indicates midcarpal instability. In patients with symptoms at the ulnar side of the wrist, the examiner should to rule out DRUJ arthritis, ulnocarpal or stylocarpal impaction syndrome.

Medical History

While obtaining a thorough complete medical history, the physician should exclude the presence of systemic inflammatory disorders (lupus, rheumatoid arthritis, and degenerative arthritis), metabolic diseases (diabetes, gout, and hypothyroidism) in addition to previous surgeries. Pregnancy, hypothyroidism, and diabetes are predisposing risk factors for carpal tunnel syndrome. Rheumatoid arthritis has a tendency to involve the wrist while gouty arthritis and pseudo gout can involve the wrist joint, although more commonly they affect the lower extremities.

Patients with septic arthritis typically present with a history of constitutional symptoms or a recent infection and a poorly moveable wrist owing to severe, deep, and unrelenting pain.

Patient's age and sex should also be considered. As example, younger patients are prone to posttraumatic carpal injuries and occult ganglion cysts, whereas older patients are susceptible to systemic diseases and degenerative processes.

Physical Examination

The physician should perform a methodical physical examination, starting with a comprehensive visual inspection of the upper extremity.

Noticeable swelling, ecchymosis, or skin changes at the level wrist can provide major clues to comprehend the mechanism of injury. Gross deformity of the wrist generally indicates an obvious pathologic process that could be due to previous fracture, dislocation, or from soft tissue and/or joint swelling. A malunited distal radius fracture is often the cause of this deformity, presenting radial deviation of the wrist, and the carpus palmary displaced on the radius. Such misalignment of the distal radius may lead to extrinsic carpal instability and wrist pain. Disruption of the distal radioulnar joint can also produce wrist deformity.

Following inspection, the physician should proceed by palpating the nonpainful areas of the wrist first and then continue to areas of maximal tenderness. This sequence is crucial because once pain/discomfort is elicited, the patient may become apprehensive, preventing further palpation. Anatomical knowledge, especially surface anatomy, can be of great help during wrist exam.

All wrist structures should be palpated and compare with the contralateral side. A systematic circumferential palpation of the wrist is performed according to patient's history and degree of pain [6]. We routinely start on the dorso-radial corner and progress to the dorso-ulnar side and then to the palmar surface. The site of pain and tenderness suggests the presence of pathology of underlying structures; however, we should take into account the intricate three-dimensional features of the wrist structures (Table 2.2).

Subsequently, active and passive range of motion of the wrist along with grip strength should be tested and compared to the contralateral wrist. [7, 8] As a rule, we measure flexion, extension, radial deviation, ulnar deviation, pronation, and supination with a goniometer. Differences in the range of motion among wrists in addition to the presence of pain at extreme range of motion will carry significant information to narrow the differential diagnosis. Assessing neurovascular status is also important, with special focus on the integrity of the median, radial and ulnar nerves, and dual-hand circulation (Allen test).

Routine palpation may not suffice to reproduce patient's symptoms; therefore, it is often necessary to perform provocative tests to locate the specific anatomic structure(s) that is originating pain. These provocative tests apply an external force that is directed to stress specific anatomic structures, which in turn would provoke an expected clinical response. A positive test correlates closely with a specific wrist pathologic diagnosis. Although the specificity of these maneuvers is not always high, the combination of a positive finding during a provocative maneuver with the remainder of the patient's clinical data (history, rest of the exam, and noninvasive imaging) almost always reach a conclusive diagnosis.

Provocative Tests

- Scaphoid Shift Test [5]: provides a qualitative assessment of scapholunate stability and periscaphoid synovitits compare to the contralateral asymptomatic wrist.
- Basically, the test is intended to induce dorsal sublixation of the proximal pole of the scaphoid over the dorsal rim of the radius as the wrist is radially deviated.

Table 2.2 Topographic palpation of the wrist

Region	Anatomic structure	Pathology
Dorso radial		
Snuffbox (distal)	STT	Carpometacarpal arthritis/ instability
		STT arthritis
Snuffbox (middle)	Floor of the snuffbox	Scaphoid fracture/nonunion
		Scaphoid Necrosis (Preiser's disease)
Snuffbox (proximal)	Radial styloid	Radial styloid fracture
		Radioscaphoid arthritis
First extensor compartment	APL/EPB	De Quervain tenosynovitis
		Intersection syndrome (proximal)
Dorso central		
3-4 dorsal recess	Lister tubercule	Dorsal synovitis
		SLIL instability
		Dorsal wrist ganglion
		Kiënbock disease
Dorso ulnar		
5-6 dorsal recess	LTIL	LTIL instability/arthritis
DRUJ space	DRUJ	DRUJ instability/arthritis
Ulnar head	ECU	ECU tendinosis/instability
Distal ulna	Ulnar styloid	Ulnocarpal/stylocarpal disorders
Midcarpal		Halt syndrome
Palmar ulnar		
FCU	FCU	FCU tendonitis
Distal ulna	Ulnar styloid	TFCC tears
Pisiform	Pisotriquetral joint	Pisotriquetral arthritis/instability
Hypotehnar eminence	Hook of the hamate	Fracture of the hook hamate
	Guyon's canal	Ulnar tunnel syndrome
Palmar central	Median nerve	Median nerve inflammation/ entrapment
Palmar radial	Palmaris longus	Palmaris longus tendonitis
	Scaphoid tubercule	Scaphoid fracture (distal pole)

APL abductor pollicis longus, *APB* abductor pollicis brevis, *EPB* extensor pollicis brevis, *FCU* flexor carpi ulnaris

- This maneuver is done by grabbing the patient's hand from its ulnar aspect and placing the physician's thumb on the palmar surface of the distal pole of the scaphoid.
- By moving the wrist from ulnar to radial deviation, the examiner exerts pressure to the distal pole of the scaphoid, which prevents the scaphoid from flexing normally.
- In patients with ligamentous laxity or instability, the combined stress of thumb pressure and normal motion of the adjacent carpus may induce the scaphoid to pop out of its fossa and up onto the dorsal rim of the radius. By diminishing the pressure exerted in the thumb, the scaphoid usually returns to its normal position. The presence of pain associated with unilateral hypermobility of the scaphoid is virtually diagnostic of scapholunate instability.
- Pisotriquetral Shear Test: offers a qualitative evaluation of the pisotriquetral joint. The examiner's thumb is placed over the pisiform and a dorsal directed pressure is applied along with a circular grinding motion over the triquetrum. Pain elicited by the maneuver is consistent with joint instability and/or degenerative. It is central to perform this test before assessing the lunotriquetral joint, to avoid pain overlapping.
- Lunotriquetral Compression Test [7]: evaluates the integrity of the lunotriquetral ligament. As its overall diagnostic accuracy is considered superior to other lunotriquetral tests, the compression test represents our current first choice. By supporting the wrist and pushing the triquetrum from an ulnar to a radial direction against the lunate, the test is considered positive if elicits pain. A positive test may indicate lunotriquetral ligament tear or instability.
- Lunotriquetral Ballottement Test [9]: detects lunotriquetral ligament injuries. While holding the lunate with the thumb and the index of one hand the triquetrum and pisiform are simultaneously displaced dorsally and palmary with the thumb and index of the other hand. Pain and excessive displaceability of the joint will suggest lunotriquetral ligament tear.
- Ulnocarpal Stress Test [10]: is considered as a screening test for intra-articular ulnocarpal disorders. The test is performed by applying axial stress to the wrist during passive supination-pronation with the wrist in maximum ulnar deviation.
- Piano-key Test [11]: examines the stability of the distal radioulnar joint and often reveals instability that cannot be detected even by imaging studies. The piano-key sign is demonstrated by depressing the ulnar head over and under the distal sigmoid notch while supporting the wrist in pronation. The result of this maneuver will be positive whenever the ulnar head returns to its normal position after the applying force is removed from the distal ulna, simulating as a piano key springing up.
- TFCC Compression Test: helps identify TFCC lesions. Under axial loading and ulnar deviation of the wrist, the test is positive when elicit a painful response and reproduce patient symptoms.
- Ulnar Fovea Test: identifies foveal disruptions of the TFCC (also ulno triquetral ligament tears). The examiner pressed his/her thumb into the ulnar fovea, between the flexor carpi ulnaris tendon and ulnar styloid between the volar surface of the ulnar head and pisiform with the forearm in neutral rotation. The test is considered positive when reproduces the patient's symptoms. Clinically, TFCC disruptions can be differentiated from ulno triquetral ligament tears by assessing DRUJ stability, since in TFCC disruptions the DRUJ is unstable whereas ulno triquetral ligament tears have stable DRUJ.

Table 2.3 Radiographic examination of the wrist: complementary views

View	Area of interest/pathologic finding
PA with radial deviation	Lunotriquetral interval/lunotriquetral instability
PA with ulnar deviation	Scapholunate interval/scapholunate instability
PA clenched fist view	Scapholunate interval/scapholunate instability
Oblique view pronated 20°	Dorsal triquetrum avulsion
	Distal pole waist scaphoid fractures
	Fourth and fifth CMC joint fracture dislocation
Oblique view pronated 60°	Scaphoid fractures
Oblique view supinated 30°	Pisotriquetral joint status
	Hook of the hamate fractures
	Second and third CMC joint fracture dislocation
Carpal tunnel view	Trapezium, scaphoid tuberosity, capitate, hook of the hamate, triquetrum, and the entire pisiform

- Midcarpal shift test [12]: confirms midcarpal instability. In this maneuver, the examiner applies an axial load to the wrist while on pronation and mild flexion. In this setting, axial load generates radial to ulnar deviation. This maneuver normally reproduces a characteristic painful "clunk". This finding is based on the loss of the smooth transition from proximal row flexion to extension as the unit moves from radial to ulnar deviation. Based on how much resistance is necessary to maintain the wrist palmary subluxed while in ulnar deviation, wrists are classified into five grades of instability.
- Ice Cream Scoop test [13]: exacerbates extensor carpi ulnaris subluxation. The wrist is first positioned in full pronation, ulnar deviation, and extension, and then is slowly moved into supination while maintaining ulnar deviation against resistance with the other hand of the examiner ("as the ice cream is scooped"). The test is considered positive if symptoms are reproduced and snapping of the extensor carpi ulnaris tendon over the distal ulna is visualized, heard, or palpated.

Radiographic Evaluation

Initially, routine x-ray examination (posteroanterior, oblique, and lateral views) may suffice for the detection of gross wrist abnormalities. However, specialized x-rays views such as a scaphoid view (posteroanterior view in ulnar deviation), 45-degree semipronated oblique and a true lateral may result instrumental for the identification of more subtle problems. We should probably include these specialized x-rays views in the initial imaging assessment [14]. X-ray imaging provides significant information regarding bone integrity, structure, and alignment along with the joint space dimension and symmetry.

A specialized posteroanterior view with the elbow on 90° of flexion (at shoulder height) and the forearm in neutral position is convenient to define ulnar variance (plus, neutral, negative) and constitutes a suitable view to analyze breaks in Gilula's lines. The Gilula's lines represent the arcs formed by the proximal and distal articular surfaces of the proximal row of carpal bones and the proximal articular surfaces of the distal row of carpal bones. A wide carpal joint space or a break in Gilula's lines suggests carpal instability.

In the neutral posteroanterior view, the lunate remains in a trapezoidal shape. A true lateral must be done though (elbow adducted to the patient's side and the wrist in neutral rotation) to allow the pisiform locate between the palmar surface of the distal scaphoid tuberosity and the capitate head. This view is particularly helpful for assessing carpal alignment. Carpal alignment has historically been determined using specific distances and measuring various angles on PA and lateral x-ray views. Several angles (capitolunate, scapholunate, and radiolunate) and indexes (carpal height, capitate-radius, and ulnar translocation) have been used showing modest (at best) diagnostic accuracy. Nonetheless, a scapholunate angle greater than 60° suggests scapholunate instability, whereas a small angle (less than 30°) points towards ulnar-sided wrist instability. Other measures can confirm this diagnosis: a radioscaphoid angle greater than 60° and a radiolunate angle greater than 15°. In case of suspecting carpal collapse secondary to Kienböck's disease, carpal height can be compared with the length of the third metacarpal. Several specialized views are sometimes required to narrow the diagnosis. The most frequently used are listed in Table 2.3.

Computed Tomography

Computed tomography (CT) constitutes an excellent imaging modality to assess bone and articular lesions and well as bone healing pattern after fracture or surgery. This technique can also detect with great precision cysts and tumors. The ability to perform multiple plane images and three-dimensional reconstruction proves particularly useful for the evaluation of bone with oblique axis like the scaphoid.

Furthermore, CT may represent the imaging method of choice for detecting DRUJ instability. This technique is also valuable in certain situations in which performing a magnetic resonance imaging (MRI) is impractical (example: evaluation of the hook of the hamate).

Magnetic Resonance Imaging

MRI is very useful for the assessment of the integrity of soft tissues of the wrist and the vascular status of the carpal bones [15]. Nonetheless, accurate reading of MRI requires considerable anatomical knowledge and radiologist`s experience. T1-weighted images provide optimal resolution for the assessment of anatomy while T2-weighted images are more suitable for the detection fluid, cysts, and tumors. This modality can evaluate the quality of carpal bone blood perfusion, including the lunate, the scaphoid, and the capitate [16]. MRI is particularly accurate to gage lunate perfusion, and is superior to bone scanning when assessing Kienböck's disease [17]. Even minimal changes in bone perfusion (example: ulnar abutment syndrome) can be identified by MRI.

MRI enables optimal visualization of occult ganglions, soft tissue tumors, tendinitis, and joint fluid collection [18]. In addition, this imaging technique may detect subtle bone abnormalities such as bone bruises and micro fractures [19]. Consequently, this imaging modality is very reliable for diagnosing occult scaphoid fractures [20].

MRI constitutes an excellent study for the evaluation of intrinsic carpal ligaments and TFCC. State-of-the-art MRI technology (with 3.0 Tesla) have an improved ability for the detection of TFCC tears compared to MRIs with 1.5 Tesla. These lesions appear as linear hyperintense defects on coronal gradient-echo or T2-weighted pulse sequences. The assessment of the scapholunate and lunatotriquetral ligaments is somewhat more challenging but it is also feasible with reasonable accuracy (71 % sensitivity and 88 % specificity), especially with addition of arthrographic contrast. Although 1.5 Tesla MRIs are capable of diagnosing scapholunate tear, 3.0 Tesla MRIs are more precise (89 % sensitivity and 100 % specificity) and thus, represents the imaging modality of choice for evaluating the status of the scapholunate ligament.

MRI identifies lesion of the extrinsic carpal ligaments; however, their role in these lesions is still unclear since the information acquired by MRI rarely changes their management.

In patients with carpal tunnel syndrome, axial imaging with T2 weighting can clearly display masses within the confines of the carpal tunnel, as well as edema and swelling of the median nerve. However, this advanced imaging modality is often unnecessary when suspecting carpal tunnel syndrome, since this syndrome is usually diagnosed with after a good history and physical exam.

Radionuclide Imaging

Bone scans have high sensitivity for detection of wrist lesions (particularly in patients with chronic wrist pain) but low specificity. Thus, bone scans are quite useful as a screening imaging modality chiefly for bone integrity. Osteonecrosis of the scaphoid, lunate, and capitate can be picked with scintigraphy. Bone scanning can also detect occult fractures or the presence of osteoblastic activity (bone turnover). In order to confirm a positive bone scan, CT imaging should then be performed to precise the location and the amount of fracture material. CT imaging can identify fractures subluxations that were overlooked by routine x-rays imaging. Scintigraphy can also be useful for the early detection of complex regional pain syndrome, and evaluating soft tissue lesions. Bone scans are usually abnormal (93 %) in cases of complete intrinsic ligament ruptures, however, detection rates diminished substantially in partial lesions. Compared to bone scans, MRIs have equal sensitivity and higher specificity for the detection soft tissue injuries.

Arthroscopy

Arthroscopic examination of the wrist enables direct visualization and palpation of intra-articular structures such as intrinsic ligaments, TFCC, and the articular cartilage. Its diagnostic accuracy is high for the detection of soft tissue injuries or small fractures, and for that reason, at the end of the day arthroscopy has gradually replaced other diagnostic studies as the gold standard [21–23]. Undoubtedly, the role of wrist arthroscopy has evolved, especially for the detection of associated soft tissue lesions associated to distal radius or scaphoid fractures in active, high demanding patients. This procedure currently has a well-established role in the evaluation of wrist pain, providing a conclusive diagnosis in most cases. However, a potential pitfall of this procedure is the identification of asymptomatic (incidental) lesions, which in turn could lead to unnecessary treatment.

References

1. Zancolli EA, Cozzi EP. The Wrist. In: Zancolli EA, Cozzi EP, editors. Atlas of surgical anatomy of the hand. New York, NY: Churchill Livingstone Inc.; 1992.
2. Zancolli EA. Structural and dynamic bases of hand surgery. 2nd ed. Philadelphia, PA: Lippincott; 1979.
3. Palmer AK, Werner FW. Biomechanics of the distal radioulnar joint. Clin Orthop Rel Res 1984:26–35.
4. Ryu JY, Cooney 3rd WP, Askew LJ, An KN, Chao EY. Functional ranges of motion of the wrist joint. J Hand Surg. 1991;16:409–19.
5. Watson HK, Dt A, Makhlouf MV. Examination of the scaphoid. J Hand Surg. 1988;13:657–60.

6. Nagle DJ. Evaluation of chronic wrist pain. J Am Acad Orthop Surg. 2000;8:45–55.
7. Linscheid RL. Examination of the wrist. In: Nakamura R, Linscheid RL, Miura T, editors. Wrist disorders, current concepts and challenges. Tokyo: Springer Verlag; 1992. p. 13–25.
8. Czitrom AA, Lister GD. Measurement of grip strength in the diagnosis of wrist pain. J Hand Surg. 1988;13:16–9.
9. Reagan DS, Linscheid RL, Dobyns JH. Lunotriquetral sprains. J Hand Surg. 1984;9:502–14.
10. Nakamura R, Horii E, Imaeda T, Nakao E, Kato H, Watanabe K. The ulnocarpal stress test in the diagnosis of ulnar-sided wrist pain. J Hand Surg Br. 1997;22:719–23.
11. Keiserman LS, Cassandra J, Amis JA. The piano key test: a clinical sign for the identification of subtle tarsometatarsal pathology. Foot Ankle Int. 2003;24:437–8.
12. Feinstein WK, Lichtman DM, Noble PC, Alexander JW, Hipp JA. Quantitative assessment of the midcarpal shift test. J Hand Surg. 1999;24:977–83.
13. Ng CY, Hayton MJ. Ice cream scoop test: a novel clinical test to diagnose extensor carpi ulnaris instability. J Hand Surg Eur Vol. 2012;38:569–70.
14. Mann FA, Wilson AJ, Gilula LA. Radiographic evaluation of the wrist: what does the hand surgeon want to know? Radiology. 1992;184:15–24.
15. Cristiani G, Cerofolini E, Squarzina PB, Zanasi S, Leoni A, Romagnoli R, Caroli A. Evaluation of ischaemic necrosis of carpal bones by magnetic resonance imaging. J Hand Surg Br. 1990;15:249–55.
16. Haygood TM, Eisenberg B, Hays MB, Garcia JF, Williamson MR. Avascular necrosis of the capitate demonstrated on a 0.064 t magnet. Magn Reson Imaging. 1989;7:571–3.
17. Imaeda T, Nakamura R, Miura T, Makino N. Magnetic resonance imaging in kienbock's disease. J Hand Surg Br. 1992;17:12–9.
18. Kettner NW, Pierre-Jerome C. Magnetic resonance imaging of the wrist: occult osseous lesions. J Manipulative Physiol Ther. 1992;15:599–603.
19. Sferopoulos NK. Bone bruising of the distal forearm and wrist in children. Injury. 2009;40:631–7.
20. Brydie A, Raby N. Early mri in the management of clinical scaphoid fracture. Br J Radiol. 2003;76:296–300.
21. Weiss AP, Akelman E, Lambiase R. Comparison of the findings of triple-injection cinearthrography of the wrist with those of arthroscopy. J Bone Joint Surg Am. 1996;78:348–56.
22. Schers TJ, van Heusden HA. Evaluation of chronic wrist pain. Arthroscopy superior to arthrography: comparison in 39 patients. Acta Orthop Scand. 1995;66:540–2.
23. Cooney WP. Evaluation of chronic wrist pain by arthrography, arthroscopy, and arthrotomy. J Hand Surg. 1993;18:815–22.

3 Lasers and Electrothermal Devices

Daniel J. Nagle

A significant part of arthroscopic wrist surgery includes debridement of the triangular fibrocartilage (TFC), interosseous ligaments, synovium, cartilage, and even bone. Until the mid-1980s, these procedures were carried out using mechanical devices such as mini-banana blades, mini-suction punches, graspers, and motorized cutters and abraders. Good results were achieved with these instruments but with some difficulty because of the small size of the wrist joint. The small joint instruments were limited in variety and efficacy. This problem was first addressed by the holmium YAG (yttrium aluminum garnet) laser and later by radiofrequency (RF) devices, both of which are small, precise cutting, and ablating tools.

Lasers

The bulk of the research on laser/RF-assisted arthroscopy has been on the knee and shoulder. There has been some controversy on the use of lasers in the knee due to the report of four cases of femoral condyle avascular necrosis [1]. Whether the laser played a role in these cases remains to be seen. Avascular necrosis has also been reported after meniscectomy performed using mechanical devices [2]. Janecki et al. reviewed 504 laser-assisted knee arthroscopies and noted no new cases of avascular necrosis of the femur [3].

There was also concern regarding the "sonic shock" produced by the vaporization of the water at the tip of the holmium YAG (Ho:YAG) laser. Gerber and his associates [4] have studied this issue and have concluded that there is no acoustic trauma associated with the use of the Ho:YAG laser.

The CO_2 laser was the first laser to be used in arthroscopy, but it proved difficult to use. The CO_2 laser energy cannot be transmitted through a fiberoptic cable and therefore requires a series of prisms in an articulated arm for delivery. Furthermore, the joint must be inflated with a gas (CO_2) because water strongly absorbs CO_2 laser light. This inflation often produces subcutaneous emphysema. Finally, the CO_2 laser produces a significant amount of char. The one advantage of the CO_2 laser is that its thermal effect remains very superficial (tissue penetration of ±50 μm) thus producing very little damage to adjacent tissue.

The shortcomings of the CO_2 laser contributed to the introduction of Ho:YAG laser-assisted arthroscopy. The holmium laser functions (as does the CO_2 laser) in the infrared region of the electromagnetic spectrum at 2.1 nm. In contrast to the CO_2 laser, the Ho:YAG energy can be transmitted through a quartz fiber and functions well underwater. Also, it is well absorbed by cartilage, fibrocartilage, synovial tissue, scar tissue, and hemoglobin. This last point explains the Ho:YAG's hemostatic capabilities.

Other types of lasers have been used in arthroscopy. The neodymium YAG laser has a wavelength of 1.064 nm, which, like the Ho:YAG and CO_2 lasers, is in the infrared region of the electromagnetic spectrum. Like the Ho:YAG laser, it can be used in a liquid medium. However, it has proved difficult to control the depth of penetration of the laser energy, and because of this the neodymium YAG laser is no longer used in arthroscopy.

Erbium lasers have also been used. Like the CO_2 and Ho:YAG lasers, the erbium is an infrared laser. The erbium laser combines the advantages of the Ho:YAG with the reduced collateral tissue injury seen with the CO_2 laser. Its use in the United Sates has been limited.

The excimer laser has also been used in arthroscopy. The wavelength of the excimer laser is in the ultraviolet region of the electromagnetic spectrum. This laser's ablative potential is based on its ability to resonate with and disrupt the covalent bonds of the tissues being ablated. This interaction produces no heat, and therefore thermal collateral injury is eliminated (hence the term *cold laser*). As mentioned, the excimer laser functions in the ultraviolet region of the

D.J. Nagle, M.D., F.A.A.O.S., F.A.C.S. (✉)
Department of Orthopedics, Northwestern University Feinberg School of Medicine, 737 N Michigan Ave., Suite 700, Chicago, IL 60611, USA
e-mail: oogien@aol.com

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*, DOI 10.1007/978-1-4614-1596-1_3, © Springer Science+Business Media New York 2015

electromagnetic spectrum; for this reason there is some concern it may be mutagenic. Hendrich et al. evaluated the mutagenic effect of ultraviolet light of the same wavelength (308 nm) as that used by the excimer laser and concluded that excimer laser energy is not mutagenic [5]. The excimer laser has not been used widely in arthroscopy, for two reasons. The first is that these lasers are extremely expensive. The second reason is that the fluence, or the amount of energy that can be transmitted through the quartz fiber carrying the laser energy, is barely sufficient to ablate fibrocartilage. Attempts to increase the fluence have resulted in destruction of the fiberoptic delivery system.

The Ho:YAG laser functions by superheating the tissues to be ablated. When the laser fires, it creates a small bubble of water vapor at its tip (the Moses effect). The tissue within this bubble absorbs the majority of the laser energy and is vaporized, leaving a layer of "caramelized" protein behind, but no char. Beyond the vapor bubble, the laser energy is quickly attenuated as it is absorbed by the water in the joint. This drop-off in energy allows the surgeon to titrate the amount of energy transmitted to the tissues in the joint. By "defocusing" the laser (pulling the tip away from the tissue), the tissue is taken out of the Moses bubble and less energy is imparted to the tissue. This allows the "melting" of chondromalacic fronds and capsular shrinkage without injuring adjacent tissues. The water in the joint not only absorbs the laser energy but it also acts as a large, continually renewed heat sink. The problems of heat buildup and collateral tissue damage are also addressed by pulsing the laser light. The time between pulses allows the tissues outside the ablation zone to transmit the energy they absorb to the heat sink (water) and thus remain protected from thermal injury. Continuously applied laser energy does not permit the flow of heat energy away from the ablation site and results in significant collateral damage. Thus, with appropriate technique, one can modulate the energy imparted to the tissues by changing the laser pulse frequency, by changing the amount of energy per pulse, and finally, by focusing or defocusing the laser.

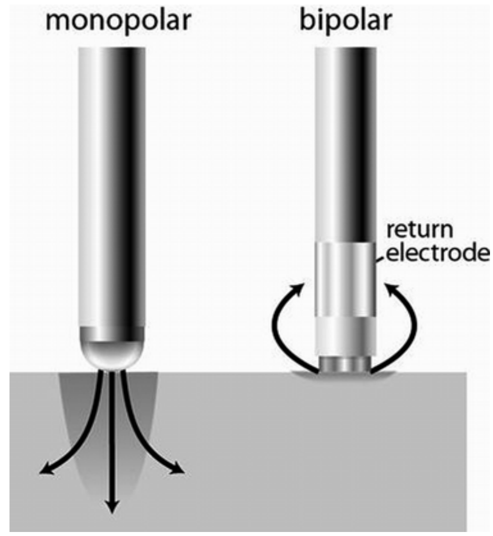


Fig. 3.1 Monopolar: electrical current is conducted into the tissue to the grounding pad. Bipolar: current is conducted away from the tip to the return electrode on the probe shaft

Table 3.1 Tissue impedance

Tissue/substance	Impedance (Ω)
Saline	90–120
Ligaments	100–140
Cartilage	350–500
Bone	1,100

Based on data from [22, 25]

Radiofrequency Devices

Radiofrequency devices, like lasers, ablate/shrink tissue by heating the tissue. The RF devices transmit energy to the tissues via radiofrequency waves in the 100–450 kHz range. This electromagnetic energy causes the electrolytes within the tissue to oscillate very rapidly. This molecular oscillation creates friction within the tissue that, in turn, heats the tissue. The RF energy produces enough friction to either denature the collagen and cause shrinkage or vaporize the tissue. Monopolar and bipolar radiofrequency devices are available. Monopolar units require that a grounding pad be attached to the patient, while the bipolar devices do not. The RF devices oscillate the polarity of the active and passive electrodes to produce the RF energy. The energy of the monopolar devices flows from the active electrode *through* the tissue being treated to the passive, ground electrode. Bipolar devices have both the active and passive electrodes in the tip of the probe. The energy flows from the active electrode back to the passive electrode, passing through the superficial layers of the tissue near the probe tip (Fig. 3.1). The depth of penetration of the monopolar devices is greater than that noted with bipolar devices (4 mm vs. 0.2–0.3 mm). With monopolar devices, the depth of tissue penetration also depends on the impedance of the tissue (see Table 3.1). It follows that the energy will penetrate deeper into a ligament than into cartilage. The RF current follows the path of least resistance.

Monopolar and bipolar devices both require a conductive milieu such as normal saline or lactated Ringer's. The tips of the RF probes are available in many shapes and sizes to accommodate the anatomy of the problem being treated.

While the following discussion focuses on the use of the Ho:YAG laser, radiofrequency (RF) devices can be used in place of the laser [6]. The only exception to this generalization is the ablation of bone, which is more readily accomplished with the laser. The RF probes can be used through the same portals described for the laser probes.

Radiofrequency devices can ablate and shrink tissue. However, one must be careful while using RF wands to not overheat the joint or the structures adjacent to the joint. Adequate inflow/outflow is essential while using the RF devices. Prolonged use of the RF probes without an adequate heat sink (fluid flow) can lead to diffuse thermal injury of the joint surfaces and adjacent peri-articular structures. The RF energy penetrates the tissue to a depth of 4 or more mm as compared to the 0.5 mm penetration of the laser. There is therefore a greater potential for injury to adjacent extraarticular structures (nerves) when using the RF probes.

Laser/RF-Assisted TFCC Debridement

Andrew Palmer [7] devised a classification scheme for TFCC tears that divides TFCC tears into traumatic tears, type I and degenerative tears, type II [7]. While both types of tears can be treated arthroscopically, types I-A, II-C, and II-D lend themselves to laser-assisted debridement (Fig. 3.2).

Before starting arthroscopic treatment of TFCC tears, the ulnar variance must be evaluated. This is done by taking an X-ray with the shoulder abducted to 90° and the elbow flexed to 90° with the hand flat on the X-ray cassette (the "90 × 90" view of Palmer) [8]. Triangular fibrocartilage debridement in face of an ulnar-plus variance is doomed to fail, as the simple debridement of the TFCC is insufficient to decompress the ulnar side of the wrist. In such cases of ulnar abutment syndrome, an ulnar shortening is needed. The results of TFCC debridement in patients with an ulnar-zero variance can be good, but there lingers the possibility of having to perform an ulnar shortening later. It is recommended that this possibility be discussed with the patient preoperatively. In contrast to the patient with an ulnar plus variance, the patient who presents with an ulnar minus variance is very likely to respond to simple debridement of the central portion of the triangular fibrocartilage [9, 10].

The technique of laser-assisted triangular fibrocartilage debridement is similar to that of mechanical debridement of the triangular fibrocartilage with the exception that the arthroscope can be left in the 3-4 portal while the laser is kept in the 4-5 portal. The laser is set to 1.4–1.6 J at a frequency of 15 pulses per second. With the help of a side-firing 70-degree laser tip, the triangular fibrocartilage can be very rapidly and precisely debrided. The 70-degree laser tip permits ablation not only of the radial and palmar portions of the TFCC tear, but also the ulnar and dorsal components. There is no need to bring the laser probe in through the 3-4 portal. During the debridement, care must be taken not to injure the ulnar head. This is avoided by firing the laser tangentially to the head of the ulna or passing the probe beneath the triangular fibrocartilage and firing distally. This latter technique presents minimal danger to the lunate or triquetrum, in that the fluid used to expand the joint acts as a heat sink and absorbs the laser energy as it emerges from beneath the triangular fibrocartilage. The central portion of the TFCC is debrided back to stable edges, taking care not to injure the dorsal and palmar radioulnar ligaments.

The arthroscopic treatment of the ulnar abutment syndrome is facilitated by using the Ho:YAG laser [11]. Hyaline cartilage is very efficiently removed with the laser at higher energy settings (2.0 J at 20 pulses per second). Not only are the ulnar head hyaline cartilage and subchondral bone rapidly removed, but, in contrast to burring, they are removed without producing much debris. Once the cancellous bone of the ulnar head is exposed, however, the bur becomes the most effective tool to complete the ulnar shortening. This is because it becomes very time consuming to focus the laser beam on each trabecula. During the ulnar head resection, care must be taken not to injure the sigmoid notch with either the laser or the bur. Also, care must be taken not to detach the insertion of the triangular fibrocartilage from the fovea at the base of the ulnar styloid. The successful arthroscopic ulnar shortening relies on teamwork. The assistant brings the surfaces of the

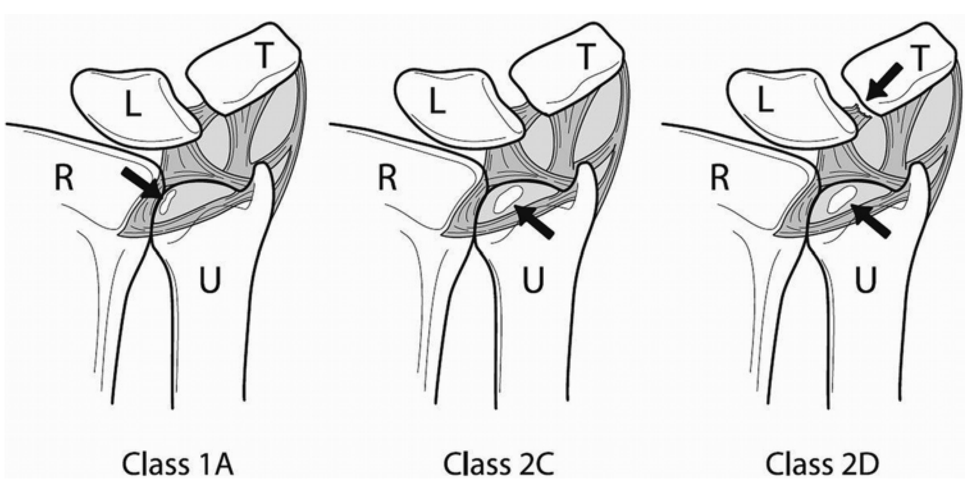


Fig. 3.2 Palmer classification of TFCC tears [Adapted with permission from Palmer AK. Triangular fibrocartilage complex lesions: a classification. *J Hand Surg Am* 1989;14:594–606. With permission from Elsevier]

ulnar head to be resected to the laser being held by the operating surgeon. By progressively supinating and pronating the forearm, an appropriate amount of ulnar head is excised. The goal is to resect sufficient ulna to produce a 2 mm negative ulnar variance. The amount of ulna resected must be verified with intraoperative fluoroscopy. Occasionally, complete visualization of the ulnar head requires that the scope be placed in the 4-5 portal with the laser entering the distal radioulnar joint through the distal radioulnar joint portal. This portal is established just proximal to the 4-5 portal and TFCC.

An effort is made to leave a smooth surface on the remaining distal ulna. The trabeculae of the distal ulna always produce a somewhat rough distal ulna at the completion of the procedure. These irregularities, however, disappear during the months following the surgery (Figs. 3.3 and 3.4). Large irregularities must be avoided, as they can catch on the proximal surface of the residual TFCC during supination and pronation.

Fig. 3.3 Ulnar abutment

The postoperative regimen after TFCC debridement, with or without ulnar shortening, includes providing the patient with a wrist splint to be worn as needed, as well as a home therapy program consisting of active and passive range of motion exercises. The sutures (wounds are closed using subcuticular sutures of 4-0 Prolene) are removed at 2 weeks. Strengthening exercises can be started at 6 weeks if needed. Premature resumption of heavy lifting or repetitive activities will lead to radiocarpal synovitis. Some patients feel so good after as little as 2 weeks that the surgeon must temper the patient's desire to return to full activity. In the case of an ulnar shortening, the recovery can be as long as 6 months, as suggested by Feldon [12]. However, the majority of patients will be improved long before 6 months.

Other Indications for Laser/RF-Assisted Wrist Arthroscopy

Synovectomy

Synovectomy is probably the most frequently performed laser-assisted procedure. This procedure is often needed to permit complete joint visualization, particularly of the lunotriquetral and ulnocarpal joints. The laser, set at 1.2–1.5 J and 15 pulses per second, vaporizes the inflamed synovium and scar tissue quickly and with minimal bleeding due to the hemostatic effect of the laser. The hemoglobin in

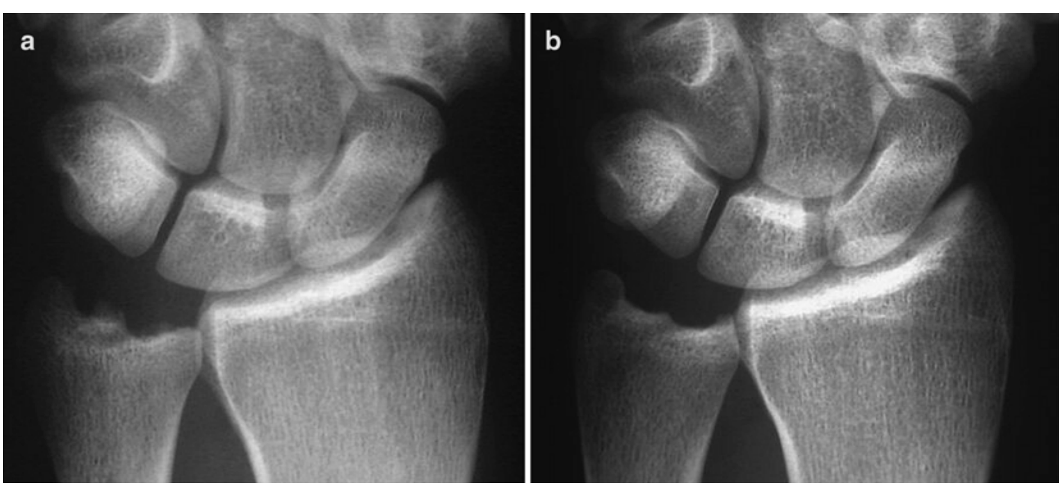


Fig. 3.4 (**a**) Early and (**b**) late post-laser-assisted arthroscopic ulnar shortening demonstrating smoothing of resection site with time. **a** is 6 weeks postoperative and **b** is 6 months postoperative

the inflamed synovium absorbs the laser energy better than the adjacent capsule, thus providing an extra level of safety for the capsule. Scar tissue and synovitis in the radiocarpal, ulnocarpal, and midcarpal joints can be rapidly debrided. When performing a dorsal wrist synovectomy, or for that matter anytime the laser is being used, care should be taken to avoid aiming the laser at the arthroscope, as the laser energy will destroy the scope.

Partial Interosseous Ligament Tears

Partial tears of the scapholunate and lunotriquetral ligaments can be nicely treated with the laser set at 0.2–1.0 J and 15 pulses per second. The ablation of these tears can be done very precisely without scuffing or injuring the adjacent intact articular cartilage.

Chondromalacia

Chondromalacia has been treated with the laser and RF devices. There is, however, evidence that at least in regard to the RF devices, significant injury to the underlying healthy cartilage can occur even when exercising caution and using low power settings [13, 14]. Based on this information, it is difficult to recommend RF treatment of chondromalacia. Chondromalacic fronds can, however, be gingerly vaporized with the laser set at 0.2–0.8 J and 15 pulses per second. The laser beam must be oriented tangentially to the joint surface so that only the fronds of frayed cartilage are treated. Great care must be taken to not injure the underlying healthy cartilage. Because the laser radiation can be directed selectively toward the chondromalacic fronds, sparing the underlying cartilage, it is safer in this situation than are RF devices. However, great care must be exercised. It should be kept in mind that the long-term effectiveness of debridement of chondromalacic fronds has not been established, and the potential for significant injury to healthy cartilage cannot be ignored even with the laser.

Bone Resection

We have seen that the Ho:YAG laser can be used to resect the distal ulna. Similarly, the laser can be used to perform radial styloidectomies, osteophytectomies, and complete resection of the ulnar head. The principles outlined in the section describing the laser-assisted arthroscopic Feldon procedure apply to these procedures as well. The articular cartilage and subchondral bone are vaporized with the laser, while the cancellous bone is removed with a bur.

Radial styloidectomy is performed with the arthroscope in the 4-5 portal and the laser and bur entering through the 1-2 and 3-4 portals. (The 1-2 portal is approached with caution, as the radial artery and branches of the superficial radial nerve course through this area. Only blunt dissection should be used in establishing the 1-2 portal.) A clear junction usually exists between the area of the radial styloid to be debrided (exposed subchondral bone) and the adjacent healthy cartilage. If this is not the case, a K-wire can be placed under both fluoroscopic and arthroscopic control through the radial styloid at the ulnar limit of the proposed bone resection. This provides an intra-articular landmark. The amount of styloid resected should be just enough to solve the problem being addressed, taking care to leave the attachments of the radioscaphocapitate and long radiolunate ligaments intact. Postoperative care after this procedure is similar to that described for a TFCC debridement.

Laser-assisted arthroscopic Darrach procedures and matched ulnar resections are logical extensions of the laser-assisted arthroscopic Feldon procedure. The technique used for these procedures is essentially the same as that used for the laser-assisted arthroscopic Feldon procedure. One would anticipate less morbidity with this technique, though no published series are currently available. The use of the laser to treat grade IV chondromalacia has been successful in our hands in a limited number of cases. Two approaches are used, depending on the clinical presentation. If the joint surfaces involved cannot be unloaded (i.e., the proximal lunate), the laser is used to ablate the detached cartilage and subchondral plate. The laser debridement is extended to expose a healthy cartilage/bone interface. This "crater" margin is "freshened" with the bur. The subchondral bone is burred back to bleeding, cancellous bone. This last step is needed, as laser cauterization slows the fibrous tissue ingrowth necessary for the success of chondroplasty in this setting. Early range of motion is essential. The use of continuous passive motion has proven to be important.

The second approach is that applied to joint surfaces that can be unloaded through limited carpal shortening. A prime example of this is chondromalacia of the proximal pole of the hamate often seen in patients with a type II lunate [15]. In this situation the goal is not to promote soft tissue ingrowth but rather to unload the lunatohamate joint. This can be accomplished by establishing a viewing portal at the radial midcarpal port and an instrument portal at the ulnar midcarpal port. The proximal pole of the hamate is ablated using the laser. The resection is continued until the lunate no longer impinges on the hamate during ulnar deviation. (Care must be exercised not to injure the ulnar limb of the arcuate ligament.) This can be verified by removing the laser and manipulating the wrist while the arthroscope is still in the radial midcarpal joint. In this case the bur is not used to freshen the hamate defect, as cauterization produced by the laser seems to decrease postoperative discomfort. This effect is attributed to a decrease in postoperative bleeding and inflammation. Though early postoperative range of motion is promoted, continuous passive motion has not been needed. It should be noted that no clinical studies of chondroplasty using the Ho:YAG laser have been published.

Capsular Shrinkage

Wrist capsular shrinkage may offer an attractive alternative to more invasive treatments for subtle forms of carpal instability. It would seem logical to apply to the wrist what has been learned from shoulder capsular shrinkage. The basic science of capsular shrinkage should be the same for both joints. However, the wrist is not the shoulder, and extrapolation of shoulder data to the wrist may not be appropriate.

The biology of capsular shrinkage has been extensively studied in animal models. Capsular shrinkage is a refined “hot poker” technique. The triple helix of collagen unwinds when heated to 60 °C; maximum shrinkage is achieved between 65 and 75 °C (Fig. 3.5). The hydrogen bonds holding the type I collagen triple helix together rupture as the collagen is heated beyond 60 °C. As the collagen triple helix unwinds, it shortens (Fig. 3.6). This shortening can reach 50 % of the resting length of the untreated collagen. The shortened, denatured collagen acts as scaffolding onto which new collagen is deposited [16]. The new collagen fibers maintain this shortened conformation, thus assuring the long-term maintenance of the shortening.

Biomechanical studies have demonstrated that the tensile strength of heated collagen decreases rapidly and does not return to normal values for 12 weeks [17]. The tensile strength returns to nearly 80 % of normal by 6 weeks after heating (Fig. 3.7). This transient loss of tensile strength would suggest that the application of stress to recently heated collagen is contraindicated. Premature loading of the shrunken collagen will lead to a lengthening of the collagen. This has been verified in an animal model [18, 19]. Based on these data, it would seem reasonable to recommend at least 6–8 weeks of joint immobilization after capsular shrinkage. Clearly, heavy loading of the joint should be avoided for 12 weeks.

Shrinkage requires very low energy settings. The RF devices must be adjusted to heat the tissue to a temperature of between 65 and 75 °C. It is wise to start at low energy and slowly increase the energy output until the desired shrinkage is observed. The laser should be set to very low energy, i.e., 0.2–0.5 J at 15 pulses per second (3–7.5 W). The laser is held away from the target ligament and slowly advanced until the ligament is seen to shrink. Once the shrinkage has stopped, continued laser exposure will only further weaken the ligament without increasing the shrinkage. The color of the

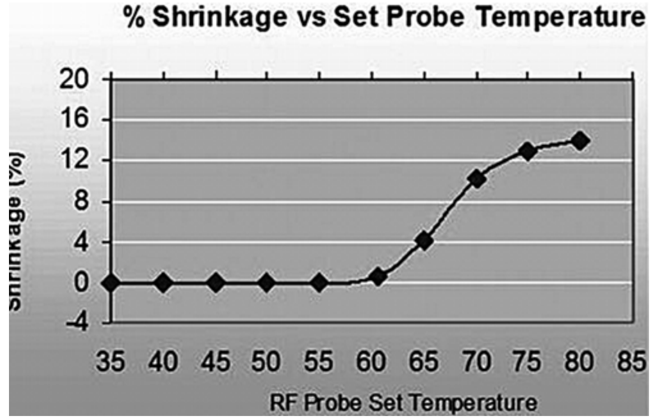


Fig. 3.5 Shrinkage vs. RF probe temperature

Fig. 3.6 The normal collagen triple helix without shrinkage

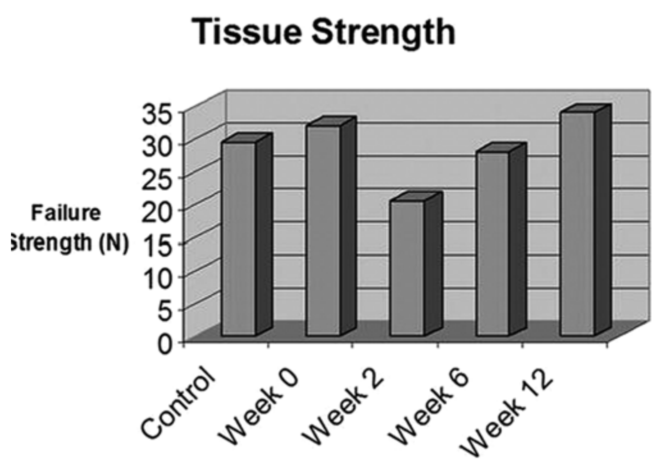


Fig. 3.7 Post-shrinkage tensile strength vs. time

ligament changes from white to light yellow during the shrinkage. Lu et al. have suggested that a cross-hatching shrinkage pattern optimizes the ingrowth of healthy tissue and hastens the recovery of the ligament [20]. During the shrinkage, traction on the wrist should be reduced as much as possible to permit optimal shrinkage.

Scapholunate Instability

Capsular shrinkage for mild scapholunate (SL) instability could be an attractive alternative to the currently available open procedures. The question is what can or should be shrunk to stabilize the SL axis. The SL interosseous ligament

Fig. 3.8 Histology of central fibrocartilaginous portion of the scapholunate ligament [Reprinted from Berger RA, Chapter 5 of The Wrist Diagnosis and Operative Treatment by Cooney WP, Lilnscheid RL, Dobyns JH. Mosby: St. Louis, 1998. Used with permission of the Mayo Foundation for Medical Education and Research, Rochester, MN]

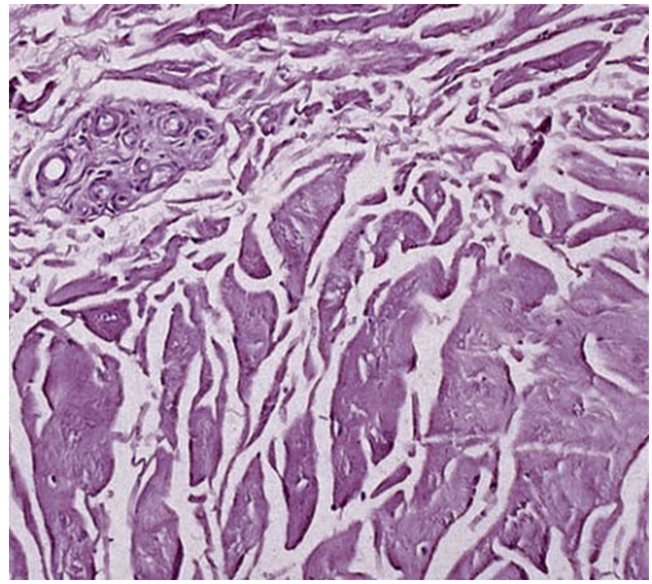


Fig. 3.9 Histology of capsule demonstrating loose collagen (CF) in a fibrous stratum (FS) [Reprinted from Berger RA, Chapter 5 of The Wrist Diagnosis and Operative Treatment by Cooney WP, Lilnscheid RL, Dobyns JH. Mosby: St. Louis, 1998. Used with permission of the Mayo Foundation for Medical Education and Research, Rochester, MN]

is a heterogeneous structure. Its central portion is composed of fibrocartilage, which is not shrinkable (Fig. 3.8). The dorsal and palmar portions of the SL ligament are, however, composed of type I collagen and are shrinkable (Fig. 3.9). Anecdotal reports would suggest that shrinkage of the dorsal and palmar aspects of the SL ligament can help patients with mild SL instability. No published studies are available, however, to substantiate these reports.

Capsular shrinkage of the dorsal intercarpal ligament (DIC) could potentially reinforce the stabilizing effect of SL ligament shrinkage. The DIC is attached to the distal dorsal aspect of the scaphoid and the dorsal triquetrum (Fig. 3.10). Shrinkage of this ligament could simulate the tensioning of this ligament noted during open capsulodesis [21]. To accomplish this, the scope and laser would be placed alternately in the radial and ulnar midcarpal portals. Again, no published data are available that support this technique.

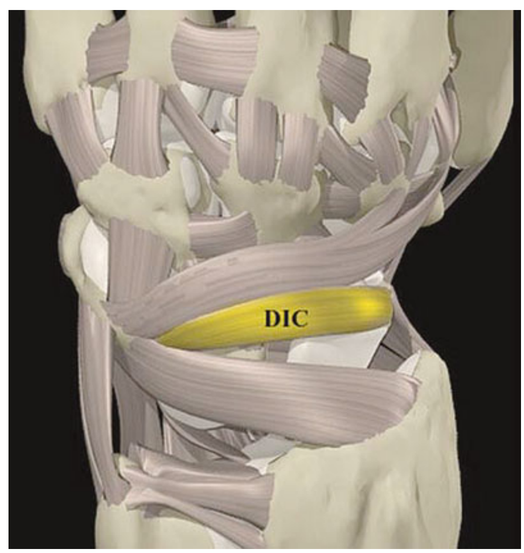


Fig. 3.10 Dorsal intercarpal ligament [Courtesy of Daniel J. Nagle]

Lunotriquetral and Ulnocarpal Instability

Mild forms of lunotriquetral instability can be treated with ulnocarpal ligament shrinkage. I have applied this technique in a limited number of cases with satisfying results. This procedure takes advantage of the anatomy of the ulnotriquetral and ulnolunate ligaments. These ligaments form a V as they diverge from their origin on the palmar distal radioulnar ligament and insert on the palmar aspect of the lunate or triquetrum (Fig. 3.11). As the ligaments are shrunk, the arms of the V shorten and approximate the lunate to the triquetrum thus stabilizing the LT joint. This stabilization can be further reinforced with the shrinkage of the LT interosseous ligament. The LT ligament histology is similar to that of the SL ligament and can therefore undergo dorsal and palmar but not central shrinkage. Isolated ulnocarpal ligament instability can also be treated with ulnocarpal ligament shrinkage.

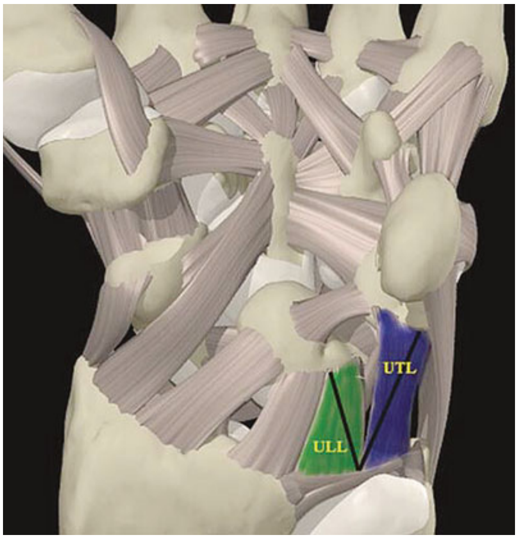


Fig. 3.11 Palmar view of ulnocarpal ligaments demonstrating "V" configuration [Courtesy of Daniel J. Nagle]

Ulnocarpal shrinkage is accomplished with the arthroscope in the 3-4 portal and the laser in the 4-5 or 6-U portal.

Midcarpal Instability

It is tempting to apply capsular shrinkage to the treatment of midcarpal instability. Midcarpal instability is associated with attenuation of the ulnar arcuate, triquetrohamate, dorsal intercarpal, ulnocarpal, and radiocarpal ligaments. All of these ligaments can be shrunk. I have had success treating patients with symptomatic chronic mild midcarpal instability and even a patient with significant midcarpal instability due to generalized ligamentous laxity. Mason and Hargreaves have reported excellent results in 13 patients with palmar midcarpal instability using radio frequency probes to shrink the radioscapholunate ligament, ulnar arcuate ligament, long and short radiolunate ligaments and accessible areas of the dorsal capsule of the midcarpal and radiocarpal joints [22]. Additional studies of the efficacy of this technique will be long in coming in view of the rarity of this condition and the broad spectrum of pathology associated with midcarpal instability.

Conclusion

Our experience since 1990 with over 350 laser-assisted wrist arthroscopies using the Ho:YAG laser has been excellent. We have encountered no laser-related complications. We have noted no increase in postoperative wrist effusion or pain. These clinical findings echo those found in multiple articles reviewing the use of the Ho:YAG laser in the knee [23] and two articles in the hand/upper extremity literature. Blackwell et al., used the Ho:YAG laser to debride central TFCC tears in 35 patients and noted results similar to those obtained using mechanical debridement [24]. Infanger and Grimm came to the same conclusion after looking at the results of laser-assisted TFCC debridement in 72 patients [25].

The Ho:YAG laser and RF devices should be viewed as additional tools in the wrist surgeon's armamentarium. The advantages of the laser/RF devices include their small size and the efficiency they bring to wrist arthroscopy, as well as their capability to cauterize and to precisely titrate the amount of power delivered to the operative site. The development of aggressive, 2.0 mm mechanical cutting devices has been slow and may be reaching its practical limits. This is not to say, however, that mechanical devices are obsolete. Certainly, the full-radius cutters and burs continue to be used routinely in wrist arthroscopy.

The future of lasers in wrist and joint surgery in general could be promising if the cost of the lasers decreases. Research is currently being done to evaluate the use of lasers to shrink the wrist capsule to correct subtle forms of carpal instability. Animal and tissue culture research has demonstrated that laser energy of the appropriate frequency can stimulate chonodroblast proliferation and cartilage production [26, 27]. Perhaps one day the laser will help create tissue rather than ablate it.

References

1. Garino JP, Lotke PA, Sapega AA, et al. Osteonecrosis of the knee following laser-assisted arthroscopic surgery: a report of six cases. Arthroscopy. 1995;11:467–774.
2. Johnson TC, Evans JA, Gilley JA, et al. Osteonecrosis of the knee after arthroscopic surgery for meniscal tears and chondral lesions. Arthroscopy. 2000;16(3):254–61.
3. Janecki CJ, Perry MW, Bonati AO, et al. Safe parameters for laser chondroplasty of the knee. Lasers Surg Med. 1998;23:141–50.
4. Gerber BE, Asshauer T, Delacretaz G, et al. Biophysical bases of the effects of holmium laser on articular cartilage and their impact on clinical application technics. Orthopade. 1996;25:21–9.
5. Hendrich C, Werner SE. Mutagenic effects of the excimer laser using a fibroblast transformation assay. Arthroscopy. 1997;13:151–5.
6. Osmond C, Hecht P, Hayashi K, et al. Comparative effects of laser and radiofrequency energy on joint capsule. Clin Orthop. 2000; 375:286–94.
7. Palmer AK. Triangular fibrocartilage complex lesions: a classification. J Hand Surg Am. 1989;14:594–606.
8. Palmer AK, Glisson RR, Werner FW. Ulnar variance determination. J Hand Surg Am. 1982;7:376–9.
9. Osterman AL. Arthroscopic debridement of triangular fibrocartilage complex tears. Arthroscopy. 1990;6:120–4.
10. Minami A, Ishikawa J, Suenaga N, et al. Clinical results of treatment of triangular fibrocartilage complex tears by arthroscopic debridement. J Hand Surg Am. 1966;21:406–11.
11. Nagle DJ, Bernstein MA. Laser-assisted arthroscopic ulnar shortening. Arthroscopy. 2002;18(9):1046–51.
12. Feldon P, Terrono AL, Belsky MR. The "wafer" procedure. Partial distal ulnar resection. Clin Orthop. 1992;275:124–9.

13. Edwards 3rd RB, Lu Y, Nho S, et al. Thermal chondroplasty of chondromalacic human cartilage. An ex vivo comparison of bipolar and monopolar radiofrequency devices. Am J Sports Med. 2002;30(1):90–7.
14. Lu Y, Edwards 3rd RB, Cole BJ, et al. Thermal chondroplasty with radiofrequency energy. An in vitro comparison of bipolar and monopolar radiofrequency devices. Am J Sports Med. 2001; 29(1):42–9.
15. Nakamura K, Patterson RM, Moritomo H, et al. Type I versus type II lunates: ligament anatomy and presence of arthrosis. J Hand Surg Am. 2001;26(3):428–36.
16. Lopez MJ, Hayashi K, Vanderby Jr R, et al. Effects of monopolar radiofrequency energy on ovine joint capsular mechanical properties. Clin Orthop. 2000;374:286–97.
17. Hecht P, Hayashi K, Lu Y, et al. Monopolar radiofrequency energy effects on joint capsular tissue: potential treatment for joint instability. An in vivo mechanical, morphological, and biochemical study using an ovine model. Am J Sports Med. 1999;27(6):761–71.
18. Naseef III GS, Foster TE, Trauner K, et al. The thermal properties of bovine joint capsule. The basic science of laser- and radiofrequency-induced capsular shrinkage. Am J Sports Med. 1997;25(5):670–4.
19. Hayashi K, Markel MD. Thermal capsulorrhaphy treatment of shoulder instability: basic science. Clin Orthop. 2001;390:59–72.
20. Lu Y, Hayashi K, Edwards 3rd RB, et al. The effect of monopolar radiofrequency treatment pattern on joint capsular healing. In vitro and in vivo studies using an ovine model. Am J Sports Med. 2000;28(5):711–9.
21. Szabo RM, Slater Jr RR, Palumbo CF, et al. Dorsal intercarpal ligament capsulodesis for chronic, static scapholunate dissociation: clinical results. J Hand Surg Am. 2002;27(6):978–84.
22. Mason WTM, Hargreaves DG. Arthroscopic thermal capsulorrhaphy for palmar midcarpal instability. J Hand Surg. 2007;32E: 411–6.
23. Lubbers C, Siebert WE. Holmium: YAG-laser-assisted arthroscopy versus conventional methods for treatment of the knee. Two-year results of a prospective study. Knee Surg Sports Traumatol Arthrosc. 1997;5(3):168–75.
24. Blackwell RE, Jemison DM, Foy BD. The holmium:yttrium-aluminum-garnet laser in wrist arthroscopy: a five-year experience in the treatment of central triangular fibrocartilage complex tears by partial excision. J Hand Surg Am. 2001;26(1):77–84.
25. Infanger M, Grimm D. Meniscus and discus lesions of triangular fibrocartilage complex (TFCC): treatment by laser-assisted wrist arthroscopy. J Plast Reconstr Aesthet Surg. 2009;62(4):466–71.
26. Torricelli P, Giavaresi G, Fini M, et al. Laser biostimulation of cartilage: in vitro evaluation. Biomed Pharmacother. 2001;55(2): 117–20.
27. Morrone G, Guzzardella GA, Tigani D, et al. Biostimulation of human chondrocytes with Ga-Al-As diode laser: ‘in vitro’ research. Artif Cells Blood Substit Immobil Biotechnol. 2000;28(2): 193–201.

Anatomy of the Triangular Fibrocartilage Complex

4

Jared L. Burkett and William B. Geissler

Introduction

Ulnar-sided wrist pain is a common presenting complaint, so a thorough understanding of the anatomy and biomechanics of the triangular fibrocartilage complex (TFCC) and distal radioulnar joint (DRUJ) is essential for the diagnosis and treatment of these disorders. Over the past 30 years, the knowledge of this complicated structure and its role in the biomechanics of the wrist has increased, leading to improved diagnosis of these injuries and to more effective reconstructive procedures for their treatment [1]. Arthroscopy allows an unparalleled visual examination of the different components of the TFCC, which can aid in differentiating pathologic versus normal anatomy. With this improved ability to see fine details and structures that might go unappreciated in open approaches, the surgeon should possess a comprehensive understanding to guide decision making and treatment during surgery.

Distal Radioulnar Joint (DRUJ)

DRUJ Anatomy

The DRUJ is a trochoid articulation formed by the sigmoid notch of the distal radius and the seat of the ulnar head. The bony anatomy of this joint is responsible for allowing translation along with pronation and supination of the forearm as the radius rotates around the fixed ulna. Af Ekenstam and Hagert examined the anatomy of the distal radioulnar joint and found that the radius of curvature of the sigmoid notch was 4–7 mm larger than the ulnar head, with the average for the sigmoid notch being 15 mm and the average for the ulnar head being 10 mm (Fig. 4.1) [2]. The articular surface of the ulnar head facing the sigmoid notch, or the seat of the ulna, occupies between 90° and 135° of the circumference of the distal ulna, with a central height of approximately 8 mm [2]. In relation to the ulnar head, the sigmoid notch is relatively flat with an articular surface of between 47° and 80° [2]. This articulation results in rotation of approximately 180°, but also allows for instability of the distal radioulnar joint, allowing palmar translation of the sigmoid notch in pronation and dorsal in supination [1, 2]. Due to this anatomical relationship, the stability of the joint contributed by articular surface contact is approximately 20 %, while the remaining stability is imparted by the soft tissue structures [3].

The thin capsule of the DRUJ attaches distally from the sigmoid notch of the radius to the volar and dorsal aspects of the radioulnar ligaments of the TFCC before inserting on the base of the ulnar styloid. Due to these attachments, the tip of the ulnar styloid is extra-articular in relation to this joint [4]. Clinically peripheral detachments are more common dorsally, as the volar attachment of the capsule to the TFCC is stronger [5].

During normal forearm supination and pronation, a sliding movement occurs in addition to a rotational movement. In neutral rotation, the principal axis of load bearing of the DRUJ is centrally in the sigmoid notch, with approximately 60 % of cartilage surface contact. With pronation, the principal axis of load bearing of the DRUJ moves distally and dorsally in the sigmoid notch, leaving a small portion, approximately 10 % of the cartilage surface of the notch, in contact with the ulna. In supination, the reverse is true with the principal axis of load bearing moving proximally and palmarly in the sigmoid notch [2, 6, 7].

To maintain stability of this inherently unstable joint, the function of the DRUJ is intricately related to soft tissue structural support. Both extrinsic and intrinsic structures are present, with the intrinsic stabilizers playing a greater role in rotational stability [1]. Extrinsic stabilizing structures that will

J.L. Burkett, M.D. (✉)
Alabama Orthopaedic Clnic, 3610 Springhill Memorial Dr N
Mobile, AL 36608, USA
e-mail: jaredlburkett@gmail.com

W.B. Geissler, M.D.
Department of Orthopaedic Surgery, University of Mississippi
Medical Center, 2500 North State Street, Jackson, MS 39216, USA
e-mail: 3doghill@msn.com

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*,
DOI 10.1007/978-1-4614-1596-1_4, © Springer Science+Business Media New York 2015

not be described in detail in this chapter include the extensor carpi ulnaris tendon, the sixth dorsal compartment, the pronator quadratus, and the interosseous ligament of the forearm [1, 3]. The TFCC is the primary intrinsic stabilizer of the DRUJ, with the volar and dorsal radioulnar ligaments providing the majority of the support the TFCC imparts to the DRUJ.

Ulnar Variance

As ulnar variance plays a role in TFCC pathology and in the treatment options for ulnar-sided wrist pain, an understanding of the biomechanics of this relationship is needed. As the radius rotates around the fixed ulna, the variance changes with position, being relatively ulnar positive in pronation and ulnar negative in supination (Fig. 4.2a, b). The differences in load transmission through the ulnocarpal joint with differing degrees of ulnar variance or wrist position can be significant. The force transmitted through the ulna has also been found to increase with pronation, extension, and ulnar deviation as this shifts the load medially compared to supination, flexion, and radial deviation [1, 8]. In addition, forced grip has been found to increase ulnar variance an average of 1.95 mm, which will increase load transmission through the TFCC and ulna [9].

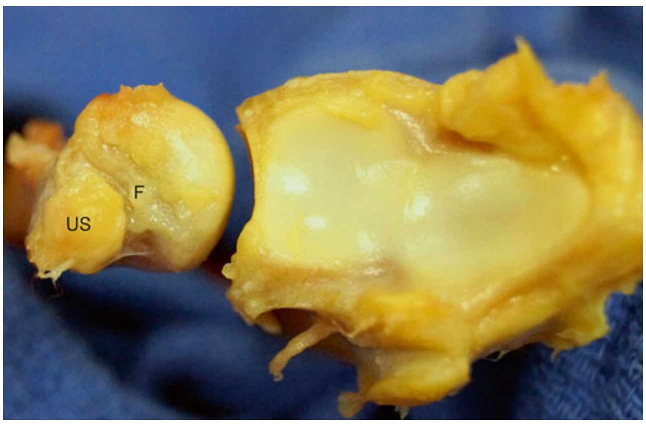


Fig. 4.1 The larger radius of curvature of the sigmoid notch compared to the ulnar head can be seen. With minimal bony restraints the stability of this joint is dependent on soft tissue structures. The fovea (*F*) of the ulnar head where the deep portion of the volar and dorsal radioulnar ligaments is seen along with the ulnar styloid (*US*) where the superficial portions of the radioulnar ligaments attach. (Specimens provided by the Anatomical Gifts Program at the University of Mississippi Medical Center)

In a patient with neutral variance, approximately 80 % of the load of the carpus will be transmitted through the radius and 20 % through the TFCC and ulna. If the variance increases by 2.5 mm, the load borne by the ulna will increase to approximately 40 %, while a decrease in variance of 2.5 mm will decrease the load borne by the ulna to approximately 4 % [10]. In addition to the increased load transmitted through the articular disc with increased variance, the space available for the TFCC is diminished, leading to a decreased thickness of the disc [11]. This increased load borne through the TFCC with increased ulnar variance helps explain the association with TFCC injuries, as greater loads and stresses are placed on this structure that already has a decreased thickness [1, 11]. In Palmer and Werner's cadaveric study, they found TFCC perforations in 17 % of ulnar minus wrists compared with 73 % in ulnar plus or neutral wrists [12].

Radiographic Evaluation

For a complete evaluation of the wrist, an accurate PA and lateral radiograph should be obtained to evaluate carpal and

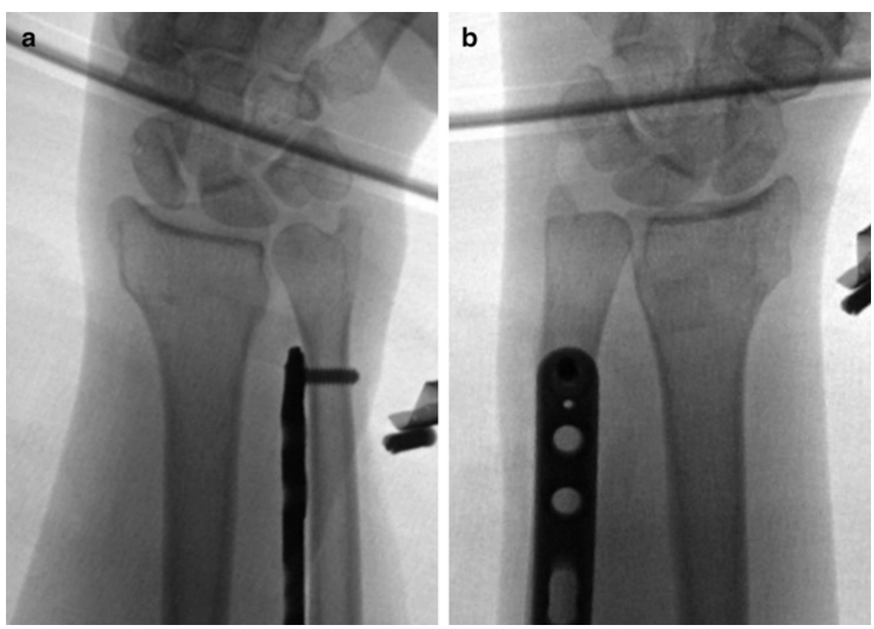


Fig. 4.2 (**a** and **b**) Flouroscopic images showing the positional changes in ulnar variance with pronation (**a**) and supination (**b**). In pronation the wrist is found to be significantly ulnar positive, while in supination the wrist is minimally positive in these images

DRUJ pathology, variance, and carpal malalignment. Due to the positional difference in the relationship of the distal radius and ulna, the recommended positioning when taking X-rays to assess for variance is that the forearm be in the zero or neutral rotation position for accurate measurements. A reliable way to obtain this view is with the shoulder abducted 90° and the elbow flexed 90° with the hand flat so that accurate reproducible results can be obtained in subsequent imaging studies [13]. When viewing the radiograph, the ulnar styloid should be at the greatest distance possible from the radius, and if it is not in this position, then the wrist is either pronated or supinated [13]. Another reliable method for obtaining acceptable radiographs is with the arm adducted to the side and the elbow flexed to 90° with the hand in neutral rotation and the thumb towards the ceiling. In this fixed position the X-ray beam can be rotated 90° to obtain a true PA and lateral radiograph.

Triangular Fibrocartilage Complex

The TFCC is a critical and complex structure that is integral to the normal kinematics and function of the wrist. Palmer and Werner, in their anatomic and biomechanical testing, described the anatomy of the TFCC as being composed of the articular disc, the meniscus homologue, the ulnar collateral ligament, the sheath of the extensor carpi ulnaris, and the dorsal and volar radioulnar ligaments (Fig. 4.3) [12]. The TFCC originates on the sigmoid notch before inserting on the ulna fovea and styloid, and distally it joins with the ulnar collateral ligament before inserting on the triquetrum, hamate, and base of the fifth metacarpal [12]. While not initially described as part of the TFCC by Palmer, the ulnocarpal wrist ligaments have since been included as components and are important stabilizers of the ulnocarpal joint [14].

These structures forming the TFCC are important in load transmission through the ulnar side of the wrist and are intrinsic stabilizers of the distal radioulnar and the ulnocarpal joints. The TFCC enlarges the contact area between the carpal bones and the ulna and transmits load between these structures. The wide but slim radial attachment is subjected to large amounts of stress during motion and is often a site of tears [15]. The importance of the TFCC in force transmission is demonstrated with resection of the articular disc, which unloads the ulnar column and decreases the load transferred through the ulna from 18 % to approximately 6 % [16]. The ulnocarpal ligament components of the TFCC contribute very little to DRUJ stability, but are significant in their contribution to ulnocarpal stability. Due to the very limited inherent bony stability of the DRUJ, the major stabilizer of this joint is the TFCC, with the palmar and dorsal radioulnar ligaments playing the most vital role in this process.

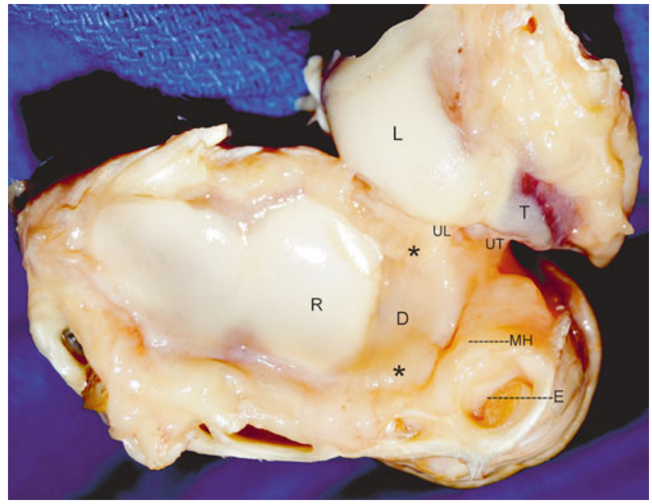


Fig. 4.3 Specimen demonstrating the different components of the ulnar side of the wrist and TFCC. *L* lunate, *T* triquetrum, *R* lunate facet of radius, *UT* ulnotriquetral ligament, *UL* ulnolunate ligament, *D* articular disc, *asterisk* volar and dorsal radioulnar ligaments, *MH* meniscus Homologue, *E* extensor carpi ulnaris subsheath

Ulnocarpal Ligaments

The ulnocarpal ligaments serve an important role in stabilizing the ulnar carpus and helping prevent supination and volar translocation of the carpus on the distal radius and ulna [17]. Stuart et al. found in their biomechanical study testing the relative contributions to stability of the DRUJ that the ulnocarpal ligament complex was not a significant contributor [3]. Although not always included as a part of the TFCC, the ulnocapitate ligament originates from the palmar aspect of the fovea, where it blends with the palmar radioulnar ligament and then runs superficial to the other ulnocarpal ligaments before inserting onto the capitate [18]. The ulnotriquetral ligament arises from the palmar aspect of the fovea and the meniscus homologue and the palmar radioulnar ligament before inserting on the triquetrum. The pisotriquetral orifice may be seen in the distal aspect of this ligament during arthroscopy. The ulnolunate ligament originates from the palmar aspect of the fovea and the articular disc, with a few fibers from the radius, and is intertwined with the palmar radioulnar ligament before inserting distally on the lunate (Fig. 4.4) [14, 19].

Moritomo et al. found that the length of the ulnotriquetral and ulnocapitate ligaments increased the greatest amount with wrist radial extension, whereas the ulnolunate increased the most with wrist extension, while the palmar radioulnar ligament had minimal change in length with any motion. This stress imparted through the ligaments might explain how a fall on an outstretched hand could lead to a foveal tear of the TFCC from excessive traction imparted through the ulnocarpal ligaments. Morimoto goes on to say, however, that pure

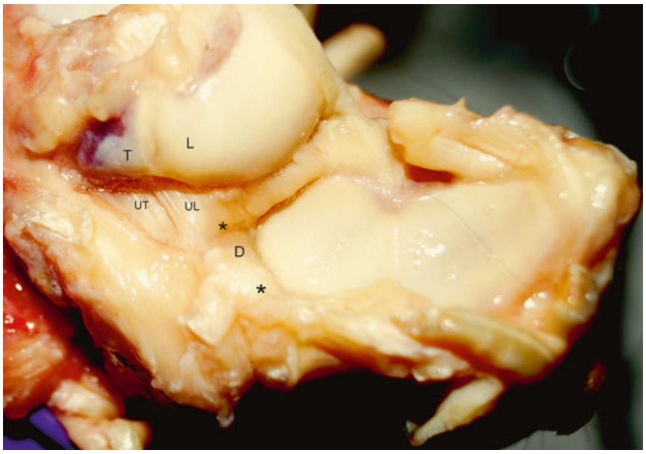


Fig. 4.4 The ulnolunate and ulnotriquetral ligament can be seen arising from the volar distal radioulnar ligament before inserting distally on the lunate and ulna, respectively. The ulnocapitate ligament is not seen as it runs volar to the other ulnar carpal ligaments. The volar and dorsal radioulnar ligaments appear as thickenings of the peripheral articular disc. *L* lunate, *T* triquetrum, *UT* ulnotriquetral ligament, *UL* ulnolunate ligament, *D* articular disc, *asterisk* volar and dorsal radioulnar ligaments

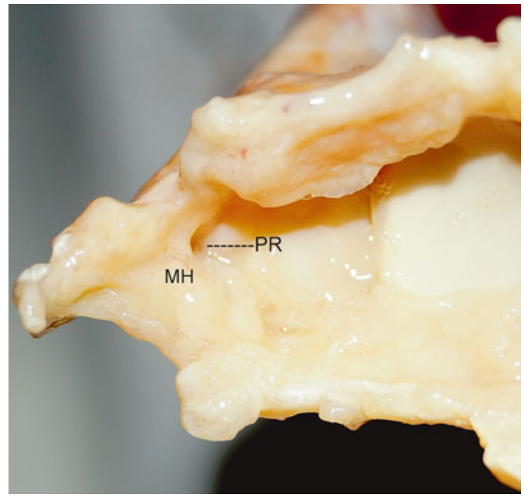


Fig. 4.5 The prestyloid recess is seen and is often found anterior to the ulnar styloid and is the area where the styloid is not covered by the meniscus homologue. The meniscus homologue (*MH*) composed of loose connective tissue located in the ulnar aspect of the radiocarpal joint and is seen to the *left* and *inferior* to the prestyloid recess (*PR*) in this image

wrist hyper-radial extension or hyperextension would not be adequate by itself to cause these injuries and that additional forces would be required to initiate a tear [19].

Meniscus Homologue

The meniscus homologue is a C-shaped vascular tissue located between the superficial portion of the radioulnar ligaments, the capsule, and the triquetrum in the ulnar aspect of the radiocarpal joint. Some debate has occurred over whether this is a true component of the TFCC, as it differs histologically by being composed of loose connective tissue instead of dense collagen and also by being lined by synovial cells on its inner surface [18]. Ishii et al. found in their study that the meniscus homologue, which they classified into three types as related to the prestyloid recess, was not identifiable as the separate structure that was previously described by Bowers and Taleisnik [14, 20, 21].

Prestyloid Recess

The prestyloid recess is a pouch often found anterior to the ulnar styloid where the meniscus homologue does not cover the ulnar styloid, and should not be confused with a tear of the TFCC [18]. It can be found at the apex of radioulnar ligaments and is typically lined with synovial villi (Fig. 4.5) [22]. Ishii described three different variations in the prestyloid recess: narrow, wide, and no-opening types [14]. The narrow opening type was found in 74 % of specimens and consisted of the meniscus homologue being attached to the ulnar styloid proximal to its radial, dorsal, and palmar aspects and distal to the ulnar styloid tip circumferential surface [14]. The prestyloid recess was found to communicate with the ulnocarpal space by a long narrow tunnel from the palmar aspect of the styloid [14]. The wide opening type was found in 11 % and consisted of the attachments similar to the narrow opening, but without attachment to the tip of the styloid [14]. A short, wide opening was found between the prestyloid recess and the ulnocarpal space [14]. The no-opening type was found in 15 % of patients, and the prestyloid recess was found to come from the radial aspect of the styloid and to communicate with the distal radioulnar joint instead of the ulnocarpal space [14]. The ligamentum subcruentum, as it was originally described, was not found in this type, but was identified in the narrow and wide opening variations [14].

Radioulnar Ligaments

The dorsal and palmar radioulnar ligaments are intracapsular intrinsic stabilizers that measure 4–5 mm in thickness and impart the majority of stability to the DRUJ in pronation and supination as translational motion occurs [1–3, 12]. The histologic makeup of these ligaments demonstrates longitudinally-oriented parallel fibers, which suggest a tissue that experiences tensile loads, a premise which supports their role as stabilizing structures [23]. The palmar radioulnar ligament forms the proximal attachment of the ulnocarpal ligaments, while the dorsal radioulnar ligmanent splits ulnarly to form the subretinacular sheath of the extensor

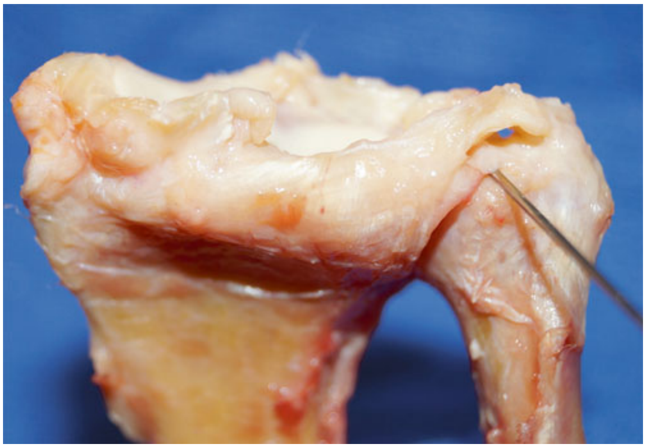


Fig. 4.6 Specimen demonstrating both the superficial and deep volar radioulnar ligaments. The superficial ligament can be seen inserting on the styloid, and the deep ligament (located *superior* to the needle) can be seen inserting into the fovea

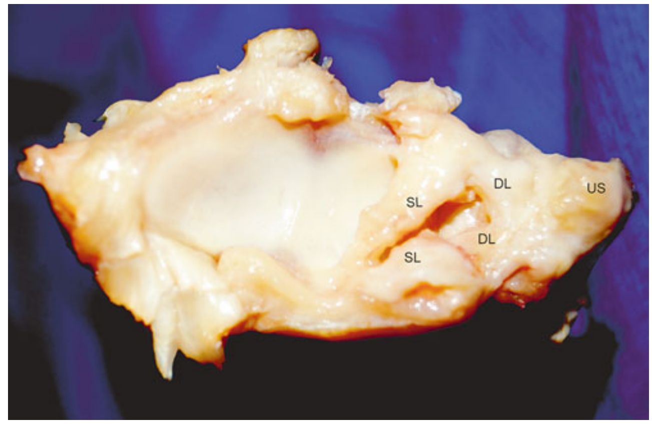


Fig. 4.8 A specimen showing the deep portion of the volar and dorsal radioulnar ligaments (*DL*) converging prior to inserting into the fovea. The articular disc has been resected and the superficial radioulnar ligaments (*SL*) have been released from the ulnar styloid (*US*) and retracted

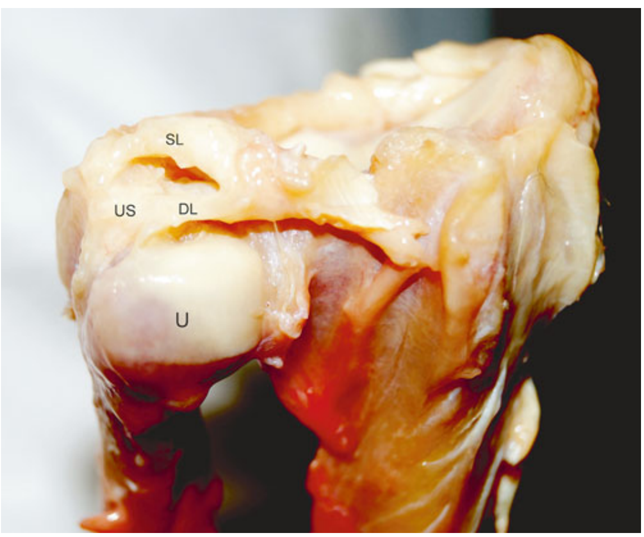


Fig. 4.7 The conjoined deep (*DL*) and superficial (*SL*) dorsal radioulnar ligament can be seen prior to splitting and inserting into their respective sites onto the fovea and the ulnar styloid (*US*). *U* ulnar head

carpi ulnaris [15]. These ligaments have both a superficial and deep portion with the insertions on the ulnar styloid and fovea, respectively (Fig. 4.6) [1, 24]. At their broad radial attachment at the distal rim of the sigmoid notch, the radioulnar ligaments are conjoined, but then split prior to reaching the ulnar styloid or fovea into a superficial and a deep portion (Fig. 4.7) [2, 14]. The insertion of the deep portion, commonly called the ligamentum subcruentum, is more lateral and proximal into the fovea compared to the more central and distal insertion of the superficial ligament. The palmar and dorsal portions of the deep ligament converge and intertwine as they insert into the fovea (Fig. 4.8) [15]. The original description of the ligamentum subcruentum was of a vascularized space separating the proximal deep and distal superficial portions of the TFCC, but this term has changed over time to describe the insertion of the deep component of the ligaments [1, 24]. Ishii, in a cadaveric study, found that the deep portion inserts on the fovea, but that there was not a clearly distinct insertion site of the superficial ligament on the styloid [14].

The insertion of the deep component of the ligament provides a better mechanical advantage for controlling rotation as its angle of insertion is less acute than that of the superficial ligament [1]. To demonstrate this concept, Kleinman uses the analogy of a team of horses, a buckboard, and a driver, in which the radius is the team of horses, the ulna is the buckboard, and the different angles of the reins going to the driver represent the deep and superficial ligaments [1]. This analogy shows how the less-acute angle of the reins, which represents the deep ligament, is more advantageous in controlling the rotation of the horses, which represents the radius [1]. The radioulnar ligaments have a spiral configuration as they insert onto the ulnar head, and this rotational insertion, along with the differing locations of insertion of the deep and superficial ligaments, allows continuous shifts in tension and compression and is the core of DRUJ stability [7].

The superficial radioulnar ligaments also provide stability to the DRUJ, but their action is the opposite of the deep ligaments, with the dorsal fibers giving stability in pronation and the palmar fibers providing stability in supination. While the superficial fibers do provide stability, they have a more acute angle of insertion and thus less mechanical advantage for rotational control. The second reason the superficial ligaments play a lesser role is that in maximum pronation or supination, the majority of the ulna has escaped out from under the superficial fibers, rendering them ineffective in

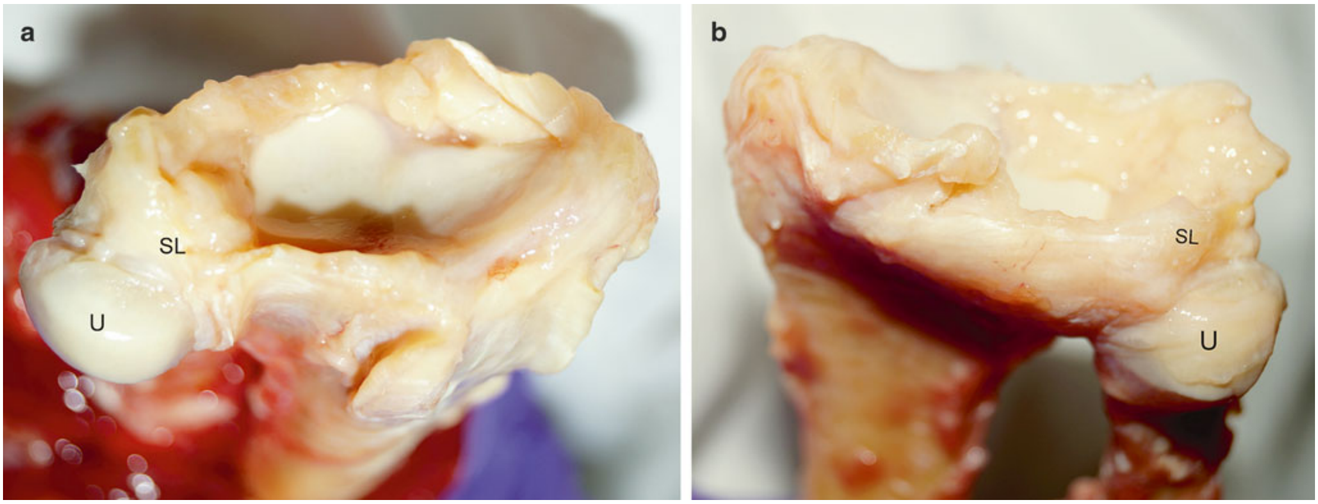


Fig. 4.9 (**a** and **b**) The ulnar head can be seen escaping from underneath the superficial fibers of the dorsal radioulnar ligament in maximum pronation (**a**), and the volar radioulnar ligament in maximum supination. This demonstrates how the superficial fibers have a diminished role in the stability of the DRUJ in the extremes of motion, and the majority of the stability is provided by the tethering role of the deep portion of the radioulnar ligaments. *SL* superficial portion of the radioulnar ligament, *U* ulnar head

these extremes of motion (Fig. 4.9a, b). In this position, the deep portion of the radioulnar ligament provides stability by providing a tethering action, thus preventing dislocation of the DRUJ [1, 2].

The Ulnar Collateral Ligament and Extensor Carpi Ulnaris Subsheath

The ulnar collateral ligament and the extensor carpi ulnaris (ECU) subsheath play an important role in the function of the TFCC. The ulnar collateral ligament is found originating on the ulnar styloid before dividing and inserting distally on the triquetrum and pisiform, and contributes to ulnocarpal stability. The ECU subsheath is formed from the deep lamina of the antebrachial fascia and is directly adjacent to the articular disc (Fig. 4.10) [4]. The subsheath plays an important role in stabilizing the extensor carpi ulnaris tendon in the ulnar groove in pronation and supination (Fig. 4.11). The role of the extensor carpi ulnaris subsheath in DRUJ stability is somewhat controversial. Iida et al found that the ECU dynamically stabilized the DRUJ and ulnocarpal joint in supination and neutral rotation after sectioning of the TFCC, and that the ECU subsheath assisted the ECU with stabilization on the ulnar side of the wrist. In contrast, Stuart et al, in their biomechanical study, did not find that the ECU subsheath was a significant contributor to DRUJ stability [3, 25]. Tang did find an increase in excursion of the ECU tendon of 30 % during 60° of wrist extension after release of the TFCC from the distal ulna in a Palmar 1B-type lesion, suggesting that the TFCC is an important part of the pulley system for the ulnar wrist extensor [26]. This might suggest that the TFCC plays a more significant role as part of the ulnar wrist extensor pulley system than the ECU subsheath does as a stabilizer of the DRUJ.

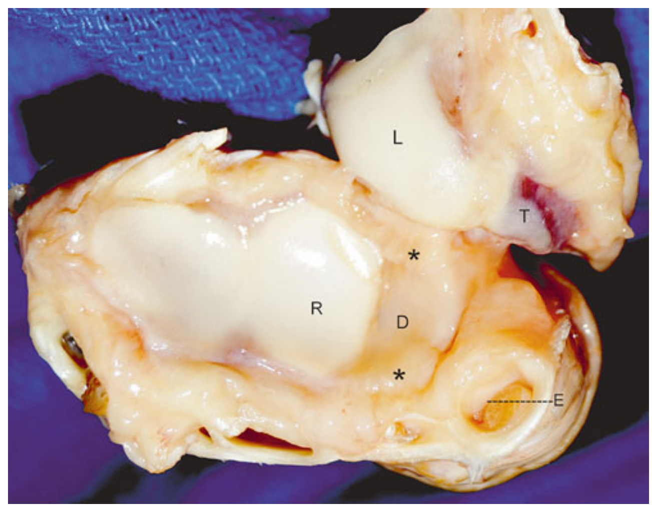


Fig. 4.10 The extensor carpi ulnaris subsheath (*E*) can be seen directly adjacent to the dorsal portion of the radioulnar ligaments (*asterisk*) and the articular disc (*D*). This tissue can provide a stout repair for peripheral tears in this location

The Articular Disc

The articular disc forms the radial and central aspect of the TFCC and extends from the radius and covers the ulnar head before reaching the meniscus homologue and capsule. It does not attach directly to the ulnar head and is

Fig. 4.11 The extensor carpi ulnaris subsheath is seen and is responsible for stabilizing the tendon in the ulnar groove during pronation and supination

bounded on its palmar and dorsal aspect by the radioulnar ligaments, which are the main supporting structures of the DRUJ. These ligaments cannot be distinctly distinguished from the disc during arthroscopy and appear as thickenings on the periphery. The disc appears wedge-shaped in the coronal plane, being thinner on the radial aspect and then thickening ulnarly. The disc is also found to be thicker on the peripheral aspects and thinner in the central region. It should be noted that the disc is thicker in people with negative ulnar variance and thinner in people with positive or neutral variance [4]. The collagen of the disc is composed of interweaving sheets of collagen fibers, which is consistent with a structure experiencing multidirectional stresses [23]. An important finding regarding surgical treatment showed that resection of the central two-thirds of the disc with maintenance of the radioulnar ligaments and the ulnocarpal ligaments had no significant effect on axial load transmission [27, 28]. Adams also found that resection of two-thirds of the disc with preservation of the peripheral 2 mm had no significant effect on the normal kinematics [29]. With resection of greater than two-thirds of the disc and resection of the peripheral 2 mm, the ulnar column is unloaded, transferring the load to the distal radius in addition to possibly destabilizing the DRUJ [27–29].

Blood Supply

Work done by Thiru et al. demonstrated that the central 80–85 % of the disc is relatively avascular, and the blood supply to the peripheral 15–20 % is supplied from contributions from the ulnar artery through the palmar and dorsal radiocarpal branches and also from the anterior interosseous artery through the palmar and dorsal branches [30]. Works by Bednar et al. and Chidgey expanded on this knowledge by showing that the vessels enter the TFCC from the palmar, dorsal, and ulnar attachments of the capsule, but that there is limited vascularity at the radial attachment [23, 31]. These anatomical studies suggest that due to the avascular nature of the central TFCC, repair would not be possible in this region, and Bednar and colleagues further expanded this to include tears along the radial attachment. While Bednar suggested from anatomical studies that radial-sided tears might not be amenable to repair, several clinical studies have shown good results with radial-sided repairs despite the poor blood supply in this region [15, 31–33]. An interesting finding was reported by Tatebe et al. with second look arthroscopic surgery in patients that had previously undergone arthroscopic surgery with or without debridement of central TFCC tear followed by an ulnar shortening osteotomy [34]. They found that 16 out of 32 patients had healed their previous central tear with fibrous connective tissue and fibrocartilaginous components with no infiltration of inflammatory cells or vascular invasion seen in the regenerated tissues [34]. Their findings showed that rounded and more ulnarly located tears had a higher tendency to heal compared with linear and radial–central tears [34].

Innervation

The innervation of the TFCC is fairly consistent with contributions from the posterior interosseous nerve in the dorsal aspect, the ulnar nerve in the volar aspect, and the dorsal sensory branch in the ulnar region [7, 35]. Cavalcante et al. found increased free nerve endings in the dorsal and ulnar aspects of the TFCC, which correlate with Ohmori's et al. findings of more free nerve endings in the region of the meniscus homologue and the collagen fiber area of the ulnar peripheral portion of the articular disc [36, 37]. Gupta et al. suggested the possible entry site for sensory nerves is the internal portion of the TFCC; located deep in the styloid recess, it has the highest density of neural elements and free nerve endings and might be a source of ulnar-sided pain [38]. Mechanoreceptors have been identified in different regions, suggesting a proprioceptive role of the TFCC [7, 36, 37]. Cavalcante et al. found a higher density of Pacini corpuscles in the dorsal and radial aspects, suggesting that this area is

Table 4.1 Classification of tears of the triangular fibrocartilage complex

Class I traumatic injuries	
Subtype	Characteristics
IA	Tears or perforations of the horizontal portion of the triangular fibrocartilage complex (TFCC)
	Usually 1–2 mm wide
	Dorsal palmar slit located 2–3 mm medial to the radial attachment of the sigmoid notch
IB	Traumatic avulsion of TFCC from insertion into the distal ulna
	May be accompanied by a fracture of the ulnar styloid at its base
	Usually associated with distal radiocarpal joint instability
IC	Tears of TFCC that result in ulnocarpal instability, such as avulsion of the TFCC from the distal attachment of the lunate or triquetrum
ID	Traumatic avulsions of the TFCC from the attachment at the distal sigmoid notch

responsible for detecting the onset or cessation of movement; they also found an even distribution of Ruffini corpuscles throughout the TFCC [37].

TFCC Injuries

Injuries of the TFCC are not uncommon, with the most common mechanism being a fall onto an outstretched hand, resulting in extension and pronation of an axially loaded carpus [39, 40]. Other common injury mechanisms of the TFCC include a rapid twisting and loading of the ulnar side of the wrist, often occurring on the athletic field or in the workplace, and a distractive force along the ulnar aspect of the wrist [27, 40]. Palmer described a classification of lesions of the TFCC which describes both traumatic (Type 1) and degenerative lesions (Type 2) (Table 4.1) [39]. An understanding of these lesions and the various treatment options of each should be familiar to the surgeon; however, this discussion will be brief and limited to traumatic lesions, and will not go into detail regarding the treatment options.

Type 1A tears involve the central avascular portion of the disc several millimeters from the radial attachment and are usually oriented from dorsal to volar (Fig. 4.12). Type 1B lesions represent a peripheral detachment of the insertion of the TFCC onto the distal ulna. Clinically this type of injury is important, as it involves detachment of the radioulnar ligaments from the ulna either from a fracture or from a pure avulsion-type injury, and can lead to DRUJ instability. Type 1C lesions represent an ulnocarpal ligament avulsion and can result in ulnocarpal instability with volar translocation of the carpus [27, 39]. Type 1D tears represent an avulsion of the TFCC from its wide but thin radial attachment to the sigmoid notch, and are more rare than central and peripheral tears [39].

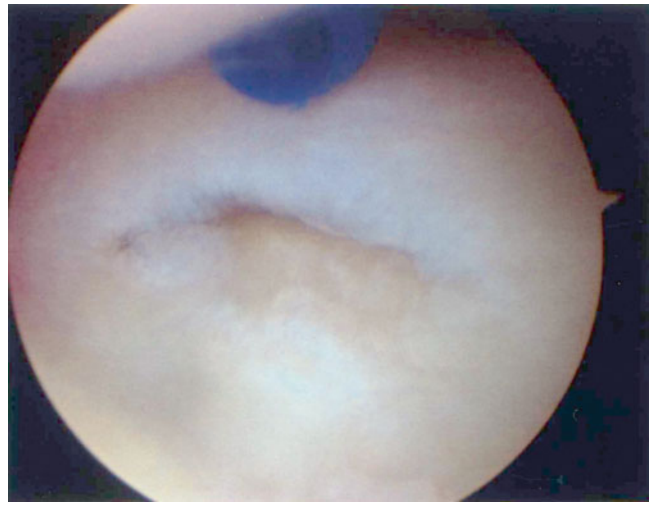


Fig. 4.12 An arthroscopic image showing a Palmer 1A tear of the *central portion* of the disc. The radioulnar ligaments are not involved, and this tear is oriented from volar to dorsal in the usual manner. The ulnar head is visible from the radiocarpal space through this full-thickness tear

Arthroscopic Anatomy of the TFCC

Arthroscopy allows better visualization of the different components of the TFCC than can often be obtained with open approaches. With this improved ability to see fine details and structures, the surgeon must possess a comprehensive understanding of the anatomy to help differentiate normal anatomical variants from a pathologic process. The TFCC can be visualized from both the radiocarpal and the DRUJ spaces and different aspects of the complex can be examined. MRI has been shown to be a valuable resource in the detection of these injuries, with Tanaka et al. finding that high resolution MRI has improved the detection of central and radial-sided lesions when compared to arthroscopy with findings of 100 % sensitivity and specificity [41]. Unfortunately, MRI was not as accurate regarding injuries to the ulnar attachment of the TFCC, DRUL, PRUL, and ulnolunate ligaments with a higher false positive rate and lower specificity [41]. Due to the remaining limitations of MRI, arthroscopy still remains a valuable technique not only for the treatment, but also for the diagnosis of these injuries.

Radiocarpal Space

From the radiocarpal space the TFCC can first be visualized as the scope is moved ulnarly along the lunate facet of the radius, exposing the broad insertion of the TFCC onto the ulnar border of the radius. The appearance of the TFCC is that of a broad white ligamentous sheet and can be very similar in appearance to the articular cartilage of the lunate

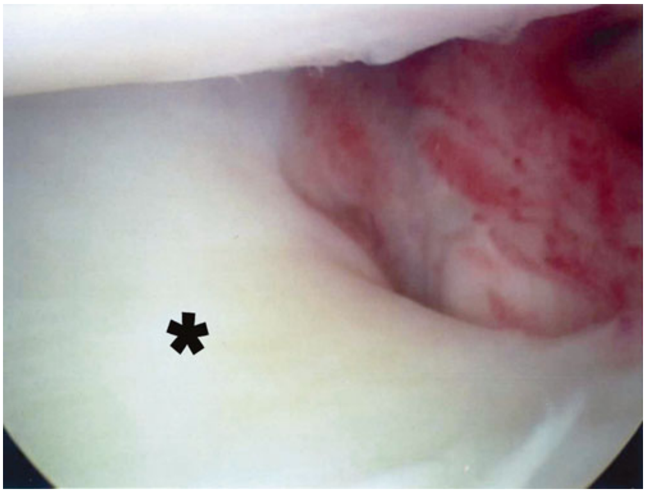


Fig. 4.13 An arthroscopic image showing the taut, white sheet-like appearance of the TFCC (*asterisk*). The volar and dorsal radioulnar ligaments cannot be seen as distinct structures arthroscopically and appear as thickenings where the TFCC meets the capsule

Fig. 4.14 The "Trampoline" test is performed by compressing the TFCC with a probe and assessing the tension. An intact disc will be taut, and a tear should be suspected if the disc is found to be soft and pliable

facet (Fig. 4.13) [22]. This junction between the medial border of the radius and the TFCC may be clear, but it may be very subtle in some patients [22]. If difficulty is encountered in differentiating where the radius ends and the TFCC begins, a probe can be utilized for help with identification, as the firm border of the radius gives way to the softer disc [42, 43]. The articular disc lies in between the dorsal and palmar radioulnar ligaments and extends from the sigmoid notch towards the ulnar styloid and meniscus homologue. The ulnar head should not be seen from the radiocarpal space with an intact TFCC, but may be visualized with a full-thickness tear [42].

The dorsal and palmar radioulnar ligaments appear as thickenings of the peripheral aspect of the disc where it joins the capsule, but they are not seen as distinct, separate structures. The insertion of the deep portion of these ligaments cannot be visualized from the radiocarpal space, but can still be evaluated. The hook test, as described by Ruch can be used to determine if there is a foveal detachment of the deep portion of the radioulnar ligaments representing a Palmer 1B-type lesion [44]. This is performed by inserting a probe in the 4–5 or the 6-R portal and pulling traction to the most ulnar aspect of the TFCC. This test is positive for a tear of the foveal attachment if the ulnar aspect of the TFCC is able to be pulled radially and distally [45]. The probe can further be used to palpate the disc and perform the trampoline test by compressing the TFCC. An intact TFCC will be taut with the tension maintained, whereas with a significant tear the disc will be soft and pliable (Fig. 4.14) [17, 42]. The central disc and the periphery should be thoroughly inspected and probed to determine the integrity of the TFCC and to ensure that there are no subtle tears present [42].

In the dorsal ulnar aspect, the TFCC can be seen attached to the floor of the subsheath of the extensor carpi ulnaris tendon. This tissue provides good fixation of the disc back to the sheath when a peripheral tear occurs in this area [40]. The ECU subsheath and the dorsal ulnotriquetral ligament should be visualized and probed after removing the covering synovium if an injury is suspected in this region [40]. The prestyloid recess can be visualized, ulnar to the short radiolunate ligament and palmar to the styloid, but should not be mistaken for a TFCC tear, as this is a normal finding. This opening can have a variable appearance and is usually lined with synovial villi and capillaries (Fig. 4.15) [15].

The ulnolunate and ulnotriquetral ligaments can be seen passing from the palmar aspect of the radioulnar ligament before attaching to the volar aspect of the lunate and the triquetrum (Fig. 4.16). The ulnolunate ligament can be seen originating from the palmar radioulnar ligament before inserting distally on the lunate just ulnar to the short radiolunate ligament. Depending on the tension of the proximal radioulnar ligament during forearm rotation, a fold may be seen between these ligaments [22]. Moving ulnarly, the ulnotriquetral ligament can be visualized originating from the palmar radioulnar ligament and inserting distally on the palmar aspect of the triquetrum. The pisotriquetral orifice may be seen as a small defect in the distal aspect of the ulnotriquetral ligament and is a communication between the ulnocarpal and pisotriquetral joints (Fig. 4.17). This is best seen using the 4–5 or 6-R portal, and through this opening

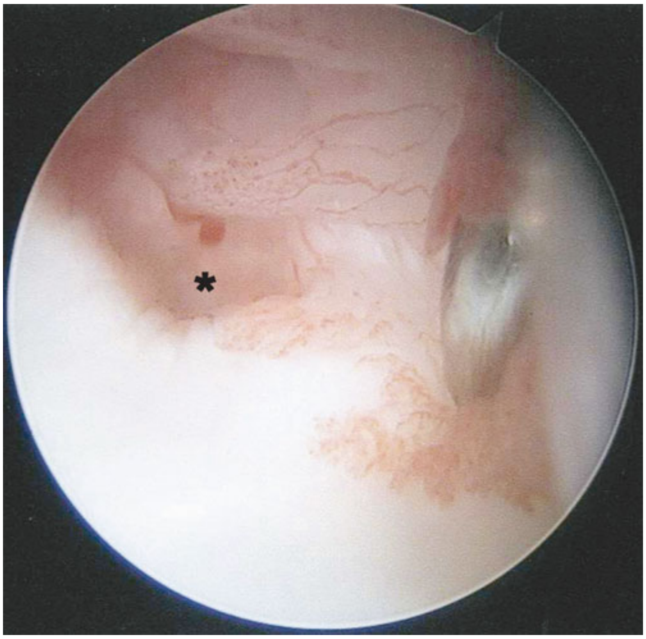


Fig. 4.15 Arthroscopic image showing the prestyloid recess (*asterisk*) with the synovial villi lined opening, along with the surrounding loose tissue of the meniscus homologue. This structure can have a variable appearance and should not be mistaken for a TFCC tear

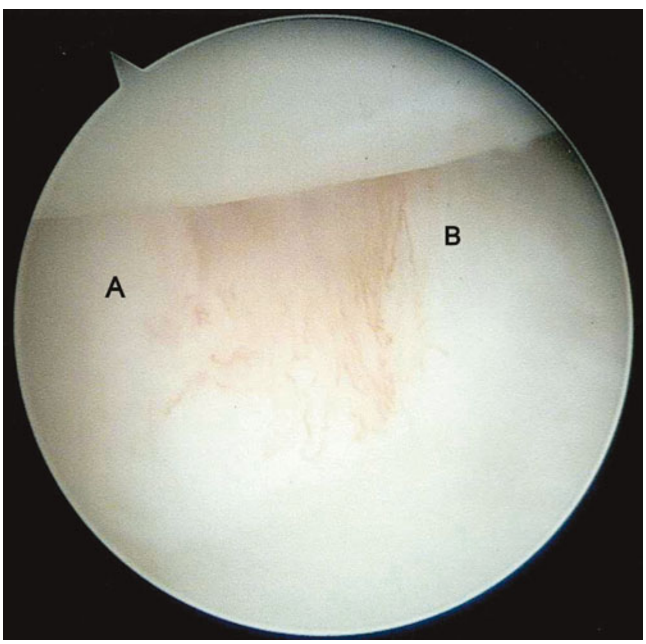


Fig. 4.16 Arthroscopic image showing the ulnolunate (*A*) and the ulnotriquetral (*B*) ligament passing from the palmar aspect of the volar radioulnar ligament to their insertions on the lunate and triquetrum respectively

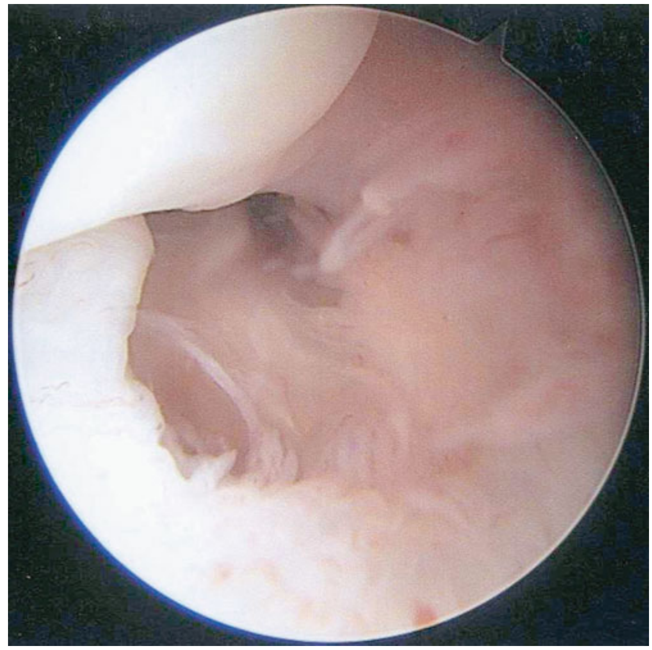


Fig. 4.17 An arthroscopic image taken from the 6R portal demonstrating the pisotriquetral orifice. This communication between the ulnocarpal and pisotriquetral joints can be located by following the ulnotriquetral ligament distally. The dorsal surface of the pisiform is not visible in this image, but it may be seen along with insertion of the flexor carpi ulnaris

the dorsal surface of the pisiform may be visualized along with the insertion of the flexor carpi ulnaris [22]. Both of these ligaments should be inspected and probed to test their integrity, as they limit wrist extension and radial deviation and can be a source of pain when injured, even though they do not contribute significantly to DRUJ stability. The lunotriquetral interosseous ligament can be located in the interval of these ligaments by following them distally (Fig. 4.18) [42]. The ulnocapitate ligament is not normally visible during radiocarpal arthroscopy as it is superficial to the ulnolunate and ulnotriquetral ligaments [22].

DRUJ Space

Although arthroscopy of the DRUJ is not as commonly performed as that of the radiocarpal space, it can provide important diagnostic information. The DRUJ can be entered using either a 2.7 mm or a 1.9 mm arthroscope for visualizing the sigmoid notch, distal ulna, undersurface of the TFCC, and the deep portion of the palmar and dorsal radioulnar ligaments along with their attachment into the fovea. Arthroscopy of this joint takes advantage of the mismatch of the radius of curvature of the ulnar head and the sigmoid notch to allow passage of the scope [22]. With the scope in the dorsal DRUJ portal, the sigmoid notch and the ulnar head can be visualized as the scope is directed distally. The ulnocapitate ligament can be seen inserting on the most radial aspect of the fovea with the radioulnar ligaments converging and inserting ulnarly on the fovea. From the volar DRUJ portal the undersurface of the TFCC can again be seen attaching to the ulnar border of the radius. A probe can

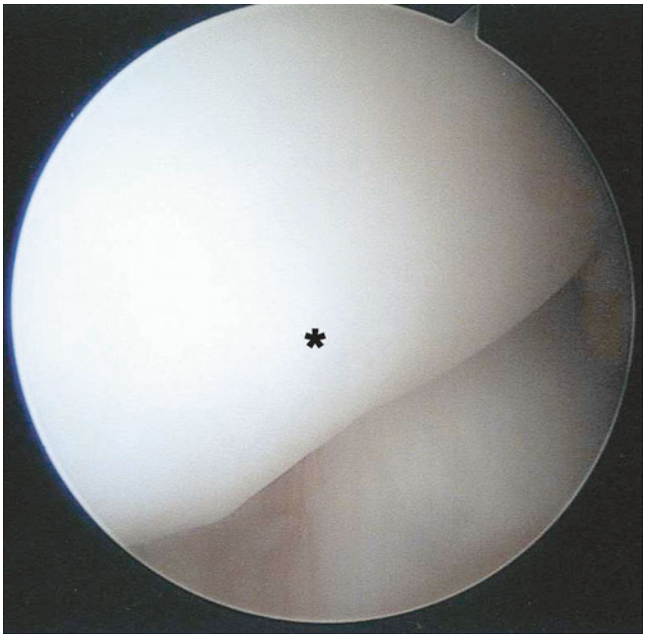


Fig. 4.18 The ulnotriquetral interval (*asterisk*) is seen in this arthroscopic image, and may be identified in the interval of the ulnolunate and ulnotriquetral ligaments by following them distally

be placed from the dorsal portal allowing this broad attachment to be evaluated. As the scope is directed ulnarly, the ulnar head and the undersurface of the articular disc come into view and can be inspected. Directing the scope more ulnarly towards the fovea exposes the deep portions of the radioulnar ligaments, which can be seen converging and inserting onto the fovea. These ligaments can then be probed to check for tears of their insertion into the fovea.

Conclusion

A thorough understanding of the anatomy and biomechanics of the TFCC is invaluable in treating patients with ulnar-sided wrist pain. While instructional texts and videos can provide a basic foundation of knowledge, the arthroscopic anatomy of the TFCC and wrist in general may best be learned through cadaveric training initially. This knowledge can then be further enhanced through clinical practice, as often the intraoperative findings may be subtle or not as classically described. Once the surgeon has mastered this sometimes difficult anatomy, pathologic findings can be identified and the proper surgical treatment may be performed.

References

1. Kleinman WB. Stability of the distal radioulnar joint: biomechanics, pathophysiology, physical diagnosis, and restoration of function what we have learned in 25 years. J Hand Surg Am. 2007;32A:1086–106.
2. Af Ekensam F, Hagert CG. Anatomical studies on the geometry and stability of the distal radio ulnar joint. Scand J Plast Reconstr Surg. 1985;19:17–25.
3. Stuart PR, Berger RA, Linscheid RL, An KN. The dorsopalmar stability of the distal radioulnar joint. J Hand Surg Am. 2000;25A:689–99.
4. Berger RA. Wrist anatomy. In: Cooney WP, editor. The wrist. 2nd ed. Philadelphia, PA: Lippincott Williams & Wilkins; 2010. p. 25–76.
5. Whipple TL. Arthroscopy of the distal radioulnar joint-indications, portals, and anatomy. Hand Clin. 1994;10(4):589–92.
6. Hagert CG. The distal radioulnar joint. Hand Clin. 1987;3(1):41–50.
7. Hagert E, Hagert CG. Understanding stability of the distal radioulnar joint through an understanding of its anatomy. Hand Clin. 2010;26(4):459–66.
8. Ekenstam FW, Palmer AK, Glisson RR. The load on the radius and ulna in different positions of the wrist and forearm. Acta Orthop Scand. 1984;55:363–5.
9. Friedman SL, Palmer AK, Short WH, et al. The change in ulnar variance with grip. J Hand Surg Am. 1993;18:713–6.
10. Palmer AK, Werner FW. Biomechanics of the distal radioulnar joint. Clin Orthop Relat Res. 1984;187:26–35.
11. Palmer AK, Glisson RR, Werner FW. Relationship between ulnar variance and TFCC thickness. J Hand Surg Am. 1984;9:681–3.
12. Palmer AK, Werner FW. The triangular fibrocartilage complex of the wrist anatomy and function. J Hand Surg Am. 1981;6:153–62.
13. Michalko K, Allen S, Akelman E. Evaluation of the painful wrist. In: Geissler WB, editor. Wrist arthroscopy. New York, NY: Springer; 2005. p. 15–21.
14. Ishii S, Palmer AK, Werner FW, Short WH, Fortino MD. An anatomic study of the ligamentous structure of the triangular fibrocartilage complex. J Hand Surg Am. 1998;23A:977–85.
15. Jantea CL, Baltzer A, Ruther W. Arthroscopic repair of radial-sided lesions of the fibrocartilage complex. Hand Clin. 1995;11(1):31–6.
16. Werner FW, Glisson RR, Murphy DJ, et al. Force transmission through the distal radioulnar carpal joint: effect of ulnar lengthening and shortening. Handchirurgie. 1986;18:304–8.
17. Osterman AL, Terrill RG. Arthroscopic treatment of TFCC lesions. Hand Clin. 1991;7:277–81.
18. Moritomo H, Kataoka T. Anatomy of the ulnocarpal compartment. In: Piñal, F d, Mathoulin C, Nakamura T. *Arthroscopic management of ulnar pain*. Berlin; New York: Springer. 2012; 1-14.
19. Moritomo H, Murase T, Arimitsu S, Oka K, Yoshikawa K, Sugamoto K. Change in the length of the ulnocarpal ligaments during radiocarpal motion: possible impact on triangular fibrocartilage complex foveal tears. J Hand Surg Am. 2008;33A:1278–86.
20. Bowers WH. The distal radioulnar joint. In: Green DP, editor. Operative hand surgery, vol. 1. 3rd ed. New York, NY: Churchill Livingstone; 1993. p. 973–1019.
21. Taleisnik J. The ligaments of the wrist. In: Taleisnik J, editor. The wrist. New York, NY: Churchill Livingstone; 1985. p. 13–38.
22. Berger RA. Arthroscopic anatomy of the wrist and distal radioulnar joint. Hand Clin. 1999;15(3):393–413.
23. Chidgey LK. Histologic anatomy of the triangular fibrocartilage. Hand Clin. 1991;7(2):249–62.
24. Kauer JMG. The articular disc of the hand. Acta Anat. 1975;93:590–605.
25. Iida A, Omokawa S, Moritomo H, Aoki M, Wada T, Kataoka T, Tanaka Y. Biomechanical study of the extensor Carpi ulnaris as a dynamic wrist stabilizer. J Hand Surg Am. 2012;37A:2456–61.
26. Tang JB, Ryu J, Kish V. The triangular fibrocartilage complex: an important component of the pulley for the ulnar wrist extensor. J Hand Surg Am. 1998;23A:986–91.
27. Bednar JM. Arthroscopic treatment of triangular fibrocartilage tears. Hand Clin. 1999;15(3):479–88.
28. Palmer AK, Werner FW, Glisson RR, et al. Partial excision of the triangular fibrocartilage complex. J Hand Surg Am. 1988;13:391–4.

29. Adams BD. Partial excision of the triangular fibrocartilage complex articular disc: a biomechanical study. J Hand Surg Am. 1993;18: 334–40.
30. Thiru RG, Ferlic DC, Clayton ML, McClure DC. Arterial anatomy of the triangular fibrocartilage of the wrist and its surgical significance. J Hand Surgery Am. 1986;11:258–63.
31. Bednar MS, Arnoczky SP, Weiland AJ. The microvasculature of the triangular fibrocartilage complex: its clinical significance. J Hand Surgery Am. 1991;16:1101–5.
32. Trumble TE, Gilbert M, Vedder N. Isolated tears of the triangular fibrocartilage: management by early arthroscopic repair. J Hand Surg Am. 1997;22:57–65.
33. Sagerman SD, Short W. Arthroscopic repair of radial-sided triangular fibrocartilage complex tears. Arthroscopy. 1996;12: 339–42.
34. Tatebe M, Horii E, Nakao E, Shinohara T, Imaeda T, Nakamura R, Hirata H. Repair of the triangular fibrocartilage complex after ulnar-shortening osteotomy: second-look arthroscopy. J Hand Surg Am. 2007;32(4):445–9.
35. Shigemitsu T, Tobe M, Mizutani K, Murakami K, Ishikawa Y, Sato F. Innervation of the triangular fibrocartilage complex of the human wrist: quantitative immunohistochemical study. Anat Sci Int. 2007;82(3):127–32.
36. Ohmori M, Azuma H. Morphology and distribution of nerve endings in the human triangular fibrocartilage complex. J Hand Surg Br. 1998;23(4):522–55.
37. Cavalcante ML, Rodrigues CJ, Mattar Jr R. Mechanoreceptors and nerve endings of the triangular fibrocartilage in the human wrist. J Hand Surg Am. 2004;29(3):432–5.
38. Gupta R, Nelson SD, Baker J, Jones NF, Meals RA. The innervation of the triangular fibrocartilage complex: nitric acid maceration rediscovered. Plast Reconstr Surg. 2001;107(1):135–9.
39. Palmer AK. Triangular fibrocartilage complex lesions: a classification. J Hand Surg Am. 1989;14:594–606.
40. Geissler WB. Arthroscopic knotless peripheral ulnar-sided TFCC repair. Hand Clin. 2011;27(4):273–9.
41. Tanaka T, Yoshioka H, Ueno T, Shindo M, Ochiai N. Comparison between high-resolution MRI with a microscopy coil and arthroscopy in triangular fibrocarilage complex injury. J Hand Surg Am. 2006;31(8):77–84.
42. Lee JH, Taylor NL, Beekman RA, Rosenwasser MP. Arthroscopic wrist anatomy. In: Geissler WB, editor. Wrist arthroscopy. New York: Springer; 2005. p. 7–13.
43. Whipple LT. Arthroscopic surgery: the wrist. Philadelphia, PA: Lippincott Williams & Wilkins; 1992. p. 55–60.
44. Ruch DS, Yang CC, Smith BP. Results of acute arthroscopically repaired triangular fibrocartilage complex injuries associated with intra-articular distal radius fractures. Arthroscopy. 2003;19(5):511–6.
45. Atzei A, Rizzo A, Luchetti R, Fairplay T. Arthroscopic foveal repair of triangular fibrocartilage complex peripheral lesion with distal radioulnar joint instability. Tech Hand Up Extrem Surg. 2008; 12:226–35.

Management of Type 1A TFCC Tears

5

Laith Al-Shihabi, Robert W. Wysocki, and David S. Ruch

History and Physical Examination

Triangular fibrocartilage complex (TFCC) injuries are amongst the most common causes of ulnar-sided wrist pain and can result from both acute and chronic mechanisms of injury. Acute injuries are typically traumatic and result from compression or shear of the TFCC between the distal ulna and the proximal carpus, while chronic injuries are degenerative and occur in the setting of positive ulnar variance and ulnocarpal impaction syndrome [1]. The most common mechanism of acute injury to the TFCC is via a fall onto outstretched hands. With the wrist in pronation, as is often the case when bracing for a fall forward, the ulna is brought into relative positivity versus the radius and a greater portion of the load is applied across the ulnocarpal joint and TFCC than would be experienced with the forearm in neutral or supination. Ulnar deviation of the wrist also increases compression through the TFCC, and extremes of pronation or supination tighten the dorsal and volar radioulnar ligaments [2–5], respectively, and may expose them to injury.

Patients will typically present with complaints of ulnar-sided wrist pain that is exacerbated by motions that stress or load the TFCC. Symptomatic weakness, mechanical catching or crepitus, and distal radioulnar joint (DRUJ) instability may also be present. Detailed inquiry should be directed towards onset and duration of symptoms, exacerbating factors, history of trauma or fracture, and any previous treatment. The physical exam is centered around identifying points of tenderness, response to provocative tests, and stability of the DRUJ. Understanding surface anatomy is key to distinguishing pain from an injured TFCC versus other causes of ulnar-sided pain such as lunotriquetral (LT) ligament injury, hamate hook fracture, ulnar artery thrombosis, piso-triquetral arthritis, or extensor carpi ulnaris tendinitis. The TFCC is palpated in the soft spot bordered by the distal ulna proximally, pisiform distally, ulnar styloid dorsally, and flexor carpi ulnaris tendon volarly. Pain in this area is considered a positive ulnar fovea sign, and has been found to have a 95.2 % sensitivity and 86.5 % specificity for ulnotriquetral ligament tears or foveal avulsion of the TFCC [6]. The ulnocarpal stress test is performed by axially loading an ulnarly deviated and extended wrist in neutral, supination, or pronation. Nakamura arthroscopically examined 45 patients with persistent ulnar-sided pain and a positive ulnocarpal stress test, and in all instances identified a source of pathology. Injuries identified included signs of ulnocarpal abutment syndrome, TFCC tears, LT ligament tears, and degenerative arthritis amongst others, suggesting it is a sensitive but not specific examination maneuver [7]. To test the DRUJ, the ulna is stabilized while the radius is manually translated dorsally and volarly in neutral, pronation, and supination. Increased excursion compared to the unaffected side is a positive result. Alternatively, the piano key test can be used to assess the DRUJ by having the patient place both palms flat onto the examination table. The patient either actively pushes their ulna down towards the table or the examiner applies a volar-directed force on the ulna 4 cm proximal to the DRUJ; pain at the DRUJ with stress is indicative of TFCC pathology, while increased ulnar motion relative to the unaffected side suggests a tear which has destabilized the DRUJ [8].

Electronic supplementary material: Supplementary material is available in the online version of this chapter at 10.1007/978-1-4614-1596-1_5. Videos can also be accessed at http://www.springerimages.com/videos/978-1-4614-1595-4.

L. Al-Shihabi, M.D.
Department of Orthopaedic Surgery, Rush University Medical Center, Chicago, IL USA

R.W. Wysocki, M.D. (✉)
Department of Orthopedic Surgery, Rush University, 1611 West Harrison, Chicago, IL 60612, USA
e-mail: robertwysocki@mac.com

D.S. Ruch, M.D.
Duke University Medical Center, Durham, NC, USA

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*,
DOI 10.1007/978-1-4614-1596-1_5, © Springer Science+Business Media New York 2015

Triangular Fibrocartilage Complex Tear Classification

The distinction between acute and traumatic vs. chronic and degenerative injuries to the TFCC forms the basis of the Palmer classification into Type I and Type II tears, respectively [1]. Further subclassifications are defined based on tear location and associated pathology. Type 1A tears are the most common [8] and occur within the central substance fibrocartilaginous disc, typically sagittally oriented and 2–3 mm ulnar to the radial border of the TFCC. This area corresponds to the region and orientation of maximal strain through the fibrocartilage when the forearm is pronated [9]. As both the bony attachments of the TFCC on the radius and ulna as well as the dorsal and volar radioulnar ligaments are left intact, stability of the distal radioulnar joint (DRUJ) is not compromised. Central tears are unlikely to heal either spontaneously or with repair as only the periphery of the TFCC is vascularized, while the central 80–85 % that includes the disc is avascular (Fig. 5.1) [10–12]. Pain is likely not from the tear proper, as the central disc is similarly poorly innervated [13], but rather traction on the peripheral TFCC from catching of unstable tear flaps during wrist motion. Simple debridement of the loose fibrocartilaginous flaps of Type 1A tears does not alter TFCC or DRUJ biomechanics [14], and is the preferred surgical treatment.

Type 1B tears involve avulsion of the TFCC from the ulnar fovea or an avulsion fracture through the base of the ulnar styloid, and the fibrocartilaginous disc may also be torn from the dorsal wrist capsule. DRUJ instability is often, but not always, associated. Tears in which the disc pulls away from the ulnar capsule with intact deep insertional fibers to the ulna are seen with ulnar sided wrist pain in the absence of DRUJ instability [15]. As 1B tears are through the vascularized periphery and may heal, surgical repair is preferred either directly to bone or to the ulnar capsule depending on whether DRUJ instability is or is not present respectively [15–20]. Type 1C tears occur along the volar margin and are associated with disruption of the ulnolunate, ulnotriquetral, or ulnocapitate ligaments of the wrist. These are typically high-energy injuries, often associated with ulnocarpal instability and volar translation of the ulnar carpus. Open repair is the most common surgical treatment to restore stability [21]. Type 1D lesions result from detachment of the TFCC from the ulnar radius, either via rupture of the radioulnar ligaments or an avulsion fracture of the radius at the sigmoid notch. If the radius and radioulnar ligaments are intact, the lesion is treated as a Type 1A tear and can be debrided [9, 22]. If DRUJ instability is present or the origin of one or more radioulnar ligaments disrupted, repair is preferred [23–25].

Type II lesions represent degeneration of the TFCC and surrounding structures due to chronic ulnar positive variance and consequent ulnocarpal impaction syndrome. Even small changes in ulnar variance can dramatically affect load-sharing, with 2.5 mm of ulnar positivity causing 42 % of load to be borne through the ulnocarpal joint vs. 18 % in an ulnar-neutral wrist [26]. In contrast to Type I tears, which represent distinct traumatic injuries, Type II lesions represent a spectrum of progressive pathology. Type 2A lesions involve wear of the proximal side of the TFCC only, without perforation or associated pathology. Type 2B lesions demonstrate the same degree of TFCC wear but in association with chondromalacia of the lunate or ulnar head. Type 2C lesions involve a perforation of the fibrocarilaginous disc, but unlike Type 1A tears they are typically ovoid in shape and more ulnar within the substance of the disc. Type 2D lesions involve both the TFCC perforations, lunate and ulnar head chondromalacia, and lunotriquetral ligament disruption. Finally, Type 2E lesions show frank degenerative arthritis of the ulnocarpal joint, lunotriquetral ligament disruption, and may also be associated with ulnar lunate collapse or DRUJ arthritis [1, 27]. Treatment for Type II TFCC lesions centers around correcting positive ulnar variance, with ulnar shortening osteotomy or arthroscopic debridement and ulna wafer resection being the most common treatments [28, 29]. For advanced pathology or failed primary surgery, either a distal ulna resection or Sauve-Kapandji procedure along with lunotriquetral pinning may be necessary.

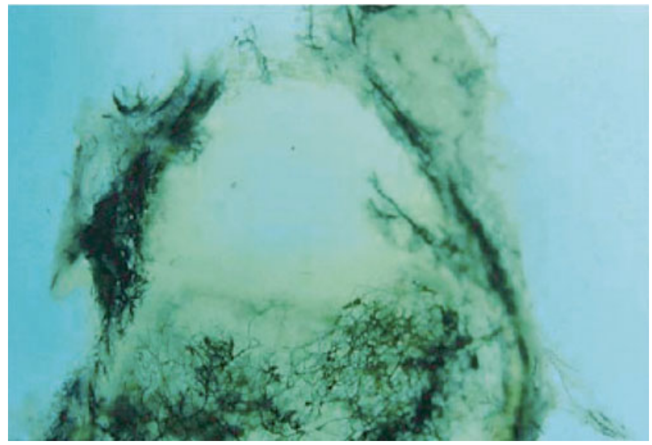


Fig. 5.1 The periphery of the TFCC is well vascularized, and thus capable of healing. The central disc is avascular and thus has poor healing potential. (Courtesy of Michael Bednar, MD)

Imaging

Standard posterior–anterior (PA), lateral, and oblique radiographs are the first-line imaging study to assess the TFCC, DRUJ, and wrist joint. Acute injury to the TFCC can be inferred by examining the integrity and alignment of the distal radius and ulna relative to the carpal bones. Widening of the DRUJ on a PA radiograph or anterior/posterior displacement of the ulna on a lateral radiograph suggests injury and instability; however, given anatomic variability it is important to compare to the unaffected extremity. Soft tissue Type 1B, 1C, and 1D injuries may still be associated with instability, however, and the presence of normal radiographs cannot exclude injury [30]. Ulnar variance should also be assessed on radiographs, including a power-grip PA in pronation if dynamic ulnocarpal impaction is suspected. Computed tomography (CT) can also be used to further clarify bony anatomy, and can compare DRUJ alignment side to side in positions of neutral, supination, and pronation to help detect subtle instability. CT scan is also more sensitive for detecting degenerative change within the DRUJ, distal ulna, or carpus associated with chronic pathology [8].

Magnetic resonance imaging (MRI) and arthrography (MRA) have largely replaced traditional arthrography as imaging modalities of choice, given the poor correlation of traditional arthrography with arthroscopic findings [31, 32]. To improve diagnostic accuracy, MRI should ideally be performed with the use of a microscopy wrist coil and at least a 1.5-T magnet [33]; newer 3.0-T magnets are significantly more accurate at imaging the TFCC, but are also more costly and less widely available [34]. Golimbu has also recommended imaging with 3 mm-thick sections and with the wrist in radial deviation to stretch ulnar tissues as techniques to improve accuracy, but no comparative studies have been performed regarding the effect of wrist position [35]. Systematic review of MRA vs. MRI by Smith demonstrated MRA to be superior to MRI for the detection of TFCC pathology, with pooled sensitivity of 84 % and specificity of 95 % for MRA vs. 75 and 81 % for noncontrast MRI [36]. Given these findings, they concluded that MRA should be the study of choice for evaluating ulnar-sided wrist pain despite the invasiveness of the procedure. Diagnostic accuracy may vary depending on location of the TFCC injury, however, as some authors report superior results at detection of central and radial tears versus those involving the radioulnar ligaments [33]. MRI or MRA findings should always be considered in the context of the history and physical exam, however, as the rate of TFCC abnormalities on MRI in asymptomatic adults has been reported as 33.7 % in those under 50, 62.5 % in those 50–59, and 100 % in those over 60 [37].

Treatment of Type 1A TFCC Tears

In the absence of DRUJ instability most acute TFCC injuries can initially be managed nonoperatively, with up to 57 % of patients symptom-free after 1 month [38]. Temporary splinting or casting of the wrist for up to 2–6 weeks along with oral analgesics and anti-inflammatory medications relieves pain and may allow peripheral tears to heal without surgery. While Type IA tears do not have a good intrinsic ability to heal, they are typically not structurally significant for wrist biomechanics and corticosteroid injections to the ulnocarpal joint can eliminate inflammation surrounding the tear, thus eliminating pain and avoiding surgical intervention in many cases [22]. Cortisone injection should not be undertaken within the first 6 weeks after symptom onset so as not to interfere with the normal biologic processes of healing. Patients with persistent pain despite nonoperative treatment or with instability of the DRUJ are indicated for surgery. High-performance athletes with confirmed TFCC tears on imaging can also be considered for early operative intervention [39, 40]. Arthroscopy is considered the gold-standard diagnostic modality to evaluate the TFCC, and the majority of tears can be treated with this approach.

Arthroscopic Evaluation

The patient's wrist is positioned, traction applied, and arthroscopic access established as described in Chap. 1. Initial evaluation is typically performed with the arthroscope placed in the 3,4 portal and instrumentation in the 6-R portal. Inflow pressure should be minimized in order to allow the TFCC to assume a more normal position within the ulnocarpal joint and minimize blanching, which allows for easier identification of inflamed soft tissue. Visual examination for obvious signs of injury or tears is performed, and associated synovitis or chondromalacia is also noted (Fig. 5.2a). Pronation and supination may aid in visualization of the entire TFCC, and stability of the DRUJ can be assessed with manual stress testing. If necessary, the arthroscope may also be moved to the 6-R portal to better view the radial and ulnar attachments of the disc. A probe is used to assess the integrity of the fibrocartilage by palpating the disc for intrasubstance tears, and when depressed it should readily spring back into its normal position (Fig. 5.2b). Loss of this so-called trampoline effect can indicate either peripheral or foveal detachment [41]. The hook and drag tests use the probe to apply traction along the periphery of the TFCC, and displacement vertically or in the direction of traction similarly indicates either a peripheral tear or foveal injury [6]. If a reparable tear is identified, its full extension must be explored in order to determine whether the repair should be to the subsheath only or, in the case of deep fiber involvement, directly to the ulna [15].

Arthroscopic Debridement of Type 1A Tears

Once the diagnosis of a Type 1A tear is made, arthroscopic debridement is the treatment of choice given the central disc's poor vascularity and inability to heal. Detailed management

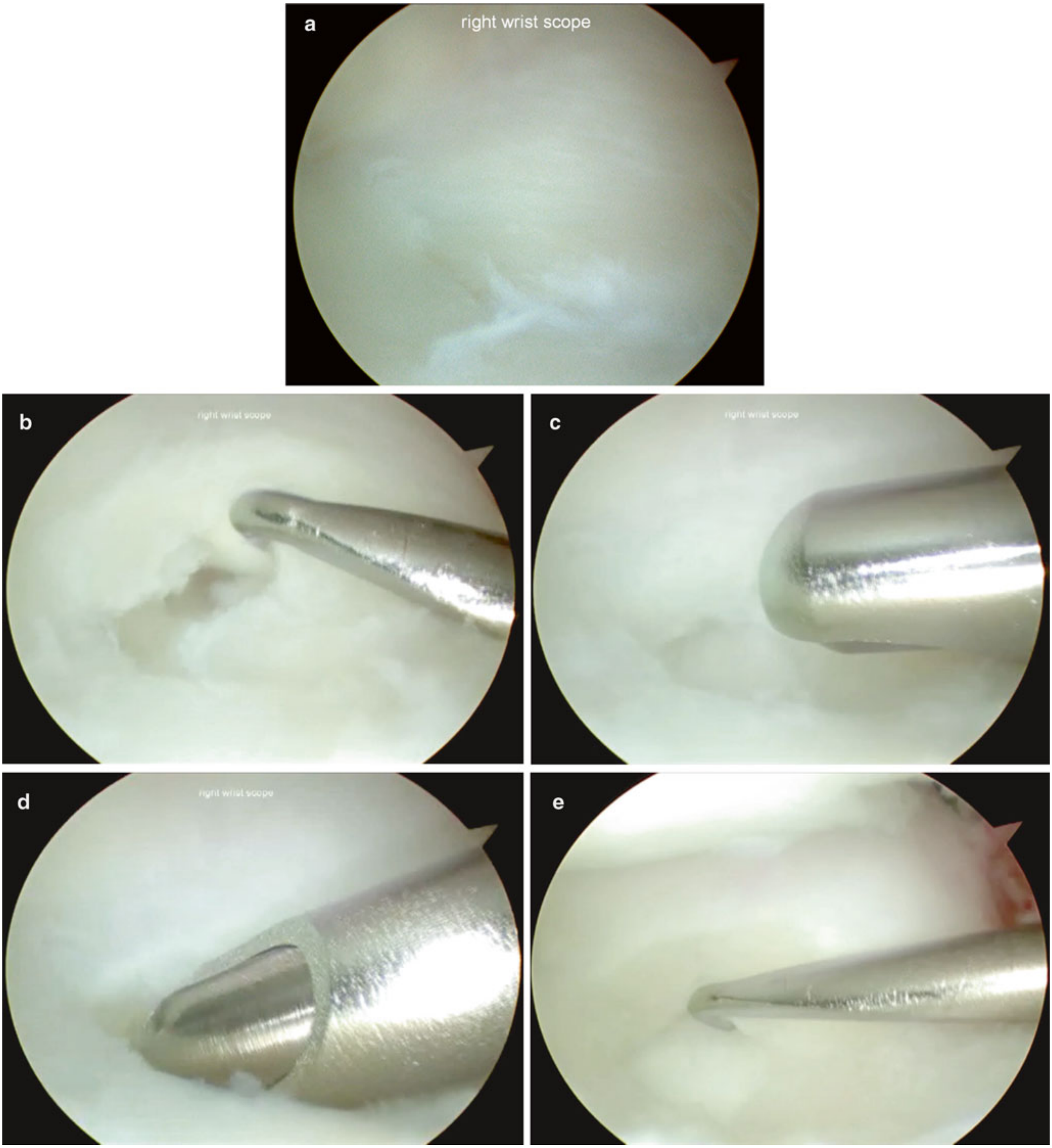


Fig. 5.2 (**a**) Demonstrates the arthroscopic appearance of a Type 1A TFCC tear, the extent and margins of which are defined with the aid of a probe (**b**). An arthroscopic shaver or other instrument is used to debride the unstable flaps of the tear back to stable edges, taking care to avoid the volar and dorsal radioulnar ligaments (**c**, **d**). The margins are then rechecked with the probe to confirm the adequacy of resection (**e**)

of tears amenable to repair will be covered in subsequent chapters. The goal of the procedure is to debride unstable flaps of the central fibrocartilage that are likely to catch on surrounding tissue back to a stable rim. Biomechanical studies demonstrate that up to 2/3 of the central region can safely be resected without destabilizing the DRUJ; more important is to avoid damage to the peripheral 2 mm of the TFCC as this tissue contains the dorsal and volar radioulnar ligaments [14, 42] (Video 5.1). Debridement techniques have been described with multiple instruments including scalpels, banana blades, shavers, radiofrequency probes, and lasers [43–45]. Each has its own advantages and disadvantages, and the ideal instrument is ultimately the surgeon's preference. Ours is to use a banana blade or arthroscopic shaver to perform the bulk of resection followed by radiofrequency ablation, if necessary, to stabilize the borders of the resection (Fig. 5.2c, d). As with arthroscopic evaluation, debridement is started with the arthroscope in the 3,4 portal and instrumentation is introduced via the 6-R portal. The radial side of the torn fibrocartilaginous disc is outlined and resected with the blade, then removed with an arthroscopic grasper. The arthroscope is then moved to the 6-R portal, and with instrumentation through the 3,4 portal the same procedure is performed on the ulnar side of the tear. The TFCC is then reexamined to ensure the absence of any further unstable tissue and the integrity of the peripheral ligaments (Fig. 5.2e). The LT ligament and articular surfaces should also be examined and repair or debridement performed as indicated. In most cases, acute IA tears should not have significant carpal chondromalacia or LT ligament insufficiency as these are more often seen with chronic Type II patterns.

In the case of a patient with a Type 1A tear and concomitant positive ulnar variance, most authors argue for the addition of a primary ulnocarpal decompression along with TFCC debridement [8, 22, 28, 29, 46, 47]. The ulnar-shortening osteotomy [46] and ulnar wafer procedure [47] have both been proposed as treatment options that can be combined with arthroscopic debridement. In an early report of arthroscopic TFCC debridement Osterman noted some patients with positive ulnar variance to have degenerative chondromalacia of the ulnar head despite traumatic mechanisms, suggesting some tears may be acute-on-chronic injuries [48]. Minami subsequently reported that patients with positive ulnar variance have inferior outcomes compared to those with neutral or negative variance after debridement alone, and argued for primary ulnar-shortening osteotomy for these patients [46, 49]. Ulnar-shortening osteotomy is also a successful secondary procedure for persistent pain after primary debridement regardless of preoperative ulnar variance [50], suggesting dynamic positive ulnar variance may contribute to failure even if routine X-rays are normal [51]. In comparing primary ulnar wafer resection to ulnar-shortening osteotomy, when combined with debridement both show equivalent postoperative pain relief and function. Higher rates of tendinitis and reoperation (for hardware removal) have been reported with ulnar-shortening osteotomy, however [28, 52].

As previously discussed, if only the central region of the TFCC is debrided and the periphery remains intact, the biomechanics and stability of the wrist will not be affected. Further, as there is no repair to protect, postoperative immobilization is unnecessary and patients are able to begin rehabilitation immediately, including unrestricted active and passive motion and light progressive strengthening once pain is diminished [42]. If an ulnar-shortening osteotomy or ulnar wafer resection is performed a splint is used for 6 weeks to protect the osteotomy or allow a clot (and subsequently fibrocartilage) to form over the distal ulna, respectively. Strengthening exercises are delayed until the osteotomy is healed radiographically in the setting of an ulnar shortening (typically 6–8 weeks)

Results

Arthroscopic debridement has become the treatment of choice and standard of care for Type 1A TFCC tears, offering superior visualization of the TFCC with a less invasive approach and superior outcomes when compared to open procedures. In separate studies, Osterman and Roth both described the initial technique of arthroscopic TFCC debridement [48, 53]. Osterman also reported on 52 patients prospectively followed after arthroscopic debridement with either a motorized shaver or pituitary rongeur for traumatic or degenerative TFCC tears. At an average follow-up of 23 months, 73 % were pain-free and 12 % further were improved; amongst the five patients who failed treatment no relationship to ulnar variance was identified [48]. Subsequent studies have found similar results. Comparing arthroscopic debridement in 11 posttraumatic vs. 5 degenerative cases, Minami found a posttraumatic etiology to be associated in all cases with an excellent recovery based on superior patient satisfaction, pain relief, and function [49]. Using Minami's criteria, Miwa also found good or excellent results in 9/10 patients undergoing debridement for Type 1A tears [54]. Using the modified Mayo Wrist Score, Husby and Haugstvedt reviewed 32 patients at a median of 39 months after arthroscopic debridement and found 27 good or excellent results vs. 4 fair and 1 poor result; all but 2 patients in their study would have had surgery performed again [55].

Amongst patients failing debridement alone, Hulsizer found a subsequent ulnar shortening osteotomy resulted in complete relief of pain for 12/13 patients regardless of preoperative ulnar variance [50]. In cases of positive ulnar variance, failure rates of up to 25 % have been described for debridement alone [49], and primary procedures to decompress the ulnocarpal joint should be considered in addition. Outcomes after debridement with ulnar-shortening osteotomy or an ulnar wafer procedure are equal or superior to those published for debridement alone. However, rates of reoperation, most commonly removal of osteotomy hardware, as well as ulnar-sided tendinitis are higher with ulnar-shortening osteotomy, leading some authors to favor the wafer procedure [28, 52]. Animal models also suggest that the clot formed by bleeding from the distal ulna may allow for fibrous reconstitution of the debrided central TFCC, but this has yet to be shown in humans [56].

Complications

Arthroscopic TFCC debridement is a minimally invasive, safe technique for the treatment of persistent ulnar-sided wrist pain due to traumatic tears of the central fibrocartilage. It is not without risk, however. The general risks of wrist arthroscopy are well-known and well-described, the most common being tendon and nerve injuries, local infections, cyst formation, and postoperative edema and stiffness [57–59]. Specific to TFCC debridement surgeons should be aware of the risks associated with their chosen instruments, such as laceration of surrounding tissues with a banana blade or burns and thermal injury with a radiofrequency device [60]. Surgeons should also develop a comprehensive, systematic preoperative workup to avoid diagnostic pitfalls, as coexistant DRUJ instability, lunotriquetral ligament injury, or ulnocarpal impaction left untreated will lead to a poor outcome and the need for additional surgery. If the correct diagnosis is made and treated, however, arthroscopic debridement yields excellent outcomes and a high degree of patient satisfaction.

References

1. Palmer AK. Triangular fibrocartilage complex lesions: a classification. J Hand Surg Am. 1989;14(4):594–606.
2. Ward LD, Ambrose CG, Masson MV, Levaro F. The role of the distal radioulnar ligaments, interosseous membrane, and joint capsule in distal radioulnar joint stability. J Hand Surg Am. 2000; 25(2):341–51.
3. DiTano O, Trumble TE, Tencer AF. Biomechanical function of the distal radioulnar and ulnocarpal wrist ligaments. J Hand Surg Am. 2003;28(4):622–7.
4. Schuind F, An KN, Berglund L, Rey R, Cooney WP, Linscheid RL, Chao E. The distal radioulnar ligaments: a biomechanical study. J Hand Surg Am. 1991;16(6):1106–14.
5. Xu J, Tang JB. In vivo changes in lengths of the ligaments stabilizing the distal radioulnar joint. J Hand Surg Am. 2009;34(1):40–5.
6. Tay SC, Tomita K, Berger RA. The "ulnar fovea sign" for defining ulnar wrist pain: an analysis of sensitivity and specificity. J Hand Surg Am. 2007;32(4):438–44.
7. Nakamura R, Horii E, Imaeda T, Nakao E, Kato H, Watanabe K. The ulnocarpal stress test in the diagnosis of ulnar-sided wrist pain. J Hand Surg Br. 1997;22(6):719–23.
8. Sachar K. Ulnar-sided wrist pain: evaluation and treatment of triangular fibrocartilage complex tears, ulnocarpal impaction syndrome, and lunotriquetral ligament tears. J Hand Surg Am. 2012;37(7): 1489–500.
9. Adams BD, Holley KA. Strains in the articular disk of the triangular fibrocartilage complex: a biomechanical study. J Hand Surg Am. 1993;18(5):919–25.
10. Thiru RG, Ferlic DC, Clayton ML, McClure DC. Arterial anatomy of the triangular fibrocartilage of the wrist and its surgical significance. J Hand Surg Am. 1986;11(2):258–63.
11. Mikić Z. The blood supply of the human distal radioulnar joint and the microvasculature of its articular disk. Clin Orthop Relat Res. 1992;275:19–28.
12. Bednar MS, Arnoczky SP, Weiland AJ. The microvasculature of the triangular fibrocartilage complex: its clinical significance. J Hand Surg Am. 1991;16(6):1101–5.
13. Gupta R, Nelson SD, Baker J, Jones NF, Meals RA. The innervation of the triangular fibrocartilage complex: nitric acid maceration rediscovered. Plast Reconstr Surg. 2001;107(1):135–9.
14. Adams BD. Partial excision of the triangular fibrocartilage complex articular disk: a biomechanical study. J Hand Surg Am. 1993; 18(2):334–40.
15. Wysocki RW, Richard MJ, Crowe MM, Leversedge FJ, Ruch DS. Arthroscopic treatment of peripheral triangular fibrocartilage complex tears with the deep fibers intact. J Hand Surg Am. 2012;37(3):509–16.
16. Hauck RM, Skahen J, Palmer AK. Classification and treatment of ulnar styloid nonunion. J Hand Surg Am. 1996;21(3):418–22.
17. Wolf MB, Haas A, Dragu A, Leclère FM, Dreyhaupt J, Hahn P, Unglaub F. Arthroscopic repair of ulnar-sided triangular fibrocartilage complex (palmer type 1B) tears: A comparison between short- and midterm results. J Hand Surg Am. 2012;37(11):2325–30.
18. Reiter A, Wolf MB, Schmid U, Frigge A, Dreyhaupt J, Hahn P, Unglaub F. Arthroscopic repair of palmer 1B triangular fibrocartilage complex tears. Arthroscopy. 2008;24(11):1244–50.
19. Moritomo H, Masatomi T, Murase T, Miyake J, Okada K, Yoshikawa H. Open repair of foveal avulsion of the triangular fibrocartilage complex and comparison by types of injury mechanism. J Hand Surg Am. 2010;35(12):1955–63.
20. Chou KH, Sarris IK, Sotereanos DG. Suture anchor repair of ulnar-sided triangular fibrocartilage complex tears. J Hand Surg Br. 2003;28(6):546–50.
21. Mikic ZD. Treatment of acute injuries of the triangular fibrocartilage complex associated with distal radioulnar joint instability. J Hand Surg Am. 1995;20(2):319–23.
22. Henry MH. Management of acute triangular fibrocartilage complex injury of the wrist. J Am Acad Orthop Surg. 2008;16(6):320–9.
23. Sagerman SD, Short W. Arthroscopic repair of radial-sided triangular fibrocartilage complex tears. Arthroscopy. 1996;12(3):339–42.
24. Cho CH, Lee YK, Sin HK. Arthroscopic direct repair for radial tear of the triangular fibrocartilage complex. Hand Surg. 2012;17(3): 429–32.
25. Jantea CL, Baltzer A, Rüther W. Arthroscopic repair of radial-sided lesions of the triangular fibrocartilage complex. Hand Clin. 1995;11(1):31–6.
26. Palmer AK. The distal radioulnar joint. Anatomy, biomechanics, and triangular fibrocartilage complex abnormalities. Hand Clin. 1987;3(1):31–40.
27. Palmer AK. Triangular fibrocartilage disorders: injury patterns and treatment. Arthroscopy. 1990;6(2):125–32.
28. Bernstein MA, Nagle DJ, Martinez A, Stogin JM, Wiedrich TA. A comparison of combined arthroscopic triangular fibrocartilage complex debridement and arthroscopic wafer distal ulna resection versus arthroscopic triangular fibrocartilage complex debridement and ulnar shortening osteotomy for ulnocarpal abutment syndrome. Arthroscopy. 2004;20(4):392–401.
29. Tomaino MM, Elfar J. Ulnar impaction syndrome. Hand Clin. 2005;21(4):567.
30. Lindau T, Adlercreutz C, Aspenberg P. Peripheral tears of the triangular fibrocartilage complex cause distal radioulnar joint instability after distal radial fractures. J Hand Surg Am. 2000;25(3):464–8.
31. Chung KC, Zimmerman NB, Travis MT. Wrist arthrography versus arthroscopy: a comparative study of 150 cases. J Hand Surg Am. 1996;21(4):591–4.
32. Weiss AP, Akelman E, Lambiase R. Comparison of the findings of triple-injection cinearthrography of the wrist with those of arthroscopy. J Bone Joint Surg Am. 1996;78(3):348–56.
33. Tanaka T, Yoshioka H, Ueno T, Shindo M, Ochiai N. Comparison between high-resolution MRI with a microscopy coil and arthroscopy in triangular fibrocartilage complex injury. J Hand Surg Am. 2006;31(8):1308–14.
34. Saupe N, Prüssmann KP, Luechinger R, Bösiger P, Marincek B, Weishaupt D. MR imaging of the wrist: comparison between

1.5- and 3-T MR imaging—preliminary experience. Radiology. 2005;234(1):256–64.
35. Golimbu CN, Firooznia H, Melone CP, Rafii M, Weinreb J, Leber C. Tears of the triangular fibrocartilage of the wrist: MR imaging. Radiology. 1989;173(3):731–3.
36. Smith TO, Drew B, Toms AP, Jerosch-Herold C, Chojnowski AJ. Diagnostic accuracy of magnetic resonance imaging and magnetic resonance arthrography for triangular fibrocartilaginous complex injury: a systematic review and meta-analysis. J Bone Joint Surg Am. 2012;94(9):824–32.
37. Iordache SD, Rowan R, Garvin GJ, Osman S, Grewal R, Faber KJ. Prevalence of triangular fibrocartilage complex abnormalities on MRI scans of asymptomatic wrists. J Hand Surg Am. 2012;37(1): 98–103.
38. Park MJ, Jagadish A, Yao J. The rate of triangular fibrocartilage injuries requiring surgical intervention. Orthopedics. 2010;33(11):806.
39. Dailey SW, Palmer AK. The role of arthroscopy in the evaluation and treatment of triangular fibrocartilage complex injuries in athletes. Hand Clin. 2000;16(3):461–76.
40. Whipple TL. The role of arthroscopy in the treatment of wrist injuries in the athlete. Clin Sports Med. 1998;17(3):623–34.
41. Hermansdorfer JD, Kleinman WB. Management of chronic peripheral tears of the triangular fibrocartilage complex. J Hand Surg Am. 1991;16(2):340–6.
42. Palmer AK, Werner FW, Glisson RR, Murphy DJ. Partial excision of the triangular fibrocartilage complex. J Hand Surg Am. 1988;13(3):391–4.
43. Nagle DJ. Laser-assisted wrist arthroscopy. Hand Clin. 1999; 15(3):495–9. ix.
44. Infanger M, Grimm D. Meniscus and discus lesions of triangular fibrocartilage complex (TFCC): treatment by laser-assisted wrist arthroscopy. J Plast Reconstr Aesthet Surg. 2009;62(4):466–71.
45. Darlis NA, Weiser RW, Sotereanos DG. Arthroscopic triangular fibrocartilage complex debridement using radiofrequency probes. J Hand Surg Br. 2005;30(6):638–42.
46. Minami A, Kato H. Ulnar shortening for triangular fibrocartilage complex tears associated with ulnar positive variance. J Hand Surg Am. 1998;23(5):904–8.
47. Tomaino MM, Weiser RW. Combined arthroscopic TFCC debridement and wafer resection of the distal ulna in wrists with triangular fibrocartilage complex tears and positive ulnar variance. J Hand Surg Am. 2001;26(6):1047–52.
48. Osterman AL. Arthroscopic debridement of triangular fibrocartilage complex tears. Arthroscopy. 1990;6(2):120–4.
49. Minami A, Ishikawa J, Suenaga N, Kasashima T. Clinical results of treatment of triangular fibrocartilage complex tears by arthroscopic debridement. J Hand Surg Am. 1996;21(3):406–11.
50. Hulsizer D, Weiss AP, Akelman E. Ulna-shortening osteotomy after failed arthroscopic debridement of the triangular fibrocartilage complex. J Hand Surg Am. 1997;22(4):694–8.
51. Tomaino MM. The importance of the pronated grip X-ray view in evaluating ulnar variance. J Hand Surg Am. 2000;25(2):352–7.
52. Constantine KJ, Tomaino MM, Herndon JH, Sotereanos DG. Comparison of ulnar shortening osteotomy and the wafer resection procedure as treatment for ulnar impaction syndrome. J Hand Surg Am. 2000;25(1):55–60.
53. Roth JH, Poehling GG. Arthroscopic "-ectomy" surgery of the wrist. Arthroscopy. 1990;6(2):141–7.
54. Miwa H, Hashizume H, Fujiwara K, Nishida K, Inoue H. Arthroscopic surgery for traumatic triangular fibrocartilage complex injury. J Ortho Sci. 2004;9(4):354–9.
55. Husby T, Haugstvedt JR. Long-term results after arthroscopic resection of lesions of the triangular fibrocartilage complex. Scand J Plast Reconstr Surg Hand Surg. 2001;35(1):79–83.
56. Whatley JS, Dejardin LM, Arnoczky SP. The effect of an exogenous fibrin clot on the regeneration of the triangular fibrocartilage complex: an in vivo experimental study in dogs. Arthroscopy. 2000;16(2):127–36.
57. Warhold LG, Ruth RM. Complications of wrist arthroscopy and how to prevent them. Hand Clin. 1995;11(1):81–9.
58. Culp RW. Complications of wrist arthroscopy. Hand Clin. 1999;15(3):529–35.
59. Ahsan ZS, Yao J. Complications of wrist arthroscopy. Arthroscopy. 2012;28(6):855–9.
60. Pell RF, Uhl RL. Complications of thermal ablation in wrist arthroscopy. Arthroscopy. 2004;20 Suppl 2:84–6.

Arthroscopic Management of Peripheral Ulnar Tears of the TFCC

6

William B. Geissler

Introduction

The wrist is a complex labyrinth of eight carpal bones, multiple articular surfaces combined with intrinsic and extrinsic ligaments, including the triangular fibrocartilage complex (TFCC) all within a 5 cm interval. This perplexing joint continues to challenge clinicians with no array of potential diagnoses and treatments. Arthroscopy has continued to revolutionize the practice of orthopedic surgery by providing the surgeon the capability to examine and treat multiple intraarticular abnormalities. Wrist arthroscopy allows for direct visualization of the cartilage surfaces, ligaments, and the components of the triangular fibrocartilage complex under bright light and magnified conditions.

The triangular fibrocartilage complex is a complex soft tissue support system whose purpose is to stabilize the ulnar side of the wrist [1]. It acts as an extension of the articular surface of the radius to support the proximal carpal row and to stabilize the distal radial ulnar joint. Palmer classically described the components of the triangular fibrocartilage complex being the fibrocartilage articular disk, the volar and dorsal radial ulnar ligaments, and the floor of the extensor carpi ulnaris tendon sheath. The central disk is wedge-shaped in the coronal section and radially inserted on the articular surface of the radius by merging with the hyaline cartilage of the sigmoid notch and lunate facet. Chigley evaluated the collagen structure of the TFCC in an attempt to correlate its biomechanical function [2]. They found that the radial side of articular disk fibrocartilage has thick collagen fibers projecting 1–2 mm into the disk. The central portion of the articular disk has an oblique wave pattern for strength, tension, and compression. The ulnar aspect of the articular disk has two main bundles. One bundle is directed to the ulnar styloid and the second bundle to the fovea. Proximal limbs of the palmar and dorsal radial ulnar ligaments conjoin and insert onto the fovea just medial to the pole of the distal ulna. These structures have previously been referred to as the ligamentum subcruetum. However, Benjamin et al. have used this same term to describe the vascularized tissue between the fovea ligaments and the ulnar styloid. The exact function of the superficial deep components of the volar and dorsal radial ulnar ligaments is controversial. The distal superficial portions of the volar and dorsal radial ligament insert directly into the base of the ulnar styloid and are independent of the function of the ligamentum subcruetum insertion.

This chapter reviews the indication for wrist arthroscopy and the management of peripheral ulnar-sided tears of the articular disk involving the triangular fibrocartilage complex. Several techniques for outside-in or inside-out repair of peripheral ulnar-sided tears of the triangular fibrocartilage complex have been previously described in the literature. In addition, a new technique allows arthroscopic-assisted fixation of the articular disk back down to bone with a knotless suture anchor technique has recently been described.

Palmer and Warner defined the articular disk of the triangular fibrocartilage complex to be an axial loadbearing structure [1]. They found that in the static state 82 % of the axial compressive load of power grasp was transmitted from the forearm through the radial carpal joint. The remainder 18 % was supported by the articular disk on the ulnar side of the wrist. The peripheral attachment of the articular disk is approximately 5 mm thick and becomes thinner near its radial insertion, narrowing to less than 2 mm. It is the central portion of the disk that accepts the majority of the compressive loads transmitted from the carpus to the ulna. The thickness of the articular disk varies from individual to individual with an inverse relationship between the thickness of the

Electronic supplementary material: Supplementary material is available in the online version of this chapter at 10.1007/978-1-4614-1596-1_6. Videos can also be accessed at http://www.springerimages.com/videos/978-1-4614-1595-4.

W.B. Geissler, M.D. (✉)
Department of Orthopaedic Surgery and Rehabilitation,
University of Mississippi Medical Center,
2500 North State Street, Jackson, MS 39216, USA
e-mail: 3doghill@msn.com

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*,
DOI 10.1007/978-1-4614-1596-1_6, © Springer Science+Business Media New York 2015

articular disk and ulnar variance. Adams demonstrated that when the disk is excised, loadbearing by the ulna drops to approximately 5 % of the total load [3].

Dorsally, the triangular fibrocartilage complex has attachments to the ulna carpus and to the sheath of the extensor carpi ulnaris. This is a frequent area of peripheral detachment of the articular disk. The floor of the sheath of the extensor carpi ulnaris is quite stout and thick. This stout, fibrous tissue allows for firm fixation of the articular disk back to the floor of the extensor carpi ulnaris utilizing outside-in arthroscopic-assisted technique. The remaining component of the triangular fibrocartilage complex is classically described by Palmer as the ulnar carpal meniscus homolog. This is a quite controversial structure as to its function and even existence. It is a layer of fibrous connective tissue with variable thickness. The prestyloid recess typically presents between the bony ulnar styloid and a thickening of the ulnar soft tissues known as the meniscus homolog. It is vital to understand that the prestyloid recess is a normal fovea and it should not be mistaken for a peripheral tear of the articular disk. The prestyloid recess is the site of the 6-U portal which is frequently used for inflow.

Although not classically described as part of the triangular fibrocartilage complex, the ulna carpal ligaments are composed of the ulna lunate and ulna triquetral ligaments. These are primarily stabilizers of the ulna and the palmar carpus. The origin has been shown by cadaver studies to be along the palmar margin of the triangular fibrocartilage complex. They insert independently on the triquetrum and lunate with additional insertion into the lunotriquetral interosseous ligament.

Thiru et al. evaluated the arterial blood supply of the triangular fibrocartilage complex in 12 cadaver specimens with latex injections [4]. They determined there were three main arterial supplies to the triangular fibrocartilage complex. The ulnar artery supplies the majority of the blood to the triangular fibrocartilage complex supporting the ulna portion to the dorsal palmar radial carpal branches. Thiru documented a complex of vessels which filled with latex dye in the peripheral 15–20 % of the ulnar articular disk. Bednar et al. similarly examined ten cadavers with an ink injection study and found penetration of the vessels into the peripheral 10–40 % of the articular disk [5]. These studies are very significant regarding procedures for arthroscopic repair of peripheral tears to the articular disk. They confirm an intact blood supply to the peripheral articular disk, and theoretically, peripheral tears of the articular disk should be able to heal following repair with this vascular blood supply.

Classification of TFCC Tears

In 1989, Palmer proposed a classification system for tears of the triangular fibrocartilage complex. [1] He divided the injuries into two basic categories. Class I are traumatic and Class II are degenerative (Tables 6.1 and 6.2).

Table 6.1 Classification of traumatic injuries class I

Class IA	Tears or perforations of the horizontal portion of the triangular fibrocartilage complex (TFCC)
	Usually 1–2 mm wide
	Dorsal palmar slit located 2–3 mm medial to the radial attachment of the sigmoid notch
Class IB	Traumatic avulsion of TFCC from insertion into the distal ulna
	May be accompanied by a fracture of the ulnar styloid at its base
	Usually associated with distal radiocarpal joint instability
Class IC	Tears of TFCC that result in ulnocarpal instability, such as avulsion of the TFCC from the distal attachment of the lunate or triquetrum
Class ID	Traumatic avulsions of the TFCC from the attachment at the distal sigmoid notch

Table 6.2 Classifications of degenerative lesions class II

Class IIA	Wear of the horizontal portion of the TFCC distally, proximally, or both; with no perforation
	Possible ulnar plus syndrome
Class IIB	Wear of the horizontal portion of the TFCC and chondromalacia of lunate and/or ulna
Class IIC	TFCC perforation and chondromalacia of the lunate and/or ulna
Class IID	TFCC perforation and chondromalacia of the lunate and/or ulna
	Perforation of the lunotriquetrum ligament
Class IIE	TFCC perforation and chondromalacia of the lunate and/or ulna
	Perforation of the lunotriquetrum ligament
	Ulnocarpal arthritis

Class I injuries are true traumatic tears and are subdivided into four basic types based on the pattern of injury. Type IA lesions involve the central avascular portion of the articular disk and are not suitable for suture repair. Arthroscopic management includes the debridement of a central tear to remove any symptomatic flaps. Type IB (ulnar avulsion) injuries occur when the ulnar side of the articular disk is avulsed from its insertion. These injuries may or may not be associated with a fracture to the ulnar styloid. Because these tears occur over in the region of a documented vascular supply, they are very amenable to arthroscopic repair by a number of techniques. Type IC injuries involve rupture of the volar attachment of the triangular fibrocartilage complex over the ulnar carpal ligaments. Type ID involves a tear of the radial attachment of the articular disk as well as the radioulnar ligament separate from the radius with or without a fracture of the radial sigmoid notch.

Class II lesions are considered degenerative tears of the triangular fibrocartilage complex and involve a central portion of the articular disk. These are stage A through E depending on the presence or absence of perforation to the triangular fibrocartilage complex, ulnar head and lunate chondromalacia, perforation of the lunotriquetral interosseous ligament, and degenerative arthritis of the radial ulnar joint. These lesions generally arise from ulna impaction and surgical management mostly consists of a variety of procedures to decrease the load across the ulnar side of the wrist, either arthroscopic or open management.

Diagnosis

Injuries to the triangular fibrocartilage complex commonly occur with extension and pronation of an axially loaded carpus. The most common mechanism occurs with a fall on an outstretched hand. Peripheral tears of the articular disk are frequently common athletic injuries, which occur in sports and require rapid twisting and loading of the ulnar side of the wrist such as golf or racket sports. Peripheral ulnar-sided tears of the articular disk may also be a common work injury. Patients often describe a mechanism of traction and torsion of the forearm which may occur with the use of a drill motor when the drill bit suddenly binds resulting in a twisting injury to the wrist.

Patients with symptoms of peripheral tears of the triangular fibrocartilage complex complain of a deep diffused aching across the ulnar side of the wrist. They may complain of pain with firm gripping as well as a clicking sensation with rotation of the forearm. They frequently complain of pain with resistance to forearm rotation such as twisting lids off jars or twisting a doorknob. Frequently, they may complain of generalized wrist weakness.

Patients with an ulnar-sided peripheral tear of the articular disk frequently describe point tenderness right at the prestyloid recess and point to that location. This pain may be accentuated by hypo-pronation or supination of the forearm. This pain may be further aggravated by passive anterior/posterior translation of the ulna in relation to the radius with the wrist in pronation and supination. Dorsal subluxation of the ulnar head in relation to the radius may be seen particularly if a large peripheral tear is present involving both the superficial and deep layers of the articular disk.

Several tests have been described that are used for the diagnosis of ulnar-sided wrist pain. The TFCC compression test is considered positive with axial loading of the articular disk with the wrist in ulnar deviation and results in significant pain. Araujo described the ulna impaction test which is considered to be positive when the wrist is positioned in ulnar deviation, hyperextension and axial load reproduces the ulnar-sided wrist pain. The piano key sign is frequently described for instability of the distal radioulnar joint, which can be seen with a peripheral tear of the articular disk. The test is positive if the distal ulna can be pressed volarly by dorsal thumb pressure in a pronated wrist as compared to the opposite side. In general, patients with a central tear of the articular disk hurt more over the ulnar head while patients with a peripheral tear present complaining about the prestyloid recess region.

Diagnostic Modalities

Patients who present with acute or chronic ulnar-sided wrist pain should be evaluated initially with standard anterior/posterior, lateral, and oblique radiographs of the wrist. It is important in the AP view to take the radiograph in neutral position to evaluate for ulnar variance. It is frequently helpful to take a fist compression view to evaluate for possible ulnar impaction which should be in the differential diagnosis. Radiographic signs of ulnar impaction include cystic changes on the medial side of the lunate (kissing lesion). These changes are indicated by excessive loading to the ulnar side of the wrist, which may require an ulnar shortening procedure. The distal radioulnar joint should also be evaluated for signs of radioulnar impingement, which must be differentiated from pain related to the triangular fibrocartilage complex. In addition, signs of acute or chronic injury to the ulnar styloid may be assessed on plain radiographs. Plain radiographs also are helpful to evaluate for signs of ulnar styloid abutment.

Triple injection arthrography was the gold standard in the past in diagnosing pathology of the triangular fibrocartilage complex [6]. However, ulnar-sided peripheral tears of the articular disk may be frequently missed by arthrography particularly in the chronic setting. This is secondary to chronic synovitis that develops over the peripheral tear blocking the flow of dye between the radial carpal and distal radial ulnar joint.

Several studies have evaluated the use of magnetic resonance imaging in diagnosing TFCC injuries [7–9]. Golimbu et al. and Skahen et al. both reported that the use of magnetic resonance imaging for detection of central and radial detachment of the articular disk with an accuracy of 95 % [7, 8]. Corso et al. in their study of ulnar-sided tears of the triangular fibrocartilage complex found sensitivity in only 76 % with magnetic resonance imaging [9]. Bednar reported his results of MR imaging and noted the sensitivity was 44 % with specificity set at 5 % for TFCC tears [5]. Fulcher and Poehling recommended the use of arthroscopy for definitive diagnosis and felt that MRI overstates some injuries of the TFCC while understating other TFCC pathology [10].

Studies comparing wrist arthroscopy with arthrography confirm that arthroscopy is the gold standard in detecting injuries to the triangular fibrocartilage complex [9]. Pederzini et al. compared MRI, arthrography, and arthroscopy on 11 patients with tears to the triangular fibrocartilage complex [9]. Utilizing arthroscopy as the gold standard, he reported 1 % sensitivity with MRI and arthrography and 80 % sensitivity for arthrography and 82 % sensitivity for MRI evaluation alone. Arthroscopy has a clear advantage of visualization of the articular disk under bright light and magnified conditions. The tension of the disk may be assessed by palpation with a probe. In most instances, a loss of tension will be detected to the articular disk when a peripheral tear is present. Frequently, synovitis has formed over the peripheral ulnar tear marking the site of pathology. Once the synovitis is debrided, the peripheral tear would be well visualized. Wrist arthroscopy is a useful adjunct and not only has the advantage of being sensitive and accurate to make the diagnosis but at the same sitting proceeding with definitive management.

Management

Indications

Patients who present with acute ulnar-sided wrist pain with normal radiographs and tenderness over the periphery of the TFCC, initial immobilization is a rule of thumb. Potentially small ulnar peripheral tears of the articular disk may heal from immobilization due to the vascular blood supply. Further diagnostic modalities are initiated after 2 or 3 months of immobilization when patients continue to be symptomatic or when an early diagnosis is important to the patient (professional athlete). MRI evaluation is certainly a common option, but the author prefers to proceed directly to wrist arthroscopy when the history and physical examination are classic for an injury to the triangular fibrocartilage complex and the patient does not improve with immobilization.

Indications for surgical intervention include persistent ulnar-sided wrist pain not relieved by conservative management for at least 3 months. Additional indications include symptomatic distal radial ulnar joint instability not improved by immobilization. It is also felt that a subluxation to the extensor carpi ulnaris tendon is usually associated with a peripheral tear to the articular disk.

Contraindications for surgical management are in those patients who are minimally symptomatic despite radiographic findings and patients with low physical demand who are medically not healthy enough for surgery. In addition, patients with significant degenerative changes either to the radial carpal or radial ulnar joint may be better managed by addressing the arthritic symptoms rather than an arthroscopic procedure.

Arthroscopic Technique

The wrist is suspended with 10 lb of traction in a traction tower (Fig. 6.1). The volar forearm and arm are well padded with towels so the skin does not come into contact with the tower itself. This will help prevent any potential burns from heat of the tower if it has been recently sterilized. The skin is incised with the tip of an 11 blade at the 3-4 portal and blunt dissection is continued with a hemostat to the level of the joint capsule. The arthroscope with a blunt trocar is introduced into

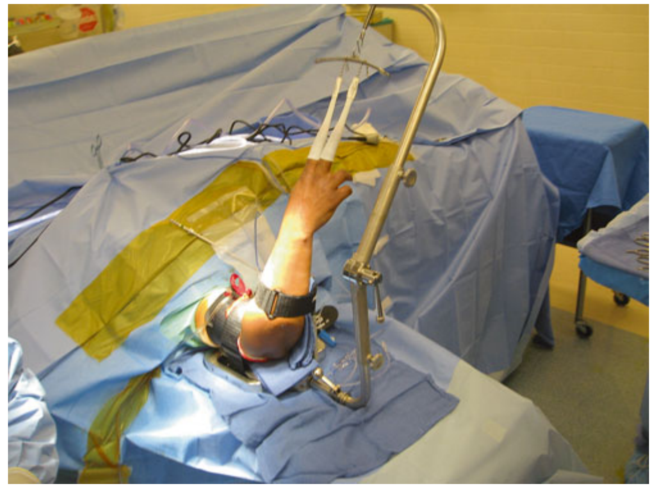


Fig. 6.1 The wrist is suspended in a wrist traction tower (Acumed, Hillsboro, OR). The wrist is suspended in approximately 10–20° of flexion to allow easier entry of instrumentation into the radiocarpal space

the 3-4 portal and a working portal is made in the standard 6-R portal. Inflow may be provided through the 1-2 portal if a tear of the triangular fibrocartilage complex is suspected. In this manner, the inflow is out of the way during the arthroscopic repair to the TFCC complex. Alternatively, inflow may be provided through the arthroscope itself or through the needle in the 6-U portal.

It is always important to identify the exact location of the 6-R portal just distal to the articular disk with an 18-gauge needle inserted into the radial carpal space. The needle is viewed arthroscopically as it is being inserted. If ideal placement is confirmed, then the skin is incised and the 6-R portal is made. In this manner, there is no potential damage to the articular disk when making the 6-R portal. Cooney described the trampoline test in which there should be good tension to the articular disk when palpated with a probe inserted through the 6-R portal [11]. The articular disk will be lax to palpation and has a sunken appearance when a peripheral ulnar tear of the articular disk is present. Synovitis is frequently present marking the location of the peripheral tear which is debrided out to further expose the injury (Fig. 6.2).

There are several arthroscopic techniques for repair of peripheral ulnar-sided tears of the articular disk. Indications for which type of repair varies from author to author. Each technique has its advantages and disadvantages. It is thought when a greater degree of instability of the distal radioulnar joint is present, arthroscopic repair back to bone will provide greater stability as compared to soft tissue repair alone.

Whipple Technique

Whipple et al. described the outside-in technique to reattach the articular disk back to the floor of the sixth compartment [12].

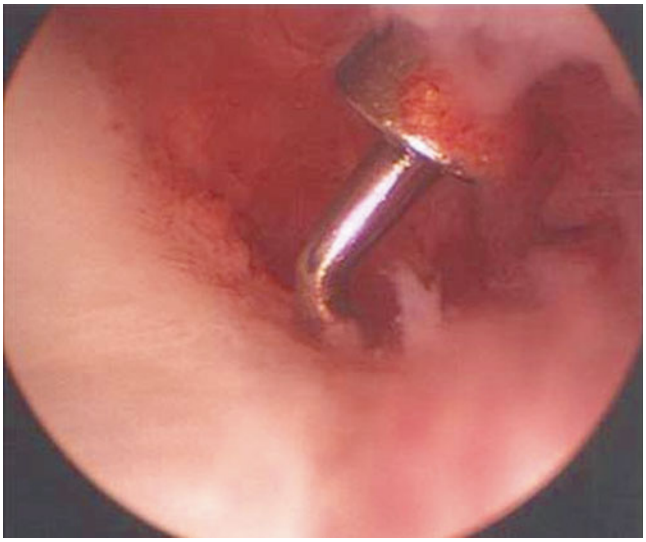


Fig. 6.2 Arthroscopic view with the arthroscope in the 3-4 portal showing a peripheral tear to the articular disk of the TFC in a right wrist. Note the proliferative synovitis about the tear

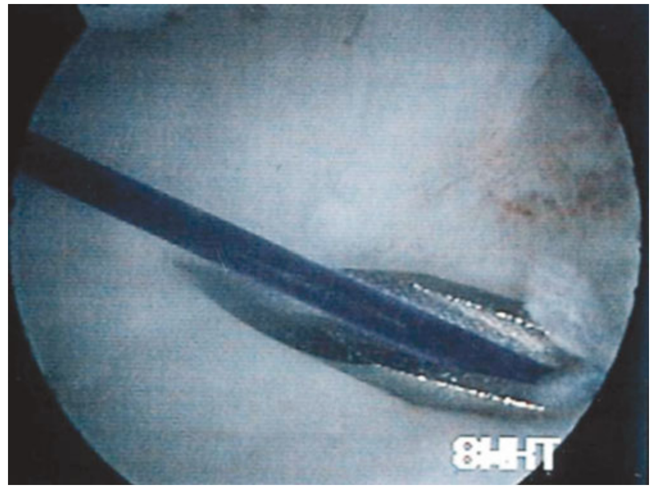


Fig. 6.3 Arthroscopic view with the arthroscope in the 3-4 portal showing an 18-gauge needle perforating through the articular disk with a stitch of monofilament suture being passed through the cannula

Fig. 6.4 Outside view showing an incision of the extensor carpi ulnaris tendon sheath. The extensor carpi ulnaris is retracted volarly and an 18-gauge needle is passed through the floor of the sheath of the extensor carpi ulnaris into the radiocarpal space and a monofilament suture is being inserted

This is ideal for peripheral tears of the articular disk that arise dorsally. The advantage of this technique is that it is relatively simple and does not require any special instrumentation. It is particularly indicated in those patients that are point tender about the prestyloid recess area and have a minimal amount of instability to the distal radioulnar joint. The disadvantage of this procedure is that it does require an incision around the extensor carpi ulnaris tendon sheath, which has to be closed after the procedure. Potentially, there would be a risk for subluxation or instability to the extensor carpi ulnaris if the sheath is not fully closed or does not heal. In addition, patients may complain about irritation of the ECU tendon secondary to the suture knots.

In this technique, the arthroscope is introduced in the standard 3-4 portal. The 6-R portal is elongated approximately 12–15 mm in length along the radial border of the extensor carpi ulnaris tendon. The extensor retinaculum is sharply released along its radial side and the extensor carpi ulnaris tendon is retracted volarly. It is important to protect the articular branch of the dorsal sensory branch of the ulnar nerve as it crosses the incision in an attempt to decrease the risk of sympathetic dystrophy. A curved or straight 18-gauge needle is inserted through the floor of the extensor carpi ulnaris tendon sheath through the peripheral tear as visualized with the arthroscope in the radiocarpal space. Once the needle is identified, it is pulled back and then perforates through the articular disk (Fig. 6.3). It is important to insert the needle as perpendicular as possible to the articular disk. The suture may potentially pull through or shred the disk if it is placed too horizontal or shallow. A 2.0 monofilament suture is placed through the needle into the joint (Fig. 6.4). One trick to help get the suture started into the needle is to cut the plastic off the needle as close as possible. This makes it easier to thread the suture into the needle and into the joint. It is sometimes frustrating to fight the pressure of the fluid being injected through the needle as one is trying to insert the suture. Following insertion of the suture through the needle into the joint, a suture retriever is inserted through the floor

Fig. 6.5 Outside view showing a suture grasper being placed through the incision distal to the articular disk to retrieve the suture

Fig. 6.6 Outside view showing the first suture passed. Note the good tissue on the floor of the extensor carpi ulnaris tendon sheath to which the suture will be tied securing the repair

of the extensor carpi ulnaris tendon sheath distal to the articular disk to grab the suture (Fig. 6.5). If a suture retriever is not available, a standard wrist arthroscopy grasper may work. Two or three sutures are placed in vertical fashion to close the tear (Figs. 6.6 and 6.7) The wrist is then taken out of traction, and the sutures are tied with the wrist in neutral position. A trick is to tie an arthroscopic slip knot to help slide the suture down against the tendon sheath of the extensor carpi ulnaris with tension. It is frequently difficult to slide

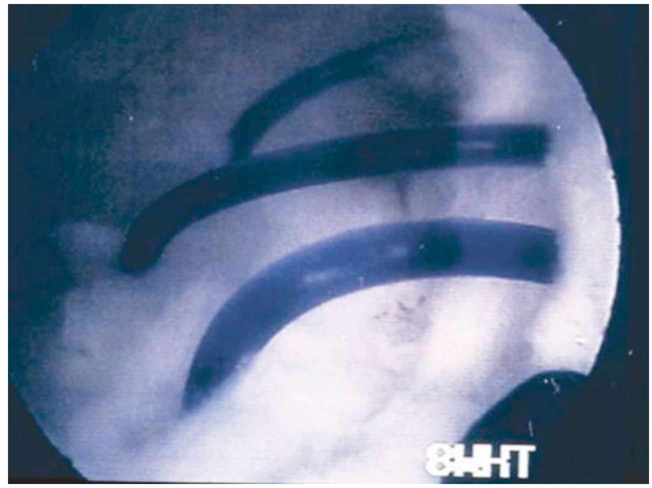


Fig. 6.7 Arthroscopic view with the arthroscope in the 3-4 portal showing three simple sutures passed through the disk securing the tear back to the capsule

the knot with the surgeon's finger down into such a small hole and maintain good tension to the repair. It is very important to use dissolvable sutures so the knots of the sutures do not continue to irritate the tendon of the extensor carpi ulnaris. It is important to close the sheath of the extensor carpi ulnaris to limit the risk of instability to the tendon.

Occasionally, a second surgery is required to remove the irritating suture knot.

Tuohy Needle Technique

Poehling et al. described this inside-out technique [13]. The advantage of this technique is that it utilizes a smaller outside incision where the sutures are to be tied down. The Tuohy needle technique allows for a horizontal mattress stitch to be placed across the peripheral tear. It allows for excellent visualization as the needle and the suture are being placed. The disadvantage of this particular technique is that sometimes it is difficult to help control the needle across the radiocarpal joint to pierce the articular disk. Another disadvantage of this technique is that it primarily repairs the superficial layer of the articular disk and does not involve the deeper layers of the ligamentum subcruetum. In addition, it is very important to dissect down to the capsule as the suture is being tied so that it does not encompass a branch of the dorsal sensory branch of the ulnar nerve.

The Tuohy needle is a needle used in the practice of anesthesia. The needle is blunt tipped and will not cut a suture as it exits the end of the needle.

In this technique, the arthroscope is placed in the 4-5 portal and a 20-gauge Tuohy needle is inserted into the radiocarpal joint through the 1-2 or 3-4 portals. Under direct

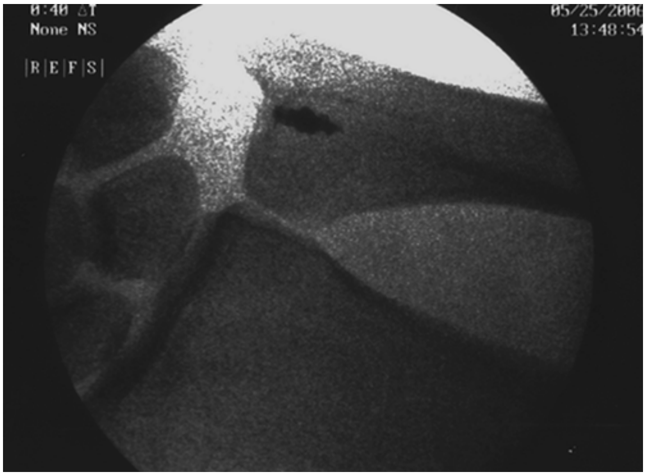


Fig. 6.8 Radiographic view showing a suture anchor placed at the base of the fovea of the ulna reattaching the articular disk back down to bone

visualization, the needle is placed through the torn edge of the triangular fibrocartilage complex and exits the skin. A 2.0 absorbable suture is threaded through the needle and exits along the ulnar side of the wrist. The suture is anchored at each end with a hemostat. The needle is then pulled back into the joint and passed back through the free edge of the peripheral tear in a horizontal mattress fashion. The needle is again advanced out through the tear and out the skin where the loop of suture is retrieved. Multiple sutures may be placed with this technique. Blunt dissection is carried down under direct visualization and the suture is tied directly on the capsule.

Suture Anchor Technique

Sutures may be placed in an arthroscopic-assisted fashion utilizing a suture anchor inserted at the base of the fovea to the ulna (Fig. 6.8). The advantage of this technique is that it allows for repair of the articular disk back down to bone with permanent suture. This technique may be indicated for greater instability to the distal radioulnar joint as determined clinically as it provides fixation of the deep layers of the articular disk back down to bone rather than the superficial fibers alone.

Another advantage of this technique is that it allows the use of a softer braided suture which may be less irritating to the surrounding soft tissues as compared to a monofilament suture. In addition, the extensor carpi ulnaris tendon sheath is not opened decreasing the risk of instability to the extensor carpi ulnaris tendon sheath and irritation from suture knots. The disadvantage of the technique is that it does require an open incision and dissection proximal to the articular disk for insertion of the anchor.

In this technique, the arthroscope is initially placed in the 3-4 portal and the working 6-R portal is made. The 6-R portal is then elongated and the fifth dorsal compartment is then opened releasing the extensor digiti minimi tendon once the tear is identified. The 6-R portal marks the distal portion of the articular disk. Blunt dissection is then continued proximal to the 6-R portal over the head of the ulna. The dorsal aspect of the ulnar head is identified through this small incision. A small burr can then be used to debride any bone to facilitate soft tissue reattach and vascularization. A small anchor with braided suture may be inserted at the base of the ulnar styloid under direct visualization.

The suture is then inserted into the sharp-pointed end of an 18-gauge needle. This loaded 18-gauge needle is then placed perpendicular to the articular disk and inserted through the disk into the joint as viewed with the arthroscope in the 3-4 portal. The tip of the needle is identified arthroscopically and pulled back. As the needle is pulled back, this leaves a loop of braided suture through the articular disk in the radiocarpal space. A suture retriever is then brought in distal to the articular disk to retrieve the suture. The process is repeated with a second limb of the braided suture so that a horizontal mattress suture has been placed. The wrist is then taken out of traction and the suture is tied over the dorsal extensor retinaculum being careful not to entrap the tendon of the extensor digiti minimi.

Arthroscope Knotless Technique

Geissler described the all arthroscopic knotless technique (Bad to the Bone) [14] (see Video 6.1). The advantage of the all arthroscopic knotless technique is that it allows for repair of both the superficial and deep layers of the articular disk back down to bone with no knots all arthroscopically. Another advantage of this technique is that it can be done rather quickly compared to the other techniques. It is the author's opinion that patients with this technique hurt less as compared to the previously described techniques and can be moved sooner. Also, since both layers of the articular disk are repaired back down to bone, this technique may be indicated in those patients who have greater instability to the distal radioulnar joint. It is important to remember that in patients with gross instability to the distal radial ulnar joint, peripheral TFCC repair alone may not provide enough stability. The disadvantage of this technique is that there is a significant learning curve. It involves passage of sutures back and forth between portals, and there is always concern of soft tissue entrapment around the suture. Also, the anchors will be inserted blindly into the previously drilled hole in the ulna.

In this technique, the standard 3-4 and 6-R portals are made (Fig. 6.9). An accessory 6-R portal is made approximately one-half centimeters distal in line with the 6-R portal. It is important to have the wrist flexed in the traction tower about 20–30° when making this portal. The portal is located

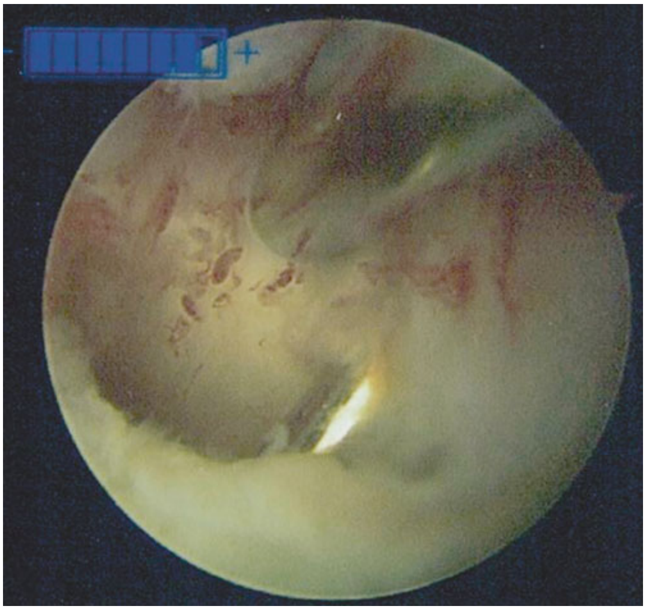


Fig. 6.9 Arthroscopic view with the arthroscope in the 3-4 portal demonstrating a peripheral tear to the articular disk in a right wrist

Fig. 6.10 A standard 3-4 outside view showing the standard 3-4 and 6-R portals have been made. An 18-gauge needle is being used to identify the most ideal location for the more distal accessory 6-R portal

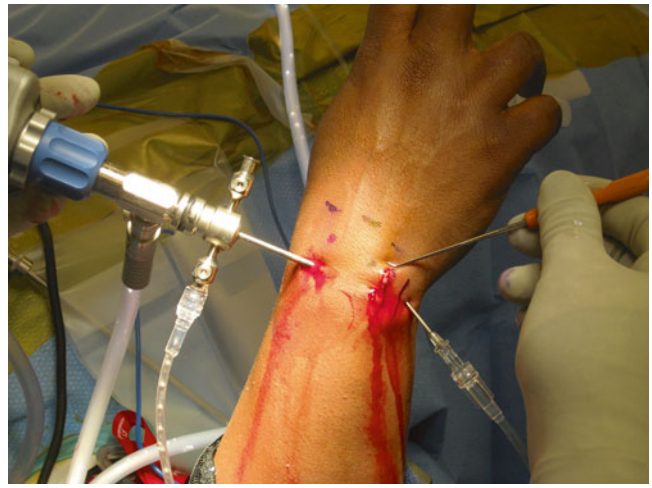


Fig. 6.11 Outside view showing a suture lasso (Arthrex, Naples, FL) being passed through the accessory 6-R portal through the articular disk

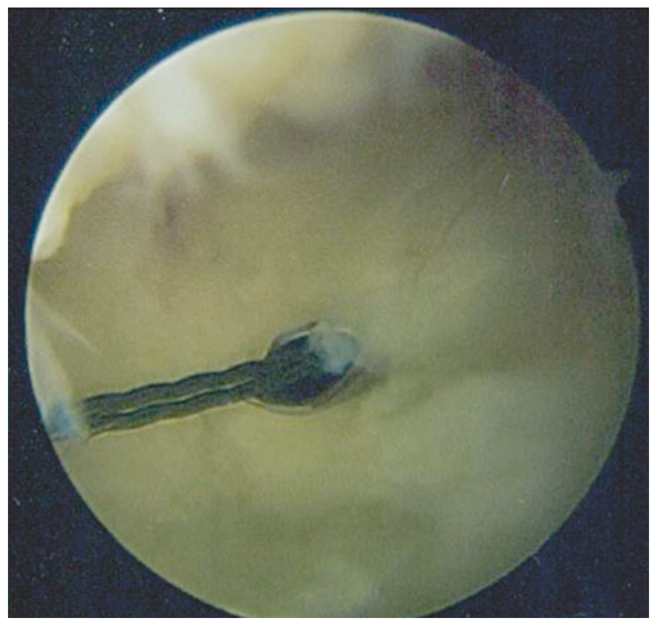


Fig. 6.12 Arthroscopic view showing the suture lasso being perforated through the articular disk with a wire retriever passed through the lasso to retrieve the suture

by utilizing an 18-gauge needle inserted through the skin aimed at the fovea of the ulna head (Fig. 6.10). The base of the ulna can be palpated with the needle. It is important that the needle is close to being parallel to the dorsum of the hand so that with eventual drilling of the bone, the drill does not slide off the volar aspect of the ulna. Once ideal placement of the accessory 6-R portal has been identified, a portal is made.

A suture lasso (Arthrex, Naples, FL) is then placed through the accessory 6-R portal into the joint as viewed arthroscopically (Fig. 6.11). The curved lasso is then placed through the tear in a proximal to distal direction and it pierces through the disk. The lasso is just gently twisted between the thumb and index finger to allow it to more easily perforate through the articular disk. A suture passing wire is then inserted through the lasso and with a crochet grasper inserted through the 6-R portal is retrieved (Fig. 6.12). A 2.0 fiber wire suture (Arthrex, Naples, FL) is then placed through the suture retriever wire and is pulled through the lasso and out distally through the handle (Fig. 6.13). The lasso is then pulled back from the disk but still kept in the radiocarpal space. The lasso is then reinserted through the articular disk and a loop of suture is formed at the end of the lasso (Fig. 6.14). This loop of suture is pulled out through the 6-R portal with the crochet grasper (Fig. 6.15).

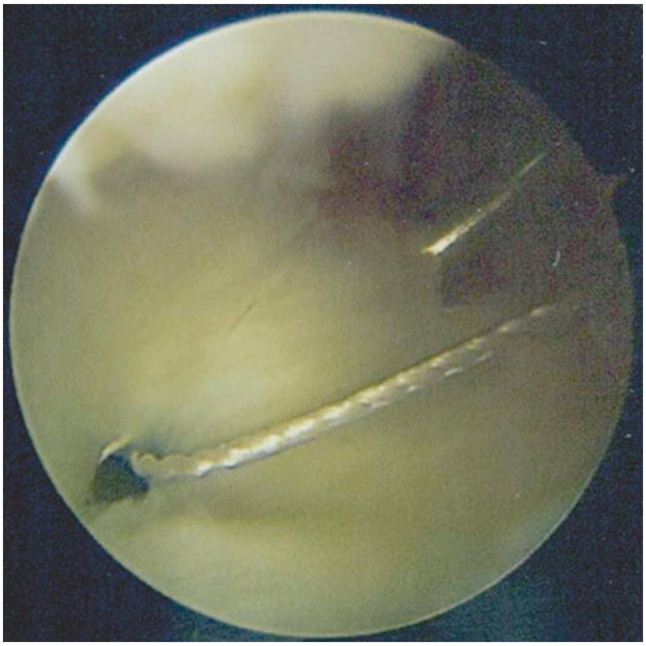


Fig. 6.13 The wire retriever is retrieving the suture through the suture lasso out distally

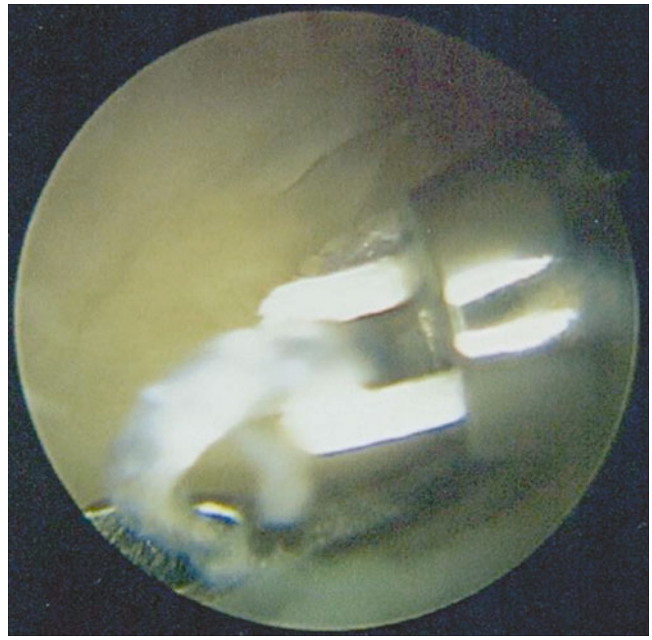


Fig. 6.15 Arthroscopic view showing the crochet hook grabbing the loop of suture retrieving both limbs out the standard 6-R portal

Fig. 6.14 The suture lasso then re-perforates through the articular disk leaving a loop of suture as view arthroscopically

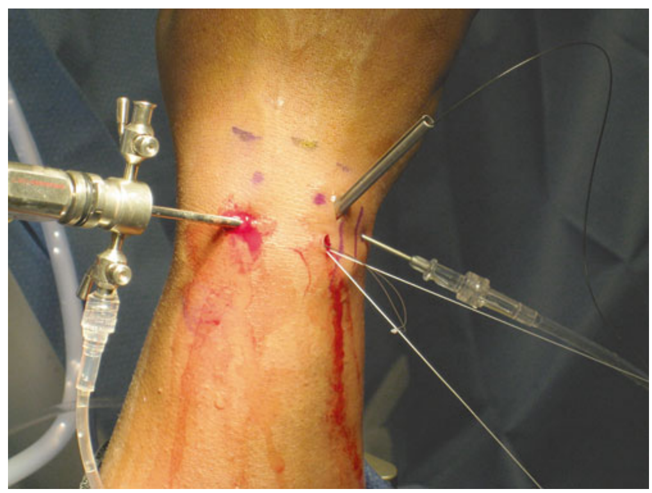


Fig. 6.16 Outside view showing the suture wire retriever pulling both limbs of the suture through the 6-R portal out through the accessory 6-R portal in the cannula

A horizontal mattress stitch with permanent braided suture is now been formed through both layers of the articular disk and both suture limbs are exiting the 6-R portal. The arthroscopic cannula developed for this technique has a serrated end and a smooth end. The smooth end of the cannula with a trocar is then inserted through the accessory 6-R portal. With a crochet grasper inserted through the cannula, the two suture limbs are pulled back from the 6-R portal through the cannula exiting the accessory 6-R portal (Fig. 6.16). The two suture limbs are then pulled through the slot in the cannula so they will not be entangled with the drill. The cannula is held firmly against the ulna head and the drill is placed. The drill is cannulated, so if the surgeon wants to place a K-wire to confirm the ideal placement into the base of the ulna, that option is available. The wire is placed and can be visualized under fluoroscopy. Once ideal placement is found, the drill is inserted through the cannula over the guide wire

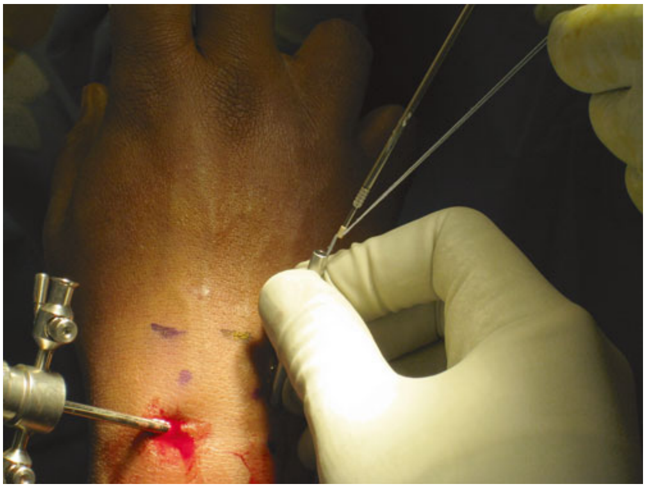


Fig. 6.17 Outside view showing the sutures being passed through a mini push lock anchor (Arthrex, Naples, FL) being inserted through the cannula securing the repair of the articular disk back to bone with a knotless technique

and the base of the ulna is drilled. Alternatively, when no guide wire is used, the drill is inserted through the cannula alone and the base of the ulna is drilled, which is recommended. Once the head of the ulna has been drilled, the cannula is not moved. The two suture limbs are then inserted into the mini push lock anchor (Arthrex, Naples, FL) and the anchor is slid down the cannula and inserted into the drill hole (Fig. 6.17). As the anchor is being passed down the cannula, it is important that the suture limbs are pulled back through the slot so they can be advanced into the bone of the ulna. As the anchor is inserted into the previously drilled hole, the sutures are then tensioned and the articular disk is evaluated arthroscopically. Once ideal tension has been confirmed, the push lock anchor is advanced into the head of the ulna. Following insertion of the anchor into the bone, the anchor is gently pulled on the handle to insure that the anchor has a good purchase into the bone of the ulna. Once confirmed, the sutures are cut (Fig. 6.18). This technique repairs the articular disk back down to bone with the all arthroscopic knotless technique (Fig. 6.19).

Rehabilitation

Postoperative management of peripheral TFCC repair is controversial with multiple techniques being suggested. In the author's practice, the patient is immobilized in slight supination in an above elbow splint for 3–4 weeks. A removable wrist splint is then used for an additional 3 weeks. Digital range of motion exercises are started immediately. Range of motion and strengthening exercises of the forearm and wrist are initiated at approximately 7 weeks.

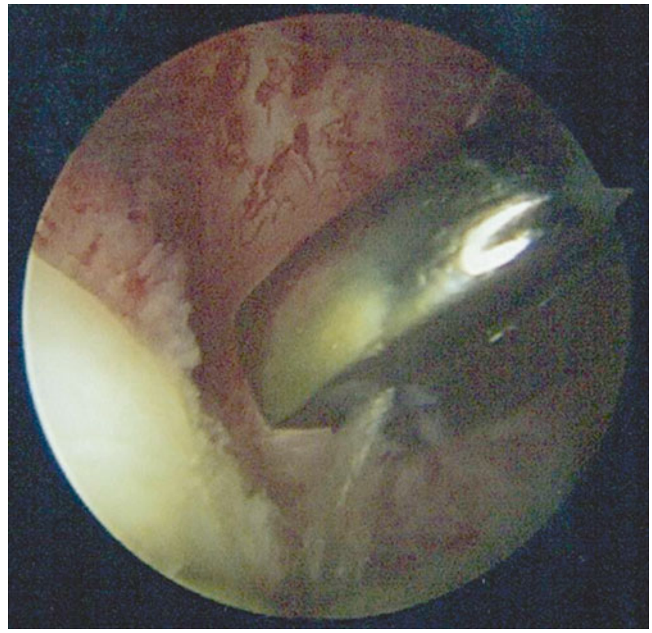


Fig. 6.18 Arthroscopic view showing the two fiber wire suture limbs being cut

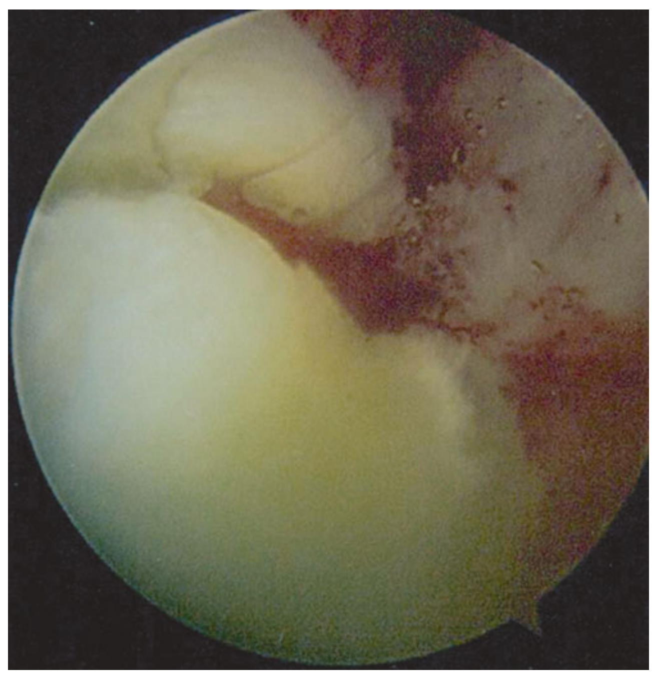


Fig. 6.19 Arthroscopic view with the arthroscope in the 3-4 portal showing repair of the articular disk back down to bone with an all arthroscopic knotless technique. Note the good tension to the articular disk

Discussion

It is controversial whether a repair of a peripheral tear of the triangular fibrocartilage complex should be repaired back to bone or if a soft tissue repair to the capsule satisfactorily restores stability. Ruch et al., in a biomechanical study, compared TFCC repairs of the articular disk back to the extensor carpi ulnaris subsheath (Whipple technique) as compared to open transosseous repair in six matched pairs of fresh frozen cadavers [15]. He reported that in both groups, distal radioulnar joint stability was restored and there was no statistical biomechanical difference.

Corso et al. reported his results in a multicenter study of patients who underwent an outside-in Whipple technique [9]. Patients were contributed to the study by Drs. Geissler, Savoie, and Whipple. He found 41 of 45 patients had a good or excellent result utilizing the Mayo modified wrist score and returned to normal activity by 3 months. Fulcher reported his results with the Tuohy needle technique. He reported a 70 % satisfaction rate at 16–24 months follow-up in 17 patients.

Estrella et al. reviewed their results in 35 patients repaired by either the Whipple or Tuohy needle techniques [16]. They found that 74 % of their patients had good or excellent results utilizing the Mayo modified wrist score. They found that the patients had significant increased grip strength and pain relief and in addition, had increased capacity to perform daily activities.

Ruch and Papadonikolakis reported their results in 35 patients who had a repair of a peripheral ulnar tear utilizing the disabilities of the arm, shoulder, and hand (DASH score) as statistical analysis to identifying factors [17]. They found that positive ulnar variance and increased age correlated with a poorer outcome. They also noted that patients who had loss of wrist rotation and grip strength reported poorer outcomes.

It is controversial in a patient with a peripheral ulnar tear in an ulnar positive patient should the ulna be shortened at the time of the repair. In the author's experience, sutures are initially placed arthroscopically, an ulnar shortening osteotomy is performed, and then the sutures are tied. It is the author's experience that in patients who are ulnar positive, an ulnar shortening osteotomy improves the patient's pain relief in addition to the repair of the articular disk.

A peripheral ulnar-sided tear of the articular disk may be the first stage of a complex multifactorial ligamentous injury (Figs. 6.20 and 6.21) Trauma to the ulnar side of the wrist usually involves a spectrum of injury. Wrist arthroscopy is a useful adjunct in the management of these complex injuries to the triangular fibrocartilage complex (Figs. 6.22, 6.23, 6.24) Current arthroscopic techniques for repair of peripheral ulnar-sided tears of the articular disk have produced good and excellent results as documented in the literature. Potential further refinements such as the newer all arthroscopic knotless technique described in this chapter may further enhance the treatment of these injuries and improve patient's satisfaction and outcomes.

Fig. 6.20 AP radiograph of a young female who sustained a severe ulnar-sided perilunate injury

Fig. 6.21 Lateral radiograph of the same patient with a severe ulnar-sided perilunate injury with subluxation of the distal radioulnar joint

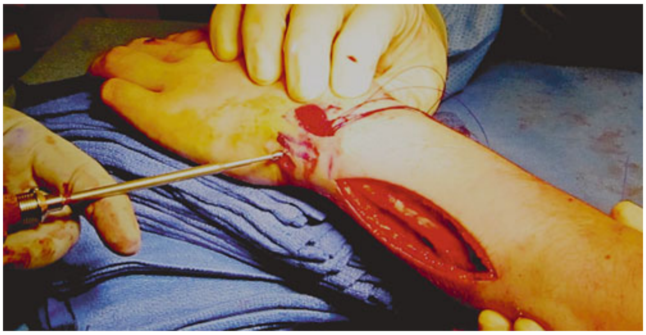


Fig. 6.22 The patient underwent arthroscopic evaluation which showed a complete tear, Geissler Grade IV, to the lunotriquetral interosseous ligament as well as a large peripheral tear to the articular disk. The patient underwent arthroscopic stabilization of the peripheral tear utilizing the Whipple technique without tying the sutures. The patient then underwent placement of a SLIC screw (Acumed, Hillsboro, OR) across the LT interval for the complete tear to the interosseous ligament. The patient then underwent an open ulnar shortening osteotomy with the ulnar shortening plate (Acumed, Hillsboro, OR) to further tighten the instability of the distal radioulnar joint

Fig. 6.23 PA radiograph following stabilization of the peripheral tear of the TFC, LT interval and open ulnar shortening osteotomy

Fig. 6.24 Lateral radiograph following stabilization. The lateral radiograph demonstrates reduction to the distal radioulnar joint as compared to preoperative radiographs

References

1. Palmar AK. Triangular fibrocartilage complex lesions: a classification. J Hand Surg. 1989;14:594–606.
2. Chidgey LK, Dell PC, Bittar ES, et al. Histologic anatomy of the triangular fibrocartilage. J Hand Surg. 1991;16:1084–100.
3. Adams B. Partial excision of the triangular fibrocartilage complex articular disk, a biomechanical study. J Hand Surg. 1993;184: 334–40.
4. Thiru RG, Ferlic DC, Clayton MI, et al. Arterial anatomy of the triangular fibrocartilage of the wrist and its surgical significance. J Hand Surg. 1986;11:258–63.
5. Bednar MS, Arnoczky SP, Weiland AJ. The microvasculature of the triangular fibrocartilage complex: its clinical significance. J Hand Surg. 1991;16:1101–5.
6. Weiss A, Akelman E, Lambiase R. Comparison of the findings of triple-injection cinearthrography of the wrist with those of arthroscopy. J Bone Joint Surg Am. 1996;78A:348–56.
7. Golimbu C, Firooznia H, Melone CJ, et al. Tears of the triangular fibrocartilage of the wrist: MR imaging. Radiology. 1989;173: 731–3.
8. Skahen JI, Palmer A, Levinsohn E, et al. Magnetic resonance imaging of the triangular fibrocartilage complex. J Hand Surg. 1990;15A:552–7.
9. Pederzini L, Luchetti R, Soragni O, et al. Evaluation of the triangular fibrocartilage complex by arthroscopy, arthrography, and magnetic resonance imaging. Arthroscopy. 1992;8:191–7.

10. Fulcher S, Poehling G. The role of operative arthroscopy for the diagnosis and treatment of lesions about the distal ulna. Hand Clin. 1998;14:285–96.
11. Cooney WP, Linscheid RL, Dobyns JH. Triangular fibrocartilage tears. J Hand Surg. 1994;19:143–54.
12. Whipple T, Geissler W. Arthroscopic management of wrist triangular fibrocartilage complex injuries in the athlete. Orthopedics. 1993;16(9):1061–7.
13. de Araujo W, Poehling G, Kuzma G. New Tuohy needle technique for triangular fibrocartilage complex repair: preliminary studies. Arthroscopy. 1996;12:699–703.
14. Geissler W. Arthroscopic knotless peripheral triangular fibrocartilage repair. J Hand Surg Am. 2012;37(2):350–5.
15. Ruch DS, Anderson SR, Ritter MR. Biomechanical comparison of transosseous and capsular repair of peripheral triangular fibrocartilage tears. Arthroscopy. 2003;19(4):391–6.
16. Estrella EP, Hung LK, Ho PC, Tse WL. Arthroscopic repair of triangular fibrocartilage complex tears. Arthroscopy. 2007;23(7): 729–37.
17. Ruch DS, Papadonikolakis A. Arthroscopically assisted repair of peripheral triangular fibrocartilage complex tears: factors affecting outcome. Arthroscopy. 2005;21(9):1126–30.

Management of Type 1D Tears

7

Fernando Corella, Miguel Del Cerro, and Montserrat Ocampos

Anatomy of the TFCC

The so-called triangular fibrocartilage complex (TFCC) is an anatomical structure which is fundamental for the stability of the distal radioulnar joint (DRUJ). It is denominated "complex" as it is not a single anatomical structure, but various. The first author to define the term was Palmer in the year 1989 [1]. Since then it has been understood that the TFCC is formed by an articular disc, the radioulnar ligaments (RUL) dorsal (DRUL) and volar (VRUL), the meniscus homologue, the ulnar collateral ligament, the ulnocarpal ligaments, and the tendon sheath of the extensor carpi ulnaris tendón (ECU) (Fig. 7.1.)

The articular disk is a triangular meniscus-shaped structure. It is thinner in its central portion and widens out in the more dorsal and palmar part, where it becomes in the radioulnar ligaments. Histologically speaking, in the union with the radius there exists a reinforcement of short collagenous fibers, oriented radially, with an extension of 1–2 mm., while the fibers of the rest of the disk have a greater tendency towards intertwining and are less organized. The area of the union of the short fibers with the rest of the articular disk is where there commonly take place the type ID tear [2].

The radioulnar ligaments stabilize the DRUJ joint. Ishii, in his anatomical study [3] shows how they have both a superficial and deep layer. The deep portion, called subcruentum ligament, is inserted in the fovea of the ulna, whereas the superficial part envelops the articular disk and becomes united to it in the more ulnar part. Nowadays it is known that the deeper part has greater importance in maintaining the stability of the distal radioulnar joint [4, 5].

F. Corella, Ph.D. (✉) • M. Ocampos, M.D.
Section of Hand Surgery, Orthopaedic and Trauma Department, Infanta Leonor University Hospital and Beata María Ana Hospital, C/ Gran Vía del Este Nº80 28031, Madrid, Spain
e-mail: fernando.corella@gmail.com

M. Del Cerro, M.D.
Hand Surgery Unit, Beata María Ana Hospital, C/ Doctor Esquerdo, 83, 28007, Madrid, Spain

The so-called meniscus homologue refers to the tissue, which is to be found between the superficial insertion of the radioulnar ligaments and the articular capsule [3]. In a certain anatomical study it has been postulated that it consists of the remains of a large apophysis of the ulnar styloid which, in primates, is joined to the pisiform and pyramidal [6].

The ulnar collateral ligament is a thick structure, which is inserted proximally into the base of the ulnar styloid and distally in the pisiform and triquetrum. It is in close contact with the ECU and distally its fibers converge with the meniscus homologue [7].

The last structure that forms the TFCC is the tendon sheath of the ECU. It is connected to the head of the ulna and the ulnar fovea by means of Sharpey fibers.

From a didactic viewpoint the TFCC has been compared to a tridimensional structure with two walls and a floor. The floor of this structure would be the articular disk and the volar and dorsal radioulnar ligaments; the palmar wall, would be formed by the ulnocarpal ligaments and the dorsal wall would be formed by the tendon sheath of the ECU.

The integrity of the TFCC is fundamental for two functions. The first of these maintains the stability of the distal radioulnar joint that, as has already been commented, is carried out fundamentally by the radioulnar ligament [4, 5, 8]. The second function refers to the correct transmission of the load. It is known that approximately 20 % of the wrist load is transferred through its ulnar border, that is to say, through the TFCC, so that any lesion may alter it [1].

Vascularization of the TFC

The ulnar artery is that which gives greater blood supply to the TFCC, above all in its ulnar portion. The more radial part is irrigated by means of volar and dorsal branches of the anterior interosseous artery.

In histological studies, such as those carried out by Bednar [9] and Thiru [10], it has been seen that the blood vessels penetrate into the TFCC from the periphery and can be

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*, DOI 10.1007/978-1-4614-1596-1_7, © Springer Science+Business Media New York 2015

observed only in an external 10–40 % of their size. These vessels may be observed above all in the dorsal, ulnar, and palmar area of the TFCC. Thus, the "radial and central portion" is relatively avascular, unlike the volar radial and dorsal radial, that is to say, the radioulnar ligaments.

It has been considered that the central area, as it has lesser vascular supply, it lacks a healing capacity. But Cooney [11] in a series of 23 patients with peripheral tears of the radial margin treated by open surgery, obtained good or excellent results in 80 % of the cases. By the same token he verified that 2 years after surgery, there still existed continuity of the reparation in four out of five patients.

That is, the fact that in histological studies the central area of the radial portion of the TFCC should not have a large number of vessels, does not mean that the radioulnar ligaments do not have them and neither does it mean that the healing may not be obtained after a correct bone bed preparation for the anchoring. In the same way that a meniscal lesion of the knee is not sutured in the white–white area, in the TFCC, healing is not attained by suturing a tear of the most central part (1A lesion), but the healing can be attained of the "central radial" portion with the radius (this would be a red–white area) or of the radioulnar ligaments with the radius (it would be a red–red area).

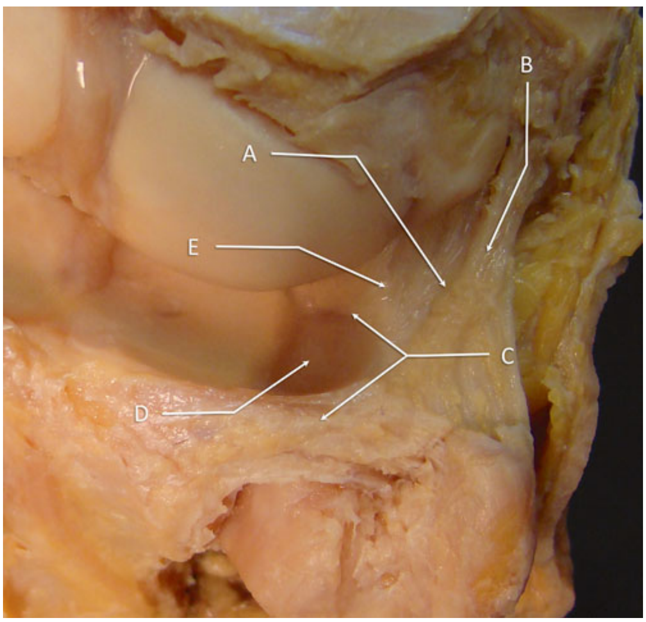


Fig. 7.1 (A) Meniscus homologue. (B) Ulnar collateral ligament. (C) Radioulnar ligaments. (D) Articular disk. (E) Ulnocarpal ligaments

Diagnosis

Physical Examination

Patients with a radial lesion usually recall a traumatic precedent, above all in a fall with the wrist in hyperextension and ulnar deviation or also a sharp twist of the wrist.

The patient complains of pain and swelling in the ulnar area of the wrist and discomfort with the movements of ulnar deviation and pronosupination. If the lesion is a significant one and involves radioulnar instability, the dorsal prominence of the ulna may be observed but it should always be compared with the contralateral wrist in order not to confuse it with a hypermobile wrist.

There exist several exploration tests of the TFCC but in our view, the most useful ones are the three following ones (Fig. 7.2)

Ulnar fovea sign [12]: with the elbow of the patient in a state of flexion, the thumb palpates the depression formed by the flexor carpi ulnaris, the ulnar styloid, the head of the ulna and the pisiform. It may be regarded as positive when pain

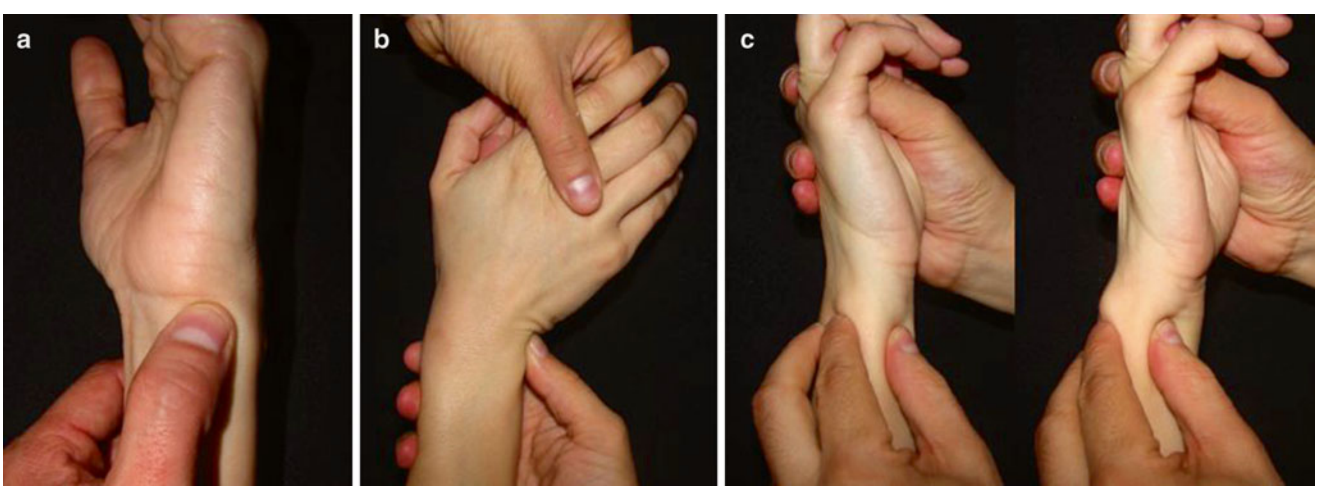


Fig. 7.2 (**a**) Ulnar fovea sign. (**b**) Ulnocarpal stress test. (**c**) Radioulnar instability exploration

appears compared with the contralateral. It is one of the most important signs in this kind of pathology, as it has a very high sensitivity and specificity (95 % and 87 % respectively).

Ulnocarpal stress test [13]: is carried out by the application of axial loading to the wrist in a state of maximal ulnar deviation while a movement of pronation and supination is applied. It is a very sensitive sign, but not a very specific one as it can be positive in a number of pathologies that affect the ulnar region of the wrist.

Radioulnar instability [5]: in order to evaluate the stability of the distal radioulnar joint, the ulna is displaced with respect to the radius in an anteroposterior plane with the wrist in a neutral position, in supination and pronation. These maneuvers should be carried out in both the affected side and the contralateral one, because instability should not be confused with articular laxness.

Diagnostic Modalities

Tears in the TFCC are not detected by simple radiographic examination, but they can reveal indirect data, which may indicate the possibility of a lesion. Thus, lateral and oblique and AP projections are useful to diagnose the presence of fractures-avulsions of the sigmoid notch and DRUJ instability as, with a complete radial desinsertion, the space of this joint will increase.

Tricompartmental arthrography has been the standard method used for the diagnosis of lesions of the intra-articular ligaments of the wrist [14]. It consists of a contrast injection under radiological control in the radiocarpal joint, midcarpal, and DRUJ. In presence of a radial tear there appears an extravasation of the contrast.

With the development of new technical advances in Magnetic Resonance Imaging (MRI), improvement has been achieved in the resolution and diagnosis of TFCC lesions, the former being the preferential technique of several authors [15, 16]. Arthro-MRI may add further information to the study and is shown to be superior to the standard MRI for the detection of complete tears of the TFCC [17].

The carrying out of helical computerized axial tomography (CT) together with arthrography combines the advantages of both techniques; the intra-articular structures and compartments remain distinctly defined in multiple planes. Thanks to this, the location of the tear may be determined with greater precision [18] and may be regarded as an alternative technique to that of Arthro-MRI [19].

But without any shade of doubt, the "gold standard" in the diagnosis of 1D-type lesions of the TFCC is still arthroscopy of the wrist, as it allows a direct visualization of the tear, determines the location and lesion type and detects other associated lesions.

Classification

In 1989, Palmer classified TFCC lesions in two large groups [1]. The first of these included traumatic lesions and he denominated them class 1, and the degenerative lesions class 2. Likewise, the traumatic lesions are subdivided according to their location, a central slit as 1A, ulnar tear as 1B, distal tear as 1C, and radial tear as 1D.

Radial tears are avulsions of the TFCC from the radial sigmoid notch and may or not include bone fragments.

Although controversy exists as to what a ID tear is and what it is not, one of the best classifications which define them is that of Nakamura [20] who subdivided the radial lesions of the TFCC into six groups (Fig. 7.3)

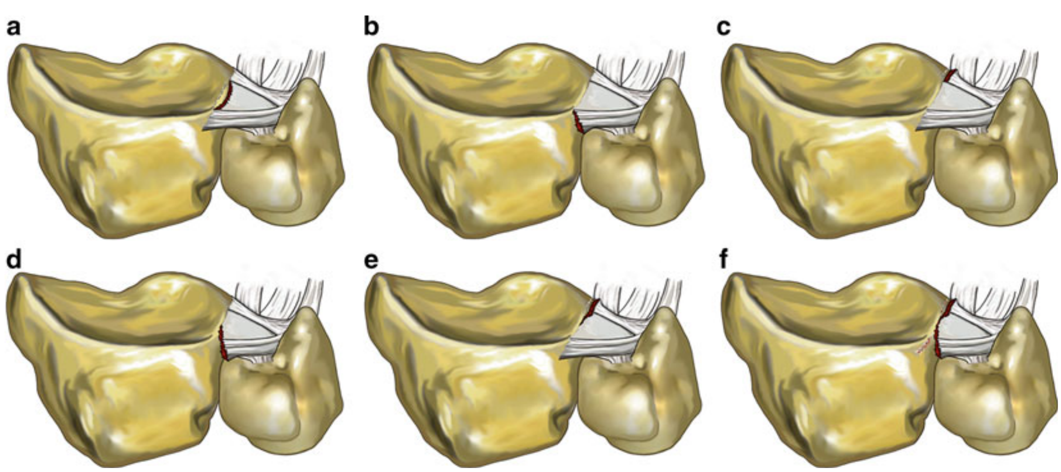


Fig. 7.3 (**a**) Fibrocartilage tear between the hyaline cartilage of the sigmoid notch of the radius and TFCC. (**b**) Dorsal edge tear between the dorsal edge of the sigmoid notch of the radius and dorsal portion of the radioulnar ligament. (**c**) Palmar edge tear between the palmar edge of the sigmoid notch of the radius and palmar portion of the radioulnar ligament. (**d**) Combination of (**a**) + (**b**). (**e**) Combination of (**a**) + (**c**). (**f**) Complete detachment of the TFCC from the sigmoid notch of the radius

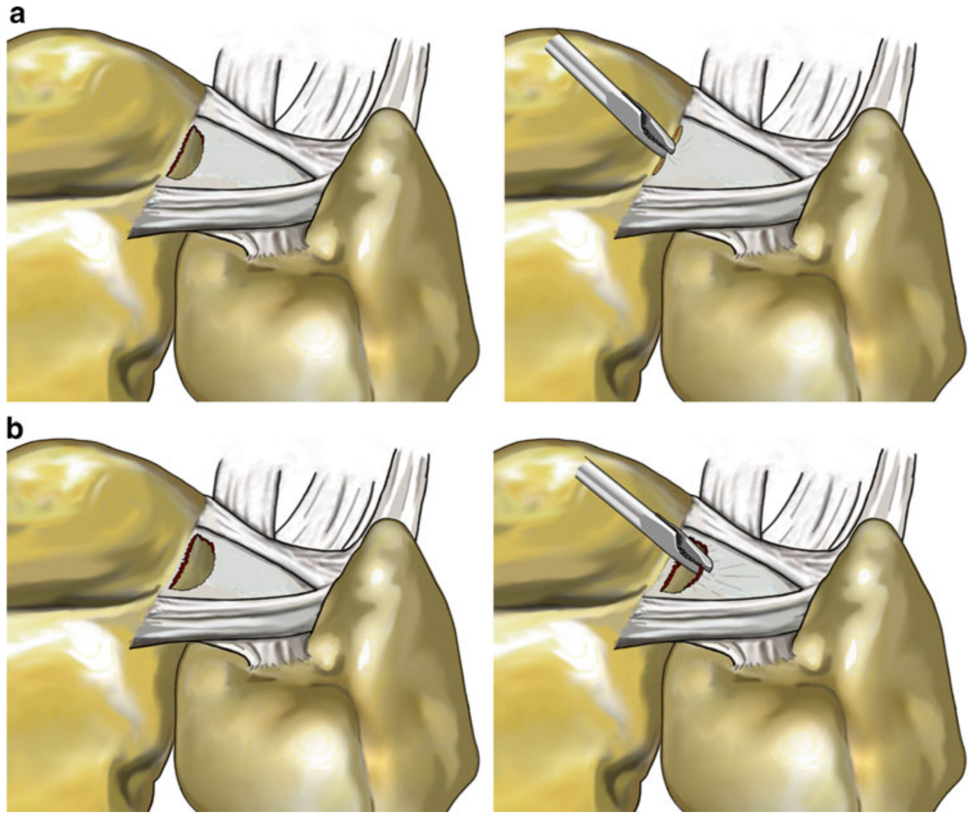


Fig. 7.4 (**a**) After the debridement the articular disc can be approximated without tension to the radius sigmoid notch. We would classify the lesion as Ida and the reattachment back down to the bone could be made. (**b**) After the debridement the articular disc cannot major be approximated without tension to the radius sigmoid notch. We would classify the lesion as IA and only a debridement would be carried out

(a) Fibrocartilage tear between the hyaline cartilage of the sigmoid notch of the radius and TFCC.
(b) Dorsal edge tear between the dorsal edge of the sigmoid notch of the radius and dorsal portion of the radioulnar ligament.
(c) Palmar edge tear between the palmar edge of the sigmoid notch of the radius and palmar portion of the radioulnar ligament.
(d) Combination of (a) + (b).
(e) Combination of (a) + (c).
(f) Complete detachment of the TFCC from the sigmoid notch of the radius.

As has already been seen, the stability of the DRUJ depends on the integrity of the radioulnar ligaments and thus a type 1D-a may not be associated with DRUJ instability, whereas a type 1D-b–f can induce DRUJ instability.

Further doubt may exist with regard to differentiating a 1D-a lesion (radial lesion) from a 1A lesion (central lesion), as the only difference is a few millimeters of fibrocartilage tissue. In our view, the most important thing is to determine the treatment to be carried out rather than an evaluation as to whether a fibrocartilage tissue exists or not between the tear and the radius.

We would advocate a debridement of the portion of the fibrocartilage united to the radius and an evaluation as to whether the articular disk can be approximated to the radius without tension. If this is the case, the reattaching of the lesion would be carried out and we would denominate it 1D-a. If the disk cannot be approximated without tension, only the debridement would be carried out and the lesion would be classified as 1A (Fig. 7.4)

Treatment

Conservative Treatment

Treatment in the acute phase of lesions of the TFCC, not associated with clinical instability, includes immobilization for 3–4 weeks, nonsteroid anti-inflammatories, steroid injections and, physiotherapy.

Indication of Surgical Treatment

Both the failure of a conservative treatment, without improvement after 3 months and the existence of associated distal radioulnar instability, indicate the need for surgical treatment.

Surgical Treatment

Many classical papers advocate the treatment of most of the lesions of the TFCC by means of debridement or excision [21, 22]. This practice has been supported by a study, which concludes that the resectioning of at least two thirds of the articular disk does not influence in the DRUJ biomechanics [23]. However, in this study the peripheral margins of the TFCC were respected, that is to say, the radioulnar ligaments. More recent studies have highlighted the importance of the integrity of these ligaments in order to maintain DRUJ stability [4, 5]. This has increased the interest of many authors to repair the TFCC instead of a debridement.

In the case of radial side tears, there exists greater agreement on carrying out a repair when the radioulnar ligaments are affected. As we have seen supra, these ligaments are vascularized structures with potential healing. Greater doubt exists with regard to the repair of a central radial tear without affecting the radioulnar ligaments but, as we have already mentioned, our view is that, if after the debridement the articular disk can be approximated without tension, we would advocate its repair back to the bone. With this reparation we believe that there may be avoided a possible progression towards the radioulnar ligaments.

One of the first open techniques described for the repair of the radial edge of the TFCC was described in 1994 by Clooney [11] who obtained good or excellent results in 80 % of his patients. Since that time numerous arthroscopic techniques have been described:

Trumble [24, 25] used a meniscal suture system with two preloaded needles; the suture was knotted on the radial side of the radius. He obtained improvement in the range of motion up to 89 % and grip strength up to 95 % with respect to the contralateral side.

Sagerman and Short [26] described a similar technique, whose difference was based on the carrying out of three bone tunnels through which there passed the meniscal suture systems. The results were good or excellent in 8 out of 12 patients.

Plancher [27] described a technique in which a suture was also carried out by passing it through the radius. With the usage of an external guide he managed to make two tunnels in the radius with a single outward opening in the sigmoid notch. A suture passer was used in an outside-inside way and the threads were knotted on the radial side of the radius.

Fellinger [28] described the repair of tears of the radial side using the T-Fix Device® (Acufix). A single bone tunnel was made through which there was passed this system in a of outside to inside manner. Once the TFCC had been traversed, the "T" form anchorage was established; maintaining united the TFCC to its insertion zone.

Jantea [29] also used an external guide to create the tunnels. In one of them a spinal needle loaded with an absorbable monofilament was passed and in the other a suture retriever. The sutures were knotted on the dorsal side of the radius. Good results were obtained in 11 out of 12 patients.

Geissler [30] developed a new anchorage system with technology similar to the system of meniscal suture RAPIDLOC® (De Puy Mitek). Through two bone tunnels the system is introduced, the fibrocartilage is perforated and the topHat is extended. It slides towards the radial region of the radius where the TFCC remains fixed.

All of these techniques require the use of bone tunnels which pierce the radius and through which the sutures are passed. With the development of new implants and instruments nowadays the reattach can be carried out arthroscopically without the necessity of carrying out bone tunnels or knots. The following explains the technique of making it.

Arthroscopic Knotless Radial-Side TFCC Repair

The portals that this technique requires are the dorsal 3/4, 6R, and 4/5 radiocarpal portals. The wrist is placed in the traction tower, applying 10 lb of traction. Firstly the 3/4 radiocarpal portal is performed, it is marked with an 18 gauge needle, the tip of a number 11 scalpel is introduced and the portal is widened with a blunt dissector. Through this portal the arthroscope is introduced, the whole of the radiocarpal joint is inspected and the TFCC is visualized.

The second portal that should be made is the 6R. As well as in the case of the 3/4 portal, an 18 gauge needle is introduced, on this occasion it is verify under arthroscopic control that it is located just above the TFCC, afterwards the tip of the scalpel is introduced and finally the portal is widened with a blunt dissector. By carrying out the portal under direct visualization, it is not probable to cause lesion of the TFCC or the articular cartilage.

A probe is introduced through the 6R portal, the tension of the TFCC is evaluated and the location and extension of the radial tear. In order to be able to classify this type of lesion correctly, particular attention should be paid to its dorsal or palmar extension, that is to say, the injury of the dorsal and palmar radioulnar ligaments (Fig. 7.5).

If the lesion extends to the radioulnar ligaments, or if it is a central tear but as has already been commented, approximation to the sigmoid notch can be made without tension, the repair of the TFCC back down to the bone can be performed as follows.

In the same way as the reattached of a peripheral ulnar tear [31], this technique requires one visualization portal (the 3/4 portal) and two working portals. Instead of carrying out a 6R accessory portal as it is made in an ulnar tear, a 4/5 portal is performed. Given the radial location of the lesion, this portal will great facilitate the technique. The 4/5 portal may be made also under arthroscopic control, first it is located with an 18 gauge needle (Fig. 7.6), afterwards incised with the scalpel and finally dilation is made. In a cadaver study published by the authors of this chapter [32], it has been found that while performing the 4/5 portal an injury of the fifth extensor tendon could happen and thus special care should be taken with it.

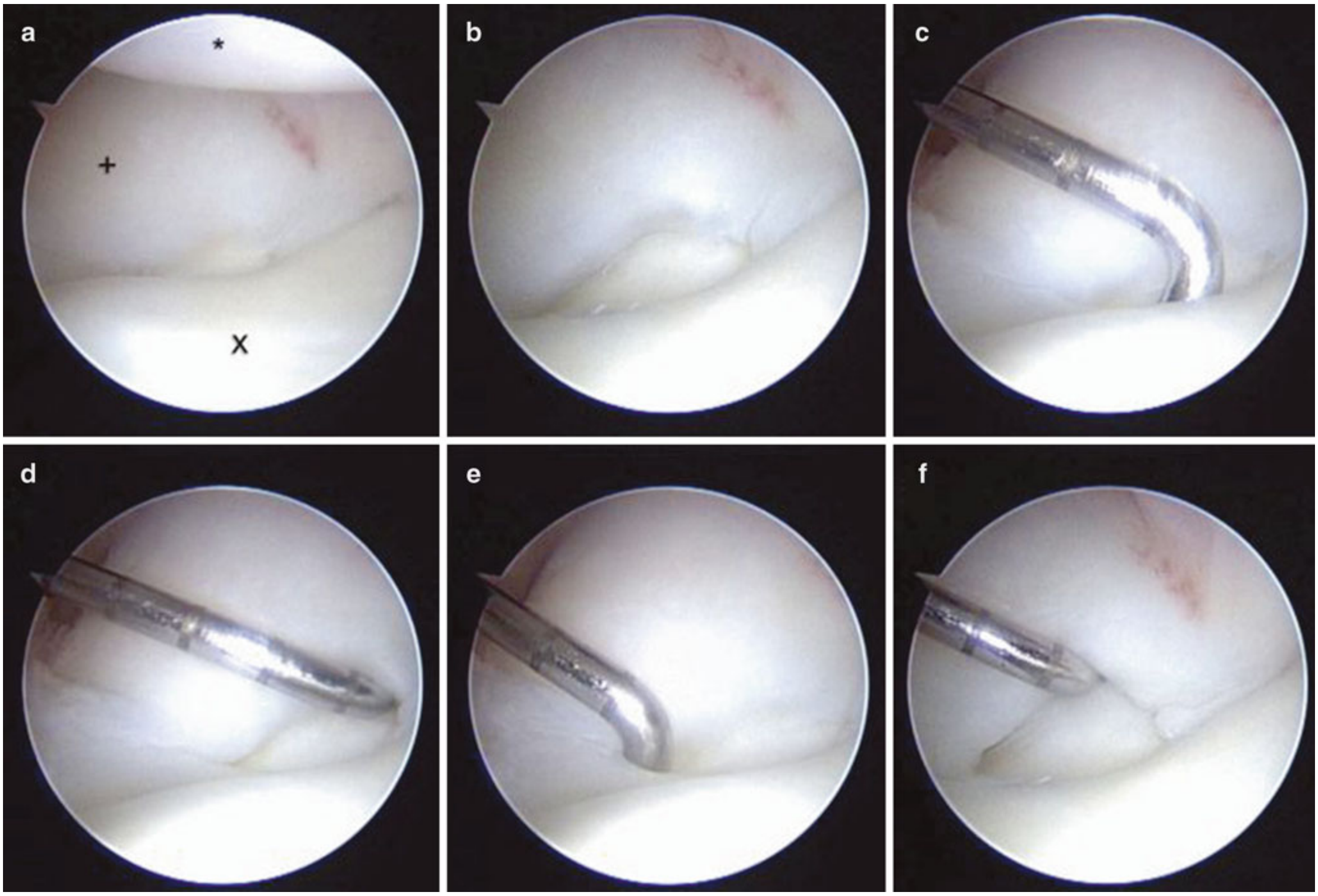


Fig. 7.5 (**a**) Ulnar compartment seen from the 3/4 portal (*Lunate, +TFCC, ˣRadius). (**b**) Radial lesion of the TFCC. (**c**) Probe in the sigmoid notch. (**d**) The tear extends to the volar radiolunar ligament. (**e**) Integrity of the dorsal radiolunar ligament. (**f**) The ulnar head is seen under the radial lesion of the TFCC

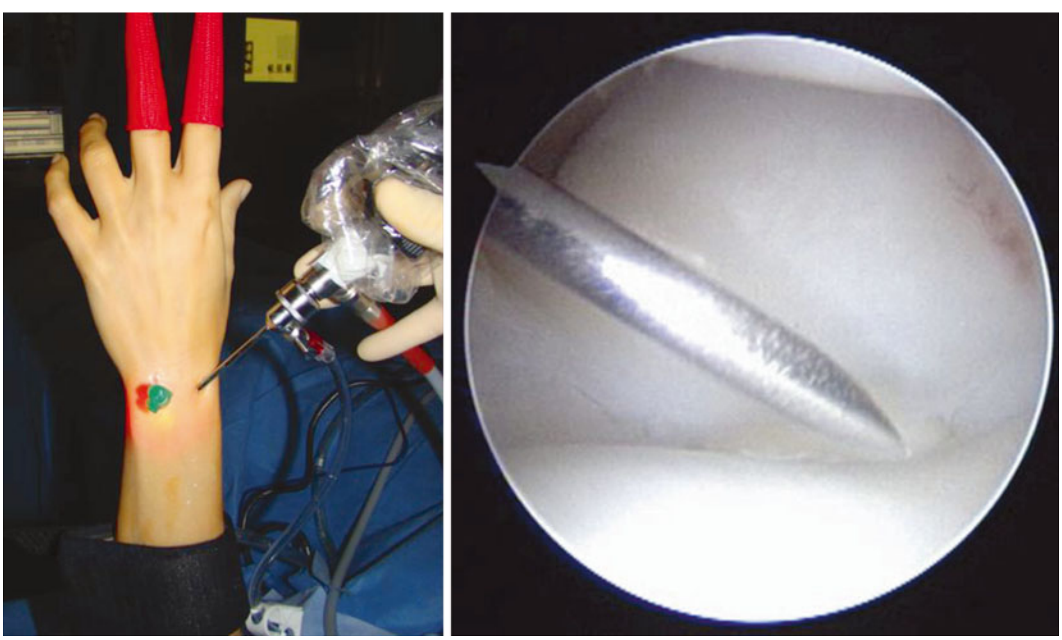


Fig. 7.6 Establishment of the working accessory portal, in this technique it would be the 4/5 portal

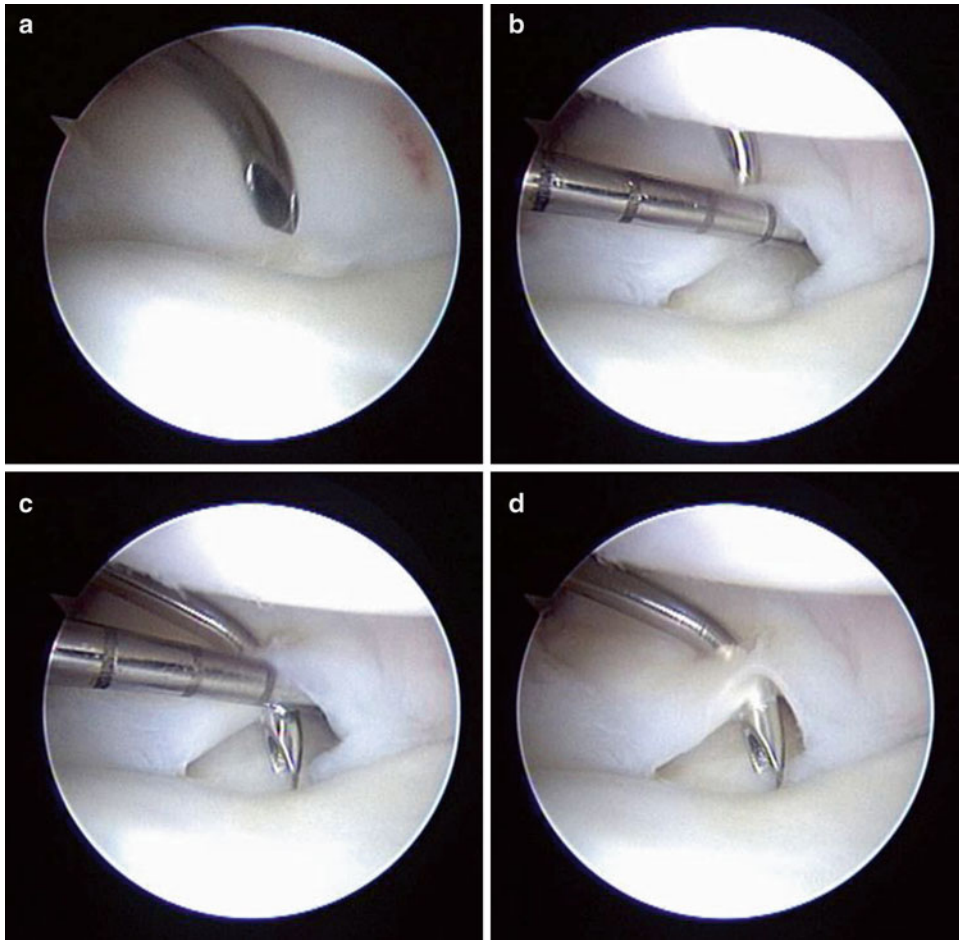


Fig. 7.7 (**a**) The TFCC SutureLasso 70 (Arthrex, Naples, FL, USA) is introduced through the 6R portal. (**b**, **c**) With the help of the probe the whole thickness of the TFCC is pierced through. (**d**) The tip of the SutureLasso appears between the inferior side of the TFCC and the ulnar head

The TFCC SutureLasso 70º® (Arthrex, Naples, FL, USA) is introduced through the 6R portal. Its tip is situated just above the articular disk, penetrating from distally to proximally, coming out just below the tear. In order to penetrate easily the TFCC, a probe may be used to make counterpressure from the inferior side. The whole thickness of the TFCC is pierced through and it can be verified how the tip of the SutureLasso appears between the inferior side of the disk and the ulnar head (Fig. 7.7)

The SutureLasso is loaded with a Fiber-Stick Suture® (Arthrex, Naples, FL, USA), which is a 2/0 Fiberwire suture with a more rigid end which facilitates its insertion in the passer. It is recovered with a Mini Suture Hook® (Naples, FL, USA) or a grasper through the 4/5 portal (Fig. 7.8).

Following this, the SutureLasso is withdrawn and, without removing it from the radiocarpal joint, it is reinserted a few millimeters from the first point and in the same distal and to proximal direction until it comes out below the TFCC. As the SutureLasso is still loaded with the Fiber-Stick, the suture is retrieved again through the 4/5 portal, and thus the horizontal mattress-type suture is complete (Fig. 7.9).

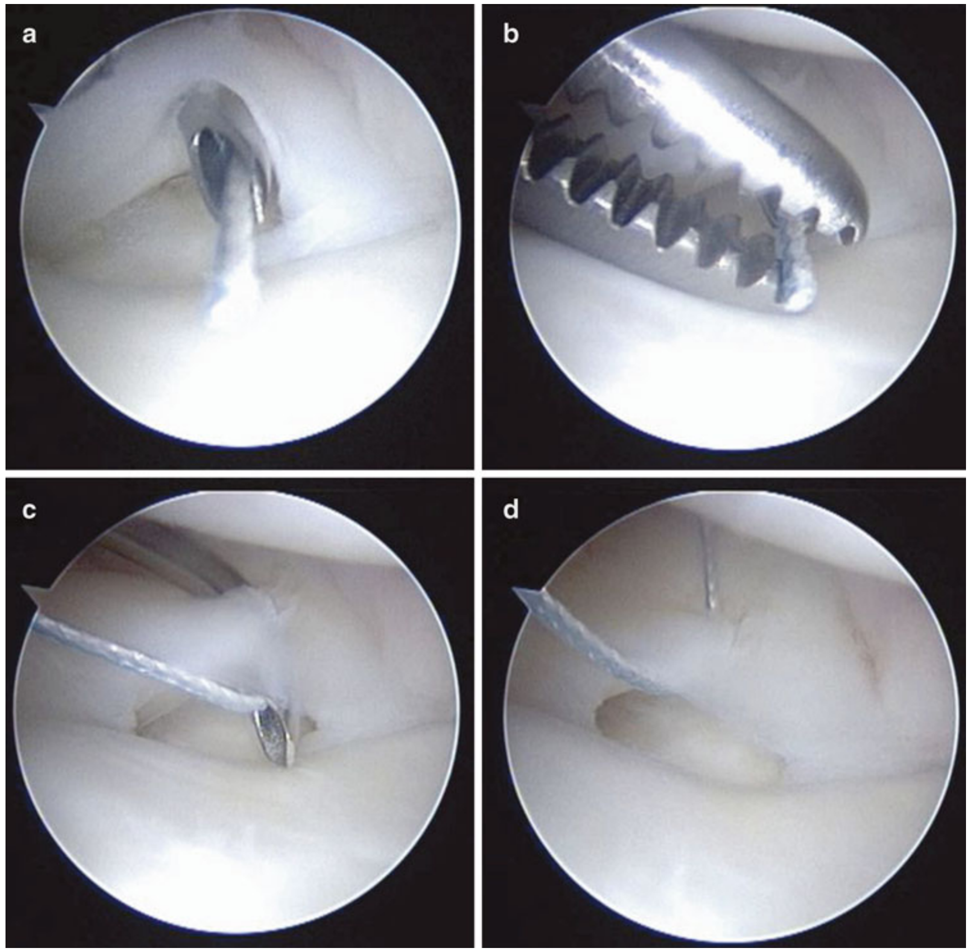
The SutureLasso is withdrawn and the slotted cannula together with the obturator of the TFCC instrument Kit® (Arthrex, Naples, FL, USA) is inserted through the 6R portal, The obturator is withdrawn from the cannula and the Mini Suture Hook is inserted to retrieve the two sutures from the 4/5 portal to the 6R portal (Fig. 7.10)

The threads are passed outside of the cannula through the slot in order that the drilling afterwards should not break them. The obturator is then inserted into the cannula and is placed at the desire point of reattachment in the sigmoid notch of the radius. Through the obturator the Guidewire of the Kit is inserted into the radius. At this point it is useful to check under fluoroscopy in order to ascertain that the position is correct. The obturator is removed and the Cannulated Drill bit from the TFCC Kit can be placed over the Guidewire and drilled until the positive stop of the drill meets the cannula (Fig. 7.11).

On retrieving the Cannulated Drill and the Guidewire it is of paramount importance that the surgeon should maintain the cannula in the same direction in order not to lose the location of the tunnel. In order to do this, it is useful for one surgeon to hold only the arthroscope and the cannula and for the other one to carry out the fixation with a 2.5 mm PushLock Anchor® (Arthrex, Naples, FL, USA). The PushLock tip is positioned in the predrilled hole, the suture tails can be tensioned by pulling on the suture and holding the PushLock anchor in place. The laser line of the PushLock should be advanced until flush with the bone, locking the anchor and suture in the predrilled hole (Fig. 7.12)

The sutures are cut and the tension is verified again (Fig. 7.13).

Fig. 7.8 (**a**) The SutureLasso is loaded with a Fiber-Stick suture (Arthrex, Naples, FL, USA). (**b**–**d**) It is retrieved to the 4/5 portal



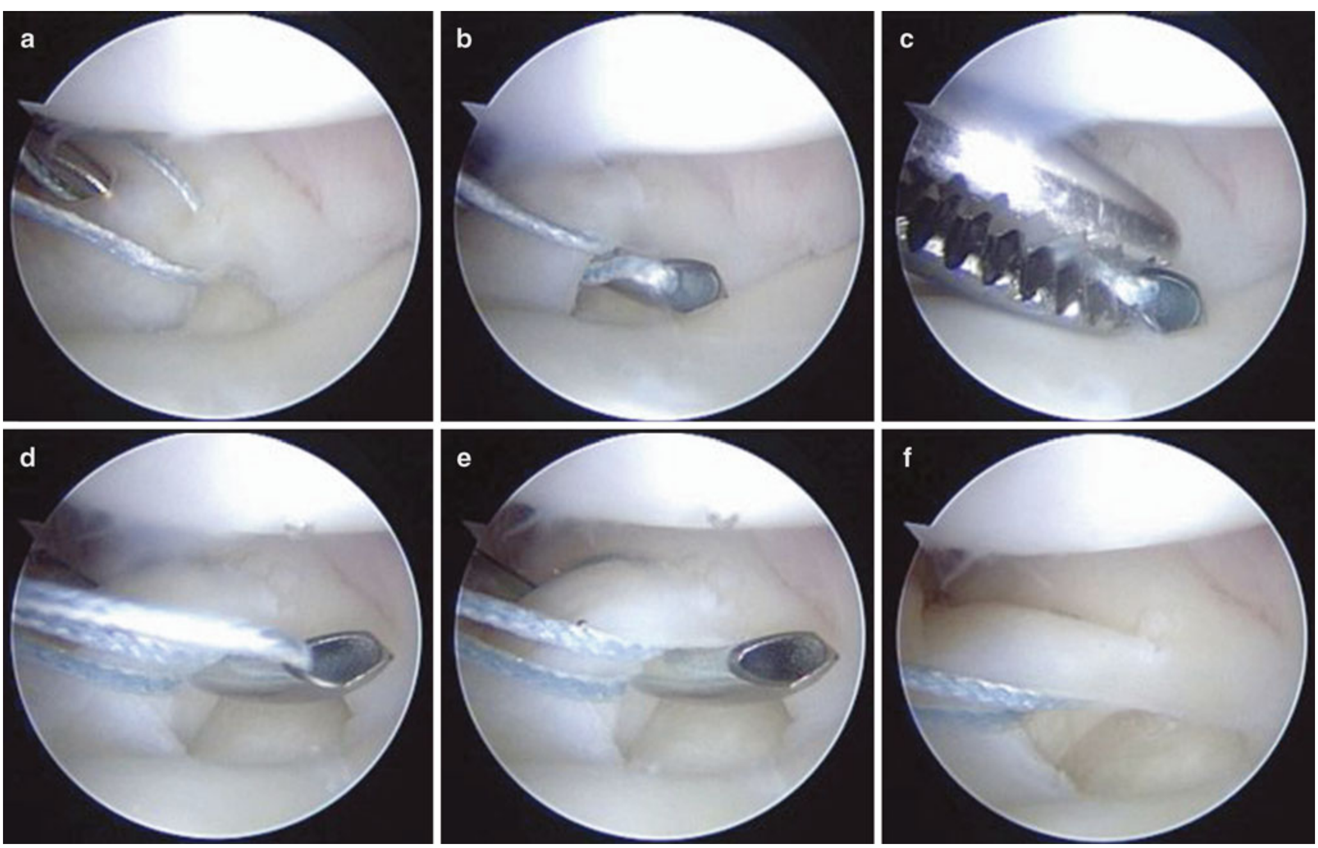


Fig. 7.9 (**a**) The SutureLasso is reinserted a few millimeters from the first point and in the same distal and to proximal direction. (**b**) It comes out again below the TFCC. (**c**–**e**) The Fiber-Stick suture is retrieved again to the 4/5 portal. (**f**) In this way, the horizontal mattress-type suture is complete, with the sutures coming out through the 4/5 portal

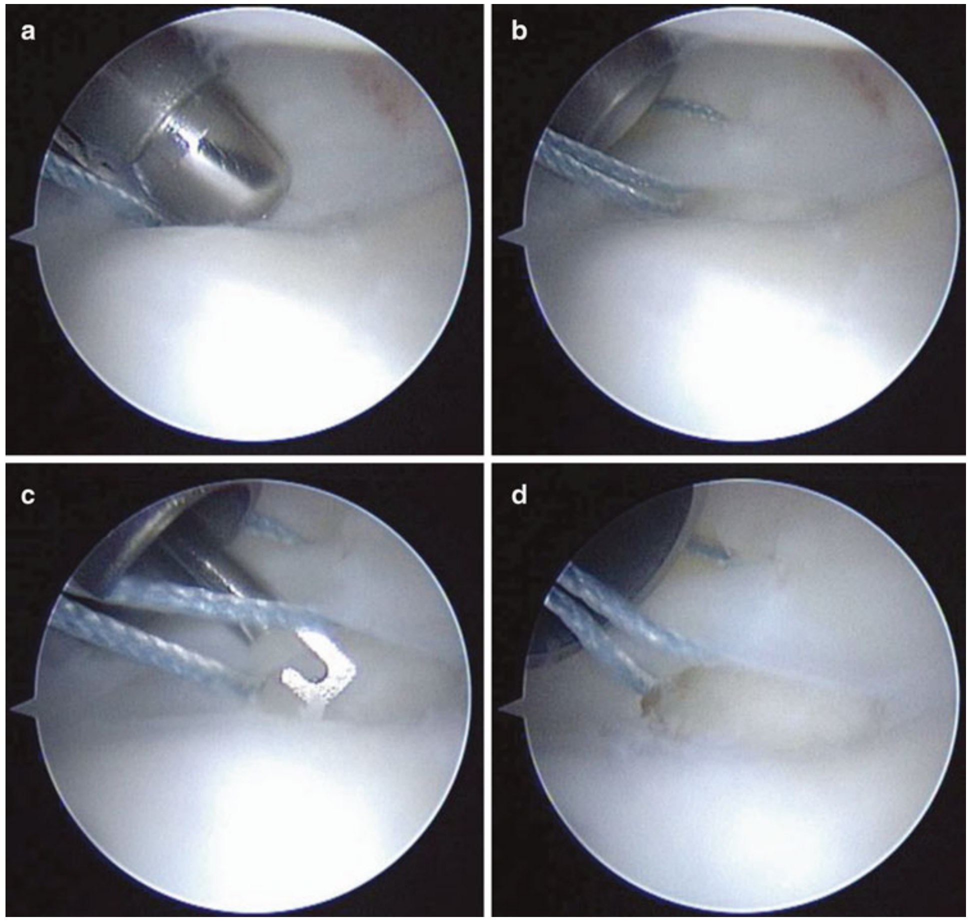


Fig. 7.10 (**a**) The slotted cannula together with the obturator of the TFCC instrument Kit (Arthrex, Naples, FL, USA) is inserted through the 6R portal. (**b**) The obturator is withdrawn from the cannula. (**c**) The Mini Suture Hook is inserted to recover the two sutures from the 4/5 portal to the 6R portal. (**d**) The two wires are retrieved from the cannula through the slot

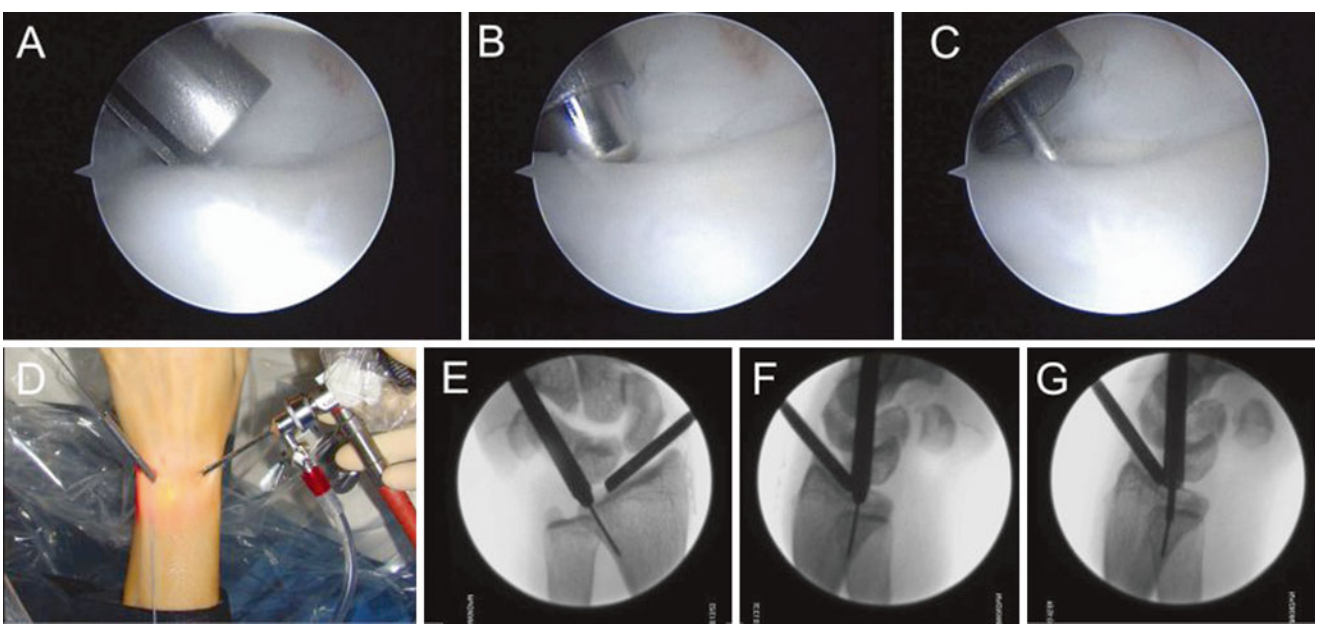


Fig. 7.11 (**a**–**d**) The Kirschner Guidewire is placed through the obturator and inserted into the radius. (**e**–**g**) Fluoroscopy control to check the correct position of the Guidewire and the drill

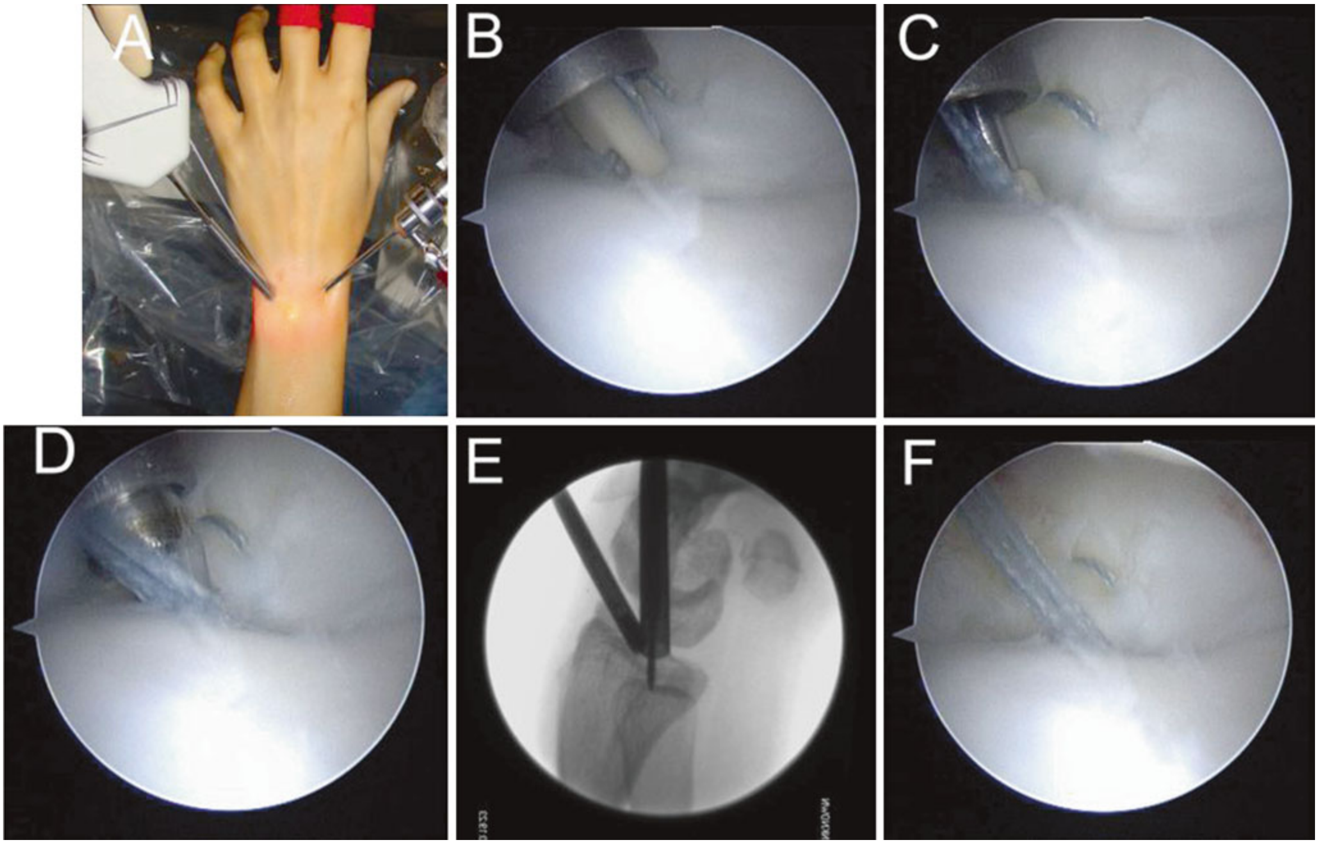


Fig. 7.12 (**a**) The 2.5 mm PushLock Anchor (Anthrex, Naples, FL, USA) and sutures are fed into the Slotted Cannula. (**b**–**d**) The 2.5 mm PushLock Anchor is introduced into the predrill hole in the sigmoid notch. (**e**) Flouroscopy control. (**f**) The radial peripheral tear is repaired back to bone, the suture tails can now be cut flush with the disk

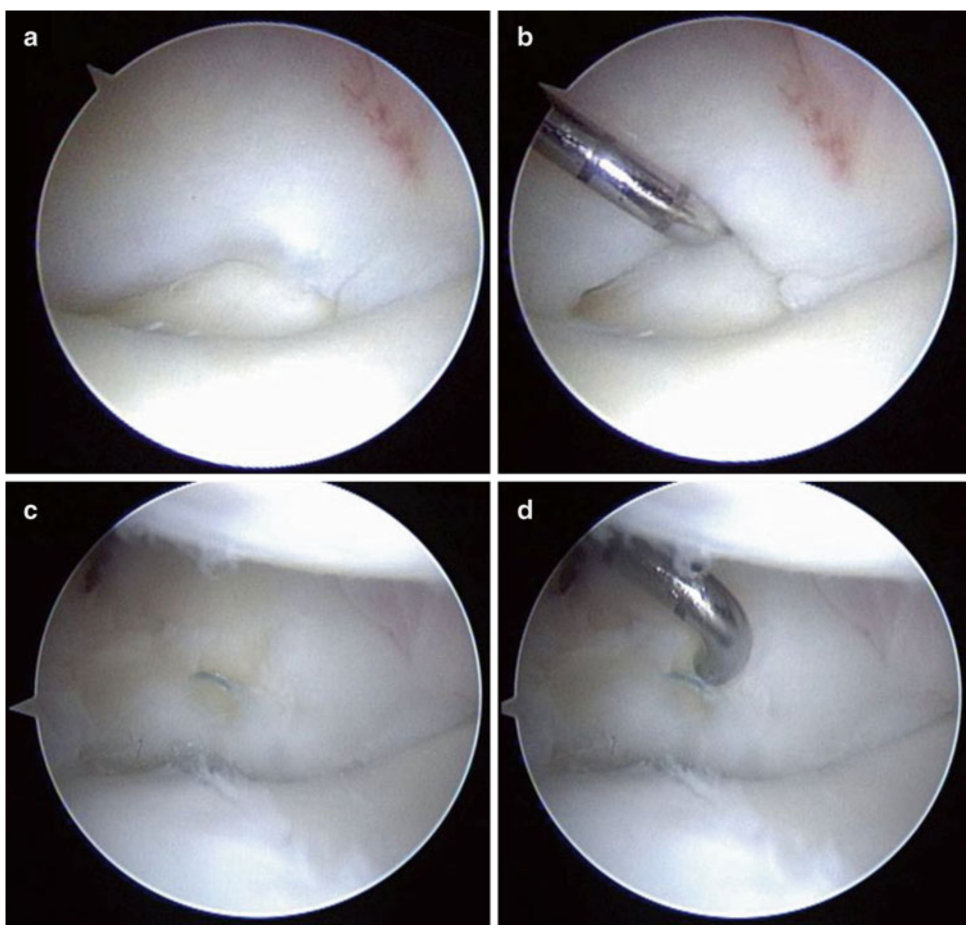


Fig. 7.13 (**a**, **b**) Initial aspect of the radial tear. (**c**, **d**) TFCC reattached to the sigmoid notch

Conclusion

Two factors have conditioned the fact that many surgeons advocate the debridement of the radial lesions of the TFCC. The first one is considering the radial side of the TFCC as an avascular zone and the second one is the fact that the arthroscopic fixation techniques were very complex.

Nowadays we know that the more dorsal and volar portion of the TFCC, that is to say, the radioulnar ligaments, are essential for maintaining adequate radioulnar stability. It is also known that these ligaments have an adequate blood supply, which allows its healing. For such motives its repair back to bone is indicated. We also know that the more central and avascular portion can heal if a correct cruentation of the radius is performed and forms an adequate bed for the reattaching. For these reason we advocate the reinsertion of radial lesions (including the central ones) always provided that a correct tension can be attained.

Advances in the development of surgical instruments have resulted in the technique for the reattaching of radial lesions presented in this chapter being simple to carry out through the 6R and 4/5 portals without the need of knots or bone tunnels through the radius.

References

1. Palmer AK. Triangular fibrocartilage complex lesions: a classification. J Hand Surg Am. 1989;14(4):594–606.
2. Chidgey LK, Dell PC, Bittar ES, Spanier SS. Histologic anatomy of the triangular fibrocartilage. J Hand Surg Am. 1991;16(6):1084–100.
3. Ishii S, Palmer AK, Werner FW, Short WH, Fortino MD. An anatomic study of the ligamentous structure of the triangular fibrocartilage complex. J Hand Surg Am. 1998;23(6):977–85.
4. Hagert E, Hagert CG. Understanding stability of the distal radioulnar joint through an understanding of its anatomy. Hand Clin. 2010;26(4):459–66.
5. Kleinman WB. Stability of the distal radioulna joint: biomechanics, pathophysiology, physical diagnosis, and restoration of function what we have learned in 25 years. J Hand Surg Am. 2007;32(7):1086–106.
6. Lewis OJ, Hamshere RJ, Bucknill TM. The anatomy of the wrist joint. J Anat. 1970;106(Pt 3):539–52.
7. Zancolli E, Cozzi EP. Atlas de anatomía quirúrgica de la mano: Médica Panamericana. 1993.
8. Haugstvedt JR, Berger RA, Berglund LJ, Neale PG, Sabick MB. An analysis of the constraint properties of the distal radioulnar ligament attachments to the ulna. J Hand Surg Am. 2002;27(1):61–7.
9. Bednar MS, Arnoczky SP, Weiland AJ. The microvasculature of the triangular fibrocartilage complex: its clinical significance. J Hand Surg Am. 1991;16(6):1101–5.
10. Thiru RG, Ferlic DC, Clayton ML, McClure DC. Arterial anatomy of the triangular fibrocartilage of the wrist and its surgical significance. J Hand Surg Am. 1986;11(2):258–63.
11. Cooney WP, Linscheid RL, Dobyns JH. Triangular fibrocartilage tears. J Hand Surg Am. 1994;19(1):143–54.
12. Tay SC, Tomita K, Berger RA. The "ulnar fovea sign" for defining ulnar wrist pain: an analysis of sensitivity and specificity. J Hand Surg Am. 2007;32(4):438–44.
13. Nakamura R, Horii E, Imaeda T, Nakao E, Kato H, Watanabe K. The ulnocarpal stress test in the diagnosis of ulnar-sided wrist pain. J Hand Surg Br. 1997;22(6):719–23.
14. Weiss AP, Akelman E, Lambiase R. Comparison of the findings of triple-injection cinearthrography of the wrist with those of arthroscopy. J Bone Joint Surg Am. 1996;78(3):348–56.
15. Anderson ML, Skinner JA, Felmlee JP, Berger RA, Amrami KK. Diagnostic comparison of 1.5 Tesla and 3.0 Tesla preoperative MRI of the wrist in patients with ulnar-sided wrist pain. J Hand Surg Am. 2008;33(7):1153–9.
16. Schweitzer ME, Brahme SK, Hodler J, Hanker GJ, Lynch TP, Flannigan BD, et al. Chronic wrist pain: spin-echo and short tau inversion recovery MR imaging and conventional and MR arthrography. Radiology. 1992;182(1):205–11.
17. Smith TO, Drew B, Toms AP, Jerosch-Herold C, Chojnowski AJ. Diagnostic accuracy of magnetic resonance imaging and magnetic resonance arthrography for triangular fibrocartilaginous complex injury: a systematic review and meta-analysis. J Bone Joint Surg Am. 2012;94(9):824–32.
18. Theumann N, Favarger N, Schnyder P, Meuli R. Wrist ligament injuries: value of post-arthrography computed tomography. Skeletal Radiol. 2001;30(2):88–93.
19. Moser T, Khoury V, Harris PG, Bureau NJ, Cardinal E, Dosch JC. MDCT arthrography or MR arthrography for imaging the wrist joint? Semin Musculoskelet Radiol. 2009;13(1):39–54.
20. Nakamura T. Radial side tear of the triangular fibrocartilage complex. Arthroscopic management of distal radius fractures. Berlin, Heidelberg: Springer-Verlag; 2010.
21. Roth JH, Poehling GG, Whipple TL. Arthroscopic surgery of the wrist. Instr Course Lect. 1988;37:183–94.
22. Osterman AL. Arthroscopic debridement of triangular fibrocartilage complex tears. Arthroscopy. 1990;6(2):120–4.
23. Adams BD. Partial excision of the triangular fibrocartilage complex articular disk: a biomechanical study. J Hand Surg Am. 1993;18(2):334–40.
24. Trumble T. Radial side (1D) tears. Hand Clin. 2011;27(3):243–54.
25. Trumble TE, Gilbert M, Vedder N. Isolated tears of the triangular fibrocartilage: management by early arthroscopic repair. J Hand Surg Am. 1997;22(1):57–65.
26. Sagerman SD, Short W. Arthroscopic repair of radial-sided triangular fibrocartilage complex tears. Arthroscopy. 1996;12(3):339–42.
27. Plancher KD, Faber KJ. Arthroscopic repair of radial-sided triangular fibrocartilage complex lesions. Tech Hand Up Extrem Surg. 1999;3(1):44–51.
28. Fellinger M, Peicha G, Seibert FJ, Grechenig W. Radial avulsion of the triangular fibrocartilage complex in acute wrist trauma: a new technique for arthroscopic repair. Arthroscopy. 1997;13(3):370–4.
29. Jantea CL, Baltzer A, Ruther W. Arthroscopic repair of radial-sided lesions of the triangular fibrocartilage complex. Hand Clin. 1995;11(1):31–6.
30. Geissler W. Repair of peripheral radial TFCC tears. Wrist arthroscopy. New York: Springer; 2005. p. xiv. 201 p.
31. Geissler WB. Arthroscopic knotless peripheral ulnar-sided TFCC repair. Hand Clin. 2011;27(3):273–9.
32. Corella F, Ocampos M, Del Cerro M. Are extensor tendons safe on your first wrist arthroscopy? J Hand Surg Eur. 2011;36(9):817–8.

Management of Ulnar Impaction

8

Megan Anne Meislin and Randy Bindra

Introduction

The ulnocarpal joint bears a fifth of the loads transmitted across the wrist. Ulnocarpal impaction or ulnar abutment is chronic overloading of the distal ulnar head against the triangular fibrocartilage and the proximal lunate and proximal triquetrum. The condition is usually associated with positive ulnar variance; this dynamic or static overloading leads to degeneration of the central aspect of the TFCC, chondromalacia of the proximal lunate, proximal triquetrum and distal ulnar head, perforation of the lunotriquetral ligament and ultimately ulnocarpal arthritis.

Pathogenesis

The triangular fibrocartilagenous complex (TFCC) consists of the articular disk, palmar radioulnar ligament, dorsal radioulnar ligament, extensor carpi ulnaris and its subsheath, ulnar capsule, ulnolunate and ulnotriquetral ligaments. Ulnar abutment is caused by increased loading through the TFCC creating a central perforation through the avascular articular disk that advances to degenerative changes to bony and ligamentous connections of the ulnocarpal joint. While ulnar abutment can occur in neutral and negative ulnar variance, it is more commonly attributed to wrists with positive ulnar variance. This may be a congenital anomaly or can result from injury or other pathologic processes that cause relative shortening of the radius. In patients with neutral variance, positive ulnar variance may be a dynamic phenomenon seen with forceful gripping. The increase in ulnar length facilitates a shift in load transfer through the wrist. Palmer showed that with neutral variance, the load across the wrist joint is born 82 % by the radius and 18 % by the ulna [1]. However, if the ulnar variance is increased by 2.5 mm, the ulnocarpal loading is increased by 42 % [1]. A cadaveric study showed 73 % of ulnar-positive wrists had TFCC perforations while only 17 % of ulnar negative had perforations [2]. In addition, ulnar positive wrists have been shown to have thinner articular disks creating less mitigation of ulnocarpal loading when compared to an ulnar neutral or negative wrist [3]. There is a strong association between age and degenerative tears with only 7 % seen by the third decade and 53 % by age 60 suggesting that relationship of the radius and ulna change with age [4].

Ulnar variance can be congenital or acquired. Isolated congenital positive ulnar variance from birth is frequently seen, however, it is important to get a detailed history so that clues of acquired positive ulnar variance can be identified. Previous injuries like distal radius fractures with malunion, radial shortening, Essex-Lopresti injury, an acute or chronic physeal injury to the radius and developmental conditions such as Madelung's deformity can cause positive ulnar variance [5]. Besides, shortening of the distal radius, change in dorsal tilt of the distal radius can also dramatically increase the ulnar loads from 20 % to as much as 65 % with dorsal tilt of 40° [6].

Ulnar variance is a dynamic phenomenon. As the axis of forearm rotation runs obliquely from the radial head to the ulnar fovea, there is a relative lengthening of the ulna as it rotates about the radius. Additionally loading the wrist by gripping can further narrow the ulnocarpal relationship.

Stages

Ulnar abutment is chronic overloading of the ulnocarpal joint that leads to a predictable pattern of degeneration of the ulnocarpal joint. Initially the central horizontal portion of the

M.A. Meislin, M.D.
Department of Orthopaedic Surgery, Loyola University Medical Center, 2160 South 1st Avenue, Maguire Bldg-Room 1700, Maywood, IL 60458, USA
e-mail: mmeislin@gmail.com

R. Bindra, M.D., FRCS (✉)
Department of Orthopaedic Surgery, Griffith University and Gold Coast University Hospital, Southport QLD 4215, AUSTRALIA
e-mail: randybindra@gmail.com

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*, DOI 10.1007/978-1-4614-1596-1_8, © Springer Science+Business Media New York 2015

I: Traumatic

A: central TFCC tear

II: Degenerative

A: TFCC wear

B: TFCC wear, lunate +/- ulnar head chondromalacia

C: TFCC perforation, lunate +/- ulnar head chondromalacia

D: TFCC perforation, lunate +/- ulnar head chondromalacia, lunotriquetral ligament perforation

E: TFCC perforation, lunate +/- ulnar head chondromalacia, lunotriquetral ligament perforation, ulnocarpal arthritis

Fig. 8.1 Palmer's classification of TFCC injuries based on arthroscopic findings

fibrocartilagenous disk, an avascular zone responsible for force transfer, starts to wear and demonstrates fibrillation. This wear causes increased stress on the ulnar head, lunate, and triquetrum resulting in chondromalacia of their opposing articular surfaces. Eventually the central disk will perforate causing the ulnar head and ulnar carpus to be exposed and able to directly articulate [7]. This leads to lunotriquetral ligament attenuation and rupture with eventual inevitable ulnocarpal arthritis [7].

In 1989, Palmer described a classification of TFCC injuries based on arthroscopic findings (Fig. 8.1). TFCC changes are broadly subdivided into two groups, traumatic (I) or degenerative (II). Degenerative perforations of the TFCC are subclassified by progressive involvement of the ulnocarpal joint. Type A is TFCC wear, type B has additional lunate and/or ulnar head chondromalacia. In type C lesions, the TFCC is perforated in the center. Type D lesions additionally demonstrate lunotriquetral ligament perforation with type E lesions signifying ulnocarpal arthritis [8].

Clinical Features

Clinical features vary with severity of the disease; the usual presenting symptom is chronic ulnar-sided wrist pain. The onset is usually insidious and progressive without any history of trauma. In early stages, pain is brought on or exacerbated with activity. Specifically, pain is exacerbated with movements that include power grip, ulnar deviation of the wrist and pronation and/or supination of the forearm. Some patients will complain of swelling over the ulnar side of the wrist and in advanced cases the pain is persistent and associated with decreased motion of the forearm and wrist.

Ulnar-sided tenderness to palpation can be elicited especially around the volar and dorsal aspects of the ulnar head, the lunate and triquetrum. A positive ulnar impaction test produces pain with passive full ulnar deviation of wrist. In order to differentiate ulnar impaction from other causes of ulnar-sided wrist pain it is necessary to provoke symptoms with physical maneuvers. Nakamura et al. described the ulnocarpal stress test in which the wrist is placed in maximal ulnar deviation, axially loaded and then the forearm is passively rotated through supination to pronation. If this causes pain then the test is positive [9]. Another test is the "press test" in which pain is reproduced by asking a seated patient to push off a chair using the affected wrist [10]. To test the lunatotriquetral ligament, the Regan shuck test or the Kleinman shear test should be performed [11].

Differential Diagnosis

It is important to differentiate ulnar abutment from other possible conditions. Pathology of the distal radioulnar joint such as arthritis or instability can be identified with pain on forearm rotation. Careful palpation and radiographic assessment is also needed to rule out other bony conditions such as pisotriquetral arthritis or hamate hook nonunions, soft tissue conditions like extensor carpi ulnar wrist tendonitis or subluxation, carpal ligamentous tears and traumatic TFCC tears also need to be taken into consideration. Lastly nerve pathology like neuritis of the dorsal cutaneous branch of the ulnar nerve must also be excluded.

Imaging

Standard posteroanterior (PA) and lateral radiographs of the wrist should be obtained. The shoulder should be abducted to 90°, the elbow flexed to 90° with the forearm pronated to obtain a neutral rotation wrist film. The PA of the wrist will show static positive ulnar variance if present. If standard films are negative, dynamic positive ulnar variance can be demonstrated with a pronated grip PA view of the wrist. A study of 22 patients with ulnar-sided wrist pain showed increase of ulnar variance of an average 2.5 mm with a pronated grip view [12]. In advanced cases, subchondral sclerosis and cystic changes are visualized within the ulnar side of the lunate, the triquetrum and the ulnar head. Radiographs must also be examined for widening of the lunotriquetral joint, carpal collapse and degenerative changes of the ulnocarpal or distal radioulnar joint.

Advanced imaging techniques may be helpful in some cases. Triple injection arthrogram is preferred over single injection to assess both the TFCC and lunatotriquetral ligaments. MR imaging with or without an arthrogram is beneficial for demonstrating integrity of the lunotriquetral ligament and TFCC. MR is particularly helpful in demonstration early stages of the disease with bony edema, cyst formation, and chondromalacia in the ulnocarpal joint [13].

Role of Arthroscopy

Arthroscopy allows confirmation of the diagnosis, staging of the disease, and the option to proceed with therapeutic procedures such as debridement or ulnar recession. Patients with a positive history, clinical exam and imaging that have failed nonoperative treatment of activity modification, NSAIDs, splinting and injection are candidates for intervention. Weiss et al. compared the effectiveness of triple injection arthrogram versus arthroscopy. They found that arthrography was 83 % specific, 56 % sensitive, and 60 % accurate when compared to arthroscopy [14]. Wrist arthroscopy has been shown to be more accurate in assessing the ligaments, articular surfaces and TFCC than arthrography [15].

Management of Ulnar Abutment

The goal of management is relief of symptoms and prevention of progression of ulnocarpal degeneration. Debridement of a degenerate TFCC will be helpful in the short term, but in the presence of uncorrected ulnocarpal loading is not likely to produce long-lasting relief [16]. Relieving the increased ulnar pressure is the essence of management and can be achieved by either shortening the ulna or recession of the distal articular surface of the ulna. The latter can be achieved arthroscopically. Debridement of the central portion of the TFCC and the resection of the distal ulna to subchondral bone can result in significant unloading of the ulnocarpal joint in a cadaver model [17].

Treatment of TFCC Wear and Perforation

In early stages of ulnar abutment, pathology is confined to the central avascular portion of the TFCC [18]. These lesions have no healing potential and should be treated with arthroscopic debridement rather than attempt to repair [19].

When debriding the TFCC, the defect should be enlarged until fresh borders of the tear are created. It is imperative to leave the dorsal and volar radioulnar ligaments intact. If not, this will alter the load bearing at the distal radioulnar joint and the stabilizing effect at the TFCC [20]. The precise mechanism of symptomatic relief achieved by enlarging the tear is not clear, and is likely by prevention of entrapment of flaps of the TFCC during impaction loading of the ulnocarpal joint.

Arthroscopic Technique

The 3-4 and 6-R arthroscopic portals are utilized for management of ulnocarpal impaction. The wrist is placed in traction with finger traps applied through the index and middle finger using an overhead boom or specialized traction device. The wrist joint is then insufflated with fluid. A routine diagnostic scope should be performed using the 3-4 portal with outflow through the 6R portal (Fig. 8.2). A probe is introduced by developing the 6R portal in order to probe the TFCC and determine the location and extent of the tear. It is not uncommon to encounter significant synovitis on the ulnar side of the joint requiring initial debridement with an arthroscopic shaver prior to examination with the probe. The articular surfaces of the lunate and triquetrum are examined carefully for any loose chondral flaps that should be debrided. The presence of a TFCC central tear with signs of chondromalacia of the lunate and possibly the ulnar head and triquetrum is classified as a Palmar IIC. If there is LTIL laxity with a TFCC tear this transitions the diagnosis to a Palmar IID or IIE.

Radial and ulnar midcarpal portals are then used to assess the stability of the lunotriquetral ligament. A shuck test should be used intraoperatively to test the lunatotriquetral laxity.

Once the disease has been staged, attention is turned to debridement of the ulnocarpal joint. Large flaps of the TFCC can be debrided with a curved punch and the edges of the tear are debrided and smoothened with a toothed powered resector inserted through the 6R portal.

Care is taken to leave the dorsal and palmar radioulnar ligament and the foveal attachment of the TFCC intact. Debridement of the central portion of the TFCC can provide temporary symptomatic relief but does not address the underlying problems of ulnocarpal abutment. Decompression of the ulnocarpal joint in the presence of ulnar positive variance is also of benefit in the management of acute traumatic TFCC tears (Palmer, type IA) as debridement alone in this scenario is associated with poorer results [21]. It is our recommendation that isolated debridement should be reserved for patients with Palmer IA tears without positive ulnar variance. It has been shown that TFCC defects, both acute and chronic that are addressed with debridement and arthroscopic wafer were satisfied with their outcome [16]. Also, Palmar reported a favorable results at 2-year follow-up with the arthroscopic wafer procedure performed in patients with Palmar IIC TFCC pathology [18].

The wafer procedure was first presented as an alternative to ulnar shortening osteotomy by Feldon in 1992 [22]. The main goal is to decrease loading across the ulnar side of the wrist. The wafer procedure is intended to resect the distal most part of ulnar head while still preserving the ulnar styloid and the attachments of the ulnocarpal ligaments and horizontal portion of the TFCC. The DRUJ is also left undisturbed by limiting the amount of resection to 2–4 mm [23]. It has been shown shortening ulnar head by 3 mm decreases the force transmitted across ulnar head by 50 %, however, more resection did little to decrease forces transmitted [17].

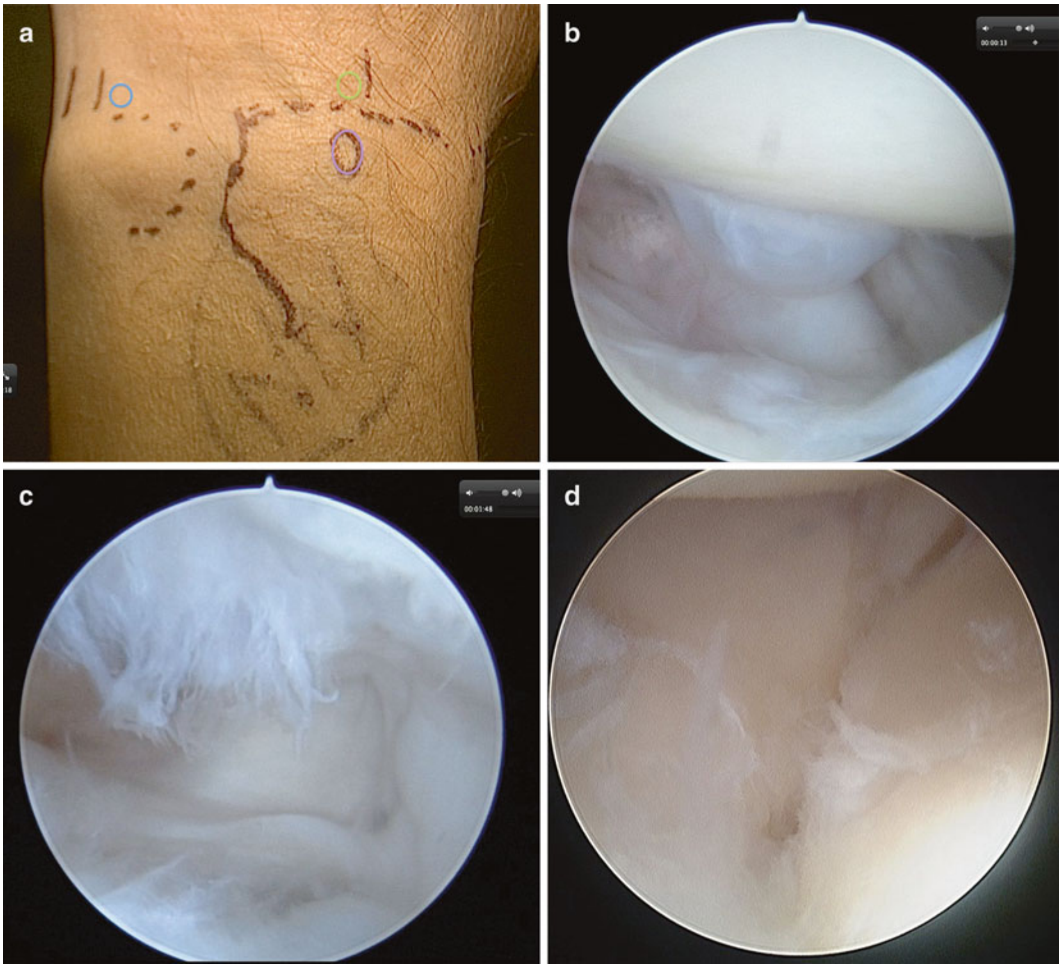


Fig. 8.2 Arthroscopic wafer procedure. (**a**) Portal placement for the wafer procedure mainly uses the 6R portal (*blue circle*) and 3/4 portal (*green oval*) with Listers tubercle denoted with a *purple oval*. (**b**) Once the scope has been introduced and a routine scope has been preformed, the radial side of the wrist will be normal without any signs of pathology pertaining to ulnar abutment. (**c**) The ulnar side of the radiocarpal joint shows a central tear and chondromalacia of the ulnar half of the lunate. (**d**) Midcarpal view shows lunotriquetral instability

In a retrospective comparative study, combined arthroscopic TFCC debridement and arthroscopic wafer procedure provided similar pain relief and restoration of function with fewer secondary procedures when compared with arthroscopic TFCC debridement and open ulnar shortening osteotomy [24]. Unlike ulnar shortening osteotomy, the wafer procedure bypasses complications such as delayed union or nonunion and late hardware problems that can occur with diaphyseal shortening of the ulna [24].

Ulnar Wafer

Arthroscopic wafer procedure involves appropriate resection of the dome of the ulnar head accessed through the central perforation in the TFCC (Fig. 8.3). Typically 2–3 mm of ulnar head removal is sufficient to remove the protuberance of the ulnar head through the TFCC tear. The initial debridement is performed using a 2.9 mm round burr that is gently seated into the distal ulna to its full depth to achieve a 3 mm shortening. A larger oval burr may then be introduced and carefully oscillated from side to side to evenly resect the distal ulna. By rotating the forearm, different parts of the distal ulna are brought into view through the central TFCC tear. In particularly sclerotic bone, a straight narrow osteotome may be introduced into the 6R portal to initiate bone resection. Upon completion, the scope is introduced into the 6R portal to confirm that there is no protruding bone spike. Intraoperative fluoroscopy is important to confirm that an appropriate amount of ulnar head has been removed evenly and that the distal radial articular surface of the distal ulna is not violated (Fig. 8.4).

Management of LT Instability

In patients with lunotriquetral instability (Palmer IID or IIE) debridement of the tear is performed. In cases with significant

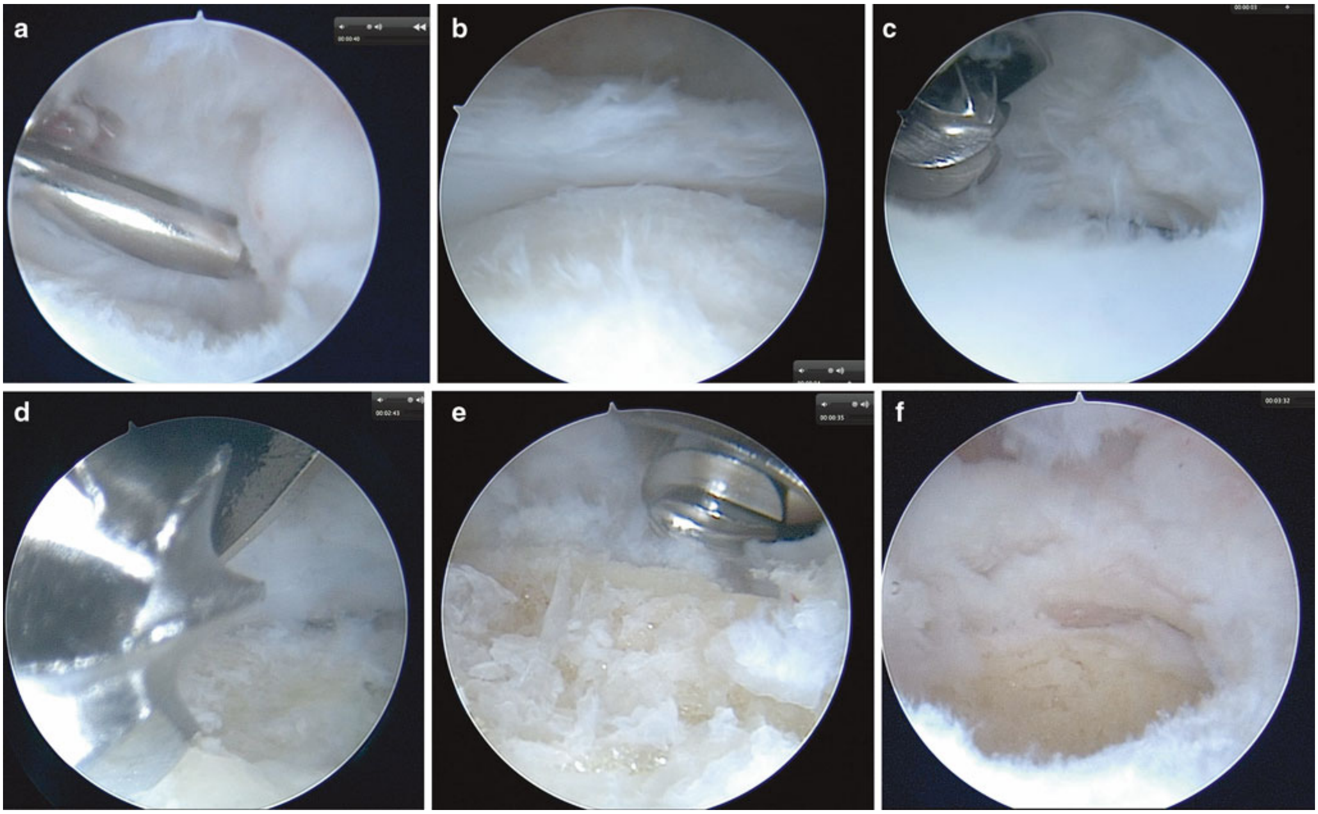


Fig. 8.3 Once finishing the diagnostic scope, (**a**) the shaver is introduced through the 6R portal to enlarge the central tear. (**b**) Debridement with the shaver allows appropriate visualization of the ulnar head. (**c**) The burr is then introduced through the 6R portal and the height of the burr is used to create the depth of resection of the ulnar head. (**d**) A more aggressive burr is then brought into the 6R portal to level off the resection to the depth of the burr and (**e**) is switched into the 3-4 portal to obtain an even resection. (**f**) After resection is completed, the forearm should be pronated and supinated to check for an even resection

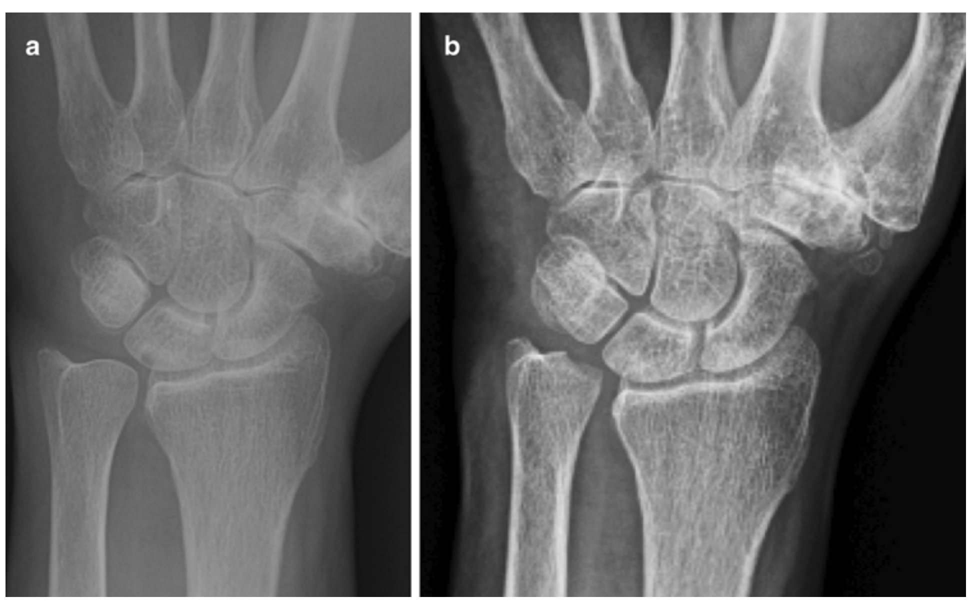


Fig. 8.4 PA x-rays of the wrist showing (**a**) ulnar positive variance with cystic changes of the lunate. (**b**) Shows the same wrist after undergoing the wafer procedure

LT instability additional stabilization may be necessary [21]. In the setting of LT instability, diaphyseal ulnar shortening osteotomy has been advocated because it tensions the extrinsic ulnocarpal ligaments, which help stabilize lunotriquetral joint [11, 23, 25]. In milder cases of attenuation and stretching of the LT ligament, thermal shrinkage may be effective [26]. A bipolar radiofrequency probe is applied to the entire are of the arthroscopically accessible portion of the LT intercarpal ligament, beginning at the distal end (dorsal and palmar parts) of the ligament and moving proximally to the membranous part. Changes in color and consistency of the ligament tissue are visually confirmed. The radiofrequency probe is applied intermittently for a few seconds at a time, and continuous irrigation is ensured throughout the entire procedure to prevent heat injury to articular cartilage and periarticular soft tissues. In cases with an LT step-off visualized from the midcarpal joint, supplemental pinning is performed. Two 1.2 mm K-wires are introduced into the lunate though an incision on the ulnar side of the wrist and then the triquetrum is reduced under vision by using of the wires as a joystick while the other is driven into the lunate. The K-wires are retained for about 6 weeks.

Postoperative Management

The wrist is immobilized in a splint immediately postoperatively. Early range of motion is encouraged within the first week after surgery. The patient uses a splint for comfort as needed. Strengthening is commenced by about 6 weeks when the patient has regained preoperative motion of the wrist.

Results

In a retrospective series 9 of 12 patients were very satisfied and 3 of 12 were satisfied after arthroscopic wafer resection. Only four patients reported minimal symptoms. Additionally, 11 of 12 patients returned to work by 8 weeks, with maximum benefit noted at a mean of 6.5 weeks [16]. Contrasting these authors, in a separate report of a large series of 42 patients, less encouraging results were reported with only 40 % of patients satisfied, 30 % were dissatisfied, and 30 % undecided [27].

Summary

The cornerstone of ulnar abutment syndrome is unloading the ulnocarpal joint by recession of the distal ulna. In the presence of a central perforation of the TFCC it is possible to perform the recession arthroscopically. Arthroscopic wafer resection allows quicker recovery and avoids the morbidity and complications of ulnar shortening. Wafer resection, however, is limited to cases where only a few millimeters of ulna shortening is needed. Additionally, in the presence of advanced LT instability, diaphyseal shortening of the ulna may be preferable.

References

1. Palmer AK, Werner FW. Biomechanics of the distal radioulnar joint. Clin Orthop Relat Res. 1984 (187):26–35.
2. Palmer AK, Werner FW, et al. The triangular fibrocartilage complex of the wrist-anatomy and function. J Hand Surg (Am). 1981;6:153–62.
3. Palmer AK, Glisson RR, et al. Relationship between ulnar variance and triangular fibrocartilage complex thickness. J Hand Surg (Am). 1984;9:681–2.
4. Mikic ZD. Age changes in the triangular fibrocartilage of the wrist joint. J Anat. 1978;126(Pt 2):367–84.
5. Tolat AR, Sanderson PL, et al. The gymnast's wrist: acquired positive ulnar variance following chronic epiphyseal injury. J Hand Surg (Br). 1992;17:678–81.
6. Palmer AK. Fractures of the distal radius. In: Green DP, editor. Operative hand surgery. 3rd ed. New York, NY: Churchill Livingstone; 1993. p. 861–928.
7. Bickel KD. Arthroscopic treatment of ulnar impaction syndrome. J Hand Surg (Am). 2008;33(8):1420–3.
8. Palmer AK. Triangular fibrocartilage complex lesions: a classification. J Hand Surg (Am). 1989;14(4):594–606.
9. Nakamura R, Horil E, Imaeda T, et al. The ulnocarpal stress test in the diagnosis of ulnar-sided wrist pain. J Hand Surg (Br). 1997;22(6):719–23.
10. Lester B, Halbrecht J, Levy IM, et al. "Press Test" for office diagnosis of triangular fibrocartilage complex tears of the wrist. Ann Plast Surg. 1995;35:41–5.
11. Sammer DM, Rizzo M. Ulnar impaction. Hand Clin. 2010;26:549–57.
12. Tomaino MM. The importance of the pronated grip x-ray view in evaluating ulnar variance. J Hand Surg (Am). 2000;25:352–7.
13. Imaeda T, Nakamura R, Shionoya K, et al. Ulnar impaction syndrome: MR imaging findings. Radiology. 1996;201(2):495–500.
14. Weiss A-PC, Akelman E, Lambiase R. Comparison of the findings of triple-injection cinearthrography of the wrist with those of arthroscopy. J Bone Joint Surg Am. 1996;78:348–56.
15. North ER, Meyer S. Wrist injuries: correlation of clinical and arthroscopic findings. J Hand Surg. 1990;15A:915–20.
16. Tomaino MM, Weiser RW. Combined arthroscopic TFCC debridement and wafer resection of the distal ulna in wrists with triangular fibrocartilage complex tears and positive ulnar variance. J Hand Surg (Am). 2001;26(6):1047–52.
17. Wnorowski DC, Palmer AK, Werner FW, et al. Anatomic and biomechanical analysis of the arthroscopic wafer procedure. Arthroscopy. 1992;8(2):204–12.
18. Palmar AK. Triangular fibrocartilage disorders: injury patterns and treatment. Arthroscopy. 1990;6:125–32.
19. Pomerance J. Arthroscopic debridement and/or ulnar shortening osteotomy for TFCC tears. J Hand Surg (Am). 2002;2(2):95–101.
20. Palmer AK, Werner FW, Glisson RR, et al. Partial excision of the triangular fibrocartilage complex: an experimental study. J Hand Surg (Am). 1988;13A:391–4.

21. Minami A. Clinical results of treatment of triangular fibrocartilage complex tears by arthroscopic debridement. J Hand Surg (Am). 1996;21(3):406–11.
22. Feldon P, Terrono AL, Belsky MR. Wafer distal ulna resection for triangular fibrocartilage tears and/or ulna impaction syndrome. J Hand Surg (Am). 1992;17:731–7.
23. Deitch MA, Stern SJ. Ulnocarpal abutment: treatment options. Hand Clin. 1998;14(2):251–63.
24. Bernstein MA, Nagel DJ, Martinez A, et al. A comparison of combined arthroscopic triangular fibrocartilage complex debridement and arthroscopic wafer distal ulna resection versus arthroscopic triangular fibrocartilage complex debridement and ulnar shortening osteotomy for ulnocarpal abutment syndrome. Arthroscopy. 2004; 20(4):392–401.
25. Nagel DJ. Arthroscopic treatment of degenerative tears of the triangular fibrocartilage. Hand Clin. 1994;10:615–24.
26. Lee J, Nha KW, Lee GY, et al. Long-term outcomes of arthroscopic debridement and thermal shrinkage for isolated partial intercarpal ligament tears. Orthopedics. 2012;35(8):1204–9.
27. DeSmet L, DeFerm A, Steenwerckx A, et al. Arthroscopic treatment of triangular fibrocartilage complex lesions of the wrist. Acta Orthop Belg. 1996;62:8–13.

Kinematics and Pathophysiology of Carpal Instability

9

Alan E. Freeland and William B. Geissler

Introduction

Although the wrist is commonly thought to move in flexion and extension in the anatomic sagittal plane and radial and ulnar deviation in the anatomic frontal (coronal) plane, it is actually a universal joint that is capable of multidirectional or global motion. Although full wrist motion may allow peak performance, most important daily functions are performed in the midrange and along the coupled dart thrower's "out-of-plane" pathway [1–9]. The dart thrower's motion (DTM) takes place primarily at the midcarpal joint, and follows a plane or corridor 30°–45° obliquely to the anatomic sagittal and coronal planes, extending from approximately 60° of wrist extension and 20° of radial deviation, through the neutral zone, to 60° of wrist flexion and 40° of ulnar deviation and back. The radioscaphocapitate ligament (RSCL), long radiolunate (LRLL), short radiolunate (SRLL), and dorsal radiolunotriquetral ligament (DRLTL) are aligned parallel, or nearly parallel, to the dart thrower's pathway.

Motion at the radiocarpal joint (RCJ) is the primary source of global wrist flexion, whereas motion at the midcarpal joint (MCJ) is the primary source of wrist extension [2–9]. The proximal carpal row (PCR) does not function as a single unit during normal global wrist motion. The scaphoid, lunate, and triquetrum each have a unique arc of motion. Scapholunate motion approaches zero during the DTM. The primary motion of the scaphoid and lunate is in the flexion-extension arc regardless of the direction of wrist motion. The scaphoid and lunate flex and the capitate extends during radial deviation. The scaphoid and lunate extend and the capitate flexes during ulnar deviation.

The wrist is comprised of eight carpal bones, seven of which act synchronously and synergistically within the confines of the wrist to allow normal wrist motion. The scaphoid, lunate, triquetrum, trapezium, trapezoid, capitate, and hamate are guided and constrained by a complex system of viscoelastic intrinsic and extrinsic ligaments. A total of 24 muscles cross or insert on the carpal bones, move the wrist and hand, and assist in providing wrist stability. No tendons insert into the bones of the intercalated PCR. The pisiform articulates with the palmar surface of the triquetrum, but acts primarily as a fulcrum to enhance flexor carpi ulnaris strength and power during wrist flexion and ulnar deviation, especially during the DTM, rather than to intrinsically influence wrist kinematics or stability.

Historical Perspective

Early investigations applied planar concepts that attempted to correlate carpal structure and function. Johnston reported in 1907 that carpal motion was initiated at the midcarpal joint and occurred largely between the carpal rows [10]. In 1943, Guilford et al. promoted the row concept of wrist motion, envisioning three "links" (rows): the distal radius, the PCR, and the distal carpal row (DCR). He described the scaphoid as a rod "linking" the carpal rows" [11]. In 1972, Linscheid et al. refined the "link" concept of carpal motion to propose the "slider crank" analogy, in which the scaphoid acts as a mobile bridge between the two carpal rows, much as the slider crank controls motion between a piston and drive shaft [12] (Fig. 9.1). In 1977, Sarrafian et al. noted that radiocarpal motion comprised 40 % and midcarpal motion 60 % of maximum wrist flexion, while motion was 66.5 % radiocarpal and 33.5 % midcarpal during maximum extension [13]. These researchers theorized that the scaphoid functioned with the PCR during flexion and with the distal carpal row (DCR) during extension.

Electronic supplementary material: Supplementary material is available in the online version of this chapter at 10.1007/978-1-4614-1596-1_9. Videos can also be accessed at http://www.springerimages.com/videos/978-1-4614-1595-4.

W.B. Geissler M.D. • A.E. Freeland, M.D. (✉)
Department of Orthopaedic Surgery and Rehabilitation, University of Mississippi Medical Center, 303 Swallow Drive, Brandon, MS 39047-6454, USA
e-mail: aejf11@bellsouth.net; 3doghill@msn.com

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*, DOI 10.1007/978-1-4614-1596-1_9, © Springer Science+Business Media New York 2015

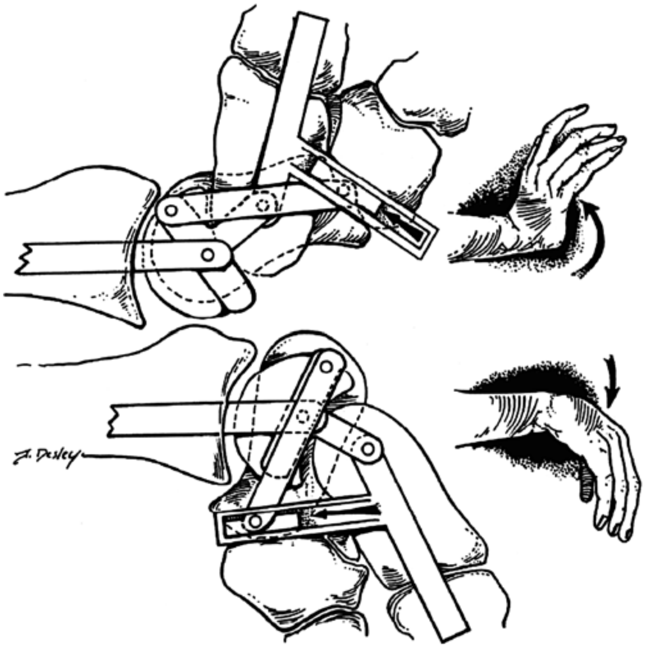


Fig. 9.1 The "slider crank" concept of wrist flexion and extension [Reprinted from Linscheid RL, Dobyns JH, Beabout JW, Bryan RS: Traumatic instability of the wrist *J Bone Joint Surg*. 1972; 54(8): 1612–1632 with permission of the *Journal of Bone and Joint Surgery*]

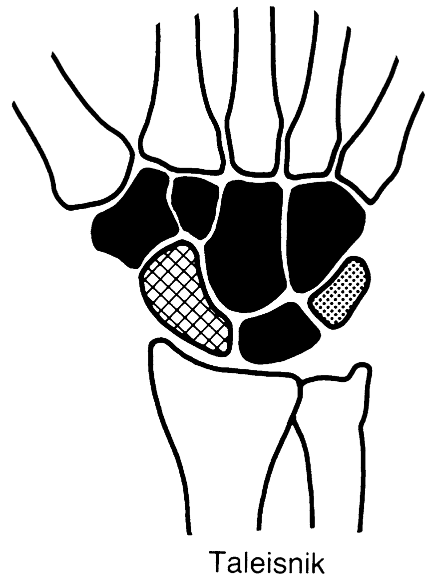


Fig. 9.2 Taleisnik's columnar concept

Although most investigators had long believed that the center of rotation (COR) of the wrist was confined solely within the head of the capitate, Wright reported in 1935 that the COR of the wrist joint resided in the head of the capitate during wrist flexion and shifted to the intercarpal joint during extension [14]. The distal carpal row DCR rotates about a fixed axis within the head of the capitate throughout radioulnar deviation [15, 16]. The distance between the base of the third metacarpal and the distal radial articular surface (carpal height index (CHT)—normal C/MC=0.56) on a neutrally positioned anteroposterior image is constant throughout radio ulnar motion.

CHI can be used to measure carpal collapse [15, 16]. The perpendicular distance from the distally projected longitudinal axis of the ulna to the axis of rotation for radioulnar deviation on a neutrally positioned anteroposterior image is used to measure carpal translation. Three-dimensional analysis of the instantaneous screw axes (ISA) calibrated for the position of the third metacarpal base with respect to the distal radius revealed that the COR of wrist motion is not fixed or limited to the capitate during global motion [3]. ISA data also demonstrated that translational motion in the normal wrist may account for the difference between this study and previous reports.

In 1921, Navarro conceptualized a columnar wrist model to better explain the sophisticated and multidirectional movements of the wrist [17]. He theorized that three interdependent columns best correlated carpal anatomy with function. The lateral column (scaphoid, trapezium, and trapezoid) supported the thumb and transferred load between the other two carpal columns. The central column (lunate, capitate, and hamate) flexed and extended the wrist. Rotation was controlled by the medial column (triquetrum and pisiform). In 1978, Taleisnik modified the column theory to exclude the pisiform, recognizing that it played no integral role in intercarpal motion [18]. He also determined that the bones of the normal DCR are securely fixed together by stout ligaments, have very little intercarpal motion, and act as a unit. He therefore included the trapezium and trapezoid, along with the capitate, hamate, and lunate, as parts of the central column. The DCR is also rigidly secured to the bases of the second and third metacarpals and, consequently, moves with the hand (Fig. 9.2). Weber took a slightly different view of the columnar theory [19]. He divided the carpus into two columns; the load-bearing radial column composed of the scaphoid, lunate, trapezium, trapezoid, and capitate and the ulnar control column, consisting of the triquetrum and hamate. He viewed the helicoid triquetrohamate joint as the key to wrist position during rotation and load changes.

Lichtman et al. formulated the next step toward a better understanding of three-dimensional wrist motion with their "oval-ring" theory [20] (Fig. 9.3). Their theory perceived the wrist as four interdependent segments: the DCR, scaphoid, lunate, and triquetrum. Ligamentous links connect each segment to its two adjacent elements. The scaphotrapezial (radial link) and triquetrohamate (ulnar link) joints form two reciprocal physiologic links. Radial deviation creates an unbalanced flexion moment at the radial link inducing proximal row flexion and palmar capitate and hamate subluxation (physiologic VISI). An unbalanced extension moment at the

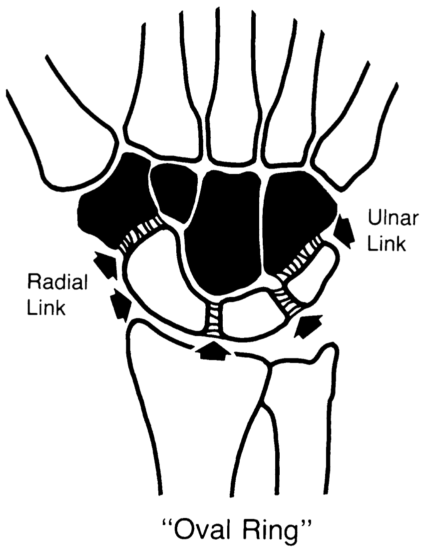


Fig. 9.3 Lichtman's oval ring [Redrawn from Lichtman DM, Schneider R, Swafford AR, Mack GR. Ulnar midcarpal instability: Clinical and laboratory analysis. *J Hand Surg* 1981; 6(5): p. 515–523. With permission from Elsevier]

ulnar link causes the triquetrum to extend against the hamate with the PCR following and the capitate and hamate transitioning dorsally (physiologic DISI). Continuity of the ligaments assures synchronous synergistic carpal motion within the moving wrist. Disruption of any link(s) results in dysfunction. Craigen and Stanley pointed out that certain elements of both the column and row theories, although sometimes contradictory, are useful in our understanding of multidimensional wrist motion [21].

During wrist flexion-extension, the motion of the capitate closely follows that of the third metacarpal, while the lunate motion is approximately 50 % of the total motion, the triquetrum 65 %, and the scaphoid 90 % [2, 22]. Similar differences in motion for these carpal bones occur during radioulnar deviation, circumduction, and the DTM. This suggests that the scaphoid, lunate, and triquetrum do not normally function as a single unit, but that each bone has a unique arc of motion during global wrist motion. This three-dimensional study of carpal rotational behavior supported a row concept of wrist motion as opposed to a carpal column model [2, 22].

Perhaps, at this point in time, we can conclude that the forearm, wrist, hand, and articular contact position at the moment of impact; point of impact; columns; rows; individual carpal bones; amount, direction, and rate of the applied and resistance forces; individual bone and articular cartilage morphology and containment; and viscoelastic ligament properties and relative strengths, especially in the PCR, interact to provide various multiplanar global wrist motions and play a role in injury susceptibility. Each of these parameters allows some measure of integral static and continuous dynamic quantification for biometric analysis, comparisons, communication, and management of these injuries as we unravel the comprehensive three-dimensional geometrics of normal and abnormal carpal motion with and without loading.

Normal Carpal Kinematics

The PCR is intercalated between the radius and ulna proximally and the DCR distally [23]. The scaphoid pivots over the radioscaphocapitate ligamentous fulcrum at its waist. The distal pole of scaphoid flexes as the trapezium and radial styloid close over it during wrist flexion and/or radial deviation. The scaphoid extends as the distance between the trapezium and radial styloid widens during wrist extension and/or ulnar deviation. The scaphoid and lunate flex and pronate during wrist flexion and/or radial deviation, while extending and supinating during wrist extension and/or ulnar deviation. Scaphoid flexion, extension, and rotation exceed that of the lunate [2, 22]. During full wrist flexion in the sagittal anatomic plane, the scaphoid flexes 35° more than the lunate and pronates three times as much. Lunate radioulnar and dorsopalmar translation in its radial fossa is minimal, but exceeds that of the scaphoid. The distal pole of the scaphoid has relatively more motion than has the proximal dorsal pole. The scaphoid moves somewhat as a rotating triplanar pendulum [2, 22]. The palmar SLIL fibers lengthen and the dorsal fibers shorten with wrist flexion [24]. The opposite occurs with wrist extension.

Radial and ulnar deviation primarily occurs in the midcarpal joint. Midcarpal motion accounts for 60 % of radial deviation and 86 % of ulnar deviation [25]. The radiocarpal and scapholunate joints remain relatively stable. In radial deviation the PCR flexes and the capitate moves slightly radiodorsally relative to the lunate. The scaphoid flexes and radially deviates. In ulnar deviation, the PCR extends and the capitate moves slightly ulnopalmarly on the lunate. Midcarpal motion relative to the capitate rotates in a plane from dorsoradial to ulnopalmar, similar to the DTM [2–9, 25, 26].

The PCR translocates radiopalmarly and rotates dorsally during ulnar deviation as the triquetrum pronates and shifts palmarly, distally, and ulnarly on the hamate's helicoid articular slope [16, 19]. The midcarpal joint slightly flexes. Conversely, the PCR translocates dorsoulnarly and rotates palmarly during radial deviation as the triquetrum supinates and shifts dorsally, proximally, and radially. The lunate geometry accommodates the rotational shifts within the PCR, maintaining a constant carpal height throughout radioulnar wrist motion in the frontal plane [15, 16]. The scaphotrapeziotrapezoidal ligament complex (STTL) and the lateral portion of the RSCL support the distal scaphoid throughout extension and ulnar deviation.

The SLIL has three anatomic regions [27, 28]. The dorsal SLIL (dSLIL) is thick and composed of short, transversely oriented collagen fibers. The palmar SLIL (pSLIL) is thin and contains obliquely oriented collagen fascicles. The proximal mid-region of the SLIL (mSLIL) is composed of fibrocartilage, with a few superficial, longitudinally oriented collagen fibers and extends distally into the scapholunate joint (SLJ) space, resembling a meniscus. The mesenteric-like radioscapholunate ligament (RSLL) separates the mSLIL and pSLIL, and spreads distally over the proximal scaphoid, SLIL, and lunate. The RSLL encloses small caliber neurovascular elements to and from the scaphoid, lunate, and SLIL. The yield strength of the dSLIL component is 260 ± 118 N, the mSLIL 63 ± 32 N, and the pSLIL 118 ± 21 N. The RSLL provides little, if any, structural support and depends upon its elasticity and neighboring structures for protection.

There is no dorsal radioscaphoid ligament (DRSL) [29–31]. Such a ligament would require an elastic coefficient three times its resting length. This prerequisite exceeds the inherent physical capacity of ligaments. The dorsal radiolunotriquetral (DRLTL) and dorsal intercarpal (DICL) ligaments form a V-shaped configuration on the dorsum of the wrist with its converging apex on the ulnar side. The DRLTL originates from the dorsal lip of the distal radius, passes over the proximal pole of the scaphoid, extends obliquely, attaching to the distal dorsal ulnar lunate, dorsal ulnar lunate ligament (DULL), and dorsal LTIL, and inserts onto the dorsal tubercle of the triquetrum. The DRLTL lends support to the midcarpal joint and passively pronates the attached carpus during forearm pronation. The DICL has a thick proximal and a thinner distal transverse band. The DICL originates from the dorsal triquetrum and hamate, extends radially, attaches to the dorsal lip of the lunate, and inserts its thickest attachment into the dorsal groove of the scaphoid where its anterior fibers blend imperceptibly with the strong dorsal fibers of the dSLIL before fanning onto the dorsal trapezium and proximal trapezoid.

The DVL substitutes for some of the function that a DRSL might provide throughout normal carpal kinematics by maintaining an indirect stabilizing effect on the proximal pole of the scaphoid by threefold narrowing and widening of the distance between the DRLTL origin and the scaphoid insertion of the DICL during maximum wrist extension and flexion, respectively. The STTL, RSCL, DRLTL, and the DICL individually and conjointly are secondary stabilizers of the scapholunate joint (SLJ) [29–32].

The normal relationship of the scaphoid, lunate, and their related ligaments is illustrated in Fig. 9.4. The normal SLIL has an inverted V appearance with the apex of the V distally ("Tushy sign"), as visualized from the radiocarpal (3-4) arthroscopic portal. From the radial midcarpal portal, the normal SLJ is congruently aligned and immobile (Fig. 9.5).

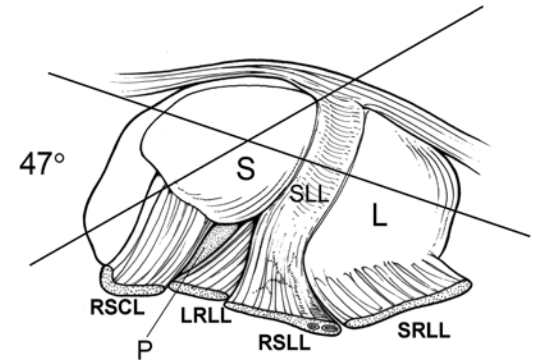


Fig. 9.4 Normal scapholunate alignment. *S* scaphoid, *SLL* scapholunate ligament, *L* lunate, *RSCL* radioscaphocapitate ligament, *P* interligamentous sulcus leading to the space of Poirier, *LRLL* long radiolunate ligament, *RSLL* radioscapholunate ligament, *SRLL* short radiolunate ligament

The scaphoid is flexed approximately 47° relative to the third metacarpal-capitate-lunate-radial longitudinal axis in the lateral X-ray view. The SLJ space is stable, congruent, and does not exceed 2 mm on the AP X-ray.

The triquetrum is the fulcrum for wrist rotation and motion in the radioulnar plane. The helicoid geometry of the triquetrohamate joint is instrumental in accommodating this screw-like movement [20]. The tensile strengths of dLTIL and pLTIL are the obverse or reciprocal of the dSLIL and pSLIL. The dLTIL yield strength 121 ± 42 N, the mLTIL 64 ± 14 N, and the pLTIL (pLTIL) 301 ± 36 N [33]. Although the pLTIL is stronger than the dLTIL, it is less flexible.

Classification of Carpal Instabilities

Although there is probably no single uncontested, comprehensive, or perfect classification for carpal instabilities, several parameters allow some measure of quantification that is useful for analysis, comparison, communication, and management of these injuries [34]. These parameters include chronicity, constancy, etiology, location, direction, and pattern.

Chronicity

Classification by chronicity relates to the time interval between injury and diagnosis. This categorization is based upon the capacity for carpal reduction and, especially, upon the intrinsic capability for ligament healing after treatment. Acute carpal instabilities are those diagnosed and treated within 1 week of injury. These instabilities are reducible and have the highest potential for ligament healing. Subacute tears are those diagnosed and treated between 1 and 6 weeks after injury. Although they are reducible, the capacity for primary ligament healing is diminished. Injuries seen after

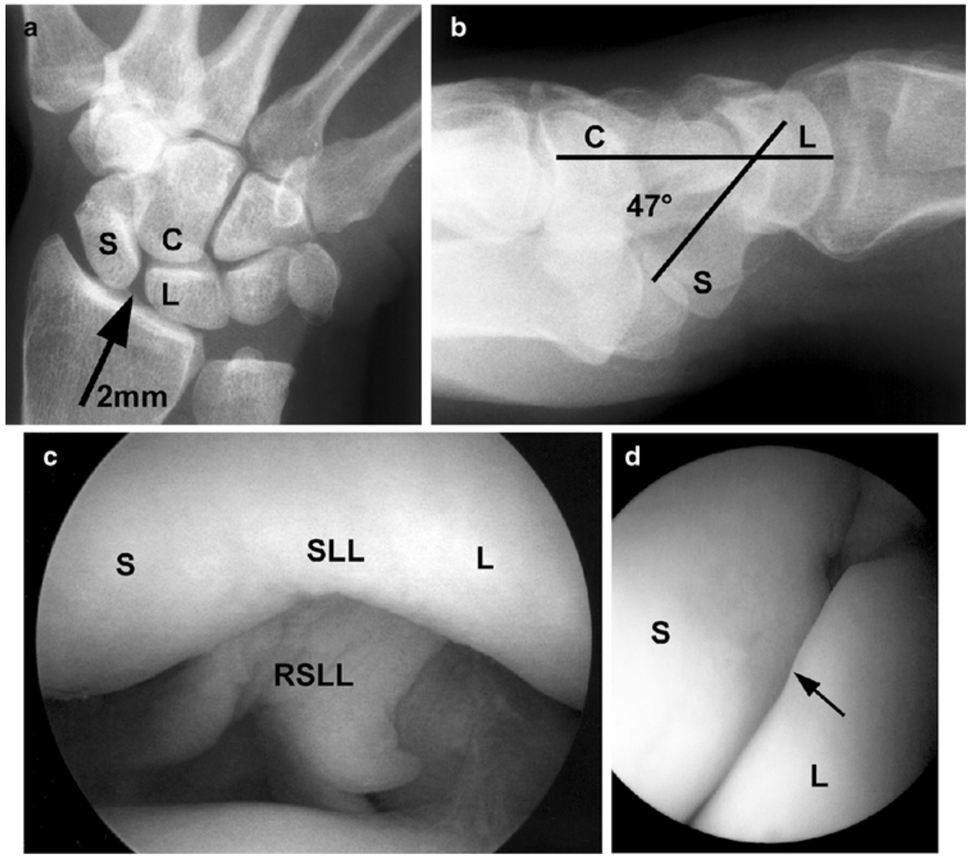


Fig. 9.5 Normal scapholunate alignment. (**a**) Normal AP X-ray (*arrow* points to the scapholunate joint). (**b**) Normal lateral X-ray and scapholunate angle. (**c**) Radiocarpal (3-4 portal) arthroscopic image demonstrating a normal SLL and RSLL. (**d**) Midcarpal arthroscopic view with normal scapholunate alignment

longer than 6 weeks from the time of injury are considered chronic, have little capacity for ligament healing, and may occasionally be irreducible.

Constancy

Carpal instability and symptoms may be apparent immediately in some cases; in others, they may take an initially indeterminate amount of time to appear as the carpi settle or the tear(s) extend. Ligaments that tear beyond the axis connecting the centers of rotation of two bones often have carpal malalignment that may be seen on standard wrist X-rays with the wrist at rest. This type of carpal collapse is termed static carpal instability. This category may be further divided into reducible and irreducible injuries.

Patients with lesser ligament injuries often have normal standard X-rays, yet carpal malalignment and symptoms occur during motion and loading. This type of carpal collapse is termed dynamic carpal instability. The diagnosis of dynamic instability may require stress X-rays, such as an anteroposterior (AP) distraction X-ray with digital traction, manual stress X-rays, a six-view AP (radial deviation, neutral, and ulnar deviation), and lateral (extension, neutral, and flexion) X-ray with a tightly gripped fist; fluoroscopic cineradiography; enhanced gap-free MRI; and/or arthroscopic evaluation. Attenuation and partial ligament tears may propagate over a period of time and use. Carpal collapse, correlative symptoms, and classification may advance accordingly.

Etiology

Trauma and synovitis are the principal causes of carpal ligament disruption. The former is more common. The healing capacity of traumatic ligament injuries is limited and unreliable, owing to a disrupted and/or meager blood supply and technical difficulties in achieving successful repair by suturing. Synovitis erodes ligaments and renders them irreparable.

Location

Location refers to the specific ligament(s) injured, fracture(s), and carpal bones and joints involved.

Direction

Direction is primarily determined by evaluating a true lateral X-ray in the sagittal plane with the resting wrist in a neutral position. The axial and tangential methods of radiographic

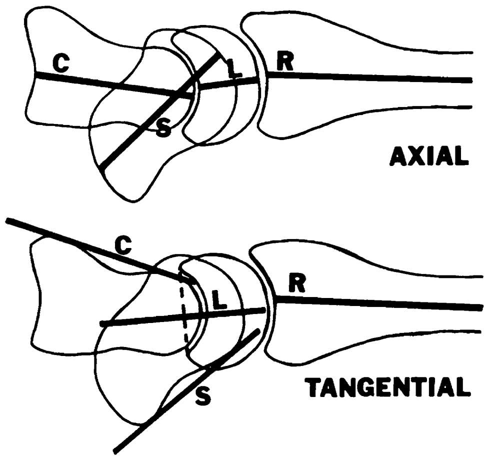


Fig. 9.6 Axial (*above*) and tangential (*below*) methods of measuring carpal angles. *C* capitate, *S* scaphoid, *L* lunate, *R* radius [Reprinted from, Garcia-Elias M, An KN, Amadio PC, et al.: Reliability of carpal angel determinations. *J Hand Surg* 1989; 14(6): 1017–1021. With permission from Elsevier]

measurement are equally accurate in assessing carpal angles [35–37] (Fig. 9.6). The scaphoid tubercle and pisiform must be maximally superimposed to assure a true lateral (sagittal plane) wrist X-ray or image and to eliminate or minimize observer variability [38, 39]. The normal scapholunate angle on lateral X-ray views increases from an average of 35° of flexion in full wrist extension to 76° in full flexion. With the normal wrist in a neutral position, the scaphoid is flexed at about 47° (the angle of Alexander).

The doubly intercalated lunate is a prime radiographic sentinel for both normal and pathophysiologic carpal kinematics [23]. First, the lunate is intercalated BETWEEN the scaphoid and the triquetrum. Lunate flexion and extension occur with the PCR and wrist during normal motion. The lunate is collinear with the capitate in a true lateral (sagittal plane) X-ray or imaging study in the normal resting wrist. The lunate is normally balanced between the scaphoid, which independently tends to flex, and the triquetrum, which intrinsically tends to extend.

In scapholunate dissociation the lunate dorsiflexes and the lunocapitate and scapholunate angles increase [23]. In lunotriquetral dissociation, the lunate palmar flexes and the lunocapitate angle increases in the direction opposite that of scapholunate dissociation. The lunotriquetral angle increases.

Second, the lunate is intercalated WITHIN the proximal row [23]. In midcarpal instability (MCI), when the lunate dorsiflexes and subluxes under the head of the capitate, the injury is termed a dorsal intercalary segment instability (DISI). When the lunate palmar (volar) flexes and subluxes over the head of the capitate, the injury is termed a volar intercalary segment instability (VISI). Knowledge of the lunate as a marker helps to sort out midcarpal, adaptive, and combined or complex carpal instabilities.

Pattern

Four intrinsic carpal instability patterns are recognized. When the ligaments restraining the scaphoid and triquetrum to the lunate are intact, the PCR flexes and extends as a unit. Scapholunate or lunotriquetral ligament injuries cause dissociative and reciprocally opposite rotation of the scaphoid and the triquetrum, respectively, within the PCR. These injuries are therefore defined as carpal instability dissociative (CID). Displaced transtriquetral, and especially transscaphoid, fractures may result in similar patterns. In displaced scaphoid fractures the proximal scaphoid fragment extends with the lunotriquetral unit and the distal fragment flexes owing to opposing forces. Ligament injuries between the radius and/or ulna and the PCR (the radiocarpal and/or ulnocarpal joints) or between the PCR and DCR (the midcarpal joint) are labeled carpal instability nondissociative (CIND). Carpal instability adaptive (CIA) refers to MCI *(CIND)* from a skeletal injury adjacent to, but not directly involving, the carpal bones and their connecting ligaments. Extra-articular distal radial fractures and malunions with loss of dorsal inclination and dorsal second and third carpometacarpal dislocations or fracture dislocations may cause *CIA* [40, 41]. If *CIA* is corrected with reduction of the causative skeletal deformity, the carpal bones usually realign in a normal or nearly normal posture. Coexisting *CID* and *CIND* are classified as carpal instability combined or complex (CIC).

Pathophysiology

Patients with ulnar negative variance are at increased risk of SLIL injury [42]. Patients with ulnar negative variance and a lunate fossa with an increased radioulnar slope on anteroposterior images are at increased risk of MCI [43]. Larger and deeper scaphoid fossae and greater palmar tilt of the distal radius and greater proximal articular curvatures may shield the wrist from incurring SLIL injury or developing instability after SLIL injury [44]. Wrists with a TYPE II lunate tend to be less susceptible to SLIL injury and progressive perilunar instability (PPI) than patients with a TYPE I lunate; however, they have an increased risk of developing lunohamate arthrosis [45, 46].

Ligament injury is one of degree and may be divided into attenuation or stretch injuries (in which the elastic coefficient of the ligament is exceeded without tearing), partial tears, and complete tears [47]. Attenuation may occasionally be associated with predynamic instability that is unapparent even with joint loading or stress. Attenuation and partial ligament tears are frequently associated with dynamic instability that is apparent only with joint loading or stress. Complete ligament tears, and in some instances specific isolated ligament sectioning, are associated with static instability, owing to some degree of adjacent external secondary ligament injury or division. Bone avulsion may occur in concert with ligament tears and sometimes helps to locate and identify these injuries.

Vertical Carpal Instabilities

Scapholunate Instability (SLI) and Progressive Perilunar Injury (PPI)

PPI results from sequential ligamentous injuries due to wrist extension, ulnar deviation, and supination in relation to a stable forearm during a fall or force on the outstretched hand (FOOSH) [48]. The sequence continues until the energy from the force is completely expended. These forces may also disrupt the wrist ligaments when they occur during other wrist injuries, particularly radial styloid fractures and intra-articular, or even extra-articular, distal radial fractures [48, 49]. Injuries to the SLIL and/or LTIL ligaments are classified as lesser arc injuries [50]. Transscaphoid, transcapitate, and transtriquetral fractures are greater arc lesions (Fig. 9.7). Fractures, in these instances, are more easily treated and heal more reliably than ligament injuries. Concurrent proximal pole fractures of the scaphoid and SLIL tears have been reported and are challenging both to diagnose and treat [51–53].

Mayfield et al. have reported four progressive, representative, integral STAGES within the SPECTRUM of PPI [48] (Fig. 9.8). STAGE I injuries are characterized by disruption of the SLIL and adjacent ligaments. The SLIL is the primary stabilizer of the scapholunate joint [54–56]. The RSCL and STTL are secondary stabilizers. The SLIL usually tears from its attachment to the scaphoid. PPI STAGE I Injuries attenuate or tear the space of Poirier palmarly and distally and progressively extend proximally to disrupt the pSLIL until there is scapholunate diastasis with disruption of the RSCL or radial styloid fracture and tearing of the dSLIL and scaphoid insertion of the DICL. Complete scapholunate instability (SLI) occurs when the DICL attachment to lunate is disrupted. Attenuation and partial SLIL tears anterior to the scapholunate axis between the centers of rotation of the scaphoid and the lunate usually result in dynamic scapholunate instability. Partial SLIL tears dorsal to the scapholunate axis between the centers of rotation of the scaphoid and the lunate and complete SLIL tears result in static scapholunate instability.

Laboratory studies have demonstrated that in vitro complete sectioning of the SLIL alone does not cause scapholunate widening or carpal instability in the resting wrist [54–56]. In vitro sectioning of the SLIL caused mild scapholunate instability during wrist flexion and extension, but only minimal scapholunate instability throughout radioulnar deviation. Loading causes slight abnormal motion between the scaphoid and the lunate that may account for predynamic or mild dynamic instability. Although laboratory sectioning of the entire SLIL causes minimal SLI, traumatic clinical SLIL disruption can cause marked static scapholunate diastasis and instability, owing to involvement of adjacent extra-articular ligaments.

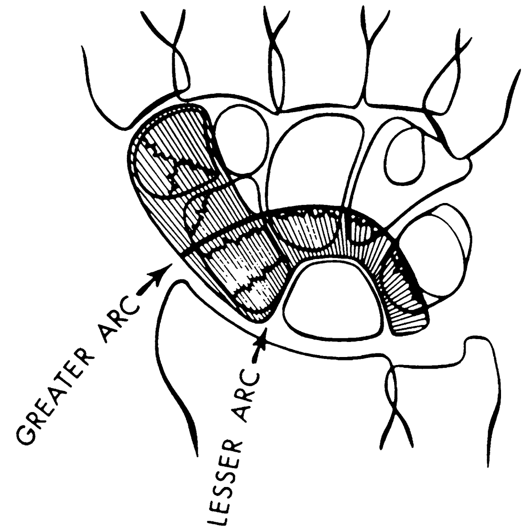


Fig. 9.7 The lesser and greater carpal arcs [Reproduced with permission from Blazar PE, Lawton JN. Diagnosis of carpal ligament injuries. In: Trumble TE (ed.): *Carpal Fracture-Dislocations*. Rosemont, IL: *American Academy of Orthopaedic Surgery*; 2002]

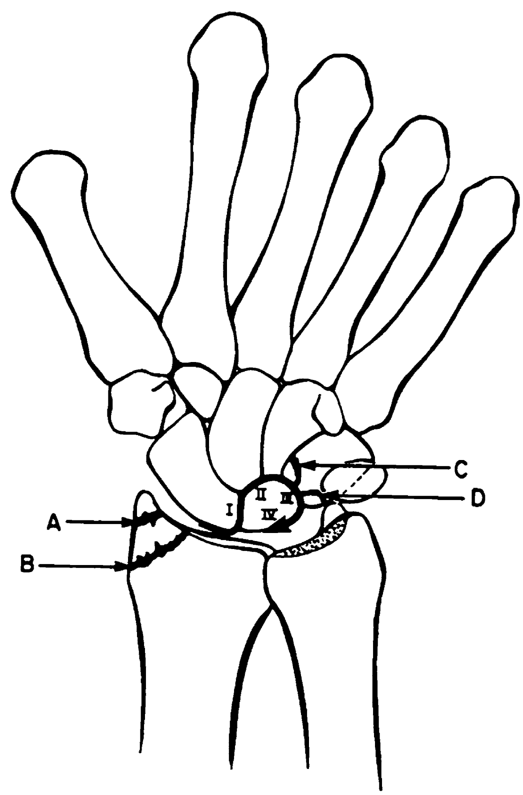


Fig. 9.8 Mayfield's STAGES of progressive perilunate dislocation [Reprinted from: Mayfield JK, Johnson RP, Kilcoyne RK: Carpal dislocations: pathomechanics and progressive perilunate instability. *J Hand Surg* 1980;5(3):226–241.with permission from Elsevier]

The computation of the total hysteresis area from the hysteresis effect is a sensitive technique that can determine the subtle onset of abnormal carpal motion [57]. Whereas the sectioning of the SLIL, RSCL, and STTL is required to produce changes in the hysteresis area in flexion-extension curves, in vitro sectioning of the SLIL alone increases the total hysteresis area during wrist radioulnar deviation. This subtle finding may identify the onset of dynamic SLI. The total hysteresis area of the lunate may increase as well; however, a paradoxical decrease of the total hysteresis effect of the lunate with hypermobile (lax) wrists may explain why some patients with SSI do not develop DISI deformities.

Further in vitro sectioning of the DICL causes scapholunate widening without static carpal collapse [31, 58]. Additional sectioning of the DICL attachments to the lunate causes greater scapholunate widening. The scaphoid flexes and dissociates from the extending lunotriquetral unit causing static carpal collapse. The proximal pole of the scaphoid subluxes dorsoradially in the scaphoid fossa of the distal radius [59]. Conversely, the lunate subluxes palmarly and ulnarly within the lunate fossa of the distal radius. Abnormal widening of the scapholunate and lunocapitate angles results.

In the intact wrist, scapholunate motion is greater in circumduction than in the DTM, where motion is, in fact, minimal [2–9, 54–56]. Following in vitro sectioning of the RSCL, STTL, and SLIL, the scaphoid flexes more and the lunate extends more during both circumduction and the DTM. Both before and after sectioning, scaphoid motion is greater than that of the lunate. Overall, after in vitro sectioning of the RSCL, STTL, and SLIL, scaphoid motion substantially increased, while lunate motion decreased. This helps to explain the observation that after SLIL tears with associated secondary restrain involvement and continuous motion, arthritic changes occur in the radioscaphoid fossa, but not in the radiolunate joint [60, 61].

Geissler combined radiocarpal and midcarpal diagnostic arthroscopic evaluation to classify the progressive SPECTRUM of SLIL injuries that occur in Mayfield PPI I injuries into four integral arthroscopic GRADES [62] (Video 9.1).

Mayfield PPI STAGE I PPI, Geissler SLIL GRADE I Injuries

Arthroscopic GRADE I SLIL injuries start palmarly and distally and progress proximally and are confined to attenuation or tear in the space of Poirier between the RSCL and LRLL and SLIL attenuation without tear (Fig. 9.9). The attenuation is visualized from the radiocarpal (3-4) portal. From the radial midcarpal portal, the normal SLJ remains congruently aligned and immobile or may have very slight widening palmarly.

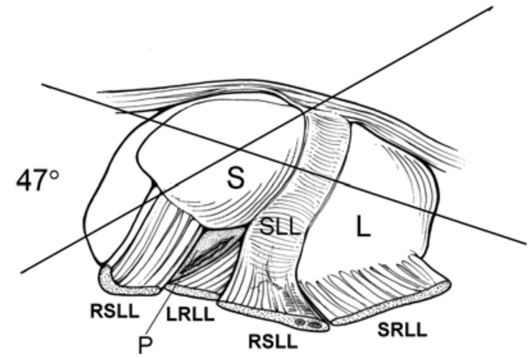


Fig. 9.9 GRADE I scapholunate ligament tear

No abnormality is seen on plain X-rays (Fig. 9.10). Arthroscopic GRADE I lesions create predynamic or dynamic instabilities.

Mayfield STAGE I PPI, Geissler GRADE II SLIL Injuries

Avulsion of the palmer radial corner of the SLIL from the scaphoid or tears of the pSLIL anterior to the scapholunate axis of rotation as seen from the radiocarpal (3-4) portal is classified as arthroscopic GRADE II lesions (Fig. 9.11). From the radial midcarpal portal, scapholunate incongruity may be apparent, but a standard probe cannot be introduced between the two bones (Fig. 9.12). Slight multiplanar instability may be demonstrated by stressing either the scaphoid or lunate with the probe or by manual stress applied to the scaphoid tubercle. Usually, there is no discernible abnormality on standard resting X-rays. Stress or MRI images may reveal the lesion. These lesions create dynamic instability.

Mayfield STAGE I PPI, Geissler GRADE III SLIL Injury

Arthroscopic GRADE III lesions extend throughout the membranous midportion of the SLIL, but do not involve or only attenuate or partially involve the dSLIL, leaving it as a soft tissue hinge (Fig. 9.13). Some arthroscopic GRADE II SLIL lesions and all GRADE III involve the mesenteric RSLL. The SLIL tear may be seen from both the 3-4 radiocarpal and the midcarpal portals and a probe (but not the 2.7 mm arthroscope) may be introduced between the scaphoid and the lunate (Fig. 9.14). Multiplanar instability is present and is easily demonstrated with the probe or by digital compression of the scaphoid tubercle. There is definite static instability. Slight scapholunate diastasis (3–4 mm) is seen on AP X-ray, and slight scaphoid flexion and lunate extension are seen on lateral resting X-ray.

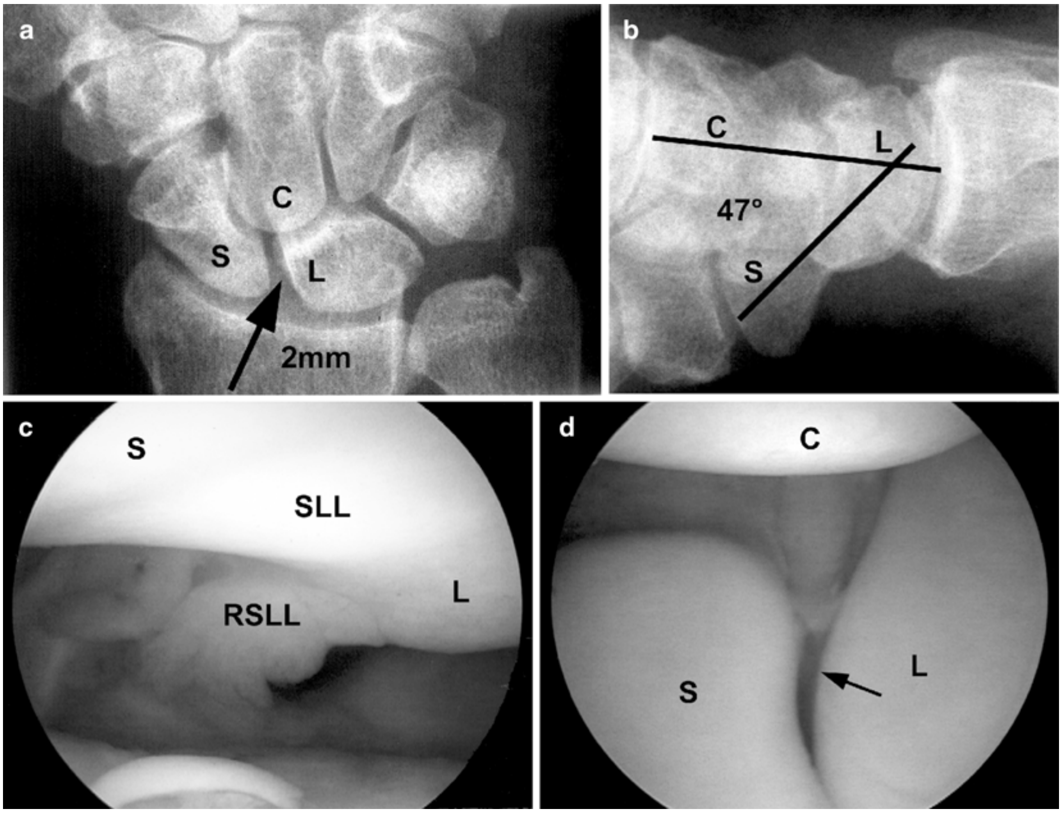


Fig. 9.10 GRADE I scapholunate ligament tear. (**a**) Normal AP X-ray (*arrow* points to the scapholunate joint). (**b**) Normal lateral X-ray and scapholunate angle. (**c**) Radiocarpal (3-4 portal) arthroscopic image demonstrating attenuation of the SLL and RSLL. (**d**) Midcarpal arthroscopic view with opening of the volar portion of the scapholunate interval

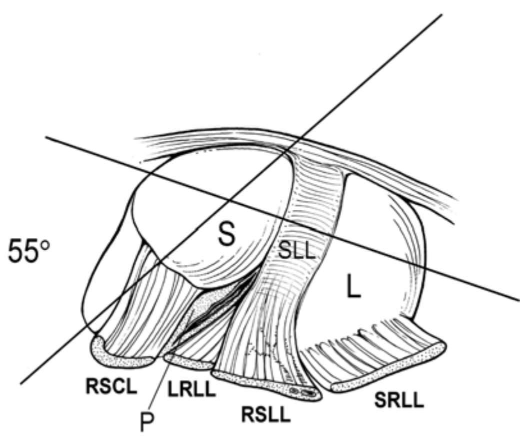


Fig. 9.11 GRADE II scapholunate ligament tear

Mayfield STAGE I PPI, Geissler Grade IV SLIL Injuries

Arthroscopic GRADE IV lesions avulse or tear the dorsal segment of the SLIL and then the insertion of the DICL from the scaphoid. The dorsal SLIL and the DICL insertion blend are difficult to distinguish at their interface (Fig. 9.15). The DICL attachment to the lunate may also be torn. The 2.7 mm arthroscope may be passed into the interval between the scaphoid and the lunate. Geissler termed this the “drive-through sign.” The head of the capitate may be visualized from the 3-4 radiocarpal portal (Fig. 9.16). Multiplanar instability between the scaphoid and lunate within the mid-carpal portal is readily apparent or easily demonstrated with manual stress testing. The scaphoid is foreshortened by carpal collapse, creating a scapholunate advanced collapsed (SLAC) wrist [60, 61]. On AP X-ray, there is a wide scapholunate gap (4–5 mm or more), and the scaphoid tubercle appears circular creating a “signet ring sign.” On the lateral X-ray view, the scaphoid is vertical, or nearly so, and if the DICL attachment to the lunate is torn, the lunate is extended.

Progressive correlative scaphoid flexion, lunotriquetral unit extension, and scapholunate gap widening may be seen on standard resting images as the tear propagates through the arthroscopic GRADES of classification.

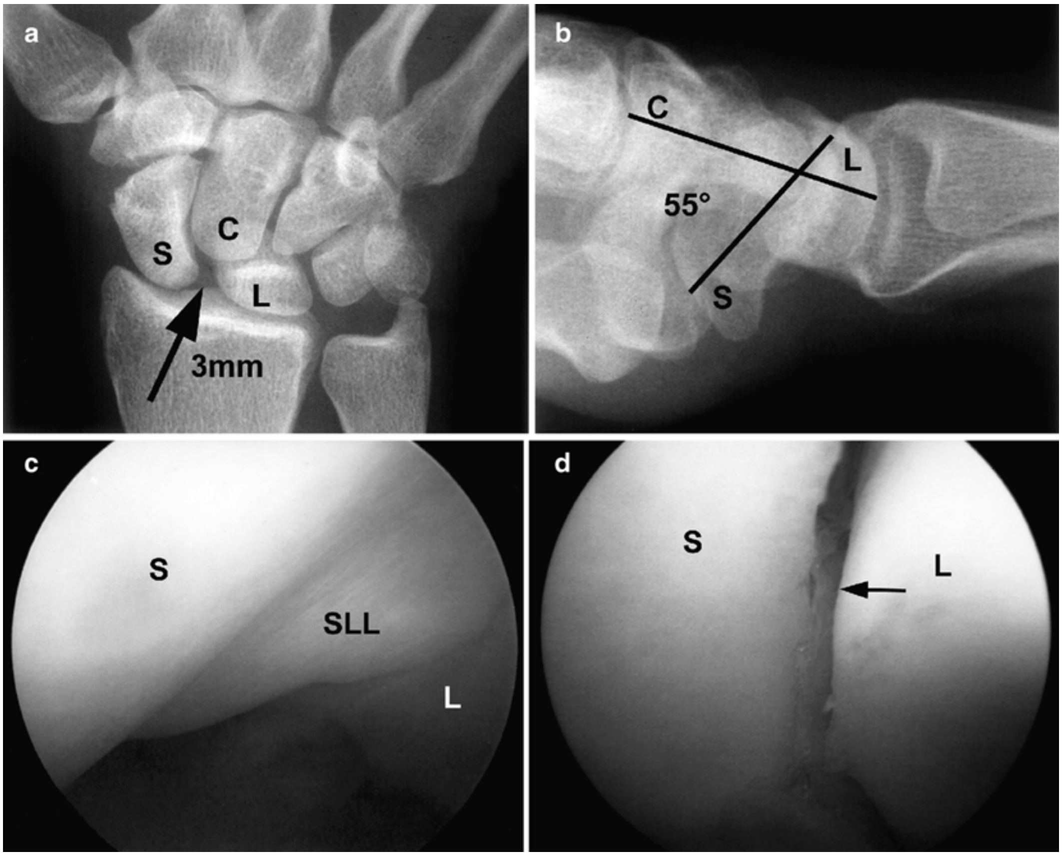


Fig. 9.12 GRADE II scapholunate ligament tear. (**a**) Slight diastasis of the scapholunate joint on AP X-ray (*arrow* points to the scapholunate joint). (**b**) Slight flexion of the scaphoid and increase of the scapholunate angle on lateral X-ray. (**c**) Radiocarpal (3-4 portal) arthroscopic image demonstrating attenuation of the SLL. (**d**) Midcarpal arthroscopic view with a uniform opening (1.0–1.5 mm) of the scapholunate interval

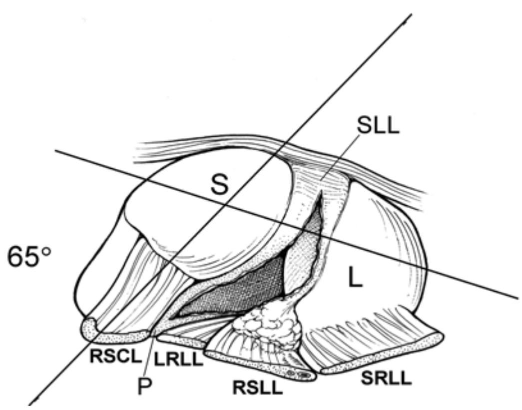


Fig. 9.13 GRADE III scapholunate ligament tear

Mayfield STAGE II PPI

Scapholunate diastasis and further separation of the space of Poirier is followed by sequential or simultaneous attenuation and/or partial or complete failure of the capitate insertion of the RSCL, the dorsal scaphocapitate segment of the DICL, dorsal capitohamate ligament/capsule, DRLTL, distal insertions of the ulnar limb of the anterior arcuate ulnolunocapitate ligament (triquetrocapitate, triquetrohamate, capitohamate ligaments/capsule), dLTIL, and/or mLTIL, causing capitolunate dissociation [48]. The midcarpal joint becomes unstable and may sublux and/or angulate (Fig. 9.8).

Mayfield STAGE III PPI

Mayfield STAGE III lesions are subclassified into TYPE A (without perilunate dislocation) and TYPE B (with perilunate dislocation) [48] (Fig. 9.8). In TYPE III A, there is failure of the DRLTL between the lunate and triquetrum and separation between the lunate and the triquetrum, indicating at least attenuation or partial tear of the LTIL, creating lunotriquetral instability. The head of the capital remains contained, albeit sometimes dorsally subluxed in the lunate concavity so as to create a DISI deformity. The radiolunate portion of the DRLTL may remain intact, whereas the lunotriquetral segment may be torn. In TYPE III B, the capi-

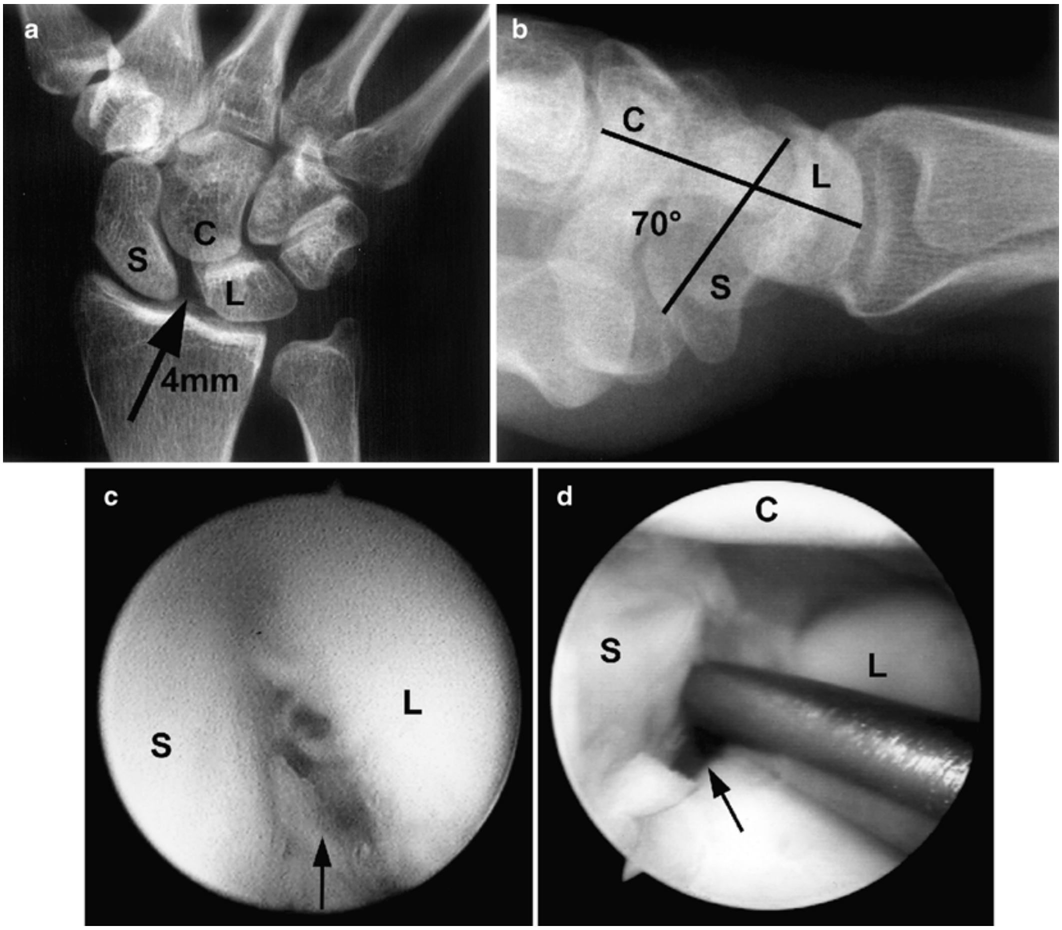


Fig. 9.14 GRADE III scapholunate ligament tear. (**a**) Four millimeter diastasis of the scapholunate joint on AP X-ray (*arrow* points to the scapholunate joint). (**b**) Moderate flexion of the scaphoid and increase of the scapholunate angle to 70° on lateral X-ray. There is slight extension of the lunate in relation to the head of the capitate, a sign of early DISI pattern. (**c**) Radiocarpal (3-4 portal) arthroscopic image demonstrating a complete tear of the volar portion and midsubstance of the SLL. The dorsal scapholunate segment remains intact. (**d**) Midcarpal arthroscopic view demonstrating increased widening and instability of the scapholunate joint sufficient to allow the introduction of a metallic probe

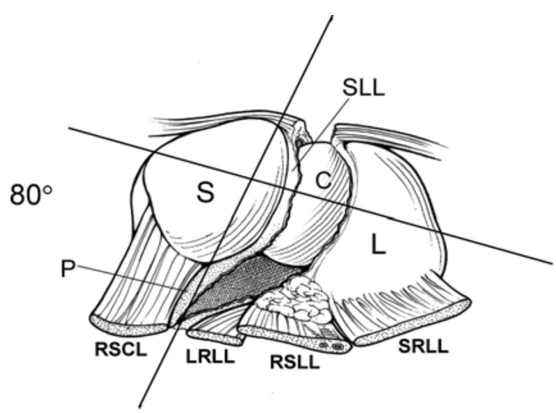


Fig. 9.15 STAGE II (GRADE IV) scapholunate ligament tears

tate is dorsally dislocated on top of the lunate (perilunate dislocation), indicating a complete tear of the SLIL, LTIL, and both the radiolunate and lunotriquetral segments of the DRLTL. When both the SLIL and LTIL are torn, the lunate may appear neutral or be flexed or extended on lateral imaging, but the scaphoid will be abnormally flexed.

Mayfield STAGE IV PPI

Palmar lunate dislocation identifies PPI STAGE IV [48]. The SLIL and LTIL are completely ruptured. The lunate attachments of the DRLTL and DICL are torn (Fig. 9.8). Palmar dislocation of the lunate occurs through the space of Poirier (between the RSCL and LRLL). Palmar ligament/capsular structures may remain sufficiently intact and act as a hinge on the palmer pole of the lunate. There is a wide gap between the scaphoid and the triquetrum. The capitate migrates proximally.

The DCR migrates proximally in terminal STAGE I and in STAGES II, III, and IV lesions. Consequently, we believe that these injuries should be considered CIC lesions.

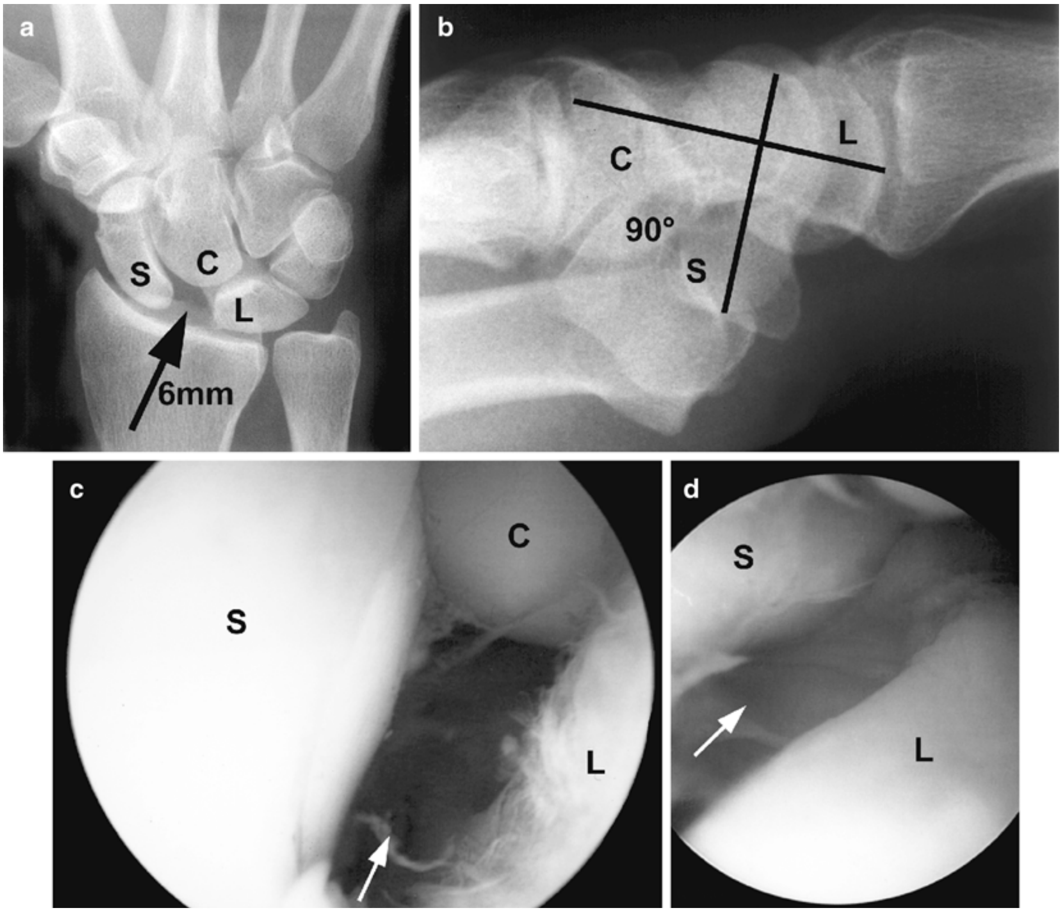


Fig. 9.16 STAGE II (GRADE IV) scapholunate ligament tear. (**a**) Six millimeter diastasis of the scapholunate joint on AP X-ray (*arrow* points to the scapholunate joint). (**b**) Severe flexion of the scaphoid and increase of the scapholunate angle to 90° on lateral X-ray. The lunate is extended and subluxed in relation to the head of the capitate, a sign of an established DISI pattern. (**c**) Radiocarpal (3-4 portal) arthroscopic image demonstrating a complete tear of the entire SLL. The head of the capitate can be visualized in the widened interval between the scaphoid and the lunate. (**d**) A midcarpal arthroscopic view demonstrating severe widening and instability of the scapholunate joint sufficient to allow the introduction of the arthroscope

Ulnar-Sided Progressive Perilunar Instability (UPPI)

Lunotriquetral dissociation is substantially less frequent than its dissociative counterpart at the SLJ. The LTIL usually tears from the triquetrum. UPPI results from a fall or a force on the hypothenar eminence of the outstretched hand positioned in radial deviation with PCR pronation. Ulnar-sided perilunate attenuation and tears progress through a spectrum of severity similar to that of SLIL and PPI diastasis [63–68] (Fig. 9.17).

Horii et al. experimentally sectioned the entire LTIL [64]. In a second STAGE they additionally sectioned both the dorsal radiotriquetral and scaphotriquetral ligaments. In both instances, all of the intercarpal joints exhibited altered kinematics, especially at the lunotriquetral joint, where motion was increased in all phases of wrist motion. Only in STAGE II did a VISI deformity occur.

Viegas et al. have identified three successive STAGES of ulnar-sided perilunate instability in the laboratory [65]. Similar to the SLIL, partial or complete laboratory partial sectioning of the LTIL alone (STAGE I) allowed very slight divergent motion between the lunate and triquetrum, without static deformity. There was no significant difference in the load distribution between a normal wrist and a STAGE I lesion. With complete division of the LTIL (STAGE II), the scapholunate complex flexed and subluxed dorsally and radially and the triquetrum extended away from the lunate. The lunotriquetral angel increased from a normal value of 14° as lunotriquetral dissociation progressed [66] (Fig. 9.18). Complete sectioning of the LTIL and the lunotriquetrohamate complex of the DRLTL (STAGE III) caused ulnar-sided MCI. Static VISI deformity occurred. The head of the capitate migrated proximally from the metacarpal-radial midaxis and subluxed palmarly against the palmar flexed lunate. The lunotriquetral and lunocapitate angles increased.

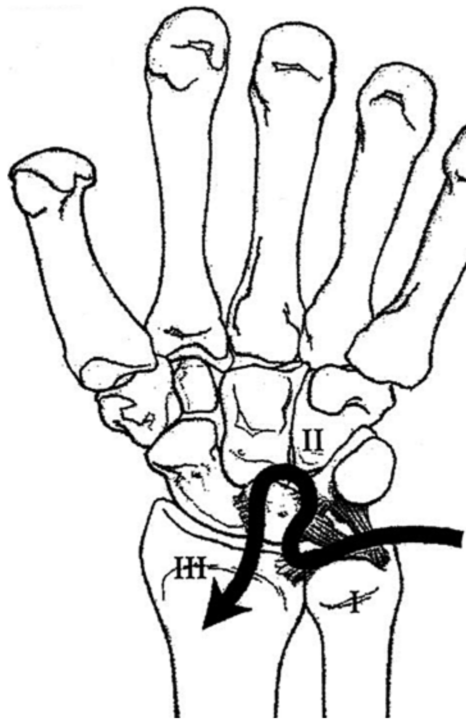


Fig. 9.17 The direction, pattern, and STAGES of progressive lunotriquetral tear leading to perilunate involvement. A STAGE I injury has disruption of the ulnolunate and lunotriquetral (ulnar leash) ligament complex. The lunotriquetral ligament is involved in a STAGE II injury. In STAGE III, the lesion progresses through the midcarpal joint and the scapholunate ligament is disrupted [Reprinted from Reagan DS, Linscheid RL, Dobyns JH. Lunotriquetral sprains. J Hand Surg 1984; 9A: p. 502–514. With permission from Elsevier]

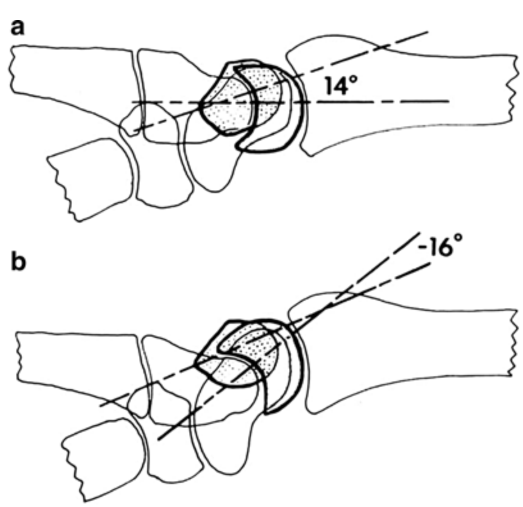


Fig. 9.18 Normal lunotriquetral angle (**a**) and the loss of this relationship with lunotriquetral tear (**b**) [Reprinted from Garcia-Elias M, Dobyns JH, Cooney WP III, Linscheid RL: Traumatic axial dislocation of the carpus. J Hand Surg 1989; 14(3):446–457. With permission from Elsevier]

The scaphoid flexed in relation to the capitate while maintaining a normal scapholunate angle. The lunate again acted as a sentinel signaling intrinsic PCR and midcarpal intercarpal instabilities. Wrist extension or ulnar deviation beyond 25° caused a "catch-up clunk" as the PCR and VISI deformities were reduced.

Ritt et al. demonstrated that sectioning of the mLTIL and dLTILL had little effect on carpal kinematics, but sectioning of the mLTIL and pLTIL resulted in flexion of the scapholunate complex and triquetrum extension, producing a VISI deformity [67]. The triquetrum supinated away from the lunate after complete sectioning of the LTIL. VISI deformity increased after additional sectioning of the adjacent components the DRLTL and DICL. Cycling increased the instability.

Taleisnik identified two clinical TYPES of ulnar carpal instability, lunotriquetral and triquetrohamate [68]. Lunotriquetral instability is a Viegas STAGE III manifestation of UPPI and has a loss of the dorsiflexion influence of the triquetrum on the lunate causing static VISI collapse. Triquetrohamate instability will be discussed under MCIs.

Axial Carpal Instability (ACI)

Axial carpal instability (ACI) refers to vertical splits between metacarpal bases and bones in both carpal rows [69, 70]. Crush or blast injuries are frequent precursors. Axial wrist dislocations are not purely intrinsic and extrinsic carpal ligamentous injuries and can be complicated by a variety of other adjacent hand and wrist bone, joint, and/or soft tissue injuries. Open wounds, intrinsic compartment syndromes, and median and ulnar nerve compression, especially of the ulnar motor branch, are frequently seen.

A longitudinal split of the carpus and metacarpal bases characterizes axial dislocations of the carpus (Fig. 9.19). Both the proximal (carpal) and distal (metacarpal) transverse arches are disrupted. There are three types of axial wrist dislocations: radial, ulnar, and combined radioulnar [69, 70]. In radial and ulnar axial carpal dislocations, the carpus splits into two columns. In radial axial dislocations, the ulnar column maintains a normal and stable relationship with the distal radius and ulna, whereas the radial column separates proximally and radially and may pronate. In ulnar axial dislocations, the radial column maintains a normal and stable relationship with the distal radius and ulna, whereas the ulnar column separates proximally and ulnarly and may supinate. In combined radioulnar axial dislocation, there are three columns. The central column, consisting of the lunate, capitate, and third metacarpal, maintains its normal relationship with the distal radius and ulna, while the radial and ulnar columns displace as detailed above. Axial dislocations may occur in combination with additional carpal ligament injuries and intercarpal deformities.

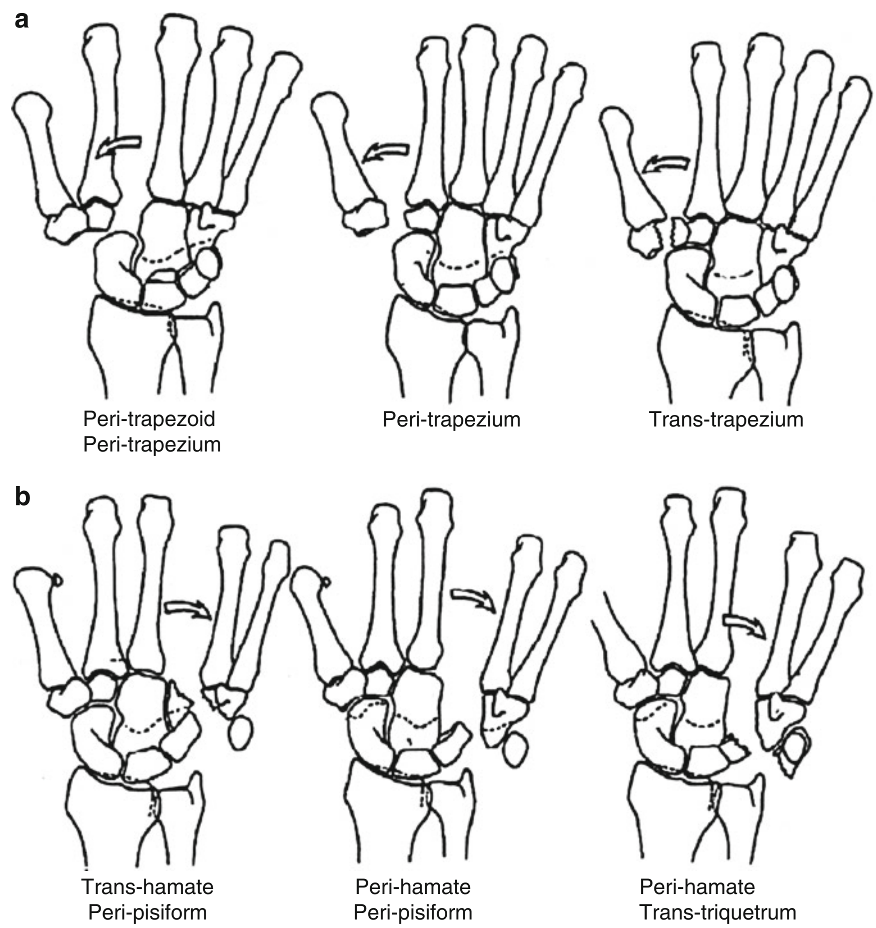


Fig. 9.19 Some of the more common patterns of (**a**) axial-radial dislocation and (**b**) axial-ulnar dislocation patterns [Reprinted from: Garcia-Elias M, Dobyns JH, Cooney WP III, Linscheid RL: Traumatic axial dislocation of the carpus. *J Hand Surg* 1989; 14(3): 446–457. With permission from Elsevier]

Transverse Carpal Instabilities

Midcarpal Instability (MCI)

MCI represents several distinct clinical entities, differing in cause and direction of the subluxation, but sharing the common characteristic of abnormal force transmission at the midcarpal joint [64–68, 71]. MCI may be caused by various combinations of injury to extrinsic ligaments as they connect the two carpal rows. Whenever one or more of these ligaments are compromised, proportionate MCI occurs. The radius, PCR (lunate), DCR (capitate), and third metacarpal longitudinal axes no longer have collinear resting and/or load midaxes on lateral imaging. The longitudinal axis of the capitate diverges from the third metacarpal-distal radius longitudinal axis. Dynamic or static VISI or DISI MCI (CIND) follows.

Here, once more, the lunate acts as a sentinel, signifying the direction and extent of MCI. Lunocapitate angles of greater than 15° on a resting, true lateral X-ray or image with the wrist in neutral position highly correlate with static instability [12]. Lunocapitate angles of less than 15° may be static, suggestive of dynamic lesions with partial ligament tears or, in the lower range, predynamic or dynamic ligament attenuation. Palmar sagging of the ulnar side of the neutral wrist, midcarpal shift testing, and stress images may assist in identifying evidence of instability. Fluoroscopic cineradiography can identify MCI and its related ulnarly directed reduction "jump" or "catch-up clunk" [72]. Ligamentous attenuation and/or laxity may be difficult to define.

There are a number of subtypes of MCI: palmar (volar), dorsal, palmar/dorsal, ulnar, radial, ulnar/radial, and capitolunate; often with overlapping features [71]. Distal radial malunions, scaphoid malunions, ulnar negative variance, second and third carpometacarpal dislocation or fracture dislocation, advanced Kienboch's disease, and rheumatoid arthritis account for additional etiologies of MCI. A specific consistent anatomic source(s) has not been verified for many of the MCI patterns published and their direction as they have been difficult to ascertain on diagnostic studies and at the time of operative intervention. We have consequently been left to informed conjecture and speculation.

MCI instability can result from extension of scapholunate and lunotriquetral instabilities into the midcarpal joint during PPI and UPPI as noted in the above sections. VISI is the most commonly reported type of MCI. VISI malalignment is not injury specific. VISI frequently results from disruption of the ulnar limb of the palmar arcuate ligament (triquetrohamatocapitate ligament complex), the lunotriquetral segment of the DRLTL, or both [71, 72]. Ulnar midcarpal instability takes place between the medial (triquetrum) and central (lunate and hamate) columns [68]. Taleisnik TYPE 2 triquetrohamate instability occurs across the midcarpal joint in the ulnar limb of the palmar arcuate ligaments (triquetrohamatocapitate ligament complex) with loss of stability of the central column presenting only during radial or ulnar deviation (dynamic VISI) [68, 71–73]. During ulnar deviation, the triquetrohamate joint and PCR undergo an exaggerated shift or relocation from palmar flexion to dorsiflexion that may be accompanied by an uncomfortable, palpable, and even audible clunk. Lunotriquetral instability has a loss of the dorsiflexion influence of the triquetrum on the lunate causing static VISI collapse.

In pure primary MCI (CIND) *between* the PCR and DCR, there is no intrinsic SLIL and/or LTIL injury or dissociation of bones within the proximal row. Rather, there is dissociation between the two carpal rows. There is a reciprocal smaller compensatory effect at the radiocarpal joint [71] (Figs. 9.20 and 9.21).

In both the VISI and DISI directions of MCI, the PCR always moves into extension and the DCR translates dorsally with ulnar deviation and engagement of the triquetrohamate joint. In VISI, it is the initial palmar PCR translocation (subluxation) in neutral that reduces with ulnar deviation [71]. In DISI, the wrist is reduced in neutral and the PCR dorsal subluxation occurs in ulnar deviation. Some MCIs with static VISI demonstrated DISI behavior of the capitolunate joint ± the radiolunate joint on dorsal stress testing [74]. These findings may represent a combined radial and ulnar MCI and/or increased ligamentous attenuation or laxity.

In vitro sectioning of the dorsal and ulnar triquetrohamate ligament/capsule in one investigation produced slight midcarpal laxity, but no clunk, whereas division of the stout ulnar limb of the palmar arcuate (triquetrohamatocapitate) ligament caused MCI and produced a clunk [72]. Ensuing studies have shown that sectioning either the palmar arm of the arcuate ligament or the DRLTL produces a VISI deformity and pathomechanics characteristic of ulnar VISI MCI [75].

In capitolunate instability pattern (CLIP) and chronic capitolunate instability (CCI), the head of the capitate progressively subluxes dorsally on the lunate, especially during ulnar deviation. The entire PCR dorsiflexes. A static or dynamic DISI deformity occurs. Louis et al. and Johnson and Carrera implicated both palmar and dorsal ligamentous/capsular structures attaching to the capitate, including the scaphocapitate segment of the RSCL and the radiolunate ligaments [76, 77]. Traumatic separation and/or extension of the space of Portier should also be considered.

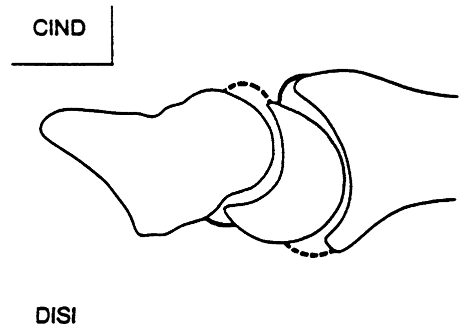


Fig. 9.20 A DISI pattern of deformity occurs with CIND owing to attenuation or tear of the palmar radiocarpal or dorsal midcarpal ligaments or of both [Reprinted from Amadio PC. Carpal kinematics and instability: A clinical and anatomic primer. *Clin Anat* 1991; 4(1): 1–12. With permission from John Wiley & Sons, Inc.]

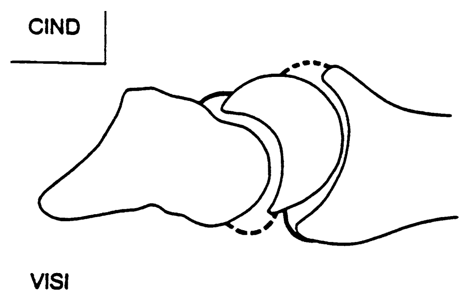


Fig. 9.21 A VISI pattern of deformity occurs with CIND owing to attenuation or tear of the dorsal radiocarpal or volar midcarpal ligaments or of both [Reprinted from Amadio PC. Carpal kinematics and instability: A clinical and anatomic primer. *Clin Anat* 1991; 4(1): 1–12. With permission from John Wiley & Sons, Inc.]

Hankin et al. postulated two types of radial MCI with rotatory subluxation of the scaphoid. They postulated that one type was due to STTL laxity and the other, to RSCL disruption. Conceivably, a combination of the two could occur. STTL complex disruption causes a radial-sided MCI with a VISI deformity [78].

Adaptive MCI has also been reported with progressive loss of lateral inclination of the radius in distal radius fractures and malunions [12, 40]. The lunate migrates and angulates dorsally in a DISI configuration to compensate for the loss of lateral angulation of the distal radius. The capitate remains collinear with the lunate, but dorsal to the longitudinal loadline of the distal radius. In these instances, the primary problem occurs at the radiocarpal joint and the reciprocal compensatory response occurs at the midcarpal joint. This type of external MCI has been attributed to repetitive loading and attenuation of the dorsal carpal ligaments and/or acquired laxity of the palmar carpal ligaments attaching to the DCR [40, 71]. Similarly, second and third carpometacarpal dislocation or fracture dislocation can cause a secondary VISI midcarpal malalignment [41]. Patients with ulnar negative variance and a lunate fossa with an increased radioulnar slope on anteroposterior images are at increased risk of MCI [43].

Radiocarpal Instability (RCI)

Posttraumatic ulnar radiocarpal translocation is a rare type of instability, often subtle, highly unstable, and potentially devastating manifestation of severe "inferior arc" injury at the radiocarpal and ulnocarpal joints [79–82]. RCI is a common sequela of radiocarpal dislocation. Shearing axial force is involved. Dorsal radiocarpal dislocation with reciprocal wrist supination and forearm pronation is more common than its palmar counterpart with concomitant wrist pronation and forearm supination. Combined radial and ulnar styloid fractures may herald "inferior arc" injuries. Excessive removal of bone during radial styloidectomy can cause TCI [83].

A spectrum of instabilities occurs, as the following structures are fractured, avulsed, attenuated, or partially or completely disrupted in a radial to ulnar sequence: radial styloid fracture, RSCL or SLIL disruption, LRLL and SRLL disruption, DRLTL disruption, palmar ulnolunate ligament (PULL) disruption, palmar ulnotriquetral ligament (PUTL) and dorsal ulnotriquetral ligament (DUTL) disruption, and ulnar styloid fracture [79–82]. The elements of injury and resistance forces determine the extent of injury until the energy is expended. Distal radioulnate joint (DRUJ) disruption frequently accompanies this injury, as do dorsal and or palmar distal radial lip fractures. Palmar and dorsal Barton's fractures are subsets of RCI. A slice fracture of the distal radius occasionally occurs. RCI may be obscure following radiocarpal reduction and may only be identified by initial distraction X-rays or, later, after the wrist settles into deformity.

The lateral radiocarpal ligament (LRCL) is thin and narrow; it offers little resistance to transverse forces. Siegel et al. demonstrated the importance of the integrity of the RSCL and the radiolunate ligaments in preventing ulnar radiocarpal translocation [83]. There are two configurations of this lesion [84]. TYPE I RCI involves ulnar translocation of the proximal carpal row as a unit owing to extrinsic radiocarpal ligament injuries with or without radial and/or ulnar styloid fractures. The less common TYPE II RCI has a dissociative lesion of the SLIL. The sulcus between the radial styloid (TYPE I injuries) and the scaphoid or between the scaphoid and lunate (TYPE II injuries) widens in proportion to the injury severity. In TYPE I RCI with radial styloid fractures and TYPE II injuries, the RSCL may remain intact. The lunate subluxes or dislocates ulnarly. The proximal pole of the scaphoid subluxes onto or beyond the scapholunate ridge of the distal radius. This constellation of injuries may present dynamic or static patterns and may be accompanied by dorsal or palmar carpal subluxation. Attenuation or tear of the RSCL and/or LRLL may only cause marginal radiocarpal palmar subluxation and dynamic instability [79–81]. Attenuation, or tear, of the SRLL and DRLTL leads to more severe dynamic instability or mild static instability, whereas disruption of the ulnocarpal ligaments accounts for severe static ulnar shift and multidirectional instability. Commensurate progressive radioscaphoid or scapholunate diastasis occurs. Static radiocarpal shifts of this nature may be identified on neutral AP and/or PA and lateral X-rays using standardized measurements of carpal position in relation to the longitudinal midaxis of the radius and third metacarpal [15].

References

1. Palmer AK, Werner FW, Murphy D, et al. Functional wrist motion: a biomechanical study. J Hand Surg Am. 1985;10A:39–46.
2. Werner FW, Short WH, Fortino MD. The relative contribution of selected carpal bones to global wrist motion during simulated planar and out-of-plane motion. J Hand Surg Am. 1997;22A:708–13.
3. Patterson RM, Nicodemus CL, Viegas SF, et al. High speed, three-dimensional kinematic analysis of the normal wrists. J Hand Surg Am. 1998;23A:446–53.
4. Werner FW, Green JK, Short WH, et al. Scaphoid and lunate motion during a wrist dart throw motion. J Hand Surg Am. 2004;29A:418–22.
5. Moritomo H, Murase T, Goto A, et al. Capitate-based kinematics of the midcarpal joint during wrist radioulnar deviation: an in vivo three-dimensional motion analysis. J Hand Surg Am. 2004;29A:668–75.
6. Crisco JJ, Coburn JC, Moore DC, et al. In vivo radiocarpal kinematics and the dart thrower's motion. J Bone Joint Surg. 2005;87A:2729–40.
7. Moritomo H, Apergis EP, Herzberg G, et al. 2007 IFSSH committee report of wrist biomechanics committee: biomechanics of the so-called dart-throwing motion of the wrist. J Hand Surg Am. 2007;32A(32A):1447–53.
8. Calfee RP, Leventhal EL, Wilkerson J, et al. Simulated radioscapholunate fusion alters carpal kinematics while preserving dart-thrower's motion. J Hand Surg Am. 2008;33A:503–10.
9. Crisco JJ, Heard WM, Rich RR, et al. The mechanical axes of the wrist are oriented obliquely to the anatomical axes. J Bone Joint Surg. 2011;93A:169–77.
10. Johnston HM. Varying positions of the carpal bones in the different movements at the wrist. Part I. Extension, ulnar, and radial flexion. J Anat Physiol. 1907;41:109–22.
11. Guilford W, Boltan R, Lambrinudi C. The mechanism of the wrist joint. Guys Hosp Rep. 1943;92:52–9.
12. Linscheid RL, Dobyns JH, Beabout JW, et al. Traumatic instability of the wrist: diagnosis, classification, and pathomechanics. J Bone Joint Surg. 1972;54A:1612–32.
13. Sarrafian SK, Malamed JL, Goshgarian GM. Study of wrist motion in flexion and extension. Clin Orthop. 1977;126:153–9.
14. Wright DR. A detailed study of the movement of the wrist joint. J Anat. 1935;70:137–43.
15. Youm Y, McMurty RY, Flatt AE, et al. Kinematics of the wrist. I. An experimental study of radio-ulnar deviation and flexion-extension. J Bone Joint Surg. 1978;60A:423–31.
16. Wolfe SW, Gupta A, Cristo JJ. Kinematics of the scaphoid shift test. J Hand Surg. 1997;22A:801–6.

17. Navarro A. Luxaciones del carpo. Anal Fac Med Montevideo. 1921;6:113–41.
18. Taleisnik J. Wrist anatomy, function, and injury. AAOS Instr Course Lect. St. Louis: Mosby, 1978, p. 61–87.
19. Weber ER. Concepts governing the rotational shift of the intercalated segment of the carpus. Orthop Clin North Am. 1984;15: 193–207.
20. Lichtman DM, Schneider JR, Swafford AR, et al. Ulnar midcarpal instability. J Hand Surg Am. 1981;6:515–23.
21. Craigen MA, Stanley JK. Wrist kinematics. Row, column or both? J Hand Surg Am. 1995;20B:165–70.
22. Berger RA, Crowninshield RD, Flatt AE. The three-dimensional rotational behavior of the carpal bones. Clin Orthop. 1982;167: 303–10.
23. Amadio PC. Carpal kinematics and instability: a clinical and anatomic primer. Clin Anat. 1991;4:456–68.
24. Upal MA, Crisco JJ, Moore DC, et al. In vivo elongation of the palmar and dorsal scapholunate interosseous ligament. J Hand Surg Am. 2006;31A:1326–32.
25. Moojen TM, Snel JG, Ritt MJ, et al. In vivo analysis of carpal kinematics and comparative review of the literature. J Hand Surg Am. 2003;28A:81–7.
26. Kaufmann R, Pfaeffle J, Blankenhorn B, et al. Kinematics of the midcarpal and radiocarpal joints in radioulnar deviation: an in vitro study. J Hand Surg Am. 2005;30A:937–42.
27. Berger RA. The gross and histologic anatomy of the scapholunate ligament. J Hand Surg Am. 1996;21A:170–8.
28. Berger RA, Imeada T, Bergland L, et al. Constraint and material properties of the subregions of the scapholunate interosseous ligament. J Hand Surg Am. 1999;24A:953–62.
29. Viegas SF, Yamaguchi S, Boyd NL, et al. The dorsal ligaments of the wrist: anatomy, mechanical properties, and function. J Hand Surg Am. 1999;24A:456–68.
30. Viegas SF. The dorsal ligaments of the wrist. Hand Clin. 2001;17: 65–75.
31. Mitsuyasu H, Patterson RM, Shah MA, et al. The role of the dorsal intercarpal ligament in dynamic and static scapholunate instability. J Hand Surg Am. 2004;29A:279–88.
32. Werner FW, Short WH, Green JK. Changes in patterns of scaphoid and lunate motion during functional arcs of wrist motion induced by ligament division. J Hand Surg Am. 2005;30A:1156–60.
33. Ritt MJ, Bishop AT, Berger RA, et al. Lunotriquetral ligament properties: a comparison of three anatomic subregions. J Hand Surg Am. 1998;23A:425–31.
34. Larsen CF, Amadio PC, Gilula LA, et al. Analysis of carpal instability. I. Description of the scheme. J Hand Surg Am. 1995;20A: 757–64.
35. Schuind FA, Leroy B, Comtet J-J. Biodynamics of the wrist: radiologic approach to scapholunate instability. J Hand Surg Am. 1985;10A:1006–8.
36. Nakamura R, Hori M, Imamura T, et al. Method for measurement and evaluation of carpal bone angles. J Hand Surg Am. 1989;14A: 412–6.
37. Garcia-Elias M, An KN, Amadio PC, et al. Reliability of carpal angle determination. J Hand Surg Am. 1989;14A:1017–21.
38. Yang Z, Mann FA, Gilula LA, et al. Scaphopisocapitate alignment: criteria to establish a neutral lateral view of the wrist. Radiology. 1997;205:865–9.
39. Larsen CF, Stigsby B, Lindequist S, et al. Observer variability in measurements of carpal bone angles on lateral wrist radiographs. J Hand Surg Am. 1992;16A:893–8.
40. Taleisnik J, Watson HK. Midcarpal instability caused by mal-united fractures of the distal radius. J Hand Surg Am. 1984;9A:350–7.
41. Freeland AE, McAuliffe JA. Dorsal carpal metacarpal fracture dislocation associated with nondissociative segmental instability. Orthopedics. 2002;25:753–5.
42. Czitrom AA, Dobyns JH, Linscheid RL. Ulnar variance in carpal instability. J Hand Surg Am. 1987;12A:205–8.
43. Wright TW, Dobyns J, Linscheid RL, et al. Carpal instability nondissociative. J Hand Surg Am. 1994;19B:763–73.
44. Werner FW, Short WH, Green JK, et al. Severity of scapholunate instability is related to joint anatomy and congruency. J Hand Surg Am. 2007;32A:55–60.
45. Rhee PC, Moran SL, Shin AY. Association between lunate morphology and carpal collapse in cases of scapholunate dissociation. J Hand Surg Am. 2009;34A:1633–9.
46. Nakamura K, Patterson RM, Viegas SF. Type I versus type II lunates: ligament anatomy and presence of arthrosis. J Hand Surg Am. 2001;26A:428–36.
47. Watson HK, Weinzweig J, Zeppierri J. The natural progression of scaphoid instability. Hand Clin. 1997;13:39–49.
48. Mayfield JK, Johnson RP, Kilcoyne RK. Carpal dislocations: pathomechanics and progressive perilunar instability. J Hand Surg Am. 1980;5:226–41.
49. Mudgal CS, Jones WA. Scapho-lunate diastasis: a component of fractures of the distal radius. J Hand Surg Am. 1990;15B:503–5.
50. Blazar PE, Lawtonj JN. Diagnosis of carpal ligament injuries. In: Trumble TE, editor. Carpal fracture-dislocations. Rosewood, IL: American Academy of Orthopaedic Surgery; 2002. p. 21.
51. Black DM, Watson HK, Vender MI. Scapholunate gap with scaphoid nonunion. Clin Orthop. 1987;224:205–9.
52. Monsivais JJ, Nitz PA, Scully TJ. The role of carpal instability in scaphoid nonunion: casual or causal? J Hand Surg Am. 1986;11B: 201–6.
53. Vender MI, Watson HK, Black DM, et al. Acute scaphoid fracture with scapholunate gap. J Hand Surg Am. 1989;14:1004–7.
54. Short WH, Werner FW, Green JK, et al. Biomechanical evaluation of ligamentous stabilizers of the scaphoid and lunate. J Hand Surg Am. 2002;27A:991–1002.
55. Short WH, Werner FW, Green JK, et al. Biomechanical evaluation of the ligamentous stabilizers of the scaphoid and lunate. Part II. J Hand Surg. 2005;30A:24–34.
56. Short WH, Werner FW, Green JK, et al. Biomechanical evaluation of the ligamentous stabilizers of the scaphoid and lunate. Part III. J Hand Surg Am. 2007;32A:297–309.
57. Berdia S, Short WH, Werner FW, et al. The hysteresis effect in carpal kinematics. J Hand Surg Am. 2006;31:594–600.
58. Elsaidi GA, Ruch DS, Kuzma GR, et al. Dorsal wrist ligament insertions stabilize the scapholunate interval: cadaver study. Clin Orthop Relat Res. 2004;425:152–7.
59. Blevens AD, Light TR, Jablonsky WS, et al. Radiocarpal articular contact characteristics with scaphoid instability. J Hand Surg Am. 1989;14A:781–90.
60. Watson HK, Ballet FL. The SLAC wrist. Scapholunate advanced collapse pattern of degenerative arthritis. J Hand Surg Am. 1984;9A:356–65.
61. Watson HK, Ryu J. Evolution of arthritis of the wrist. Clin Orthop. 1986;202:57–67.
62. Geissler WB, Freeland AE, Savoie 3rd FH, et al. Intracarpal soft tissue lesions associated with intra-articular fracture of the distal end of the radius. J Bone Joint Surg. 1996;78A:357–65.
63. Shin AY, Murray PM. Biomechanical studies of wrist ligament injuries. In: Trumble TE, editor. Carpal fracture-dislocations. Rosewood, IL: American Academy of Orthopaedic Surgery; 2002. p. 14.
64. Horii E, Garcia-Elias M, An KN, et al. A kinematic study of lunotriquetral dissociations. J Hand Surg Am. 1991;16A:355–62.
65. Viegas SF, Patterson RM, Peterson PD, et al. Ulnar sided perilunate instability: an anatomic and biomechanical study. J Hand Surg Am. 1990;15A:268–77.
66. Reagan DS, Linscheid RL, Dobyns JH. Lunotriquetral sprains. J Hand Surg Am. 1984;9:502–14.

67. Ritt MJ, Linscheid RL, Cooney WP, et al. Lunotriquetral ligament properties: the lunotriquetral joint: kinematic effects of sequential ligament sectioning, ligament repair, and arthrodesis. J Hand Surg Am. 1998;23A:432–45.
68. Taleisnik J. Triquetrohamate and triquetrolunate instabilities (medial carpal instability). Ann Chir Main. 1984;3:331–43.
69. Garcia-Elias M, Dobyns JH, Cooney 3rd WP, et al. Traumatic axial dislocations of the carpus. J Hand Surg Am. 1989;14A:446–57.
70. Freeland AE, Rojas SL. Traumatic combined radial and ulnar axial wrist dislocation. Orthopedics. 2002;245:1161–3.
71. Lichtman DM. Understanding midcarpal instability. J Hand Surg Am. 2006;31A:491–8.
72. Lichtman DM, Schneider JR, Swatford AR, et al. Ulnar midcarpal instability—clinical and laboratory analysis. J Hand Surg Am. 1981;6A:515–23.
73. Garth Jr WP, Hoffamann DY, Rooks MD. Volar intercalated instability secondary to medial carpal ligament laxity. Clin Orthop. 1985;201:94–105.
74. Aspergis EP. The unstable capitolunate and radiolunate joints as a source of wrist pain in young women. J Hand Surg Am. 1996;21B:501–6.
75. Trimble T, Bour CT, Smith RJ, et al. Kenematics of ulnar carpus related to the volar intercalated segment instability pattern. J Hand Surg Am. 1990;15A:384–92.
76. Louis DS, Hankin FM, Greene TL. Chronic capitolunate instability. J Bone Joint Surg. 1987;69A:950–1.
77. Johnson RP, Carrera GF. Chronic capitolunate instability. J Bone Joint Surg. 1986;68A:1164–76.
78. Hankin FM, Amadio PC, Wojtys EM, et al. Carpal instability with volar flexion of the proximal row associated with injury to the scapho-trapezial ligament: report of two cases. J Hand Surg Am. 1988;13B:298–302.
79. Graham TJ. The inferior arc injury: an addition to the family of complex carpal fracture-dislocation patterns. Am J Orthop (Belle Mead NJ). 2003;32(9 Suppl):1–19.
80. Rayhack JM, Linscheid RL, Dobyns JH, Smith JH. Posttraumatic ulnar translocation of the carpals. J Hand Surg Am. 1987;12A:180–9.
81. Allieu Y, Garcia-Elias M. Dynamic radial translation instability of the carpus. J Hand Surg Am. 2000;25B:33–7.
82. Freeland AE, Ferguson CA, McCraney WO. Palmar radiocarpal dislocation resulting in ulnar radiocarpal translocation and multidirectional instability. Orthopedics. 2006;29:604–8.
83. Siegel DB, Gelberman RH. Radial styloidectomy: an anatomic study with special reference to radiocarpal intracapsular ligamentous morphology. J Hand Surg Am. 1991;16A:40–4.
84. Moneim MS, Bolger JT, Omer GE. Radiocarpal dislocation-classification and rationale for management. Clin Orthop. 1995;192:199–209.

10 Management of Scapholunate Ligament Pathology

Mark Ross, William B. Geissler, Jeremy Loveridge, and Gregory Couzens

Introduction

Management of pathology involving the scapholunate ligament complex presents a number of unique challenges. These challenges are derived not only from difficulty in defining the temporal, structural, and biomechanical nature of such pathology, but also from the lack of uniformly good outcomes from a wide variety of existing surgical treatments.

Initially arthroscopy offered the capacity to directly visualize interosseous ligaments within the wrist and even a dynamic evaluation of some intercarpal relationships. A partial tear of the SLIL may be difficult to detect with imaging studies, but is identifiable arthroscopically. In addition arthroscopy allows the assessment of the status of articular cartilage, with greater accuracy than imaging techniques, for planning therapeutic intervention. It continues to remain the gold standard for diagnosis [1, 2]. Improvements in resolution and scanning protocols have seen improved diagnostic utility from Magnetic Resonance Imaging (MRI).

Nevertheless, the utility of wrist arthroscopy has been extended to facilitate treatment options for SL ligament pathology beyond diagnosis.

The indications for wrist arthroscopy continue to expand from Whipple's original description [3] as new techniques and instrumentation develop. Further advances in instrumentation, such as electrothermal shrinkage and pathology specific arthroscopic drill guides, will continue to play a role in the management of pathology of the SLIL.

M. Ross, M.B.B.S., F.R.A.C.S. (Orth) (✉) • J. Loveridge, M.B.B.S., F.R.A.C.S. (Orth) • G. Couzens, M.B.B.S., F.R.A.C.S. (Orth)
Brisbane Hand and Upper Limb Research Institute, 9/259 Wickham Terrace, Brisbane 4000, QLD, Australia
e-mail: research@upperlimb.com; markross@upperlimb.com; jloveridge@drs.org.uk; greg.couzens@upperlimb.com

W.B. Geissler, M.D.
Department of Orthopaedic Surgery and Rehabilitation, University of Mississippi Medical Center, Jackson, MS, USA
e-mail: 3doghill@msn.com

Anatomy

Improved understanding of the biomechanics of the carpus and their dynamic relationships has altered the conceptualization of the SL interface. We have moved from considering the SLL in isolation to considering it one component of the "SL ligament complex" (SLLC) that involves both intrinsic and extrinsic ligamentous components [4]. The intrinsic portion of the SLLC includes the palmar, central membranous, and dorsal portions. The dorsal portion appears to be the primary biomechanical functioning component of the interosseous ligament. It is composed of stout transverse fibers to resist rotation. The volar portion of the interosseous ligament is comprised of longer oblique fibers that allow for sagittal rotation. The central membranous portion of the ligament frequently demonstrates perforations, which increase in frequency with age [4, 5].

The extrinsic components include the volar radioscaphocapitate, long radiolunate, and short radiolunate ligaments on the volar aspect [6]. Further secondary stabilizers of the SL interval include the capsule of the scapho-trapezo-trapezoid (STT) joint and the dorsal intercarpal (DIC) ligament [7, 8].

Radiographic abnormalities may not be seen initially until attenuation or failure of the extrinsic stabilizers occurs. This may result in delayed detection of SL pathology on plain radiographs.

Pathomechanics/Mechanism of Injury

Injury is usually caused by a fall onto the outstretched wrist resulting in a dorsiflexion injury. Wrist extension and carpal supination are the primary mechanisms of injury to the SLL. Similar to other ligamentous injuries in the body, the interosseous ligament may stretch and eventually tear. The SL ligament may double in length prior to failure. Mayfield has shown the percent elongation to failure to be up to 225 % [9]. A spectrum of injury is seen to the SLL itself. An isolated injury to the SLL may not yield SL disassociation or widening

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*, DOI 10.1007/978-1-4614-1596-1_10, © Springer Science+Business Media New York 2015

on plain radiographs. However, a combined injury to both the intrinsic and extrinsic ligaments will usually cause SL diastasis [10]. The difficulty is that there is a paucity of natural history studies that define the evolution of either acute or chronic SL pathology. Although some patients present with the typical history of a hyperextension injury to the wrist, other patients may not recall an acute injury in a fall, but rather a "popping" or giving way sensation on heavy lifting, or even no history of injury at all. Many patients who present with an established Scapholunate Advanced Collapse (SLAC) wrist do not recall any history of acute injury. It is clear that there is a complex interplay between acute traumatic disruptions, serial lesser injuries, and attenuation over time from subclinical events.

Assessment

History

A history of acute dorsiflexion injury should raise concern about injury to the SLLC. Patients may present with dorsal wrist pain and giving way or mechanical symptoms without a history of serious acute injury.

Examination

Physical examination reveals localized tenderness directly over the dorsum of the SL interval. The principle provocative maneuver to assess SL instability is the "scaphoid shift test" [7]. This test evaluates motion of the scaphoid during radial deviation and wrist flexion while pressure is applied to the tubercle of the scaphoid in a volar to dorsal direction. Partial tears to the SLL may produce pain directly over the dorsum of the SL interval with no palpable click. Pain over the scaphoid tubercle when palpated is not clinically significant. A complete tear of the SLL results in subluxation of the proximal pole of the scaphoid over the dorsal lip of the distal radius. When this occurs, a palpable shift or click is felt. Both the injured and noninjured wrist should be assessed with the scaphoid shift test to evaluate for inherent laxity, particularly in individuals with a classified generalized ligamentous laxity [11]. The radiocarpal joint may be injected with local anesthetic to evaluate for potential shift if pain prevents performance of the test.

Imaging

Plain Radiographs

Radiographs are essential at the initial evaluation to assess the SL articulation. It should be stressed from the outset that all radiographic views may only be definitely interpreted when compared with the opposite side. Standard radiographic views include the postero-anterior view in ulnar deviation; an oblique, true lateral; and clenched-fist views.

In the PA view, three smooth radiographic arcs may be drawn to define normal carpal relationships [12]. A step off in the continuity of any of these arcs indicates an intercarpal instability at the site where the arc is broken. Any overlap between the carpal bones or any joint width exceeding 4 mm strongly suggests carpal ligamentous injury. A standardized clenched-fist view in 30° ulna deviation has been shown to yield the widest diastasis in ruptured SLL injuries [13].

A "Terry-Thomas" sign is considered present when the space between the scaphoid and lunate appears abnormally wide as compared to the opposite wrist [14]. The SL interval should be measured in the middle of the flat medial facet of the scaphoid. Less than 3 mm is considered normal, 3–5 mm is suspicious and any asymmetric SL gap greater than 5 mm is said to be diagnostic of SL dissociation [15]. The scaphoid ring sign occurs when the scaphoid has collapsed into flexion and has a foreshortened appearance on a PA radiograph. The ring sign is present in all causes of scaphoid flexion, regardless of the etiology [16]. Therefore, the presence of a scaphoid ring sign does not necessarily indicate instability of the SL interval.

In lateral radiographs, the SL angle is defined by a line tangential to the two proximal and distal convexities of the palmar aspect of the scaphoid. The angle formed by this line and a line through the central axis of the lunate determines the SL angle. Normal values range between 30° and 60°, with an average of 47°. Angles greater than 80° are strongly indicative of SL instability [16]. Assessment of the radiolunate and capitolunate angles may also give an assessment of the degree of intercalated segment instability.

On the lateral radiograph, concentricity between the arc of the proximal pole of the scaphoid and the scaphoid facet of the radius is usually seen. When there is carpal instability dorsal translation of the proximal pole is seen with loss of this concentric relationship. Subtle manifestation of this altered relationship may be identified on sagittal plane high-resolution MRI scanning before plain radiographic abnormality is identified.

Assessing the contralateral side radiographically for comparison is useful. In addition the sensitivity of plain radiographs may be increased by performing so-called "dynamic views." There are a variety of views described. Although not truly dynamic these static stress views look at changes in carpal alignment with specific wrist positioning and with load from grip. Flexion and extension lateral views and radial/ulnar deviation PA views are most frequently suggested and a standardized clenched-fist pencil view in 30° ulna deviation has been shown to yield the widest diastasis in ruptured SLIL injuries [13, 17].

Fluoroscopy

True dynamic assessment of carpal motion and intercarpal relationships can be achieved with the use of fluoroscopy.

Ultrasound

Ultrasound has been used for assessment of SLL injury. It offers the possibility to assess the pathology dynamically in real time. The SLL and proximal pole of the scaphoid are identified and ultrasound is performed in the transverse and longitudinal planes. The wrist is scanned in ulna and radial deviation, the clenched-fist view, and resisted extension. Ultrasound scans can show osteophytes, a joint effusion, bulging of the SLL, and a degenerate capsule. The technique and the interpretation of the findings can be difficult especially due to the variations in anatomy and kinetics. Its main role is probably to complement clinical examination and other imaging studies. It has the potential to show subtle rotatory instability of the scaphoid [18].

Dao et al. in 2004 reported on the efficacy of ultrasound for evaluating dynamic SL ligament instability and compared it to Arthroscopy [18]. Of the 64 wrists analyzed, ultrasound had a low sensitivity of 46.2 %, a high specificity of 100 %, and an accuracy of 89.1 %. The authors recommended its use as an adjunct to other diagnostic modalities for this purpose [18].

Taljanovic et al. in 2008 described the use of ultrasound for assessment of SL ligaments and its correlation with MR and MRA. For the SL ligament, the results were concordant for all imaging modalities in 15, partially concordant in 3 (18.75 %), and discordant in 1 (6.25 %). The arthroscopic and imaging findings were concordant for three SL ligaments [19].

The preliminary results are encouraging. Sonography may be used at least as a screening imaging modality in evaluation of the SL ligament.

MRI

Patients who are suspected clinically of having a SLL injury, but whose radiographs are normal should undergo MRI scanning of the injured wrist with interpretation by an experienced radiologist. The SL ligament can be challenging to assess on MRI.

High-resolution MR imaging using 3.0 T magnetic strength is optimal for definitively demonstrating the three components of the SL ligament (dorsal, volar, and membranous components) and their integrity [20].

High-resolution MRI of the SL ligament is best performed on a 3 T magnet with a dedicated 8ch or 16ch wrist coil. It is also accepted that interpretation of the MRI should be completed by a radiologist with expertise in wrist imaging [20]. In the unit of two of the senior authors (MR, GC) high-resolution noncontrast MRI is performed on a Siemens 3 T Verio platform using the Invivo 8ch wrist coil. Patients are positioned with the arm above their head while lying prone in the scanner i.e. “Superman position” [20]. The reason for this is that this position is at the isocentre of the magnet providing the best Signal to Noise Ratio possible. Two mm slice axial views are performed from the proximal radius and ulna to distal to the capitate. Direct coronal views of the wrist are obtained with the slice orientation parallel to the anterior border of the distal radius and ulna. Sagittal views are obtained with the slice orientation perpendicular to the wrist joint. Proton density scans with fat suppression are used. A T1 coronal sequence with 2 mm slices and a 3D axial gradient echo sequence with 0.5 mm slices are also performed.

Fig. 10.1 Dorsal scaphoid translation and cartilage loss on proximal scaphoid on sagittal plane MRI

High-resolution coronal, and axial images delineate whether the dorsal or volar fibers are intact. The intact dorsal band is well demonstrated on the most dorsal of the coronal plane slices that show scaphoid and lunate, with dark linear fibers being visible. Secondary signs of SLL rupture are seen with dorsal scaphoid translation in relation to the scaphoid facet of the radius and cartilage loss, which are best seen on the sagittal views (Fig. 10.1). Widening of the SL interval should not be an exclusive indication that the SLL has been ruptured, as it could still be intact, but redundant. Ganglia are often present with SLL tears, and visualization is best seen on T2 weighted scans with uniform fat suppression.

Computed Tomography

Recently Kakar described a novel imaging technique for 4D CT imaging (3D + time) which has promising clinical utility in accurately diagnosing SL instability [21]. 4D CT allows dynamic image data (4D movies) to be recorded whilst the patient moves their wrist through various movements including radial-ulnar deviation, flexion-extension, and dart thrower's motion.

Classification of SLL Pathology

This table summarizes the various methods of classifying SL ligament pathology and identifies what level of pathology each type of assessment can ascertain (Table 10.1). Various systems for classifying SLL pathology have been described, both temporally and structurally.

Temporal Classification

There is no clear consensus on what constitutes acute, subacute, and chronic injuries. Whichever criteria are used, the principle aim is to define the potential for healing of the native ligament.

Larsen et al. classified *carpal instability* in a temporal way. Acute was defined as less than a week old, subacute was defined as between 1 and 6 weeks, and chronic was described as more than 6 weeks old [22].

Geissler and Haley defined an acute injury as up to 3–4 weeks old. Subacute was defined as an injury more than 3–4 weeks old and up to 6 months old. A chronic injury was defined as symptoms present greater than 6 months [23].

The current trend has been to consider injuries as "chronic" at an earlier time point due to the observed poorer outcomes in terms of radiographic maintenance of SL gap after direct ligament repair, at relatively early intervals after the apparent index injury.

This lack of consensus as to what constitutes an acute injury means that algorithms for management based on temporal classification remain inconsistent.

Table 10.1 Classification of SLL pathology

Classification type	Description		
Temporal	Acute		
	Subacute		
	Chronic		
Structural	Imaging	Radiographs	Static radiographs—complete static dissociation
			Dynamic radiographs/fluoroscopy—complete dynamic dissociation
		MRI	Incomplete and partial • Dorsal band • Membranous • Volar band
			Complete—dynamic or static
	Arthroscopic	Geissler classification	See Table 10.2 for detail
	Operative	Incomplete	
		Complete	Dynamic
			Static • Reducible • Irreducible

Clinical Examination Classification Systems

Clinically we can define four types of instability: (1) predynamic instability; (2) dynamic instability; (3) reducible static instability; (4) nonreducible instability [24]. Predynamic instability was initially termed by Kirk Watson [7] and applies to instability that may be observed clinically on physical examination but not by radiographic studies, and corresponds to a Geissler grade I or II instability [23]. Dynamic SL instability is applied to a complete SL ligament tear, but the secondary scaphoid stabilizers remain intact [25]. SL instability can be observed radiographically under loaded conditions or in specific wrist positions, "clenched fist" or loading the wrist in ulnar deviation. Static reducible SL dissociation occurs when the ligament tear is chronic and irreparable; the secondary stabilizers are insufficient and a DISI deformity results; carpal subluxation is reducible [24].

Structural Classification

A structural classification can be based on imaging studies, or arthroscopic or open operative evaluation. Imaging studies may be static X-ray films, stress/positional radiographs, fluoroscopy, ultrasound, or MRI.

Arthroscopic Structural Classification

The key to treatment of SL ligament complex pathology is recognition of what is normal and what is pathological anatomy. Both the radiocarpal and midcarpal spaces must be evaluated arthroscopically when carpal instability is suspected. Wrist arthroscopy is usually not considered complete if the midcarpal space has not been evaluated, particularly with a suspected diagnosis of carpal instability.

The SLL is best visualized with the arthroscope in the 3-4 portal. It should have a concave appearance as viewed from the radiocarpal space (Fig. 10.2). In the midcarpal space, the SL interval should be tight and congruent without any step-off (Fig. 10.3). This is in contrast to the lunotriquetral (LT) interval, in which a 1-mm step off occasionally is seen which is considered normal and slight motion is seen between the lunate and triquetrum. When it tears, the SLIL hangs down and blocks visualization with the arthroscope in the radiocarpal space from the 3-4 portal. The normal concave appearance between the carpal bones becomes convex. However, the degree of rotation of the carpal bones and any abnormal motion or separation is best appreciated from the unobstructed view available in the mid-carpal space.

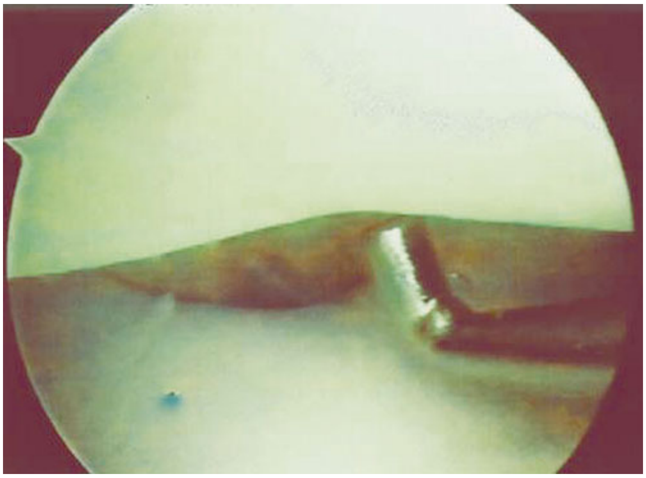


Fig. 10.2 Arthroscopic view of the normal concave appearance of the SLIL as seen from the 3-4 portal in the radiocarpal space

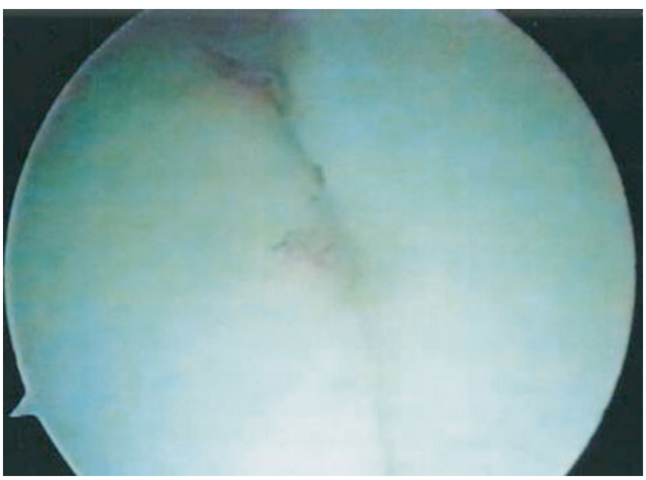


Fig. 10.3 Arthroscopic view of the normal, tight, congruent SL interval as seen from the midcarpal space

A spectrum of injury to either the SL or LT interosseous ligament is possible. The interosseous ligament appears to attenuate and then tear from volar to dorsal. Geissler devised an arthroscopic classification of carpal instability and suggested management of acute lesions to the interosseous ligament (Table 10.2) [23, 25]. The management options as listed from this original article have evolved as the understanding of the compromise of ligament healing potential over time has changed.

In *Grade I* injuries, there is loss of the normal concave appearance of the scaphoid and lunate as the interosseous ligament bulges with the convex appearance (Fig. 10.4). Evaluation of the SL interval from the midcarpal space shows the SL interval still to be tight and congruent. These mild Grade I injuries usually resolve with simple immobilization.

In *Grade II* injuries, the interosseous ligament bulges similarly to grade I injuries as seen from the radiocarpal space. In the midcarpal space, the SL interval is no longer congruent. The scaphoid flexes and its dorsal lip is rotated distal to the lunate (Fig. 10.5). This can be better appreciated with the arthroscope placed in the ulnar midcarpal portal looking across the wrist to assess the wrist to assess the amount of flexion to the scaphoid. This is analogous to the dorsal translation of the proximal pole of the scaphoid that can be identified on sagittal plane MRI imaging (Fig. 10.1).

In *Grade III* injuries, the interossesous ligament starts to separate, and a gap is seen between the scaphoid and lunate from both the radiocarpal and midcarpal space. A 1 mm probe may be passed through the gap and twisted between the scaphoid and lunate from both the radiocarpal and midcarpal spaces (Fig. 10.6). Sometimes the gap between the scaphoid and lunate is not visible until the probe is used

Table 10.2 Geissler arthroscopic classification of carpal instability

Grade	Description	Management
I	Attenuation/hemorrhage of interosseous ligament as seen from the radiocarpal joint. No incongruency of carpal alignment in the midcarpal space	Immobilization
II	Attenuation/hemorrhage of interosseous ligament as seen from the radiocarpal joint. Incongruency/step-off as seen from the midcarpal space. A slight gap (less than width of probe) between carpals may be present	Arthroscopic reduction and pinning
III	Incongruency/step-off of carpal alignment is seen in both the radiocarpal and mid carpal space. The probe may be passed through gap between carpals	Arthroscopic/open reduction and pinning
IV	Incongruency/step-off of carpal alignment is seen in both the radiocarpal and mid carpal space. Gross instability with manipulation is noted. A 2.7 mm arthroscope may be passed through the gap between carpals	Open reduction and repair

Based on data from [25]

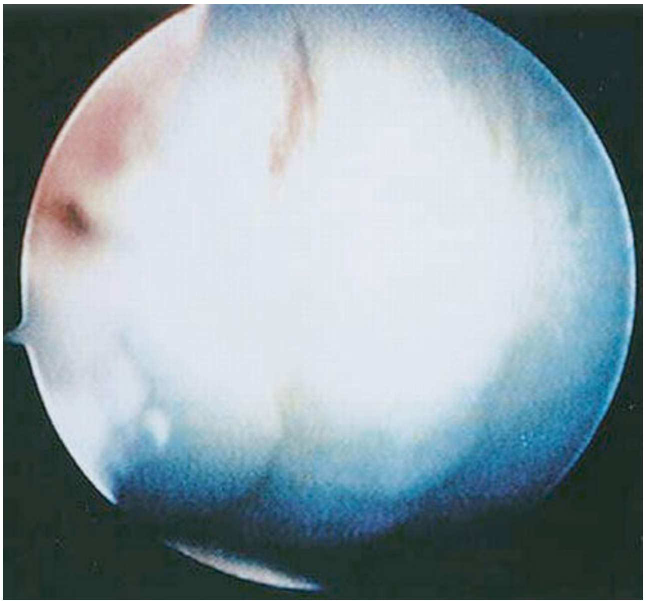


Fig. 10.4 Arthroscopic view of a Grade I interosseous ligament injury to the SLIL as seen from the 3-4 portal in the radiocarpal space. Note that the normal concave appearance at the SL interval has now become convex

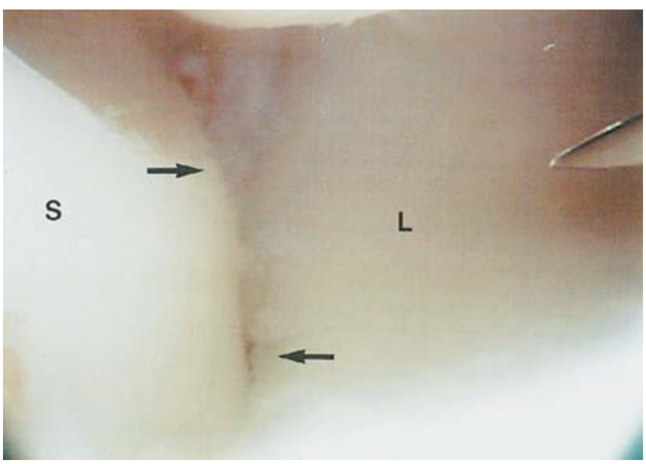


Fig. 10.5 Arthroscopic view of a Type II SLIL injury as seen from the radial midcarpal space. The dorsal lip of the scaphoid is no longer congruent with the lunate as it is palmar flexed. (*S* scaphoid, *L* lunate)

to push the scaphoid away from the lunate. A portion of the dorsal SLIL may still be attached.

In *Grade IV* injuries, the interosseous is completely torn, and a 2.7 mm arthroscope may be passed freely from the midcarpal space to the radiocarpal space between the scaphoid and lunate (the drive-through sign) (Fig. 10.7). This corresponds to the widened SL gap seen on plain radiographs with a complete SL dissociation.

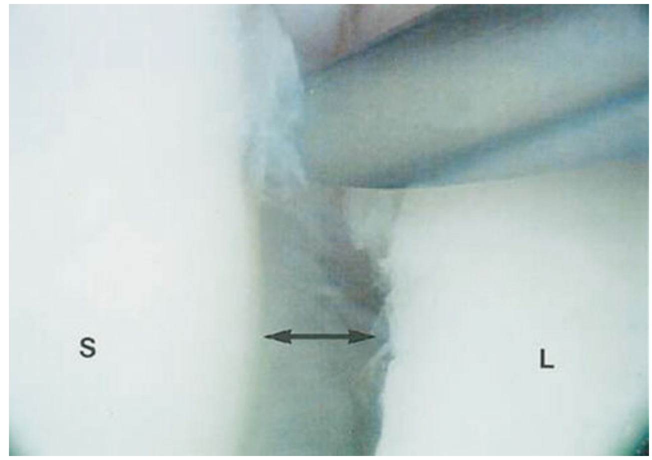


Fig. 10.6 Arthroscopic view of a Type III SLIL tear as seen from the radial midcarpal space. Note the gap between the scaphoid and lunate (*S* scaphoid, *L* lunate)

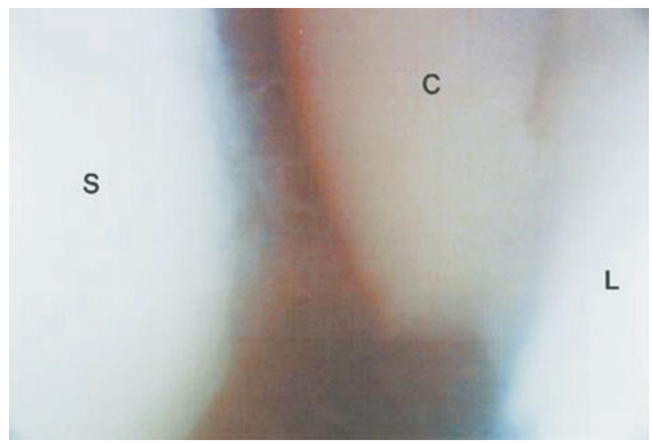


Fig. 10.7 Arthroscopic view of a Type IV SLIL tear. The scaphoid and lunate are completed separated, and the arthroscope may pass freely between the radiocarpal and midcarpal spaces. The capitate is seen between the SL intervals (*S* scaphoid, *L* lunate, *C* capitate)

Radiographic Structural Classification

Incomplete/Partial Rupture: Dorsal, Membranous, Volar Band

Partial rupture—usually only the palmar band of ligament is ruptured or occasionally only the dorsal segment is ruptured.

Static and dynamic radiographs are usually normal. Chronicity of the injury and partial healing may also be identified with high-resolution MRI scanning. Dorsal translation of the proximal pole relative to the facet of the radius may be identified on sagittal plane MRI images in spite of normal static plain radiographic alignment and may be an early indicator of functionally more significant partial injury. Early chondral loss on the proximal pole may also be identified on MRI before plain radiographic abnormality.

Complete Rupture: Static vs. Dynamic

Static vs. Dynamic dissociation is best identified by comparing static vs. stress radiographs, or by fluoroscopy.

1. Complete rupture—dynamic—All components of SLIL are ruptured but the extrinsic ligaments/secondary stabilizers are usually intact. Static plain radiographs may be normal but there is disruption of normal relationships on stress radiographs.
2. Complete rupture—static—Complete SL ligament rupture and extrinsics also injured and static plain radiographs demonstrate widened SL interval on PA radiographs and increased SL angle on the lateral radiographs (modified by Watson) [26].

Static Reducible vs. Static Irreducible

This is determined intraoperatively. Static deformity is present on resting plain radiographs. It may be easily reducible during surgery to repair or reconstruct the SLIL. When deformity is not reducible intraoperatively salvage options should be utilized. This usually follows a temporal relationship with the more chronic ruptures leading to a static deformity, which may then become irreducible.

Treatment

Correct classification of the injury can assist in selection of appropriate treatment options. Nonetheless the greatest challenge is that there is no consensus on which surgical treatment option should be undertaken. Various options exist including pinning, repair, capsulodesis, and reconstruction and each have been applied to virtually all grades of injury. Moreover, surgical interventions can be either open or arthroscopic.

The authors have defined a unified classification system for treatment options of SL ligament complex pathology (Table 10.3).

Closed Pinning: Image Intensifier or Arthroscopically Guided

This surgery may be appropriate for acute lower grade injuries.

The wrist is evaluated arthroscopically for direct visualization of SLL injury and indirect evidence of disordered intercarpal mechanics. Arthroscopic assessment is achieved through the preferred means of arthroscopy and traction. The wrist may be suspended at approximately 10 lbs of traction

Table 10.3 Classification system for treatment options for SL pathology

Treatment options		
Closed pinning	Fluoroscopic guided	
	Arthroscopic guided	
Open repair and pinning		
Capsulodesis, capsulorrhaphy and partial repair	Arthroscopic—volar or dorsal	"Abrasion" capsulorrhaphy
		Shrinkage
		Suture
	Open	Dorsal—Blatt/reverse Blatt (often adjunct to open repair or reconstruction)
Reconstruction: defined as an attempt to re-establish a soft tissue relationship between scaphoid and lunate ± stabilisation through other soft tissue augmentation)	Local tissue	Dorsal intercarpal ligament
	RASL (arthroscopic or open)	
	Free tissue grafts—"Bone–Tissue–Bone"	Bone–Retinaculum–Bone
		Hand/wrist graft options
		Foot/tarsal graft options
		Other tissue
	Tendon grafts	Brunelli
		Three ligament tenodesis
		Scapholunate axis method
		Scapho-luno-triquetral tenodesis
Salvage	PRC [59]	
	Partial fusion (arthroscopic or open)	Four-corner fusion ±e/o scaphoid
		Radio-scapho-lunate fusion
		Capitolunate fusion
		STT fusion
	Total wrist fusion	

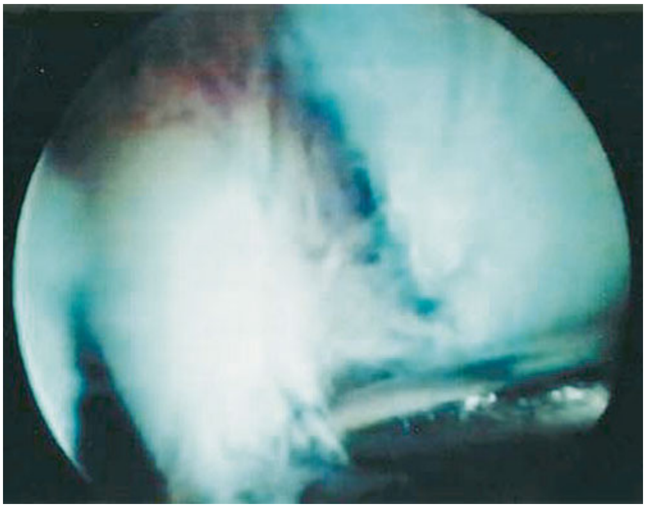


Fig. 10.8 Arthroscopic view of a Type II SLIL tear as seen from the 3-4 portal in the radiocarpal space. A probe is used to palpate the interosseous ligament and the separation which was not initially noted, is identified

in a traction tower [27, 28]. Alternately traction may be applied with the forearm horizontal using a variety of traction devices [28, 29]. The 3-4 portal is the most ideal viewing portal for visualization of the SLL. A working 4-5 or 6-R portal is also used. The wrist is systematically evaluated from radial to ulnar. The SL interval is probed. The degree of injury may not be fully appreciated until the tear is palpated with a probe (Fig. 10.8). Torn fibers of the SLL, if present, are then debrided with the arthroscope in the 6-R portal, and a shaver inserted into the 3-4 portal. A probe is inserted into the SL interval to note particularly any gap between the scaphoid and lunate. Following arthroscopic debridement of a torn SLL from the radiocarpal space, the midcarpal space is then evaluated. The arthroscope is initially placed in the radial midcarpal space. Close attention is paid to any rotational displacement of the scaphoid with the dorsal lip being rotated distal to that of the lunate. This may be best visualized with the arthroscope placed in the ulnar midcarpal portal. Also, any gap where the probe or arthroscope itself can be passed between the scaphoid and lunate is identified. If this is achieved easily then there are serious doubts as to whether closed pinning is appropriate [28].

Patients with a Grade II lesion may be most ideally suited for arthroscopic-assisted reduction and pinning although efficacy of this treatment must me be interpreted in the context of the interval since injury, which will affect the healing potential. Alternate treatment options with arthroscopic capsular abrasion or shrinkage have also been advocated for Grade II pathology particularly in more chronic injury and will be discussed later. Use of closed pinning for Grade III injuries is difficult to justify based on current literature.

For arthroscopic pinning the arthroscope is placed in the 3-4 portal after the midcarpal space has been evaluated in patients who have an acute or perhaps subacute Grade II SLIL injury. A 0.045 Kirschner wire (k-wire) is inserted through a soft tissue protector or through a 14-G needle placed dorsally in the anatomic snuff-box to the scaphoid. A soft tissue protector may be used in order to avoid injury to the sensory branches of the radial nerve. A small incision is made, and blunt dissection is continued down with a hemostat; a soft tissue protector may be placed directly on the scaphoid.

The k-wire can then be seen as it enters the scaphoid with the surgeon looking down the radial gutter with the arthroscope. In an easier alternative technique, the wrist is taken out of traction and the k-wires can be positioned under fluoroscopic control. If there is concern regarding the reduction then placing the arthroscope in the ulnar mid-carpal portal during stabilization allows the surgeon to look across the wrist to better judge the rotation of the scaphoid in relation to the lunate.

Additionally, a probe may be inserted through the radial midcarpal space to control the palmar flexion of the scaphoid. The wrist may be extended and ulnar deviated to help further reduce the palmar flexion of the scaphoid. After the first wire is placed controlling the reduction, an additional wire may be placed in the SL interval. Placement of wires between scaphoid and capitate remains controversial. A scapho-capitate wire gives excellent control of scaphoid rotation but some authors have questioned the advisability of violating the uninjured scapho-capitate articulation. In addition, immobilization of the midcarpal joint through scapho-capitate wires may be considered undesirable in the context of renewed interest in the “Dart throwing” plane of motion.

The k-wires are best buried under the skin as this avoids secondary infection and need for premature removal. The wrist is immobilized in a below elbow thermoplastic splint. Gentle inner range radiocarpal flexion-extension range of motion exercise is usually possible, as restricted by the wires. The k-wires are then removed in theater after 6–8 weeks. Grip strength exercises for the wrist are initiated at 3 months.

Treatment for patients with Grade III and Grade IV injuries to the SLL, either acute, subacute, or chronic remains unclear. Results of closed treatment for higher-grade injuries have largely been unsatisfactory [30] and the dichotomy between repair and reconstruction has remained difficult to clarify. There has undoubtedly been a trend toward earlier adoption of reconstruction for higher-grade injuries.

Whipple reviewed the results of arthroscopic management of SL instability, utilizing the previously described techniques in patients who were followed for 1–3 years [31]. In his series, patients were classified into two distinct groups of 40 patients each, according to the duration of symptoms and the radiographic SL gap. Thirty-three patients (83 %)

who had a history of instability for 3 months or less and had less than 3 mm side-to-side difference in the SL gap had maintenance of the reduction and symptomatic relief. When symptoms were present for greater than 3 months and there was more than a 3 mm side-to-side SL gap only 21 patients (53 %) had symptomatic relief following arthroscopic reduction and pinning. Patients with less than 3 months symptoms duration and 3 mm side-to-side SL gap were followed for 2–7 years. Whipple found that 85 % continued to maintain their stability and comfort in his series. This report emphasized the need for early diagnosis and intervention prior to the onset of fixed carpal alignment and diminished capacity for ligamentous healing.

Open Repair and Pinning

Patients with acute Grade III and Grade IV injuries to the SLIL are best treated with open repair or reconstruction. The efficacy of direct repair remains controversial; however, there is little doubt that the trend is toward earlier adoption of reconstructive techniques rather than direct repair due to the strong impression that complete ruptures lose the capacity for primary healing very soon after injury. The critical interval has not been defined and indeed it may be that once a complete rupture of the SLIL has occurred the potential for healing may be compromised. Furthermore the tear morphology may influence the healing potential. When the ligament is avulsed from either the scaphoid or lunate, it may have a greater capacity to heal than a midsubstance rupture. Prior to arthrotomy, the wrist is evaluated arthroscopically for any additional injuries, including potential cartilaginous loose bodies, triangular fibrocartilage complex tears, and possible injury to the LT interosseous ligament. Open repair is undertaken through a dorsal 3-4 extensor compartment approach. A Berger ligament sparing arthrotomy [32] is preferred by the authors. It is essential that an intraoperative assessment is made as to the healing potential of the residual ligament and alternate reconstructive or salvage procedures undertaken if the residual ligament is of poor quality or there is concern regarding the cartilage surfaces of the carpus and radius.

Capsulodesis, Capsuloraphy, and Partial Repair

Restraint of scaphoid flexion has long been identified as a desirable intervention in the treatment of SL pathology [33–35]. The dorsal subluxation of the proximal scaphoid and loss of congruence of the distal pole in relation to the radial styloid have long been considered the principal initial biomechanical abnormalities requiring intervention. Procedures that restrict scaphoid flexion have been advocated as an alternative to repair or reconstruction. There is no consensus as to when such alternate stabilizing procedures should be undertaken in preference to repair or other reconstructive options.

Arthroscopic Techniques for Capsulodesis, Capsuloraphy, and Partial Repair

Abrasion Capsulodesis

Although not previously reported in the literature, a new surgical technique receiving attention is abrasion capsulodesis. Although alternative arthroscopic capsular tightening has been reported with thermal shrinkage there are some concerns given the adverse experience of thermal techniques in the shoulder. Although there have not been reports of similar problems in the wrist, abrasion of the dorsoradial capsule has been considered as a safer alternative. In lower grade injuries this may improve stability by inciting a scar reaction with an increase in the extrinsic restraint to scaphoid flexion. The dorsal radial capsule is abraided with a chondrotome blade to stimulate a scar reaction. Consideration may be given to temporary k-wire pinning (either SL or scapho-capitate) to prevent scaphoid flexion, and flexion is usually restricted for 4–6 weeks with a thermoplastic splint. This technique is currently being studied in a prospective cohort by Ross and colleagues in Brisbane.

Arthroscopic Dorsal Capsular Thermal Shrinkage

Thermal capsular shrinkage using a thermal probe has been suggested in the treatment of Grade 2 injuries [36]. Although this technique demonstrated a number of unsatisfactory results in treatment of anterior shoulder instability, it has been argued that the wrist capsule behaves differently and that it is easier to immobilize the wrist and allow adequate healing.

In Geissler grade 1 and 2 SL instability, Danoff et al. in a small series have used arthroscopic thermal capsular shrinkage [37]. Using the fact that collagen shrinks with heat, nonablative thermal energy was also applied to the palmar SLIL in predynamic instability to effectively tighten up the ligament. Seven of eight patients had improved pain and preserved mobility, one patient failed this treatment and progressed to fusion**.**

Darlis et al. performed arthroscopic debridement and capsular shrinkage on 16 patients with 14 reported good to excellent results (8 of those pain free) and 2 failures [38]. Similarly, Hirsh et al. reported on a cohort of ten patients with 90 % pain free at an average follow-up of 28 months [39]. In contrast, Geissler reported on his findings in the management of 19 patients with chronic partial tears of the SLL (Geissler Grade II or III) or LT tears [36]. He reported variable results from poor to excellent using the Mayo wrist score at 6–22 months post-operation. Grade II tears appeared to have better results than Grade III injuries. However, as these are preliminary studies with small samples, no firm conclusions can be drawn.

Arthroscopic Suture Capsulorrhaphy, Capsulodesis, or Partial Repair

In the circumstance where complex open reconstruction is considered undesirable then arthroscopic reconstruction of chronic tears may be considered.

Mathoulin et al. describe an arthroscopic dorsal capsule-ligamentous repair for chronic reducible SL ligament tears [40, 41]. The technique involves passing a 3/0 PDS suture through a needle visualized arthroscopically and passed into the remnants of ligament and capsule between the scaphoid and lunate at the distal capsular reflection of the SLL and then tied to form a capsuloplasty. In his series of 36 patients with a mean 13-month follow-up, the results of the technique were generally excellent. The main advantage of the technique appeared to be the reduction in postoperative stiffness related to minimizing the dorsal capsular dissection needed during conventional surgical exposure with open techniques and hence the minimizing of scar tissue. Patient's pain scores were generally excellent, they regained 96 % grip strength compared to the contralateral side and seven of the sports persons were able to return to the same level of sport postoperatively.

Del Pinal et al. [42] describe an all inside technique for arthroscopic suturing of the volar SL ligament. This technique used sutures introduced volarly via a Tuohy needle to plicate the volar ligament remnants and the long radiolunate ligament. Although this appears a favorable procedure, the technique had been applied to four patients with minimal follow-up reported, hence no meaningful conclusions for this technique can be made.

Recently, van Kampen and Moran reported on a new technique of a volar capsulodesis used to reconstruct the volar SLL using a portion of the long radiolunate ligament [43]. Although only results from a preliminary cadaveric study are published, they found that this approach allowed a strong repair with no compromise to the vascularity of the scaphoid or lunate.

Open Capsulodesis

Blatt's original description [33] in 1987 used a dorsal radial flap of wrist capsule to differentially restrict scaphoid flexion. He left the flap of capsule attached to the radius and advanced it dorsally on the scaphoid. In his original series of 12 patients of late rotatory subluxation, he reported excellent recovery of range of movement, average grip strength recovered to 80 % and the majority returning to the preinjury work. Later Muermans and colleagues reported on 17 cases (11 cases of preradiographic instability; 3 dynamic; 3 static) with an average age of 30 years [44]. Patients had previously undergone conservative management and were on average 23 months post injury at the time of surgery. On blinded examination, they reported ten patients with excellent to good outcomes (pain and ADL) and six had fair to poor results. Sixteen patients had a negative Watson test. However, X-rays failed to reveal any significant improvement in SL gap or angle.

The reverse Blatt procedure leaves the capsule attached to the scaphoid and advances it proximally on the dorsal radius. It has been employed as an adjunct to various other open repairs and reconstructions [32]. Megerle et al. followed up 59 patients for an average of 8 years following dorsal capsulodesis [45]. A Berger flap was performed and a slip of the proximal aspect of the dorsal intercarpal ligament left attached distally onto the scaphoid and either sutured to the lunate (36 untethered cases) or distal radius (16 tethered cases) periosteum or attached with an anchor. K-wires were used to transfix the reduced SL interval while the capsulodesis healed. The k-wires were removed at 12 weeks. Carpal reduction was not maintained over time and 78 % went on to have radiographic evidence of Arthritis and an average SL angle of 70°.

Reconstruction

We have defined this as an attempt to reestablish a soft tissue connection between scaphoid and lunate that may be augmented by other secondary stabilizing soft tissues to provide additional stability.

The various techniques described use local tissue or tendons as grafts, such as flexor carpi radialis (FCR), the majority of which are still left attached to the wrist distally, and others use autologous free tissue grafts as a bone–tissue–bone construct.

Local Tissue: Dorsal Intercarpal Ligament

Dobyns et al. [13] described the early technique for reconstruction in 1974. The Mayo capsulodesis in 1982 [2] used half of the dorsal intercarpal ligament left attached to the distal pole of the scaphoid but detached from its ulna side and reattached to the dorsal lunate with suture anchors and to the dorsal radiocarpal ligament. Moran and colleagues reported on an update of results of 14 patients who had a Mayo capsulodesis, and compared these to 15 patients who had a modified Brunelli tenodesis procedure [46]. They reported similar wrist range of movement (63 % and 64 % of the unaffected side, respectively) and grip strength (91 % and 87 % of the unaffected side, respectively) in both groups. No failures were reported in the capsulodesis group.

More recently, Gajendra et al. reported on the long-term outcomes of dorsal intercarpal ligament capsulodesis (DILC) for chronic SL dissociation [47]. The DILC was followed up in 16 patients for on average 84 months and despite a 58 % satisfaction rate thus far, radiographic signs of arthrosis was present in 50 %. Despite this it is still advocated by the authors for the treatment of reducible static SL dissociation.

Local Tissue: RASL

This technique is difficult to classify and may be considered a variation on repair. Nevertheless we consider it more analogous to a reconstruction, particularly where the cartilage between the scaphoid and lunate is removed to encourage fibrous tissue growth between the two surfaces. The "Reduction and Association of the Scaphoid and Lunate" (RASL) procedure reported by Rosenwaser et al. involves open reduction of the SL diastasis and holding the reduction with a headless compression screw [48]. Thirty-two patients with an average follow-up of 6.2 years results have now been reported. Range of motion was maintained at 80 % of the unaffected side and grip strength at 90 %. Radiographic reduction parameters were well maintained at follow-up with two failures resulting in SL advanced collapse and salvage.

The RASL procedure has also been described as an arthroscopic technique and a modified articulated screw (SLIC screw) has been proposed by Geissler to decrease problems with screw breakage.

Free Tissue Grafts: Bone–Tissue–Bone

These techniques harvest ligament or ligament like tissue as free grafts with their bony origins from sacrificeable locations elsewhere in the body

Bone–Retinaculum–Bone

Weiss et al. described the bone-retinaculum-bone autograft technique of reconstruction in 1997 [49]. The graft was harvested from Listers tubercle between second and third compartments and the overlying retinacular tissue, and the bone plugs were inserted into the scaphoid and lunate. This technique was initially advocated in dynamic instability but not in static cases.

The long-term follow-up at an average of 11.9 years has now been reported [49–51].

Clinical and radiographic outcomes deteriorated moderately from the initial report. There were three failures, resulting in one proximal row carpectomy and two total wrist arthrodeses. Findings at repeat surgery in the failed group included an intact graft without any apparent abnormalities, a partially ruptured graft (after a subsequent reinjury), and a completely resorbed graft.

This bone–retinaculum–bone reconstruction may be a viable treatment option for dynamic SL instability in which the scaphoid and lunate can be reduced. Results may deteriorate but are similar to those reported previously from other techniques. Problems with graft strength or stiffness may necessitate further surgery.

Bone–Tissue–Bone: Hand/Wrist Options

Harvey and Hanel [52, 53] tested the SL ligament in cadavers against bone tissue bone grafts taken from cadaveric second metacarpal–trapezoid ligaments, third metacarpal-capitate ligaments, and the dorsal retinaculum. The third metacarpal–carpal bone–tissue–bone technique in a clinical series was published in 2002 [54]. Although used in chronic SL ligament injuries, with numbers of cases not included in the report, the results were documented to be best when there was a shorter period between injury and reconstruction and when there was a dynamic deformity with a radiolunate angle no more than 30°. The complications were related to bone fragmentation at the screw site acutely or at a later date secondary to trauma.

Harvey et al. later described lack of healing with graft pullout and graft stretching as complications from his non vascularized bone–tissue–bone reconstructions and developed the third metacarpal-carpal vascularized pedical graft from the radial sided intermetacarpal artery to address these short-comings [55].

Capitohamate autografts have been advocated by Ritt and colleagues in 1996 [56].

Bone–Tissue–Bone: Tarsal options

Svoboda et al. [57] in 1995 tested bone-ligament-bone grafts from cadavers as potential ligament complex grafts to reconstruct the SL ligament using the dorsal ligament of the fourth and fifth metatarsals, a dorsal tarso-metatarsal ligament graft and a dorsal calcaneo-cuboid graft. The tarso-metatarsal ligament graft produced in vitro results closest to the SL ligament.

Davis et al. in 1998 described a bone-ligament-bone graft harvested and biomechanically tested from the cadaveric foot [58]. They used the dorso-medial portion of the navicular-first cunieforrm ligament.

Free Tissue Grafts: Tendon

Four Bone Technique

Almquist et al. described a four bone technique of SL ligament reconstruction in 1991 using a graft harvested from extensor carpi radialis brevis [59]. The ECRB tendon remained attached distally. Tunnels in the capitate, scaphoid, lunate, and distal radius allowed passage of the tendon graft from its attachment distally to its reattachment proximally on the radius. The graft is passed first from dorsal to volar through the capitate tunnel. It is then passed through the scaphoid tunnel from volar to dorsal. In this way it allows tendon graft to pass between the dorsal scaphoid and dorsal lunate before passing through the lunate tunnel exiting on the volar aspect of the lunate. Finally the graft passes from here onto the volar aspect of the distal radius or through a tunnel into the volar distal radius to be tensioned and finally anchored in the tunnel or to suture anchors. The SL interval is also stabilized with a wire loop.

The results of this technique have been published for the first 36 patients with an average age of 34 years at an average of 4.8years follow-up. Average flexion was 37 degrees and average extension is 52 degrees. Grip strength remained on average 73 % of the contralateral side. A return to preinjury levels was noted in 86 % with no evidence of advancing arthritic changes on X-ray.

Brunelli Technique

In 1995, Brunelli and Brunelli described a technique using local tissue for a tenodesis effect with a partial FCR tendon graft [34, 60]. It was left attached distally and passed through a tunnel in the scaphoid from volar to dorsal and then sutured to the dorsal capsule of the radius. This aims to address the rotary subluxation of the scaphoid with scaphoid flexion and proximal pole subluxation dorsally. Although this does not attempt to anatomically reconstruct the SL ligament, we mention it in the reconstructive tendon graft section because it introduced the concept of harvesting a portion of the FCR left attached distally and passing the tendon volar to the STT joint and through to the dorsal aspect of the wrist via a transosseous tunnel in the scaphoid. This has formed the basis of many of the subsequent successful techniques for reconstruction.

Three Ligament Tenodesis

The "modification" of the Brunelli technique popularized by Garcia-Elias and Stanley in 2006 as the three ligament tenodesis (3LT) eliminates the tether to the radius [61]. It reinforces the volar capsule of the STT joint to add restraint to scaphoid flexion, in keeping with the Brunelli technique, while reconstructing the dorsal band of the SL ligament and reinforcing the dorsal intercarpal ligament. They published a series of 38 patients with an average age of 31 years with symptomatic SL dissociation (21 wrists stage 3; 8 stage 4; 9 stage 5). The majority had dynamic instability (79 %). At an average follow-up of 46 months (7–98 months) satisfactory pain relief was achieved in 28 patients. 29 resumed normal preinjury work. Acceptable range of movement was achieved (Mean Flexion 51°; mean extension 52°). Average grip strength was 65 % of contralateral side. Progression of carpal collapse was noted in two wrists.

Nienstedt published his 10 year results with a small series using a modified Brunelli procedure using a strip of FCR tendon as a ligament substitute for static SL instability [62], based on the technique originally described by Van Den Abbeele and colleagues [63]. The FCR tendon was passed through the scaphoid tunnel and fixed to the dorsal lunate with an anchor. The mean follow-up was 13.8 years in a cohort of 8 patients. The reduction of the SL gap from 5.1 mm preoperatively and obtained intraoperatively to 2.4 mm was maintained to 2.8 mm long term. Average DASH score was 9, and six out of eight patients were pain free. One case had occasional slight pain and the other had chronic pain. With small numbers valid conclusions are difficult but the follow-up interval is significant and maintaining radiographic parameters with only one case developing arthritis might suggest a successful procedure.

Scapholunate Axis Method (SLAM)

In 2012 Lee et al. described the SL axis method (SLAM), which involves drilling a tunnel between the scaphoid and lunate and anchoring a free tendon graft in the lunate with an intraosseous bullet anchor and in the scaphoid with an interference screw [64]. This was compared to the modified Brunelli and Blatt capsulodesis in 12 cadavers and in this experimental data was deemed a more anatomical and less restrictive reconstruction.

Cable Augmented Quad Ligament Tenodesis

Bain et al. in 2013 described a small series using tensionable suture anchors and an FCR tendon graft combination [65]. The technique was adapted from the modified Brunelli and has the theoretical advantage of maintaining SL reduction with a cable during the healing phase. Initial clinical results were promising but longer-term follow-up is needed.

Scapho-Luno-Triquetral Tenodesis (SLT)

The open reconstruction technique favored by Ross, Couzens, and colleagues has been developed for the treatment of dynamic or intraoperatively reducible static SL instability where other forms of SL reconstruction may previously have been considered [66]. It may also offer an augmentation for acute and semi-acute repairs of the SL ligament. It has also been successfully used in acute reconstruction/repair following perilunate dislocations where both the SL ligament and LT ligaments are damaged. Since development of this technique in 2009, Ross and colleagues have performed this operation on over 60 patients with grade three or four SL ligament injuries [66]. They have reported preliminary results on the first 11 consecutive patients who received this technique and were prospectively reviewed over a 12–24 month period [66]. At an average follow-up of 14 months (12–24 months) post operation they reported good early radiological and clinical outcomes. When comparing preoperative clinical results with their most recent follow-up, the cohort demonstrated pain relief with normal activities, improved Patient Rated Wrist Evaluation, QuickDASH, range of movement and grip strength scores. Radiological outcomes (SL angle and SL gap) were improved.

The technique involves passage of a distally based partial FCR graft across the volar STT joint and through a scaphoid tunnel. The graft exits the scaphoid between the scaphoid and lunate and is then passed through a second tunnel in the lunate and triquetrum (Fig. 10.9). It is tensioned and anchored with an interference screw in the ulnar aspect of the triquetrum then passed back across the midcarpal joint to reinforce the dorsal intercarpal ligament. It can also be used to augment acute and semi-acute repairs of the SL ligament. By reconstructing the SL ligament and LT ligaments it is also suitable for treatment of perilunate dislocations. This technique may be suitable for adaption to arthroscopic, or arthroscopic-assisted techniques, particularly with the development of procedure-specific targeting jigs and instruments. The authors are undertaking this development currently.

This technique is contraindicated in SL Advanced Collapse (SLAC) or irreducible static instability intraopera-

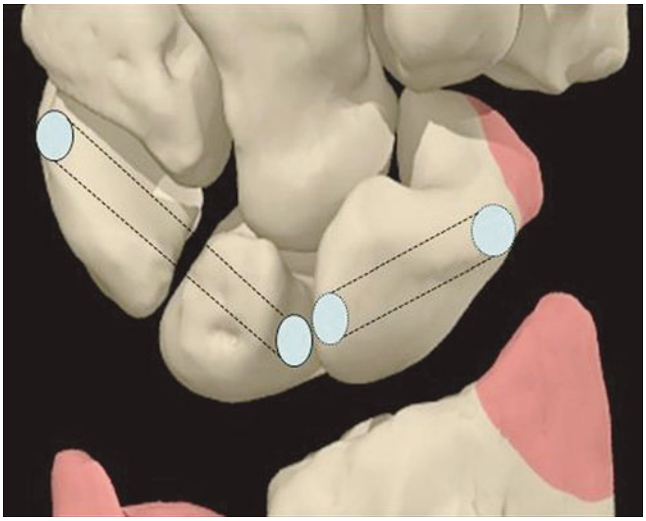


Fig. 10.9 Scapho-luno-triquetral tenodesis transosseous tunnel placement

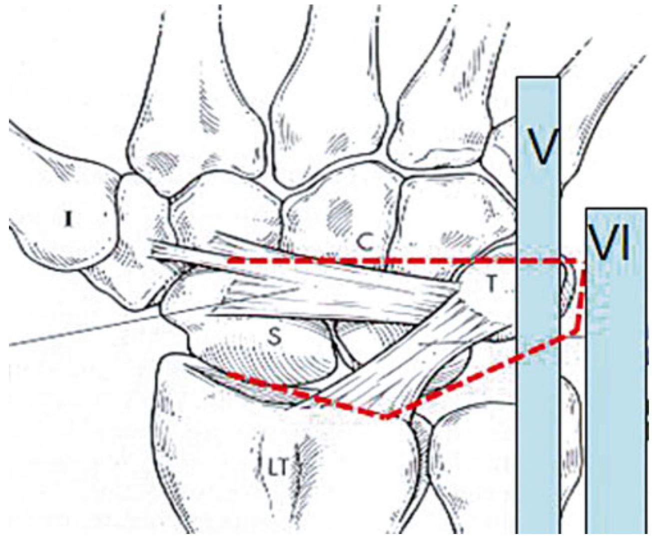


Fig. 10.10 Modified Berger flap exposure for the Scapho-luno-triquetral tenodesis technique

tively. The authors believe that this technique combines a large number of desirable features from previous procedures and addresses many of the potential facets of SL pathology to achieve a stable reconstruction of carpal stability. The features include:

1. In keeping with the initial intent of Brunelli's original description [60] the procedure provides a volar restraint to flexion of the distal pole of the scaphoid, and a reinforcement of the volar capsule of the STT joint.
2. There is no tethering of the dorsal carpus to the scaphoid. Therefore, there is no absolute restraint to radio carpal flexion.
3. The tunnels are positioned at, or close to, the isometric point of rotation between the scaphoid and the lunate. As a consequence, the potential for the normal sagittal plane rotation between the scaphoid and the lunate is not restricted. In addition, as the graft is tensioned, there is uniform apposition of the scaphoid and the lunate facets. This avoids excessive tensioning dorsally, with consequent opening on the volar aspect, or vice versa, as may occur with volar or dorsal reconstruction or capsulodesis techniques.
4. As the graft is tensioned, there is automatic reduction of the major aspects of pathology, including the rotary dorsal subluxation of the proximal scaphoid, and closure of the gap between the scaphoid and the lunate.
5. The transosseous passage of the graft avoids soft tissue bulk or formation of dorsal scar tissue, as occurs when a tendon graft is passed dorsally in the region of the dorsal band of the SL ligament, and anchored to the lunate dorsally.
6. The central positioning of the graft between the scaphoid and lunate does not compromise the possibility of repairing any residual native SLIL that may remain.
7. The triquetrum is ideally suited for anchoring of a tendon using an interference screw, and this anchoring in the triquetrum avoids excessive instrumentation or anchor placement in the lunate or scaphoid.
8. Passage of the graft across the LT interval allows additional stabilization of the LT interval. Many of these injuries are part of a spectrum of peri-lunate injury, and as a consequence, there may be subtle recognised or unrecognized pathology affecting the LT ligament. As a consequence, this reconstruction is particularly suitable for reconstruction of complete peri-lunate injuries.
9. The secondary passage of the tendon graft across the dorsal aspect of the mid carpal joint back to the scaphoid reinforces and reconstructs the dorsal intercarpal ligament, which may also be secondarily involved in these patterns of injury. This secondary reconstruction also provides an additional reinforcement to the relationships of the proximal row of the carpus in the coronal plane.

Scapho-Luno-Triquetral Tenodesis (SLT): Surgical Technique

Exposure

A standard mid-line approach over the central dorsal aspect of the wrist is utilized.

A ligament sparing Berger capsular flap [44] is developed further to the ulnar side than is usual, to gain access to the ulnar border of the triquetrum immediately radial to the ECU subsheath, which is not opened (Fig. 10.10). In addition to the usual elevation of the third and fourth compartments, division of the septum between fourth and fifth compartment and elevation of the extensor digiti minimi tendon is required (Fig. 10.11).

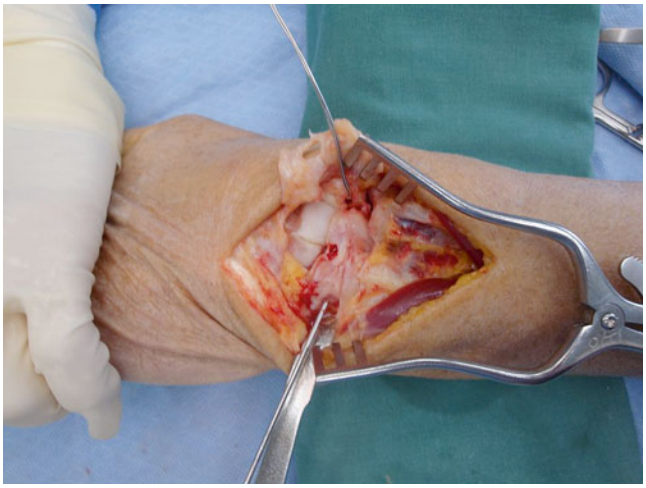


Fig. 10.11 Exposure for scapho-luno-triquetral tenodesis

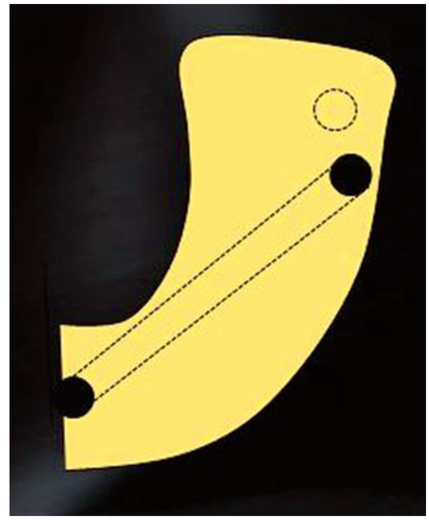


Fig. 10.12 Scaphoid tunnel placement for the scapho-luno-triquetral tenodesis technique

Exposure of the ulnar aspect of the triquetrum, drilling the LT tunnel, and graft tensioning can be facilitated by placing a small Hohmann retractor in the vicinity of piso-triquetral joint. If there is a peri-lunate dissociation, the lunate and triquetrum should be reduced anatomically and pinned with a k-wire before drilling the LT tunnel. Elevate the flap, stopping over the dorsal ridge of the scaphoid. This preserves the capsular attachments to the dorsum of the scaphoid that carry the blood supply.

Alternate Exposure

Once a degree of familiarity is achieved with the technique using the large dorsal exposure described above, it may be possible to decrease the dorsal exposure by accessing the ulnar border of the triquetrum through a separate direct ulnar approach. This allows a limited dorsal exposure. The fifth compartment does not need to be elevated and the capsulotomy is more limited incorporating only a portion of the typical Berger flap, without the need to extend the flap past the triquetrum.

Expose the ulnar side of the triquetrum through a separate small direct ulnar incision approximately 2 cm long just volar to ECU. Care should be taken to protect dorsal branches of the ulnar nerve which have variable anatomy in this region. The LT tunnel can be drilled via this approach. Use of fluoroscopy to check cannulated drill guide wire positioning is recommended before drilling the definitive tunnel.

After it has been tensioned and secured with the interference screw through the ulnar incision the graft can be passed subperiosteally under the sixth and fifth compartments back toward the central dorsal exposure of the scaphoid and lunate, using a fine hemostat. Prior to this passage back to the dorsal incision, the graft may also be secondarily secured with sutures to the soft tissues over the ulnar triquetrum in the floor of the "ulnar snuff box". The remainder of the attachment of the graft to the dorsal scaphoid is the same as described with the more extensive dorsal exposure.

Harvesting the Graft and Preparation

Volar exposure of the scaphoid is similar to the volar approach for scaphoid fixation and grafting described by Russe [67]. Expose the tubercle and the distal half of the scaphoid. Minimize the division of the radio-scapho-capitate ligament at this point. Harvest approximately 40 % of FCR tendon using a technique allowing the tendon to be stripped from proximal to distal, leaving it attached distally. Tendon graft thickness should correspond to the transosseous tunnel diameter, which is usually 3 mm. Once the portion of tendon is harvested, mobilize it until it is distal to the ST joint.

Preparing the Scaphoid Tunnel

Drill a hole using a 3 mm cannulated drill bit, in a process similar to a traditional style Brunelli reconstruction [34, 60], except that the entry point dorsally is on the articular facet of the scaphoid for the lunate (not at the dorsal insertion of the SL ligament). The tunnel should be just dorsal to the center point of lunate facet of the scaphoid. The exit point on the volar side of the scaphoid is a few millimeters proximal and radial to the normal point that would be used for a traditional dorsal band reconstruction (Fig. 10.12). The position of the tunnel exit on the volar side needs to be accurate so that the tunnel can enter on the lunate facet of the scaphoid without violating the scapho-capitate joint. The point on the scaphoid facet should be just dorsal to the mid-point of the articular surface for the lunate. The reason for this is that if the corresponding point on the facet of the lunate is volar to the mid-point, the tendon graft will be traveling obliquely, from dorsal on the scaphoid, to volar on the lunate. This causes the

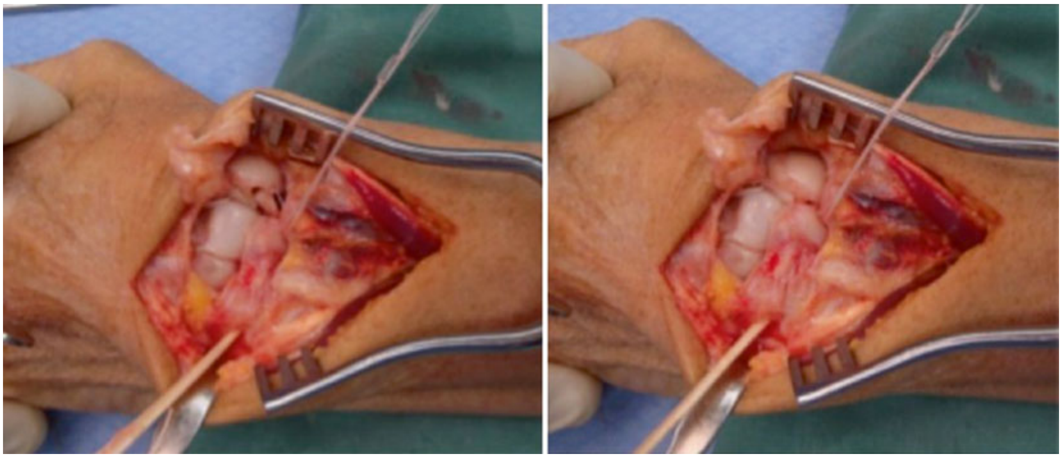


Fig. 10.13 Tensioning the tendon to reduce the SL interval for the Scapho-luno-triquetral tenodesis

graft to naturally reduce the rotary subluxation between the scaphoid and the lunate, and correct the dorsal subluxation of the proximal pole of the scaphoid, as it is tensioned.

Preparing the Luno-Triquetral Tunnel

The LT tunnel is drilled from the ulnar side of the triquetrum, across the LT joint to exit on the lunate just volar to the mid-point of the articular facet. Care is taken not to make the entry point on the ulnar aspect of the triquetrum too dorsal to avoid the risk of fracturing the tunnel when the interference screw is inserted. Care must also be taken not to enter too proximal on the triquetrum as the medial-lateral dimension of the triquetrum decreases significantly in its more proximal portion, and the tunnel needs to be long enough to accommodate the 8 mm length of the interference screw without it protruding across the LT joint.

Passing the Graft

The graft is then passed sequentially through the scaphoid from volar to dorsal then across the LT tunnel. The tendon needs to be approximately the same dimension as the tunnel so that the interference screw fit is tight. Ensure there is no slack in the graft between the FCR insertion and the volar entry to the tunnel before tensioning dorsally (Fig. 10.13).

Reducing the Joint

Pull on the tendon as it exits the triquetrum. The dorsal subluxation of the scaphoid will reduce and close the SL interval. Insert the interference screw (e.g. 3×8 mm PEEK screw, Arthrex Inc.) into the triquetrum volar to the tendon (Fig. 10.14). We have found that it is best to tension the graft with the wrist in ulnar deviation to ensure maximum tension. A similar bio-composite (e.g. TCP) screw would be preferable. We are reluctant to use a PLA screw due to probable cyst formation in small carpal bones.

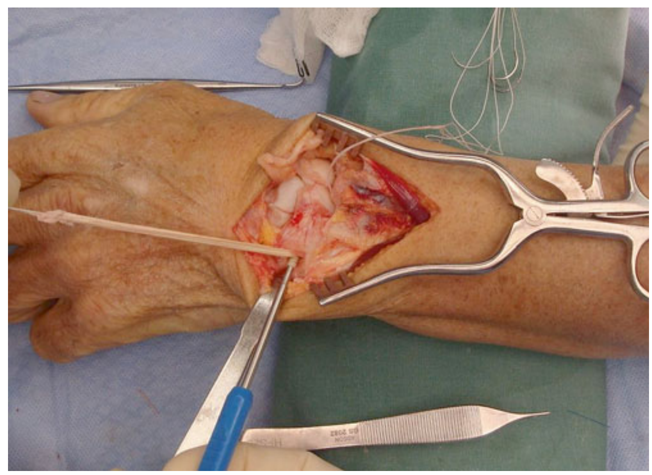


Fig. 10.14 Inserting the interference screw for the Scapho-luno-triquetral tenodesis

Once the graft is secured if there is any residual SL ligament tissue, it may be repaired using the surgeon's preferred technique. The graft is then passed across the dorsum of the mid-carpal joint. The goal is to augment (or reconstruct) the dorsal inter-carpal ligament. Place a small absorbable anchor with 2° suture in the waist of the scaphoid, being careful to avoid the tunnel containing the FCR graft. Suture the graft to the waist of the scaphoid. This is also the base of the Berger flap so use either an artery forceps (Hemostat) or tendon braiding forceps to pass the graft through the base of the Berger flap.

Closure

To protect the reconstruction, a single 1.1 mm wire is placed between the distal pole of the scaphoid and the capitate, or between the scaphoid and lunate, being careful not to perforate the graft. Surgeon preference may be to use two wires. The K-wire is left in situ for 6–8 weeks.

Rehabilitation

Post operatively the patient is allowed to mobilize the wrist to 30° of flexion and 30° of extension. If only one SL wire is used, oblique axis (dart throwing) motion can be commenced early with the wire in situ. Custom-made thermoplastic wrist splint is worn at all other times until the k-wire is removed (i.e. 6–8 weeks). After the wire is removed, wrist mobilization exercises are upgraded to include orthogonal flexion/extension exercises and oblique dart throwing type exercises which focus on the mid-carpal joint.

SLT Case Presentation

A 40-year-old male right-hand dominant cane farmer presents with an acute SL dissociation (with static deformity) and simultaneous distal radius fracture of his left wrist. Preoperative X-ray is depicted in Fig. 10.15. Surgery for internal fixation of distal radius and SL reconstruction using the scapho-lunato-triquetral tenodesis technique was performed at 10 days post injury. At 7 months post surgery, he had good radiological outcome (Fig. 10.16). He had returned to normal work and function, and had achieved a good clinical outcome (Fig. 10.17).

Salvage

Wrist arthroscopy can be used to evaluate the degree and extent of articular cartilage degeneration in patients with SL ligament pathology. The status of the articular cartilage as determined arthroscopically helps to determine whether a reconstructive procedure, such as ligament reconstruction or capsulodesis versus a salvage procedure (e.g., a four-corner fusion or proximal row carpectomy), is indicated [68, 69]. Arthroscopic evaluation of the status of the articular cartilage of the head of the capitate is extremely useful in determining the indications for 4 corner fusion versus proximal row carpectomy. In selecting individuals with early SLAC wrist who desire only minimal arthroscopic intervention, debridement, and radial styloidectomy may be an option. This is further described in a later chapter.

Fig. 10.15 Preoperative X-ray depicting SL dissociation and undisplaced distal radius fracture

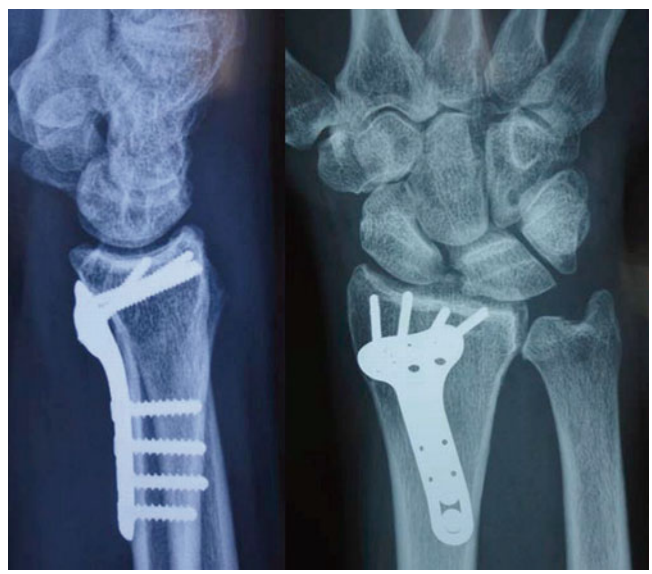


Fig. 10.16 Postoperative X-ray depicting ORIF distal radius fracture and SL ligament reconstruction using the authors technique

Fig. 10.17 Range of movement at 7 months post surgery

The hitherto unpredictable results of soft tissue reconstructions have led some authors to consider bony procedures preferentially [68, 69]. The chronicity of the injury and the difficulty in reducing the SL relationship will influence this decision.

Proximal Row Carpectomy

Proximal row carpectomy is a motion preserving salvage procedure not reliant on bony union. It allows earlier mobilization than four corner fusion and is technically less demanding [69].

Fusion

Partial Intercarpal Fusions

Limited carpal fusions may be a suitable salvage for some patients [70].

STT Joint Fusion

There is a paucity of recent literature on the use of STT joint fusion as a salvage technique since Kirk Watson and colleagues described this initially in 1991 [35].

Scapho-Capitate Fusion

The concern with scapho-capitate fusion is the alteration in carpal mechanics with loss of midcarpal oblique plane motion and increased contact stresses between the scaphoid and radius. Deletang et al. in 2011 reported on 31 scapho-capitate fusions for chronic scapholunate instability were followed for an average of 5 years [71]. The conclusion was that capsulodesis and ligament reconstruction provide the same functional results as SC fusion, but with slightly less stiffening.

Luegmair et al. in 2013 reported on scapho-capitate arthrodesis for SL instability in manual workers [72]. This high-demand group of 20 patients with an average follow-up of 10 years had a significant reduction in pain symptoms and maintained an average 87° flex-extension arc and 41° radio-ulnar deviation arc. Grip strength was 60 % of the opposite wrist. All patients united, 90 % of patients returned to work but 30 % had radiocarpal arthritis at last follow-up.

Four Corner Fusion ± Excision of Scaphoid

Four corner fusion and proximal row carpectomy are often compared and contrasted as salvage procedures. Cadaveric work by DeBottis et al. in 2013 showed a reduced range of motion compared to normal wrists with either procedure [73]. Wrist flexion was reduced similarly in both by 12–13°. Extension was decreased by 20° in the four corner fusion and 12° in the PRC.

Radio-Scapholunate Fusion

RSL arthrodesis is technically challenging although improved implants including memory staples and specific internal fixation implants have helped to improve union rates. It remains important to respect the three dimensional relationship of the scaphoid and lunate to preserve the shape of the articulation with the proximal capitate.

Bain et al. described RSL arthrodesis with distal pole of scaphoid excision and triquetral excision for isolated radiocarpal arthritis secondary to a variety of pathologies [74]. The midcarpal joint must be normal for this limited arthrodesis to be justified. Resection of the distal scaphoid and triquetrum was shown to increase range of motion in prior cadaveric studies [75].

Mühldorfer-Fodor et al. report on the results RSL arthrodesis for posttraumatic arthritis with or without distal pole of scaphoid excision [76]. The distal pole excision group had not only better radial deviation but better union rates too. Although this procedure is suitable for salvage in failed SL ligament reconstruction, in this cohort of 35 patients with follow-up, however, only two cases were due to SL pathology the majority of cases were arthritis secondary to intraarticular distal radial fractures.

Capitolunate Fusion

Wang et al. report on capitolunate and triquetrohamate fusions for scapholunate advanced collapse and scaphoid nonunion advanced collapse salvage [77]. In a consecutive series of 27 patients there was a 96 % union rate. Postoperative results showed a 21 % reduction in mean flexion-extension arc compared to preoperatively. There was no change in radio-ulnar deviation. The mean grip strength postoperatively increased by 27 %.

Total Wrist Fusion

Total wrist fusion is best reserved for salvage of pan carpal arthritis or failed limited carpal arthrodesis or other motion preserving procedures [78]. The overwhelming challenge of all treatments for SL pathology is avoidance of the need for total wrist fusion.

Summary of Treatment Options

Partial Tears

Acute partial tears may heal without treatment or may benefit from simple immobilization. There may also be a role for closed pinning, with or without arthroscopic assistance. Symptomatic chronic partial tears are less likely to be suitable for closed pinning; however, the residual ligament function may be too good for major reconstruction. In these cases capsulodesis (arthroscopic or open), or capsulorrhaphy (abrasion, thermal, suture) may be appropriate.

Complete Tears-Dynamic

In acute dynamic tears most authors would favor primary repair over reconstructive techniques. This still requires a pragmatic assessment of ligament quality intraoperatively before proceeding to repair. In chronic dynamic tears the balance shifts toward reconstruction over repair. The challenge is in establishing the interval that defines a chronic tear.

Complete Tears: Static

When these tears are reducible at operation the preference may be for reconstruction or capsulodesis, although there are some authors who consider this pathology beyond the limit of soft tissue reconstruction to achieve stability and prefer partial fusion. Consideration may also be given to less invasive arthroscopic capsulodesis or capsulorraphy techniques.

In a static irreducible dissociation the only predictable options are partial or total fusion.

Conclusion

The management of SL ligament injury is continuing to evolve with both arthroscopic and more anatomical open reconstruction techniques being developed. The biggest dilemma facing the surgeon is when to apply repair versus reconstructive versus salvage techniques. This challenge is complicated by the difficulty in defining chronicity of the injury, the poor results of open primary repair in many series, and the lack of good natural history studies for both partial and complete ligament tears. In addition it remains difficult to make direct outcome comparisons with other techniques in the published literature. There is currently no standard for reporting preoperative and postoperative outcome data in relation to either clinical or radiographic results for SLIL pathology.

Acknowledgements We would like to acknowledge Dr Nick Daunt, Radiologist, QLD XRay for his assistance with the "Imaging" section of the chapter. We would also like to acknowledge Susan Peters, Senior Research Coordinator and Hand Therapist, Brisbane Hand and Upper Limb Research Institute for assistance with manuscript preparation.

References

1. Walsh JJ, Berger RA, Cooney WP. Current status of scapholumate interosseous ligament injuries. J Am Acad Orth Surg. 2002;10:32–42.
2. Cooney WP. Evaluation of chronic wrist pain by arthrography, arthroscopy and arthrotomy. J Hand Surg. 1993;18:815–22.
3. Whipple TL, Marotta JJ, Powell JH. Techniques of wrist arthroscopy. Arthroscopy. 1986;2:244–53.
4. Berger RA. The Anatomy of the ligaments of the wrist and distal radioulnar joints. Clin Orth Rel Res. 2001;383:32–40.
5. Berger RA, Landsmeer JMF. The palmar radiocarpal ligaments: a study of adult and fetal wrist joints. J Hand Surg Am. 1990;15: 847–54.
6. Chung KC, Zimmerman NB, Travis MT. Wrist arthrography versus atthroscopy: a comparative study of 150 cases. J Hand Surg Am. 1995;27:591–4.
7. Watson HK, Ashmead D, Makhlouf MV. Examination of the scaphoid. J Hand Surg Am. 1988;13:657–60.
8. Lk R, An KN, Linschield RL. The effect of scapholunate ligament section on scapholunate motion. J Hand Surg Am; 1996;12: 767–71.
9. Mayfield JK, Williams WJ, Erdman AG, et al. Biochemical properties of human carpal ligaments. Orthop Trans. 1979;3:143.
10. Mead TD, Schneider LH, Cherry K. Radiographic analysis of selective ligament sectioning of the carpal scaphoid: a cadaver study. J Hand Surg Am. 1990;15:855–62.
11. Wynne-Davies R. Heritable disorders in orthopaedic practice. Oxford: Blackwell Scientific; 1973. p. 138.
12. Gilula LA. Carpal injuries: analytic approach and case exercises. Am J Roentgenol. 1979;133:503–17.
13. Dobyns JH, Linscheid RL, Chao EYS, et al. Traumatic instability of the wrist. Instr Course Lect. 1975;24:182–99.
14. Frankel VH. The Terry Thomas sign. Clin Orthop Relat Res. 1977;129:321–2.
15. Cautilli GP, Wehbe MA. Scapholunate distance and cortical ring sign. J Hand Surg Am. 1991;16:501–3.
16. Linschied RL, Dobyns JH, Beabout JW, Bryan RS. Traumatic instability of the wrist: Diagnosis, classification and pathomechanics. JBJS. 1972;54:1612–32.
17. Lawland A, Foulkes GD. The "clenched pencil" view: a modified clenched fist scapholunate stress view. J Hand Surg. 2003;28:414–8.
18. Dao KD, Solomon DF, Shin AY, Puckett ML. The efficacy of ultrasound in the evaluation of dynamic scapholunate ligamentous instability. JBJS. 2004;86A:1473–8.
19. Taljanovic MS, Sheppard JE, Jones MD, Switlick DN, Hunter TB, Rogers LF. Sonography and sonoarthrography of the scapholunate and lunotriquetral ligaments and triangular fibrocartilage disk: initial experience and correlation with arthrography and magnetic resonance arthrography. J Ultrasound Med. 2008;27:179–91.
20. Ringler MD. MRI of wrist ligaments. J Hand Surg Am. 2013;38: 2034–46.
21. Kakar S. Use of dynamic 4DCT for the diagnosis of scapholunate instability. J Wrist Surg. 2013;1(S1):520.
22. Larsen CF, Amadio PC, Gilula LA, Hodge JC. Analysis of carpal instability: I description of the scheme. J Hand Surg Am. 1995; 20:757–64.
23. Geissler WB, Haley T. Arthroscopic management of scapholunate instability. Atlas Hand Clin. 2001;6:253–74.
24. Luchetti R, Atzei A, Cozzolino R, Hairplay T. Current role of open reconstruction of the scapholunate ligament. J Wrist Surg. 2013;2:116–25.
25. Geissler WB, Freeland AE, Savoie FH, et al. Intracarpal soft tissue lesions associated with intraarticular fracture of the distal end of the radius. J Bone Joint Surg. 1996;78:357–65.
26. Watson HK, Ballet FL. The SLAC wrist: scapholunate advanced collapse pattern of degenerative arthritis. J Hand Surg Am. 1984;9: 358–65.
27. Geissler WB, Freeland AE, Weiss APC, Chow JCY. Techniques in wrist arthroscopy. JBJS Am. 1999;81:1184–97.
28. Gupta R, Bozentka DJ, Osterman AL. Wrist arthroscopy: principles and clinical applications. J Am Acad Orth Surg. 2001;9:200–9.
29. Geissler WB. Arthroscopic management of scapholunate instability. J Wrist Surg. 2013;2:129–35.
30. Tang JB, Shi D, Gu YQ, Zhang QG. Can cast immobilization successfully treat scapholunate dissociation associated with distal radius fractures? J Hand Surg Am. 1996;21:583–90.
31. Whipple TL. The role of arthroscopy in the treatment of scapholunate instability. Hand Clin. 1995;11:37–40.
32. Berger RA, Bishop AT, Bettinger PC. New dorsal capsulotomy for the surgical exposure of the wrist. Ann Plast Surg. 1995;35:54–9.
33. Blatt G. Capsulodesis in reconstructive hand surgery. Dorsal capsulodesis for the unstable scaphoid and volar capsulodesis following excision of the distal ulna. Hand Clin. 1987;3:81–102.

34. Brunelli GA, Brunelli GR. A new technique to correct carpal instability with scaphoid rotary subluxation : a preliminary report. J Hand Surg. 1995;20A:S82–5.
35. Watson HK, Belniak R, Garcia-Elias M. Treatment of scapholunate dissociation: preferred treatments—STT fusion vs. other methods. Orthopedics. 1991;14:365–8.
36. Geissler WB. Electrothermal shrinkage in interosseous ligament tears (SS-29). Arthroscopy. 2002;18:24–5.
37. Danoff JR, Birman MV, Rosenwasser MP. The use of thermal shrinkage for scapholunate instability. Hand Clin. 2011;27:309–17.
38. Darlis NA, Weiser RW, Sotereanos DG. Partial scapholunate ligament injuries treated with arthroscopic debridement and thermal shrinkage. J Hand Surg Am. 2005;30:908–14.
39. Hirsh L, Sodha S, Bozentka D, et al. Arthroscopic electrothermal collagen shrinkage for symptomatic laxity of the scapholunate interosseous ligament. J Hand Surg Br. 2005;30:643–7.
40. Mathoulin CL, Dauphin N, Wahegaonkar AL. Arthroscopic dorsal capsuloplasty in chronic scapho-lunate ligament tears: a new procedure. Hand Clin. 2011;27:563–72.
41. Wahegaonkar AL, Mathoulin CL. Arthroscopic dorsal capsule-ligamentous repair in the treatment of chronic scapho-lunate ligament tears. J Wrist Surg. 2013;2:141–8.
42. del Piñal F, Studer A, Thams C, Glasberg A. An all-inside technique for arthroscopic suturing of the volar scapholunate ligament. J Hand Surg Am. 2011;36:2044–6.
43. Van Kampen RJ, Moran SL. A new volar capsulodesis for scapholunate dissociation. J Wrist Surg. 2013;1(2):s16–7.
44. Muermans S, De Smet L, Van Ransbeeck H. Blatt dorsal capsuldesis for scapholunate instability. Acta Orthopaedica Belgica. 1999;54:434–8.
45. Megerle K, Bertel D, Germann G, Lehnhardt M, Hellmich S. Long-term results of dorsal intercarpal ligament capsulodesis for the treatment of chronic scapholunate instability. J Bone Joint Surg Br. 2012;94:1660–5.
46. Moran SL, Ford JS, Wulf CA, Cooney WP. Outcomes of dorsal capsulodesis and tenodesis for treatment of scapholunate instability. J Hand Surg Am. 2006;31:1438–46.
47. Gajendran VK, Peterson B, Slater Jr RR, Szabo RM. Long-term outcomes of dorsal intercarpal ligament capsulodesis for chronic scapholunate dissociation. J Hand Surg Am. 2007;32:1323–33.
48. Rosenwasser MP, Miyasajsa KC, Strauch RJ. The RASL procedure: reduction and association of the scaphoid and lunate using the Herbert screw. Tech Hand Up Extrem Surg. 1997;1:263–72.
49. Weiss APC, Sachar K, Glowacki KA. Arthroscopic debridement alone for intercarpal ligament tears. J Hand Surg Am. 1997;22:344–9.
50. Weiss AP, Providenc RI. Scapholunate reconstruction using a bone-retinaculum-bone autograft. J Hand Surg Am. 1998;23:205–15.
51. Soong M, Merrell VA, Orthoman F, Weiss AP. Long-term results of bone-retinaculum-bone autograft for scapholunate instability. J Hand Surg Am. 2013;38:504–8.
52. Harvey E, Hanel D. Autograft replacements for the scapholunate ligament: a biomechanical comparison of hand based autografts. J Hand Surg. 1999;24A:963–7.
53. Harvey E, Hanel D. What is the ideal replacement for the scapholunate ligament in a chronic dissociation? Can J Plast Surg. 2000;8:143–6.
54. Harvey EJ, Hanel DP. Bone—ligament—bone reconstruction for Scapholunate disruption. Tech Hand Upper Extr Surg. 2002;6:2–5.
55. Harvey EJ, Sen M, Martineau P. A vascularized technique for bone-tissue-bone repair in scapholunate dissociation. Tech Hand Up Extrem Surg. 2006;10(3):166–72.
56. Ritt MJ, Berger RA, Bishop AT, An KN. The capitohamate ligaments. A comparison of biomechanical properties. J Hand Surg Br. 1996;21:451–4.
57. Svoboda S, Eglseder A, Belkoff S. Autografts from the foot for reconstruction of the scapholunate interosseous ligament. J Hand Surg. 1995;20A:980–5.
58. Davis CA, Culp RW, Hume EL, Osterman AL. Reconstruction of the scapholunate ligament in a cadaver model using a bone-ligament-bone autograft from the foot. J Hand Surg Am. 1998;23(5):884–92.
59. Almquist EE, Bach AW, Sack JT, Fuhs SE, Newman DM. Four bone ligament reconstruction for treatment of chronic complete scaholunate separation. J Hand Surg. 1991;16A:322–7.
60. Brunelli GA, Brunelli GR. [A new surgical technique for carpal instability with scapho-lunar dislocation (Eleven cases) (French). Ann Chir Main Memb Supér. 1995;14:207–13.
61. Garcia-Elias M, Lluch AL, Stanley JK. Three-ligament Tenodesis for the treatment of Scapholunate dissociation: indications and surgical technique. J Hand Surg. 2006;31A:125–34.
62. Nienstadt F. Treatment of static scapholunate instability with modified Brunelli tenodesis: results over 10 years. J Hand Surg Am. 2013;38:887–92.
63. Van Den Abbeele KL, Loh YC, Stanley JK, Trail IA. Early results of a modified Brunelli procedure for scapholunate instability. J Hand Surg Br. 1998;23:258–61.
64. Lee SK, Zlotolow DA, Sapienza A, Karia R, Yao J. The scapholunate axis method: a new technique for scapholunate ligament reconstruction. J Wrist Surg. 2013;1:S17.
65. Bain GI, Watts AC, McLean J, Lee YC, Eng K. Cable-augmented, quad ligament tenodesis scapholunate reconstruction: rationale, surgical technique, and preliminary results. Tech Hand Up Extrem Surg. 2013;17:13–9.
66. Ross M, Loveridge J, Cutbush K, Couzens G. Scapholunate ligament reconstruction. J Wrist Surg. 2013;2:110–5.
67. Russe O. Fracture of the carpal navicular: diaganosis, non-operative treatment, and operative treatment. JBJS Am. 1960;42:759–68.
68. Strauch RJ. Scapholunate advanced collapse and scaphoid non-union advanced collapse arthritis—update of evaluation and treatment. J Hand Surg Am. 2011;36:729–35.
69. Wall LB, Stern PJ. Proximal row carpectomy. Hand Clin. 2013;29:69–78.
70. Mulford JS, Ceulemans LJ, Nam D, Axelrod TS. Proximal row carpectomy vs. four corner fusion for scapholunate (SLAC) or scaphoid nonunion advanced collapse (SNAC) wrists: a systematic review of outcomes. J Hand Surg Eur. 2009;34(2):256–63.
71. Deletang F, Segreta J, Dapb F, Daute G. Chronic scapholunate instability treated by scaphocapitate fusion: a midterm outcome perspective. Orthop Traumatol Surg Res. 2011;97:164–71.
72. Luegmair M, Saffar P. Scaphocapitate arthrodesis for treatment of scapholunate instability in manual workers. J Hand Surg. 2013;38:878–86.
73. Debottis DP, Werner FW, Sutton LG, Harley BJ. 4-corner arthrodesis and proximal row carpectomy: a biomechanical comparison of wrist motion and tendon forces. J Hand Surg Am. 2013;38:893–8.
74. Bain GI, Ondimu P, Hallam P, Ashwood N. Radioscapholunate arthrodesis—a prospective study. Hand Surg. 2009;14(2–3):73–82.
75. McCombe D, Ireland DCR, McNab I. Distal scaphoid excision after radioscaphoid arthrodesis. J Hand Surg Am. 2001;26(5):877–82.
76. Muhldorfer-Fodor M, Phan Ha H, Hohendorff B, Low S. Results after radioscapholunate arthrodesis with or without resection of the distal scaphoid pole. J Hand Surg Am. 2012;37:2233–9.
77. Wang ML, Bednar JM. Lunatocapitate and triquetrohamage arthrodesis for degenerative arthritis of the wrist. J Hand Surg Am. 2012;37:1136–41.
78. Hayden RJ, Jebson PJ. Wrist arthrodesis. Hand Clin. 2005;21:631–40.

11 Arthroscopic Scapholunate Reconstruction

Christophe L. Mathoulin and Abhijeet L. Wahegaonkar

Introduction

Scapholunate ligament (SL) injuries are often caused due to a fall on an outstretched hand with the wrist in extension. These injuries cause instability of the scapholunate joint and untreated injuries lead to arthritic changes—the so-called SLAC wrist.

These injuries may be associated with fracture of the distal radius. Acute injuries (presenting within 2 months) are usually difficult to diagnose. Arthroscopy is a valuable tool for the diagnosis and treatment of acute SL dissociation at an early stage and has the potential of achieving stable fixation without the need for open surgery. However, chronic lesions of the scapholunate ligament before the onset of arthritic changes remain a challenge for the treating surgeon, who has often to achieve stability at the cost of mobility.

Anatomical Basis of the Scapholunate Complex

The SL complex consists of intrinsic and extrinsic components (Fig. 11.1). The intrinsic portion of the scapholunate interosseous ligament is composed of three parts: dorsal, palmar, and an intermediate central part. The dorsal part is the most important from a biomechanical point of view. It consists of very thick transverse fibers that resist rotation. The palmar portion of the ligament consists of long fibers, which allow oblique sagittal rotation. Finally, the central part is actually a non-vascularized fibro-cartilage, which is often found to be torn due to degenerative changes in the elderly. Central perforations of the intermediate portion are commonly seen on wrist arthrograms, with preservation of the dorsal and palmar components of the SL ligament complex, and therefore preserving stability of the SL articulation. The extrinsic components of the scapholunate ligament complex are the radio-scapholuno-capitate ligament and the long and short radio-lunate ligaments.

The importance and contribution of these ligaments in maintaining scapholunate stability are still not fully understood. Just like other ligaments in the body, the interosseous ligament bone scapholunate can be stretched to a yield point. Mayfield [1] showed that an elongation of approximately 225 % is required before failure of the SL ligament occurs, while the SL ligament can elongate to twice its length before it ruptures. Despite this, it seems that the trauma must involve the scapholunate complex itself to result in a rupture. Isolated lesions of the scapholunate ligament may not cause scapholunate dissociation on radiographs. Conversely, a simple weakening of the scapholunate ligament not visible on radiographs may cause mechanical problems and painful phenomena. For scapholunate diastasis to be complete and visible on radiographs, the intrinsic and extrinsic systems must both be involved. More frequently, radiological abnormalities are not seen initially after a lesion of the scapholunate ligament but only appear over time due to the progressive destruction of the extrinsic ligamentous system. This explains the frequent delay in diagnosis of this pathology.

Factors Affecting the Stability of the Distal Pole of the Scaphoid

Structures stabilizing the distal pole of the scaphoid play a significant role because of the forces transmitted by the first metacarpal ray during abduction and opposition. The flexor carpi radialis (FCR) plays both an active and a passive role:

C.L. Mathoulin, MD (✉)
Institut De La Main, Clinique Jouvenet,
6 Squre Jouvenet, Paris 75016, France
e-mail: cmathoulin@orange.fr

A.L. Wahegaonkar, M.D., F.A.C.S., M.Ch. (Orth)
Department of Hand and Microvascular Reconstructive Surgery, Brachial Plexus and Peripheral Nerve Surgery, Sancheti Institute for Orthopaedics and Rehabilitation, 16 Shivajinagar, Pune, Maharashtra 411005, India
e-mail: abhiwahe@yahoo.com

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*, DOI 10.1007/978-1-4614-1596-1_11,

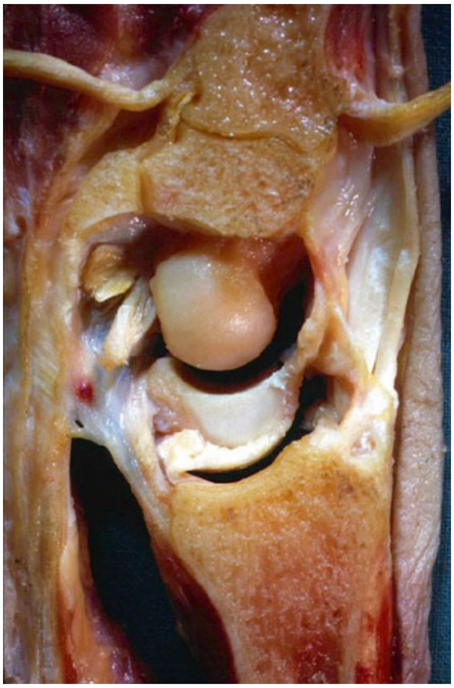


Fig. 11.1 Anatomical cut on fresh corpse, lateral section through the wrist at the metacarpal II. The remaining portion of the scaphoid is removed and radiocarpal and intercarpal palmar and dorsal ligaments loose, the scapholunate ligament is cut at its anchorage to the scaphoid, its palmar and dorsal ends are connected to the capsular ligament devices palmar and dorsal

the fibrosseous subsheath of the FCR is superimposed on the distal scaphoid, reinforcing the scapho-trapezio-trapezoid ligament and scapho-capitate ligament.

The Scapholunate Interosseous Ligament

The scapholunate interosseous ligament functions as a torsion bar by acting as a viscoelastic dampener and it interconnects the scaphoid and the lunate. It is a nonhomogeneous structure having three distinct parts: the anterior (volar) ligament is confluent with the long and short radio-lunate ligaments. The intermediate membranous fibrocartilaginous and non-vascularized part corresponds to the area that can be depressed on arthroscopic palpation. The posterior (dorsal) part is the strongest and most resistant part, and it is securely attached to the dorsal capsule which inserts onto the dorsal scapholunate ligament and is continuous with the dorsal scapho-triquetral ligament and dorsal intercarpal ligament.

Anatomical Review

- From a strictly anatomical point of view, the scapholunate articulation is characterized by the juxtaposition of two flat facet joints, producing a syndesmosis between the scaphoid and the lunate.
- Although the scapholunate interosseous ligament has been divided into three distinct anatomical parts, it would not be realistic to assign a role to any one particular part of the ligament. The nomenclature of "interosseous" ligament should be limited to the intermediate fibrocartilaginous non-vascularized therefore unrepairable part. The anterior (volar) and posterior (dorsal) parts of the scapholunate ligament, however, are perfectly integrated into the palmar and dorsal extra synovial ligaments, respectively. These parts of the SL complex are well vascularized and have a cellular structure that has the potential to heal after surgical repair.

The proximal carpal row is a complex system that must have some degree of torsional elasticity allowing flexion-extension of the scaphoid, and at the same time have stability that can withstand compressive stresses transmitted through the distal carpal row, without deforming much. This system is much more flexible on the palmar aspect permitting limited movements between the carpal bones in the sagittal plane and allows controlled chain torsion between the scaphoid, the lunate, and the triquetrum. Therefore, procedures aimed at reconstruction of the dorsal capsular ligament by a dorsal capsulodesis to restore SL stability invariably lead to stiffness of the wrist joint.

Diagnosis of SL Instability

Patients with a lesion of the scapholunate ligament often have a history of a hyperextension injury to the wrist joint due to a fall on an outstretched hand. Wrist extension and supination is the main mechanism of injury. In acute injury, clinical examination reveals localized edema and pain localized to the dorsal scapholunate interval. Scapholunate instability can be evaluated by Watson's "scaphoid shift test." This test analyzes scaphoid mobility with the wrist in radial deviation and palmar flexion, while pressure is applied on the scaphoid tuberosity in a palmar to dorsal direction.

Patients with a partial lesion of the scapholunate ligament experience pain localized on the dorsal aspect of the wrist over the scapholunate interval; but there is no "click" on performing the Watson's test. Pain experienced on the volar aspect of the scaphoid tubercle during this maneuver is not clinically significant. Patients with a complete lesion of the scapholunate interosseous ligament demonstrate subluxation of the proximal pole of the scaphoid on the posterior margin of the radius even without application of manual pressure on the scaphoid tubercle. One must, however, examine both wrists to verify that there is no constitutional instability in hypermobile patients. It is also possible to perform the Watson's test under local anesthesia if the patient experiences too much pain.

Fig. 11.2 X-ray of the wrist against objectifying an important scapholunate space

Fig. 11.3 X-ray of the wrist profile objectifying a dorsal deviation of the lunate (DISI)

Plain radiographs are essential in clinically suspected lesions of the scapholunate ligament. These include a standard postero-anterior (PA) radiograph (Fig. 11.2), radial and ulnar deviation PA views, and a strict lateral view (Fig. 11.3) and a clenched fist PA view. Gilula's lines and the scapholunate interval are assessed on the PA views whereas the scapholunate angle is measured on the lateral view. A scapholunate gap of more than 4 mm is indicative of a scapholunate ligament injury. Dynamic views are also essential to diagnose a dynamic instability that would otherwise be missed on plain radiographs. The scapholunate angle, i.e., the angle between the axis of the scaphoid and a line joining the two horns of the lunate, is measured. Normal values are between 30° and 60° with an average of 47°. An angle greater than 60°, which is the result of palmar flexion of the scaphoid, should be considered pathognomonic of scapholunate instability. The TERRY-THOMAS sign is considered positive when the space between the scaphoid and the lunate appears abnormally large compared to the opposite side. Scapholunate interval greater than 5 mm even though asymptomatic is the result of a scapholunate dissociation. The scaphoid ring sign is also useful for the diagnosis of scapholunate instability. It is seen on PA radiographs due to an overlap of the distal tubercle and proximal pole of the scaphoid with the scaphoid in palmar flexion following injury to the scapholunate interosseous ligament. On normal lateral radiographs of the wrist, a C-shaped line can be drawn together palmar edges of the scaphoid and radius. In scapholunate dissociation, flexion of the scaphoid causes an abnormal scaphoid V-shaped pattern (V-sign).

Treatment

Acute Lesions

In acute injuries, the first step is assessment and grading of the lesions. The patient is operated under regional anesthesia. With the patient in a supine position and the arm resting on an arm table, the elbow is flexed to 90°. A vertical traction of 5–7 lb is applied. In this way, the wrist can be analyzed at the same time by arthroscopy and fluoroscopy. We can also control the reduction and stabilization of the scapholunate injury. The joint is insufflated with 3–5 cc of normal saline. An abnormal passage of fluid from the radiocarpal joint to the midcarpal is already an indicator to an underlying lesion of the scapholunate ligament. The trocar and the arthroscope are introduced through a standard 3-4 radiocarpal portal. Care should be taken while inserting the trocar in order to avoid damage to the cartilage. The 4-5 or the 6R radiocarpal portal is used for passing a hook probe or instruments. It is possible to switch the position of the arthroscope and instruments at any time. The wrist is systematically examined starting from the radial side to the ulnar side. A lesion of the scapholunate ligament may not be properly appreciated until it is palpated/tested with the probe. The arthroscopic examination is then performed in the midcarpal joint. The arthroscope is introduced through radial midcarpal portal. Particular attention is paid to the dorsal edge of the scaphoid, which is in an abnormal anatomical position in case of complete scapholunate dissociation. In small wrists, it may be easier to insert the arthroscope through an ulnar midcarpal portal. A thorough examination of the radiocarpal and the

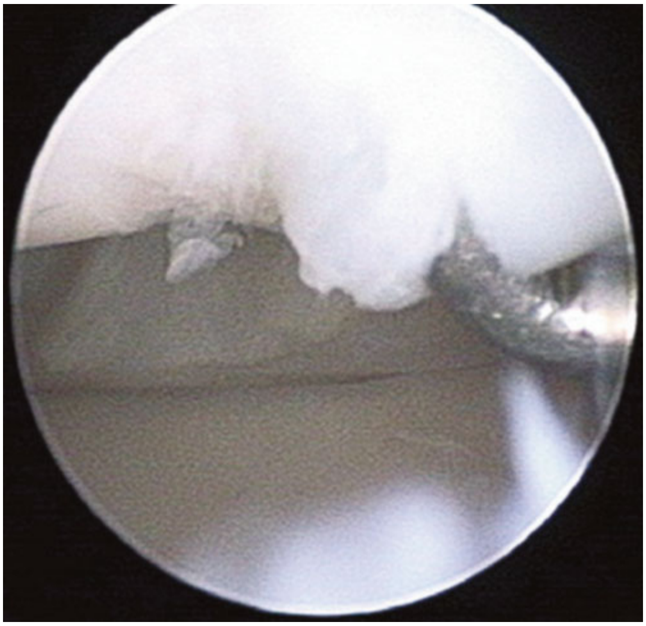


Fig. 11.4 Arthroscopic view of a radiocarpal stage I lesions, simple perforation of the scapholunate ligament

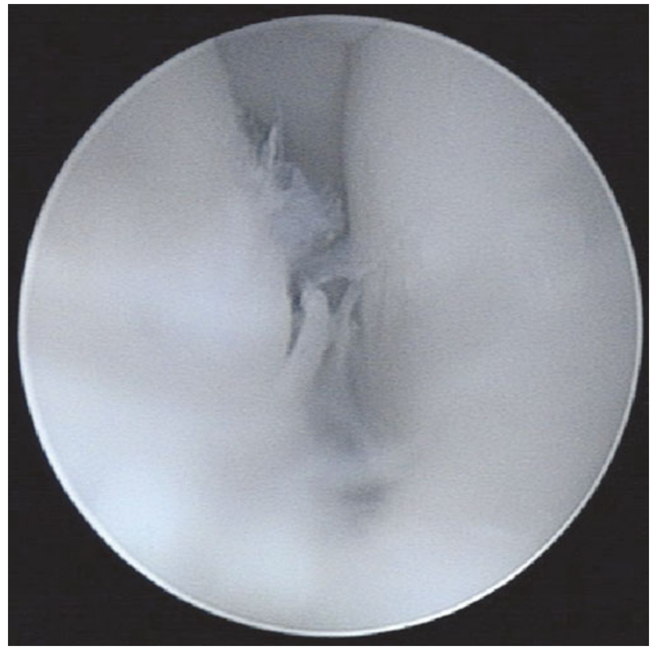


Fig. 11.5 Arthroscopic view of midcarpal injury stage II showing a moderate gap between the scaphoid and lunate

midcarpal joints will reveal any injury to the scapholunate ligament. The ability to insert a probe/scope between the scaphoid and the lunate bones, the existence of a gap between the two bones, and the existence of a step-off between the lunate and the proximal pole of the scaphoid are all indicative of a rotational instability.

The normal ligament has a smooth and slightly concave bulge that is seen perfectly in the radiocarpal space. Often this normal concave aspect becomes convex when the ligament is traumatized and becomes weakened. Normally, there is a close contact between the scaphoid and the lunate without any step-off when seen through the midcarpal portals. With the scapholunate ligament intact, it is impossible to pass a probe from the midcarpal joint to the radiocarpal joint or vice versa. In the midcarpal joint, the position of the dorsal edge of the scaphoid is also examined. With increasing severity of scapholunate ligament injury, this tends to move into palmar rotation. GEISSLER [2] has described an arthroscopic classification of carpal instabilities. In stage I (Fig. 11.4), radiocarpal examination reveals a loss of the normal concave appearance of the scapholunate ligament, which then appears convex. This marks the beginning of weakening of the scapholunate interosseous ligament. A midcarpal examination in stage I reveals a normal and congruent SL aspect without any step-off.

In GEISSLER stage II lesions (Fig. 11.5), radiocarpal arthroscopy reveals an SL ligament that appears convex as in stage I. However, midcarpal joint arthroscopy reveals a loss of congruence the scapholunate space. The scaphoid begins to flex and the dorsal edge is rotated relative to the lunate resulting in a slight step-off between the scaphoid and the lunate bones.

Fig. 11.6 Arthroscopic view of medial carpal injury stage III showing a larger gap allowing a probe between the scaphoid and the lunate the radiocarpal joint to the medial carpal

In GEISSLER stage III (Fig. 11.6), radiocarpal arthroscopy reveals damage to the SL ligament that begins in the midportion and extends toward the dorsal part. Often we begin to see an abnormal space between the scaphoid and

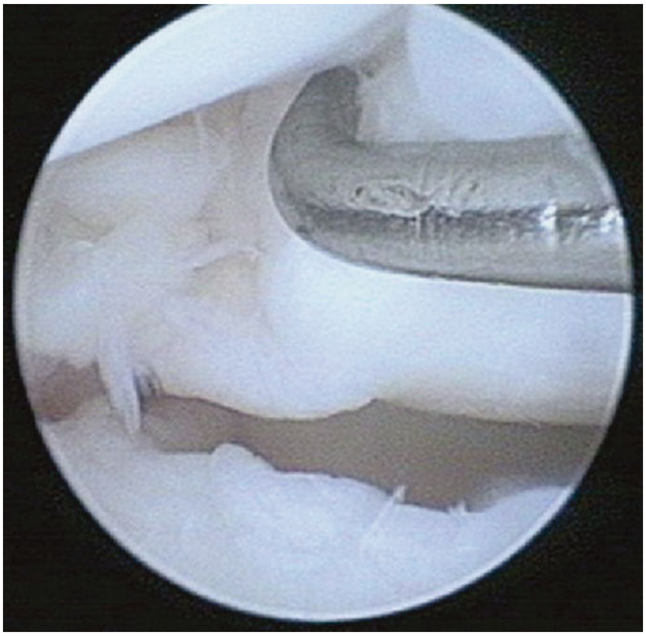


Fig. 11.7 View of a radiocarpal arthroscopic stage IV lesion, showing a complete tear of the scapholunate ligament

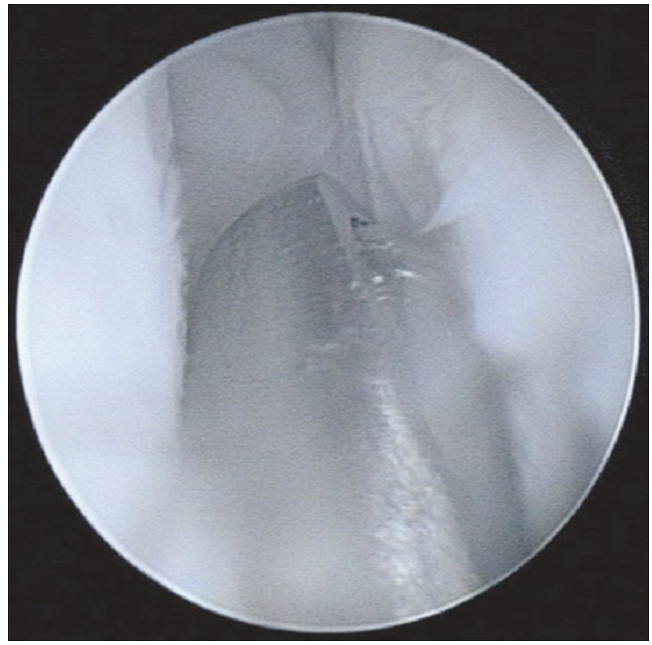


Fig. 11.8 Arthroscopic view of midcarpal injury stage IV showing a very large gap between the scaphoid and lunate letting a cutting 3 mm of the radiocarpal joint to the midcarpal

lunate. A probe can be passed through the scapholunate space and into the midcarpal joint. Often a remnant of the scapholunate ligament remains attached to the lunate. Midcarpal joint examination reveals an abnormal discrepancy between the scaphoid and lunate with a step-off. A 2 mm probe can easily pass through the space between the scaphoid and lunate.

In GEISSLER stage IV (Figs. 11.7 and 11.8), the ligament is completely torn. A 2.7 mm arthroscope can pass without difficulty from the radiocarpal joint to the midcarpal joint or back through the space between the scaphoid and the lunate ("Drive Through Sign"). There is usually no continuity of the ligament between the scaphoid and the lunate at this stage.

Patients with acute stage II or III lesions are ideal candidates for treatment by arthroscopic reduction and stabilization. The principle of treatment is to reduce the lunate and scaphoid in normal alignment and stabilization with K-wires. Under fluoroscopic control and longitudinal traction, the arthroscope is placed in the 3-4 radiocarpal portal. 1.5 mm × 10 mm K-wires are inserted percutaneously taking care not to damage the sensory cutaneous branches of the radial nerve. Leverage between the head of the capitate and the posterior horn of the lunate can provide a satisfactory reduction. Sometimes K-wires in the scaphoid and the lunate used as joysticks can control the rotation of the carpal bones. Normally 2 or 3 K-wires are placed across scapholunate space (Fig. 11.9). The K-wires are left buried under the skin and the patient is immobilized in a below-elbow splint. Ideally, the pins are removed at 8 weeks postoperatively.

Fig. 11.9 X-rays control after reduction and fixation with two pins of a scapholunate ligament injury

Rehabilitation of the wrist is commenced after removal of the K-wires and the recovery of normal mobility and strength usually requires 3 months approximately.

In GEISSLER stage IV lesions, repair by conventional open surgery is classically described. The incision passes between the third and fourth dorsal extensor compartments. The extensor pollicis longus is released from its compartment and retracted radially. The extensor digitorum tendons are retracted medially. The dorsal capsule is opened. The dorsal portion of the scapholunate ligament is repaired using small anchors and a non-absorbable suture and the repair is protected with K-wires passed from the scaphoid into the lunate. Typically, a radial dorsal capsular flap is fixed to the lunate with the aid of a small anchor. The dorsal capsule is meticulously repaired. The K-wires are usually left for 8 weeks, when they are removed before starting rehabilitation.

Chronic Scapholunate Ligament Injuries

The treatment of chronic scapholunate ligament injuries poses the most difficult challenge for hand surgeons. In fact, untreated chronic scapholunate instability eventually leads to arthritic changes in the long term [3, 4]. Very often the diagnosis is delayed and is made at an advanced stage in which arthritic changes have already set in making salvage procedures imperative and precluding sporting activities, especially among athletes. The importance of treating these injuries as soon as possible cannot be overemphasized.

Numerous reconstruction techniques have been described in literature [5–27]; however they all result in loss of mobility in an attempt to restore the stability of the SL joint.

Recently a new technique of arthroscopic repair of the dorsal capsule-ligamentous portion of the SLIOL has been described to treat all stages of acute and chronic SL ligament injuries, with encouraging results [28]. The advantage of this new technique appears to be the preservation of mobility compatible with sporting activities. Some professional athletes with chronic, severe injury to the scapholunate ligament were able to resume their sporting activities.

Surgical Technique

The surgery is performed on an outpatient basis under regional anesthesia and with an upper arm tourniquet. The elbow is flexed to 90° on an arm table and the hand is suspended by means of a hand holder with traction of 3–5 kg.

Standard arthroscopic 3-4 and 6R portals for the radiocarpal joint and MCR and MCU for the midcarpal joint are used. The joints are insufflated with normal saline. A small transverse incision is made with a 15 number scalpel followed by blunt dissection with a mosquito forceps. The 2.4 mm arthroscope is introduced through the 3-4 portal and the instruments through the 6R portal—these two portals are interchangeable according to need. The midcarpal joint is explored through the MCU portal. Exploration and palpation of the structures in the two joints confirm the lesion and provide the staging.

Table 11.1 Arthroscopic Geissler's classification

Geissler classification of cartilage lesions
Stage 1 attenuation/hemorrhage SL in RCJ; no incongruency in MCJ
Stage 2 attenuation/perforation of SL in RCJ; small incongruency in MCJ
Stage 3 perforation of SL in RCJ/incongruency and step-off in MCJ (>probe)
Stage 4 incongruency and step-off in RCJ and MCJ: Gross instability with manipulation

Table 11.2 Garcia-Elias's staging system

Stages	I	II	III	IV	V	VI
Dorsal SLL intact?	Yes	No	No	No	No	No
Repairable SLL?	Yes	Yes	No	No	No	No
Scaphoid alignment normal?	Yes	Yes	Yes	Yes	No	No
Carpal malignment reducible?	Yes	Yes	Yes	Yes	No	No
Cartilage in RC and MC joint normal?	Yes	Yes	Yes	Yes	Yes	No

Intraoperative Staging

To evaluate the extent of scapholunate dissociations we use two classification systems, which stage cartilage status and the scapholunate ligament lesion under arthroscopic vision.

Geissler and Haley [3] described four stages of arthroscopic scapholunate lesions (Table 11.1), and Garcia-Elias et al. [4] subdivided scapholunate dissociations into six different stages based on five clinical and arthroscopic criteria (Table 11.2).

Only Garcia-Elias stages 2, 3, and 4 were treated with this technique. The carpal alignment is noted as either being preserved (stages 2 and 3) or amenable to correction if malalignment was seen (stage 4). If the arthroscopic findings coincided with one of the three stages above, then the procedure of dorsal capsuloligamentous repair was performed. Usually, the scapholunate ligament is detached from the scaphoid and remains attached to the lunate, but on the dorsal aspect, close to the normal insertion of scapholunate ligament to the capsule, there are remnants of the scapholunate ligament on both the dorsal horn of lunate and the scaphoid. It is difficult to visualize the dorsal scapholunate ligament (particularly its scaphoid portion) from a 6R portal because, when the wrist is in traction, the dorsal capsule is apposed against the ruptured ligament. However, using correct triangulation with a 30° oblique scope in the 6R portal after releasing the traction allows for proper visualization of the torn ligament in this region. A needle is inserted under direct vision through the 3-4 radiocarpal portal into the radiocarpal joint. Care is taken not to directly enter the open part of the capsule. The needle is inserted through the dorsal capsule up to 1 mm from the capsular hole and then the needle is directed through the radial remnant of the S-L ligament obliquely

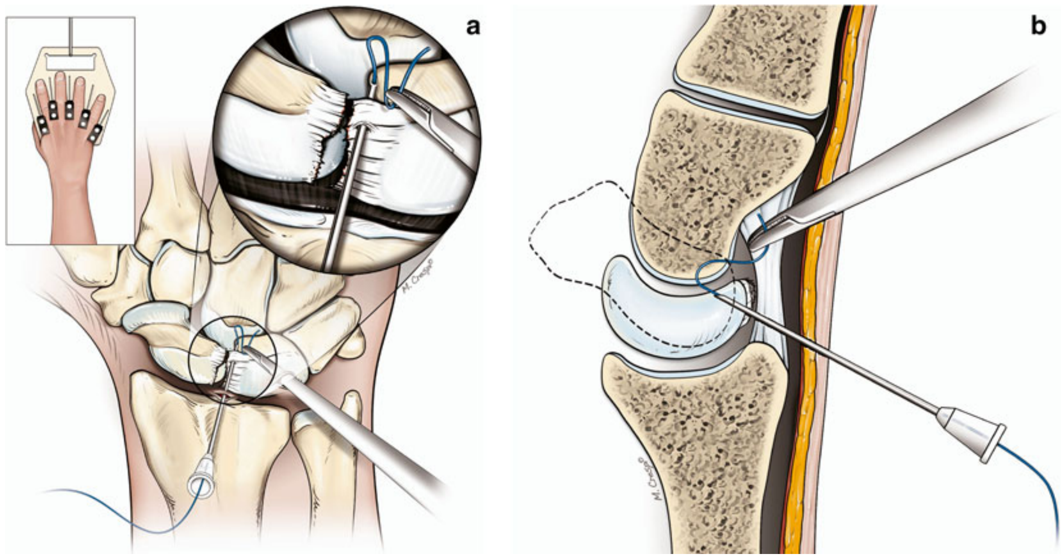


Fig. 11.10 (**a**) Schema representing of face and profile the passage of the first suture through the dorsal capsule and then a remaining dorsal fragment of the scapholunate ligament attached to the dorsal horn of lunate. (**b**) The passage made by radiocarpal to midcarpal joint

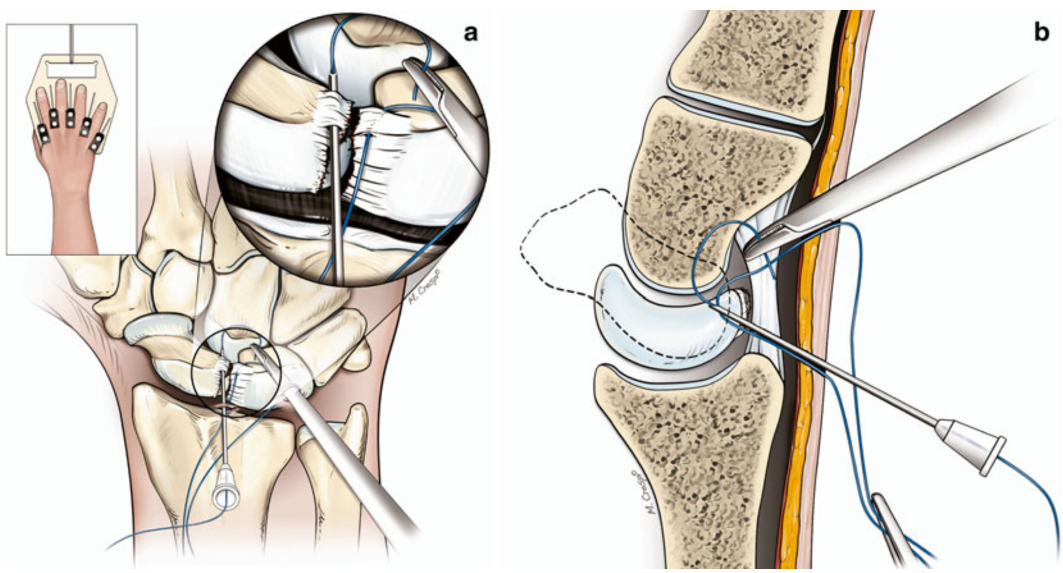


Fig. 11.11 (**a**) Schema representing of face and profile the passage of the second suture through the dorsal capsule and then a remaining dorsal fragment of the scapholunate ligament attached to the dorsal scaphoid. (**b**) The passage made by radiocarpal to midcarpal joint

from dorsal to palmar and proximal to distal, with the tip of the needle seen in the midcarpal joint. The scope is then switched to the MCU portal and a 3.0 PDS suture is passed through the needle and pulled out through the MCR portal with a hemostat under direct vision from the MCU portal (Fig. 11.10a, b). A second suture is then passed parallel to the first one in the lunate/ulnar remnant of SL ligament and brought out through the same portal (Fig. 11.11a, b). A knot is tied between the two sutures. Following this, distal to proximal traction is applied to the both proximal ends of the sutures in order to place the first knot into the midcarpal joint between the scaphoid and the lunate, volar to the dorsal part of SL ligament (Fig. 11.12). A second knot is tied between the two proximal ends and introduced in the 3-4 portal incision, dorsal to the capsule. This knot lies outside the wrist joint on the dorsal capsule. The net effect of this achieves a capsuloligamentous repair between the scapholunate ligament and the dorsal capsule overlying the ligament (Fig. 11.13a, b). However, it must be borne in mind that if the scapholunate ligament has been completely avulsed off the bone instead of being torn and if there are no remnants, this procedure cannot be performed. The procedure for stage 4 cases is slightly different from that described above. In such instances, the scaphoid must be reduced and stabilized with both the lunate and capitate. This is done by external and internal maneuvers under fluoroscopic control. Once the reduction is confirmed then the capsuloligamentous repair can be performed. The scaphoid is stabilized with 1.2 mm parallel K-wires passed through the scaphoid into the capitate (Fig. 11.14). The final dorsal knot is performed after SL stabilization and fixation with K-wires. The radiocarpal and midcarpal joints are thoroughly lavaged before instrument retrieval. The portal incisions are not sutured. A bulky dressing and a simple volar splint are applied upon completion of the surgery. The splint is removed at 6 weeks postoperatively while the K-wires are removed between 6 and 8 weeks postoperatively.

Results

Between April 2008 and September 2011 we operated 79 patients with this technique. There were 34 males and 23 females with a mean age of 38.72 ± 11.33 years (range 17–63 years). The dominant side was involved in 52 cases.

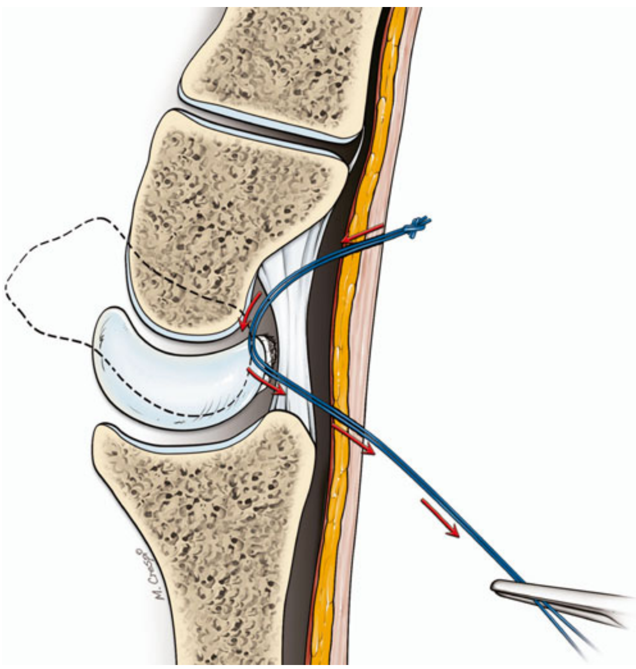


Fig. 11.12 After a first knot was tied between the two sutures, a distal to proximal traction was applied to the both proximal ends of the sutures to place the first knot into the midcarpal joint between the scaphoid and the lunate, volar to the dorsal part of SL ligament

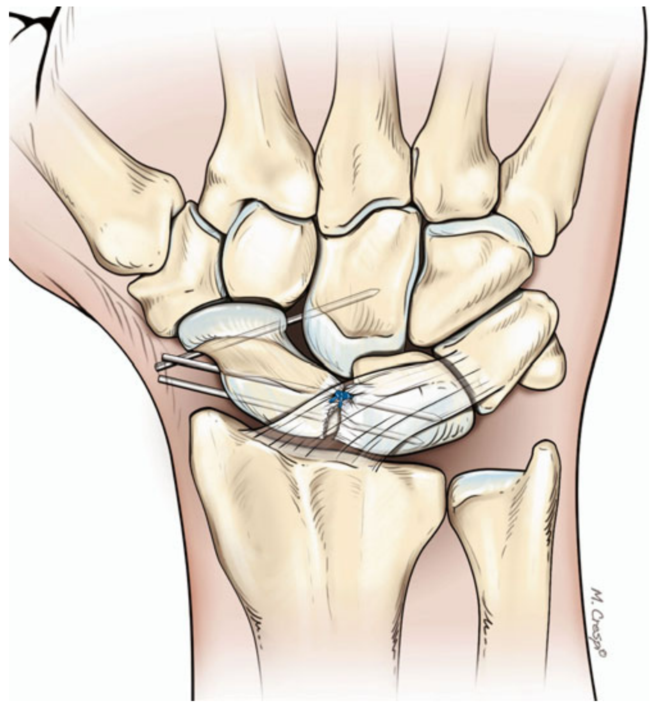


Fig. 11.14 Schema representing of face the stabilization of scaphoid by 1.2 mm parallel K-wires applied through the scaphoid into the capitate in only stage 4 according to the Garcia-Elias's staging. The final dorsal knot was performed after SL fixation

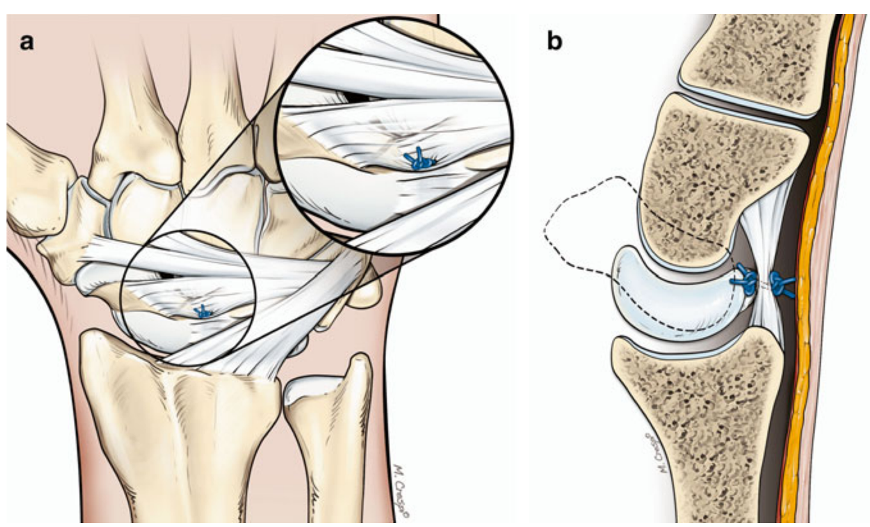


Fig. 11.13 (**a**) Schema representing of face and profile the second knot tied between the two proximal ends and introduced in the 3-4 portal incision, dorsal to the capsule. This knot lies outside the wrist joint on the dorsal capsule. (**b**) The net effect of this achieves a capsuloplasty between the scapholunate ligament and the dorsal capsule overlying the ligament

The mean time since injury was 9.42 ± 6.33 months (range 3–24 months) and the mean follow-up was 30.74 ± 7.05 months (range 18–43 months). The mean range of motion improved in all directions. The mean difference between the post- and preoperative extension was 14.03° (SEM = 1.27°; $p < 0.001$); while the mean difference between the post- and preoperative flexion was 11.14° (SEM = 1.3°; $p < 0.0001$) with flexion and radial deviation reaching 84.3 % and 95.72 %, respectively, of the unaffected wrist. The mean difference for the VAS score was −5.46 (SEM = 0.19; $p < 0.0001$). The mean postoperative grip strength of the affected side was 38.42 ± 10.27 kg (range 20–60 kg) as compared to mean preoperative grip strength of 24.07 ± 10.51 kg (range 8–40 kg) ($p < 0.0001$). The mean postoperative grip strength of the operated side was 93.4 % of the unaffected side. The DISI was corrected in all cases on postoperative radiographs. The mean difference between the post- and preoperative SL angles was −8.95° (SEM = 1.28°; $p < 0.0001$). The mean postoperative DASH score was 8.3 ± 7.82 as compared to mean preoperative DASH score of 46.04 ± 16.57 ($p < 0.0001$). There was a negative corelation between the overall DASH score and the postoperative correction of the DISI deformity with a lower DASH score associated with increasing SL angles (Fig. 11.7).

Using Garcia-Elias's staging system three patients were classified as stage 2, 25 patients as stage 3, and 29 patients as stage 4. Twenty patients required temporary K-wire fixation. Sixteen patients had associated TFCC lesions which are treated arthroscopically in the same operative session. All the patients returned to work in an average period of 9 weeks (range 1–12 weeks) and all the professional-level athletes continued their sporting activities at the same level as prior to the injury (Fig. 11.15a–g). Fifty-six patients (98.2 %) were very satisfied or satisfied with their result. One patient had a fair result and was unsatisfied, mainly due to postoperative wrist stiffness.

Radiographic Results

The mean difference in the means of the preoperative and postoperative SL angle was −8.95° (SEM = 1.28°, $p < 0.0001$). The DISI remained uncorrected in 11 patients (19 %) postoperatively.

Discussion

Scapholunate dissociation occurs due to the rupture of the scapholunate ligament and at least one of the extrinsic ligaments that stabilize this complex.

Untreated scapholunate dissociation eventually leads to osteoarthritic changes that worsen with time—the so-called SNAC wrist. Numerous open surgical techniques have been described for the treatment of chronic SL tears, but they often result in stiffness and reduced mobility of the wrist joint. The best results are obtained by arthroscopic techniques particularly in the acute phase. Our understanding of scapholunate instability has improved a lot in recent years. Salva-Coll and Garcia Elias et al. in 2011 [29] have shown the importance of extrinsic elements in maintaining SL stability, particularly the flexor carpi radialis tendon.

Meade et al. [30] in 1990, Short et al. [31], Looy et al. in 2001, and Berger et al. [32] in 1999 have shown that the dorsal portion of the scapholunate ligament was the primary stabilizer of the scapholunate interval.

Mataliotakis et al. [33, 34] in 2009 and 2011 have shown the importance of proprioception in maintaining scapholunate stability through a protective action of the neighboring musculo-tendinous units. This chapter suggests that proprioception plays an important role in the preserving scapholunate stability and it is important to protect not only the anterior interosseous nerve, but also the posterior interosseous nerve.

Gamal Elsaidi et al. [35] in 2004 performed a systematic anatomical study of the effect of serial sectioning of ligaments on the palmar, dorsal, and the interosseous portions of the SL ligament and the extrinsic ligaments and they demonstrated that the dorsal tilt of the lunate (DISI pattern) reflecting scapholunate instability resulted only after cutting the insertion of the dorsal intercarpal ligament.

We also conducted cadaveric anatomical studies with radiological analysis and arthroscopy examination with and without axial loads, performed in the following sequence:

Normal Wrist

– Section of the dorsal capsule-ligamentous septum (the structure located between scapho-triquetral ligament, the proximal portion of the dorsal intercarpal ligament) and the dorsal portion of the scapholunate ligament
– Sectioning of the scapholunate interosseous ligament
– Sectioning of the dorsal intercarpal ligament

These studies demonstrated a systematic worsening of the scapholunate dissociation after sectioning of the attachment between the capsule and the dorsal scapholunate ligament.

A new anatomical work was performed showing the existence of the anatomical structure that was consistently found in all specimens, and which consists of two transverse arches united by a third arch, which is wider than the other two. This capsule-ligamentous structure strongly reinforces the dorsal portion of the scapholunate ligament with the dorsal capsule. Our principle of arthroscopic repair aims to repair and reinforce the dorsal attachment between the capsule and the scapholunate ligament, in a minimally invasive manner to maintain mobility, which might explain the good results in our series.

Surprisingly, a repeat second look arthroscopy in a few cases at 2 months revealed a good repair of the dorsal portion but a complete absence of the interosseous part of the repaired scapholunate ligament.

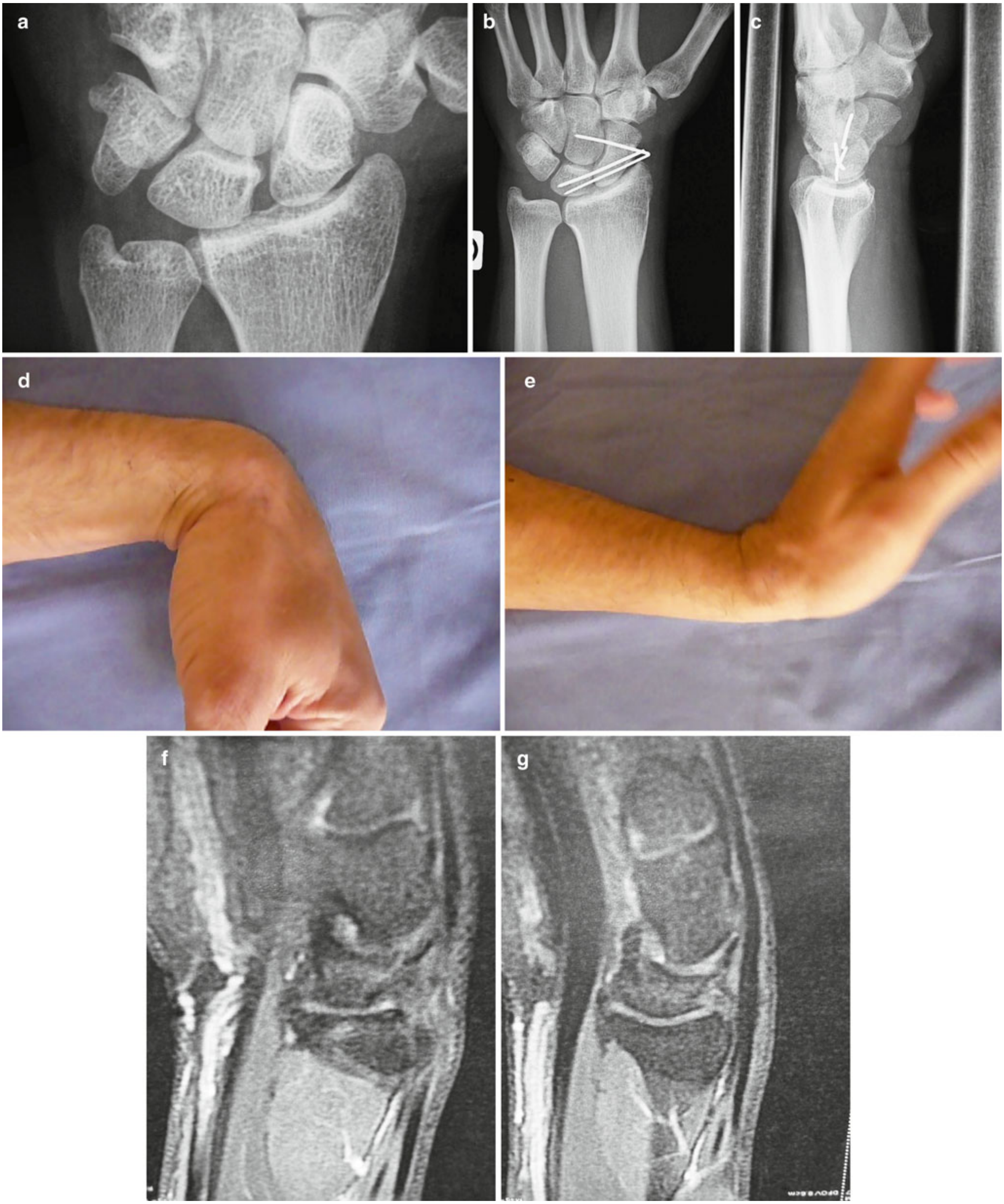


Fig. 11.15 (**a**) Clinical case of scapholunate dissociation 9 months after injury—(Garcia-Elias's stage 4). (**b**, **c**) X-rays showing the correct reduction and stabilization of scapholunate space after arthroscopic dorsal capsuloplasty. (**d**, **e**) 24 months of follow-up, recovery of excellent range of motion in both extension and flexion. (**f**, **g**) MRI after 18 months showing the correct reduction of lunate, and the reality of the dorsal capsuloplasty with a thickening of the capsule compared with the horn of the lunate and even a tightening of this capsule toward the lunate

The intermediate portion of the interosseous ligament scapholunate is avascular and probably has no role in maintaining scapholunate stability.

Proprioception is probably not assessed properly and plays an important role in maintaining scapholunate stability. Arthroscopic techniques are less invasive compared to open surgical techniques and therefore cause lesser denervation and loss of proprioception.

There is a controversy regarding the existence of a distal lesion of the scapho-trapezio-trapezoidal ligament between the trapezoid, trapezium, and distal and anterior aspect of the scaphoid. Some authors even consider that there may be flattening of the scaphoid in cases of rupture of this ligament. However, we have never encountered such a case, even in cases with stage 5 SL tears with complete flexion of the scaphoid. We did observe a stretching of this ligament, but never a ligament tear as seen at the dorsal portion of the scapholunate ligament.

We also observed isolated lesions of the dorsal capsule-ligamentous septum causing detachment of the dorsal capsule from the dorsal portion of the scapholunate ligament. In these isolated lesions midcarpal arthroscopy systematically revealed a scapholunate dissociation that could progress to a Geissler stage III.

This probably constitutes the first stage of SL instability or predynamic instability.

Finally the role of extrinsic ligaments is being elucidated in different studies. Their importance is well established, particularly the volar long radio-lunate and the radio-scaphocapitate ligament, and dorsally the dorsal radiocarpal ligament and the dorsal intercarpal ligaments. A new concept of scapholunate complex is evolving, in the same way as the triangular ligament had evolved into the TFCC.

References

1. Mayfield JK. Patterns of injury to carpal ligaments. A spectrum. Clin Orthop Relat Res. 1984;187:36–42.
2. Geissler WB, Haley T. Arthroscopic management of scapholunate instability. Atlas Hand Clin. 2001;6(2):253–74.
3. Pilny J, Kubes J, Hoza P, Sprlakova A, Hart R. Consequence of nontreatment of scapholunate instability of the wrist. Rozhl Chir. 2006;85:637–40.
4. Watson HK, Ballet FL. The SLAC wrist: scapholunate advanced collapse pattern of degenerative arthritis. J Hand Surg Am. 1984;9(3):358–65.
5. Garcia-Elias M, Lluch AL, Stanley JK. Three-ligament tenodesis for the treatment of scapholunate dissociation: indications and surgical technique. J Hand Surg. 2006;31A:125–34.
6. Blatt G. Capsulodesis in reconstructive hand surgery. Dorsal capsulodesis for the unstable scaphoid and volar capsulodesis following excision of the distal ulna. Hand Clin. 1987;3(1):81–102.
7. Busse F, Felderhoff J, Krimmer H, Lanz U. Scapholunate dissociation: treatment by dorsal capsulodesis. Handchir Mikrochir Plast Chir. 2002;34:173–81.
8. Deshmukh SC, Givissis P, Belloso D, Stanley JK, Trail IA. Blatt's capsulodesis for chronic scapholunate dissociation. J Hand Surg Br. 1999;24(2):215–20.
9. Slater RR, Szabo RR, Bay BK, Laubach J. Dorsal intercarpal ligament capsulodesis for scapholunate dissociation: biomechanical analysis in a cadaver model. J Hand Surg Am. 1999; 24A:232–9.
10. Szabo RM, Slater RR, Bay BK, Palumbo GF, Gerlach T. Dorsal intercarpal ligament capsulodesis for chronic static scapholunate dissociation: clinical results. J Hand Surg Am. 2002;27:978–84.
11. Wintman BI, Gelberman RH, Katz JN. Dynamic scapholunate instability: results of operative treatment with dorsal capsulodesis. J Hand Surg Am. 1995;20A:971–9.
12. Gajendran VK, Peterson B, Slater Jr RR. Long-term outcomes of dorsal intercarpal ligament capsulodesis for chronic scapholunate dissociation. J Hand Surg Am. 2007;32(9):1323–33.
13. Moran SL, Ford KS, Wulf CA, Cooney WP. Outcomes of dorsal capsulodesis and tenodesis for treatment of scapholunate instability. J Hand Surg Am. 2006;31(9):1438–46.
14. Brunelli F, Spalvieri C, Bremner-Smith A, Papalia I, Pivato G. Dynamic correction of static scapholunate instability using an active tendon transfer of extensor brevi carpi radialis: preliminary report. Chir Main. 2004;23(5):249–53.
15. Chabas JF, Gay A, Valenti D, Guinard D, Legre R. Results of the modified Brunelli tenodesis for treatment of scapholunate instability: a retrospective study of 19 patients. J Hand Surg Am. 2008; 33A:1469–77.
16. Talwalkar SC, Edwards AT, Hayton MJ, Stilwell JH, Trail IA, Stanley JK. Results of tri-ligament tenodesis: a modified Brunelli procedure in the management of scapholunate instability. J Hand Surg Am. 2006;31B:110–7.
17. De Smet L, Van Hoonacker P. Treatment of chronic static scapholunate dissociation with the modified Brunelli technique: preliminary results. Act Orthop Belg. 2007;73:188–91.
18. Links AC, Chin SH, Waitayawinyu T, Trumble TE. Scapholunate interosseous ligament reconstruction: results with a modified Brunelli technique versus four-bone weave. J Hand Surg Am. 2008;33(6):850–6.
19. Harvey EJ, Berger RA, Osterman AL, Fernandez DL, Weiss AP. Bone-tissue-bone repairs for scapholunate dissociation. J Hand Surg Am. 2007;32(2):256–64.
20. Almquist EE, Bach AW, Sack JT, Fuhs SE, Newman DM. Four bone ligament reconstruction for treatment of chronic complete scapholunate separation. J Hand Surg Am. 1991;16A:322–7.
21. Bleuler P, Shafighi M, Donati OF, Gurunluoglu R, Constantinescu MA. Dynamic repair of scapholunate dissociation with dorsal extensor carpi radialis longus tenodesis. J Hand Surg Am. 2008;33A:281–4.
22. Ogunro O. Dynamic stabilization of chronic scapholunate dissociation with Palmaris longus transfer: a new technique. Tech Hand Up Extrem Surg. 2007;11:241–5.
23. Rosenwasser MP, Miyasajsa KC, Strauch RJ. The RASL procedure: reduction and association of the scaphoid and lunate using the Herbert screw. Tech Hand Up Extrem Surg. 1997;1(4): 263–72.
24. Zarkadas PC, Gropper PT, White NJ, Perey BH. A survey of the surgical management of acute and chronic scapholunate instability. J Hand Surg Am. 2004;29(5):848–57.
25. Weiss APC. Scapholunate ligament reconstruction using a bone-retinaculum-bone autograft. J Hand Surg Am. 1998;23A: 205–15.
26. Siegel JM, Ruby LK. A critical look at intercarpal arthrodesis: review of the literature. J Hand Surg Am. 1996;21(4):717–23.
27. Pomerance J. Outcomes after repair of the scapholunate interosseous ligament and dorsal capsulodesis for dynamic

scapholunate instability due to trauma. J Hand Surg Am. 2006;31(8):1480–6.
28. Mathoulin C, Dauphin N, Sallen V. Capsulodèse arthroscopique dorsale dans les lésions chroniques du ligament scapho-lunaire. Chir Main. 2009;28(6):398.
29. Salva-Coll G, Garcia-Elias M, Liusà-Pérez M, Rodriguez-Baeza A. The role of the flexor carpi radialis muscle in scapholunate instability. J Hand Surg Am. 2011;36(1):31–6.
30. Meade TD, Schneider LH, Cherry K. Radiographic analysis of selective ligament sectioning at the carpal scaphoid: a cadaver study. J Hand Surg Am. 1990;15(6):855–62.
31. Short WH, Werner FW, Sutton LG. Dynamic biomechanical evaluation of the dorsal intercarpal ligament repair for scapholunate instability. J Hand Surg Am. 2009;34(4):652–9.
32. Berger RA, Imeada T, Berglund L, et al. Constraint and material properties of the subregions of the scapholunate interosseus ligament. J Hand Surg Am. 1999;24(5):953–62.
33. Mataliotakis G, Doukas M, Kostas I, Lykissas M, Batistatou A, Beris A. Sensory innervation of the subregions of the scapholunate interosseous ligament in relation to their structural composition. J Hand Surg Am. 2009;34(8):1413–21.
34. Vekris MD, Mataliotakis GI, Beris AE. The scapholunate interosseous ligament afferent proprioceptive pathway: a human in vivo experimental study. J Hand Surg Am. 2011;36(1): 37–46.
35. Elsaidi GA, Ruch DS, Kuzma GR, Smith BP. Dorsal wrist ligament insertions stabilize the scapholunate interval: cadaver study. Clin Orthop Relat Res. 2004;425:152–7.

Arthroscopic Management of Lunotriquetral Ligament Tears

12

Michael J. Moskal and Felix H. Savoie III

Introduction

The diagnosis and treatment of ulnar-sided wrist pain is complex. Arthroscopic evaluation is particularly valuable to examine the anatomy and pathoanatomy of ulnar-sided wrist disorders [1]. Physical examination, radiographs, as well as MRI or arthrography, often do not reveal the full extent of an injury. Wrist arthroscopy facilitates clear characterization of an injury, the quality of the articular surfaces, associated synovitis, as well as treatment based upon an arthroscopic evaluation. Arthroscopic evaluation as well as arthroscopic assessment techniques may allow for specific treatment based upon surgical findings correlated to clinical findings. Arthroscopic treatment needs to be undertaken in the clinical context of history, physical examination, and radiology studies.

Ulnar sided wrist injuries can be owing to repetitive trauma or to a single traumatic event such as a twisting injury or a fall on an outstretched hand with a pronated forearm in which a dorsally directed force causes the wrist to be extended and radially deviated [2]. Although isolated traumatic lunotriquetral ligament tears are not common. Intercarpal pronation causes a disruption of the ulnar ligaments by tearing the lunotriquetral interosseous ligament with associated injury to the disc-triquetral and disc-lunate ligaments tearing leading to greater lunotriquetral instability. It is important to recognize that instability can arise from intrinsic as well as extrinsic ligamentous injury [3–5]. Failure to recognize and treat all the components of a destabilizing injury will lead to a compromised result of treatment.

Lunotriquetral (LT) interosseous ligament tears may be associated with ulnar-sided wrist pain. However, LT ligament tears may not be isolated pathology. Ulnar sided wrist pain is typically intermittent and associated with forearm rotation with wrist deviation. Pain from a mechanical etiology may be due to impingement of ligament or fibrocartilage tears, instability of the lunotriquetral and or distal radioulnar (DRUJ) joints, and arthritic change. Symptoms of pain and weakness are common and often associated with a give way sensation.

Clinical scenarios are appropriate for arthroscopic treatment involve the following anatomical pathology.

1. Isolated lunotriquetral instability.
2. Lunotriquetral instability associated with triangular fibrocartilage cartilage complex (TFFC) tears.
   (a) Traumatic peripheral tears.
   (b) Degenerative radial or central tears.
3. Lunotriquetral instability, degenerative TFFC tears, and ulnar abutment syndrome.

Physical Examination

A comprehensive physical examination is appropriate in the clinical setting. In the context of this chapter, examination focused on ulnar-sided pathology is detailed in brief. Inspection, range of motion in comparison to the opposite side, and palpation are performed. The extensor carpi ulnaris (ECU) is the main anatomic landmark to guide palpation. Radial dorsal and ulnar volar to the ECU is the area of capsular attachment of the peripheral TFC and both areas should be routinely palpated. Additionally, palpate the area dorsal lunotriquetral joint, extensor carpi ulnaris, the extensor digiti quinti, and flexor carpi ulnaris.

After inspection and palpation, provocative maneuvers for lunotriquetral instability are helpful: lunotriquetral ballottement (compressing the triquetrum against the lunate),

M.J. Moskal, M.D. (✉)
Orthopaedic Surgery Department, University of Louisville, 130 Hunter Station Way, Sellersburg, IN 47172, USA
e-mail: Moskal@msn.com

F.H. Savoie III, M.D.
Department of Orthopaedics, Tulane University School of Medicine, 1430 Tulane Avenue, SL-32, New Orleans, LA 70112, USA
e-mail: fsavoie@tulane.edu

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*,
DOI 10.1007/978-1-4614-1596-1_12, © Springer Science+Business Media New York 2015

shuck test as described by Reagan [6], shear test as described by Kleinman [7, 8], distal radioulnar translation (to infer stability) [9, 10]. Localized pain and crepitus may accompany the aforementioned provocative tests.

Ulnar deviation should be performed with the wrist in a flexed, extended and neutral position. Flexing and extending an ulnar deviated wrist my produce pain associated with crepitus can be a useful indicator of associated ulnar pathology with LT tears. Ulnar deviation with axial load with the pronated forearm associated with a palpable clunk may be due to lunotriquetral instability but also may be seen in midcarpal instability. Pain and/or weakness resisted wrist flexion with the forearm in supination increases the suspicion for symptomatic TFC tears.

The radiographic evaluation of a painful wrist should include at least a zero rotation posteroanterior [11, 12] and a true lateral of the wrist views. Particular attention should be focused toward ulnar variance [13, 14], lunotriquetral interval and the integrity of the subchondral joint surfaces, greater and lesser arc continuity [15], and radiolunate and scapholunate angles should be recorded. In cases where the physical examination findings are equivocal, an arthrogram or MRI can be obtained.

Ulnar Ligamentous Anatomy

The lunotriquetral interosseous ligament (LT) is thicker both volarly and dorsally [16] with a membranous central portion. Normal lunotriquetral kinematics is imparted from the integrity of the LT interosseous [3], ulnolunate (UL), ulnotriquetral (UT) [3–5], dorsal radiotriquetral (RT), and scaphotriquetral (ST) ligaments [3, 4, 6]. Severe instability (VISI) requires damage to both the dorsal RT and ST ligaments [3, 4, 6]. The TFCC is the primary stabilizer of the distal radioulnar joint via the dorsal and volar radioulnar ligaments [17, 18], helps to stabilize the ulnar carpus, and transmits axial forces to the ulna [9, 19]. TFCC compromise is often a part of more extensive ulnar-sided injuries [20]. The TFCC originates from the ulnar aspect of the lunate fossa of the radius and inserts on the base of the ulnar styloid and distally on the lunate, triquetrum, hamate, and fifth metacarpal base. The volar and dorsal aspects of the lunotriquetral ligament merge with the ulnocarpal extrinsic ligaments volarly and the dorsal radiolunotriquetral ligament dorsally anchoring the triquetrum [21].

The ulnocarpal volar ligaments are composed of the ulnolunate (UL) also known as the disc-lunate, the ulnotriquetral (UT) also known as the disc-triquetral ligaments, and the ulno-capitate. The ulnolunate (UL) and ulnotriquetral (UT) ligaments originate on the volar triangular fibrocartilage complex (TFCC) and inserts on the volar lunate and volar triquetrum, respectively, as well as the LT ligament [20, 22, 23]. Just palmar to the disc carpal ligaments is the ulno-capitate ligament. The ulno-capitate ligament provides a direct attachment from the ulna to the palmar ulnar ligamentous complex. The integrity of the triangular fibrocartilage, volar radiocarpal, as well as dorsal radiocarpal ligaments is visible during arthroscopy. Our approach to LT injuries had evolved from the anatomical concepts of the ulnar ligaments in relationship to the lunotriquetral joint and the TFCC.

Arthroscopic Operative Technique

Chronic isolated lunotriquetral ligament injuries have been treated with ligament repair, ligament reconstruction, and lunotriquetral joint fusion. Compromise of the dorsal extrinsic ligaments (dorsal radiotriquetral and scaphotriquetral) with LT instability producing a VISI deformity is a contraindication to arthroscopic ligament plication. Arthroscopic stabilization of ulnar-sided instability can be used in conjunction with associated pathology such as ulnar abutment syndrome and TFCC tears when associated with a LTIOL tear.

The arthroscopic approach to symptomatic LT instability is a soft tissue procedure reconstruction based upon the contributing factors of the ulnar carpal ligaments to lunotriquetral joint stability. Included in arthroscopic reduction and internal fixation of the lunotriquetral joint, suture plication of the ulnar ligaments serves to shorten the disc-carpal ligaments and augment the palmar capsular tissue.

In the management of capitolunate instability [24], ligament plication of the central portion of the volar radiocapitate ligament was tethered to the radiotriquetral ligament by a volar approach. Ligament plication of the UT-UL ligaments is reminiscent of this technique as was developed by one of us (FHS). Arthroscopic volar ulnar ligament plication allows direct visual assessment of pathology and visual assessment of the plication effect during radiocarpal and radiocarpal and midcarpal arthroscopy.

Typical portals used during arthroscopic capsulodesis (ligament plication) and arthroscopic reduction and internal fixation are the 3-4, 6-R, volar 6-U, and the radial and ulnar midcarpal portals. Depending upon each unique case, the addition of a 4-5 portal as either the working or viewing portal can be helpful. (Fig. 12.1) The arthroscopic video system should be positioned to allow a clear view of the monitor by the surgeon and assistant. After the limb was exsanguinated, a traction tower is used and eight to ten pounds of traction are applied through finger traps with the arm strapped to the hand table. Diagnostic radiocarpal arthroscopy should include visualization should also be from the 6-R portal to ensure complete visualization of the lunotriquetral interosseous ligament (LTIOL) from dorsal to palmar. Midcarpal assessment begins with the arthroscope inserted into the radial midcarpal portal and the ulnar midcarpal portal as the working portal. The lunotriquetral joint is assessed for congruency and laxity of the triquetrum.

1. Congruency
   (a) The lunate and triquetrum should be colinear. If the view of the lunotriquetral joint from the midcarpal radial portal is blocked by a separate lunate facet [25], place the arthroscope in the midcarpal ulnar portal to gain visualization. Under these conditions, the radial articular edge of triquetrum should be aligned with the most ulnar articular edge of the hamate facet of the lunate (Figs. 12.2a, b).
   (b) Although congruent, the LT joint may be unstable due excessive laxity.
2. Laxity
   (a) Assuming normal, the scapholunate joint can be used as a reference. Laxity should be assessed both upon triquetral rotation and separation from the lunate.
   (b) Upon midcarpal arthroscopic assessment of an unstable LT joint, the dorsal portion of the triquetrum is often rotated such that its articular surface is distal to the lunate (Fig. 12.3). The triquetrum can be translated to a reduced state in which the articular surfaces of the triquetrum and lunate are collinear.
   (c) An unstable LT joint may have colinear articular surfaces however, the triquetrum can be ulnarly translated so as to "gap open" the LT joint. The normal SL joint can be used as a reference.

The final midcarpal assessment of the LT joint is the dorsal capsular structures. The dorsal radiocarpal and dorsal intercarpal ligaments attach to the lunate and triquetrum in part. In certain cases, avulsions of the dorsal capsuloligamentous structures have been observed (Fig. 12.4).

The arthroscope is placed in the 3-4 portal during disc-lunate to ulno-capitate to disc-triquetral ligament plication. The volar 6-U (v6-U) is established. The v6-U portal is similar to the normal 6-U portal; however, it is placed just dorsal

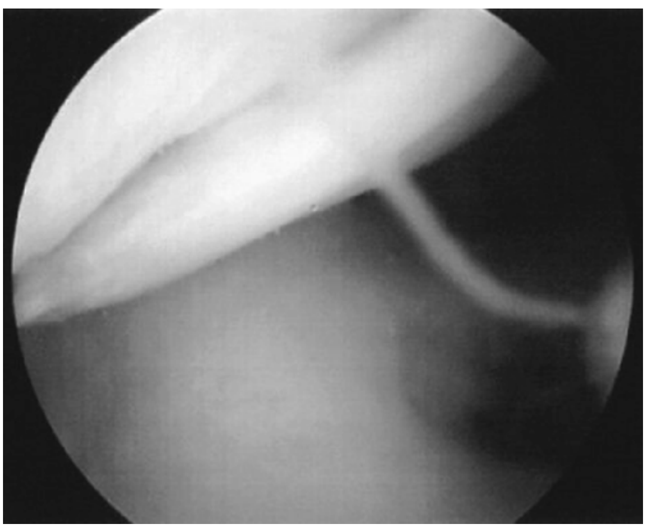


Fig. 12.1 A lunotriquetral ligament tear as seen from the 6-R portal

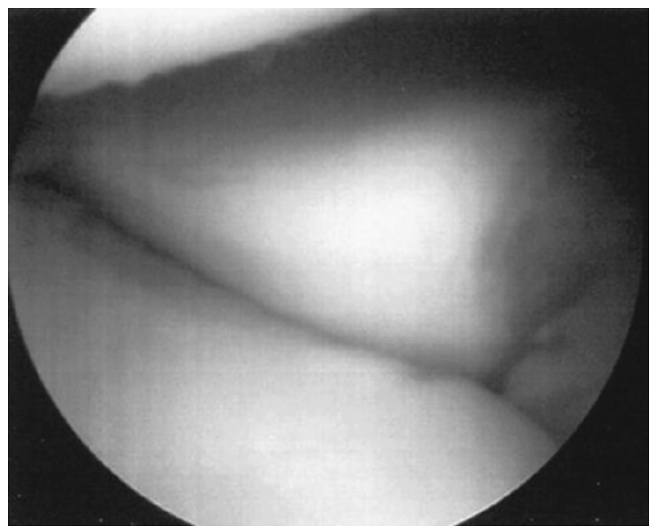


Fig. 12.3 As seen from the radial midcarpal portal, the dorsal portion of the triquetrum is rotated distally with respect to the dorsal portion of the lunate

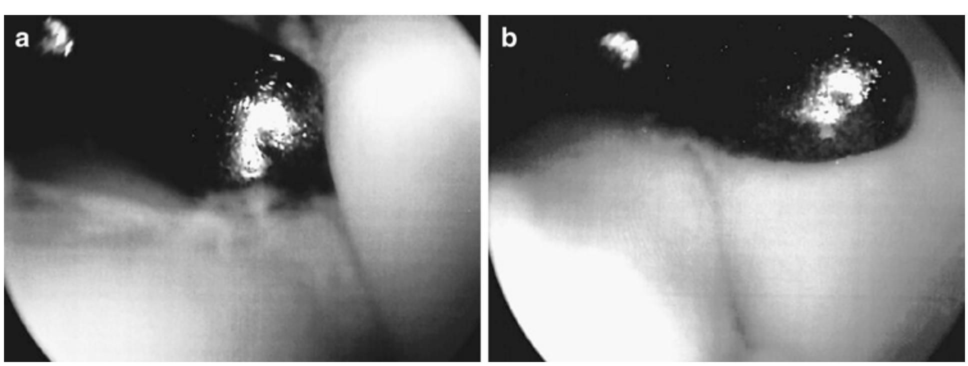


Fig. 12.2 (**a**) An incongruent LT joint as seen from the ulnar midcarpal portal. The probe has been inserted from the radial midcarpal portal. The triquetrum is to the right and the lunate is to the *left*. (**b**) The triquetrum has been reduced and stabilized with K-wires and now is congruent with the lunate (*left*)

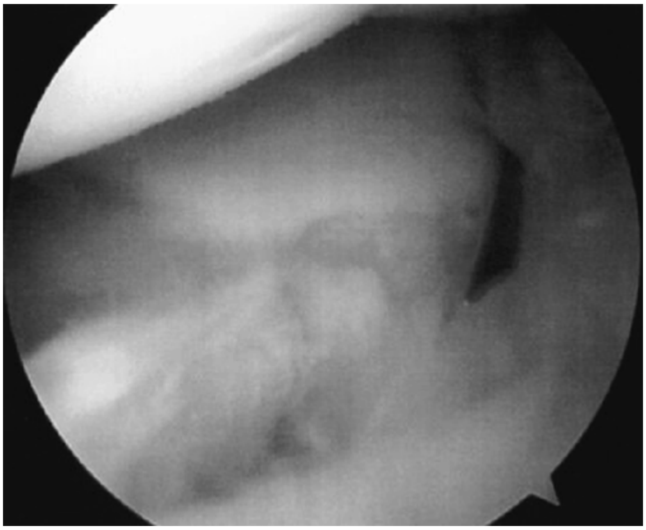


Fig. 12.4 Viewing from the radial midcarpal portal, the dorsal capsuloligamentous structures have been avulsed from their bony attachment

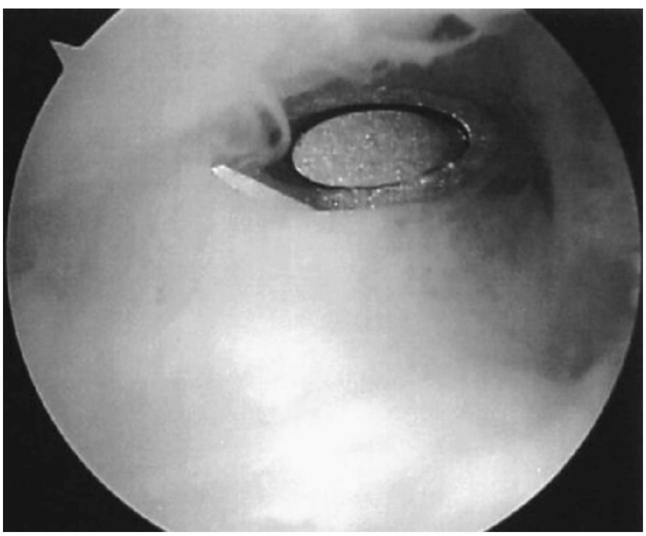


Fig. 12.5 The spinal needle has entered the radiocarpal joint at the level of the ulnar carpal ligaments. Some fraying of the disc-carpal ligaments is seen and is associated with LT ligament injury

to the disc-carpal ligaments (Fig. 12.5). Care is taken to avoid injury to the dorsal sensory branches of the ulnar nerve during placement.

The interval between the disc-lunate and disc-triquetral ligament identifies the lunotriquetral joint and interosseous ligament. Debridement of the lunotriquetral ligament, disc-carpal ligaments, and additional pathology is performed. Through the v6-U portal, an 18 G spinal needle is passed just volar to the disc-triquetral, ulno-capitate, and disc-lunate entering the radiocarpal joint at the radial edge of the UL ligament just distal to the articular surface of the radius. A #2-0 PDS suture is placed through the needle into the joint. The suture is retrieved either sequentially through the 6-R and the through the v6-U or directly through the v6-U using a wire loop suture retriever and then and tagged as the first plicating suture (Fig. 12.6a–c). In likewise fashion, a second plicating suture is placed approximately 5 mm distal to the first so that the suture loops are parallel to the lunate and triquetrum and is tagged as the second plicating suture (Fig. 12.7a–c). Tension on the first stitch often facilitates a second needle passage through the ulnolunate and ulnotriquetral ligaments. Adequacy of the plication (tension the stitch) and its effect on LT interval stability should be assessed after each suture passage.

Finally, through the v6-U portal, a spinal needle is passed through the volar aspect of the capsule at the pre-styloid recess and then through the peripheral rim of the TFCC. The wire retriever is introduced through the ulnar capsule and the suture is brought out the v6-U portal to tighten the ulnar capsule (Fig. 12.8a, b). The three sets of sutures are tied at the termination of the procedure after the lunotriquetral joint has been congruently reduced and stabilized with K-wires.

Viewing through the midcarpal radial portal, a midcarpal ulnar (MCU) portal working is created. A spinal needle can be placed from ulnar to radial across the distal aspect of the LT joint and used as a guide for percutaneous pin placement into the triquetrum. The triquetrum is reduced congruent to the lunate articular cartilage with traction on the plication sutures and firm pressure on the triquetrum on the triquetrum.

The initial K-wire should be inserted 2–3 mm proximal to the spinal needle. Two 0.045 smooth K-wire are placed percutaneously through the lunotriquetral joint (Fig. 12.9). The first pin is advanced across the lunotriquetral interval from ulnar to radial under fluoroscopic guidance and the second pin is placed using the first pin as a guide to placement. After satisfactory reduction of the lunotriquetral joint, traction is released, the forearm is held in neutral rotation, and the plication stitches are tied at the 6-U portal with the knots placed below the skin (Fig. 12.10). The peripheral ulnar capsular stitch is retrieved. The K-wires are either cut subcutaneously or bent outside the skin.

If lunotriquetral instability is present with TFCC pathology, ligament plication is not altered and treatment of the traumatic peripheral tears or degenerative tears with or without ulnar abutment syndrome is performed. In degenerative TFCC tears, the central avascular portion is debrided to a stable rim prior to plication. With peripheral traumatic TFCC tears, additional sutures are placed in the dorsal capsule and peripheral TFCC after the initial plication sutures. In the presence of lunotriquetral tears and positive ulnar variance [6, 26, 27], arthroscopic wafer can be added in the presence of ulnar abutment.

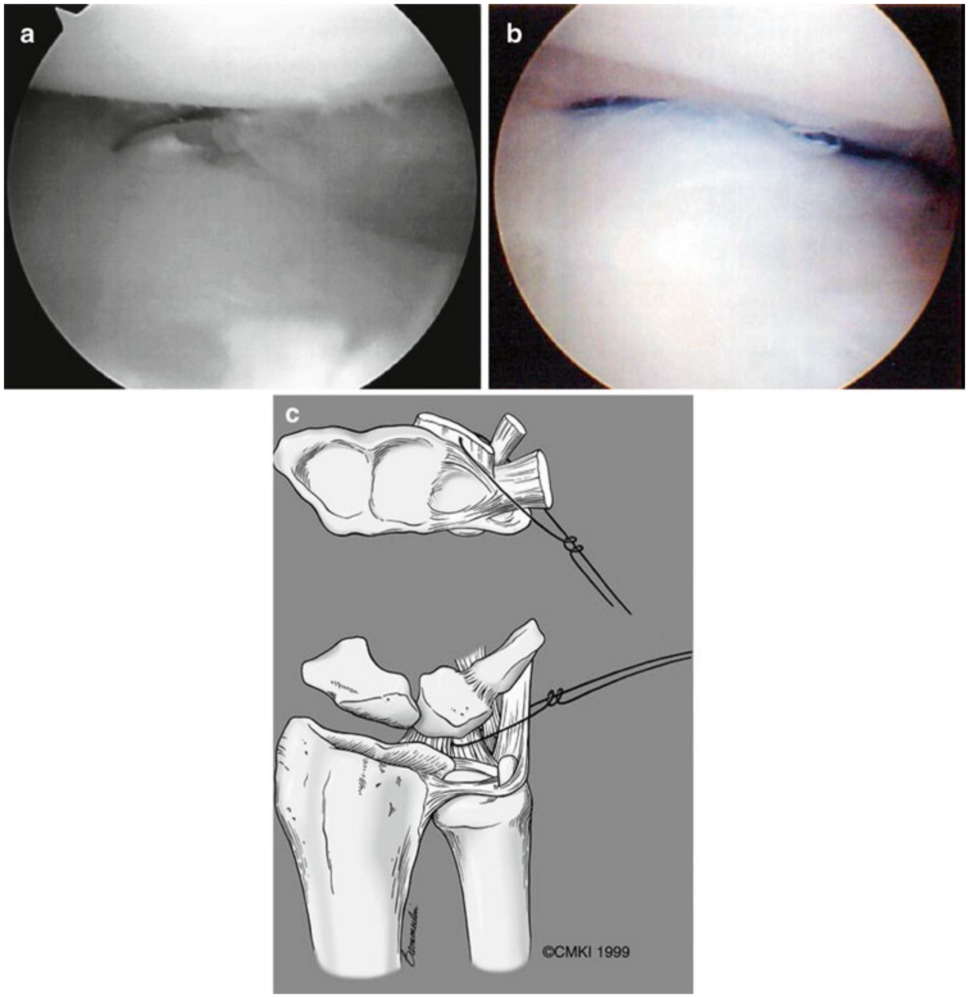


Fig. 12.6 (**a**) The spinal needle has traversed from ulnar to radial just palmar to the ulnar carpal ligaments. The tip of the needle has reentered the radiocarpal joint radial to the disc-carpal ligament. In the photo, the lunate is above and the ulnar border of the distal radius (lunate fossa) is seen obliquely at the level of the spinal needle. (**b**) A 2-0 PDS suture has been passed through the spinal needle and retrieved out the v6-U portal. The disc-carpal ligaments are visualized with the lunate above. (**c**) The suture passage is diagrammatically represented. The disc-triquetral ligament is to the right. The first 2-0 PDS plication suture is passed from ulnar to radial with a spinal needle through the volar 6-U portal. The disc-triquetral, ulno-capitate, and disc-lunate ligaments are incorporated in the suture [**c**: With permission from The Christine M. Kleinert Institute for Hand and Microsurgery, Inc.]

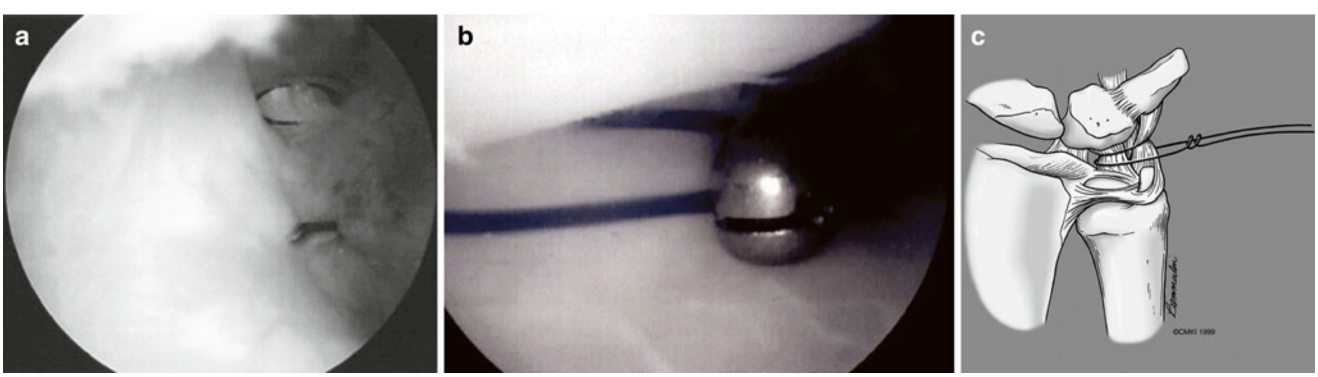


Fig. 12.7 (**a**) The disc-triquetral ligament is to the *left*. The first plicating suture is seen below and to the *right* (ulnar) exiting the ulnarly through the v6-U portal. The spinal needle is seen distal (*above*), as it is ready to be passed for the second plicating suture. (**b**) The second 2-0 PDS plication suture. Tension on the first suture facilitates placement of the second suture, which is placed approximately 5 mm distal to the first suture. (**c**) The plication sutures are represented diagrammatically [**c**: With permission from The Christine M. Kleinert Institute for Hand and Microsurgery, Inc.]

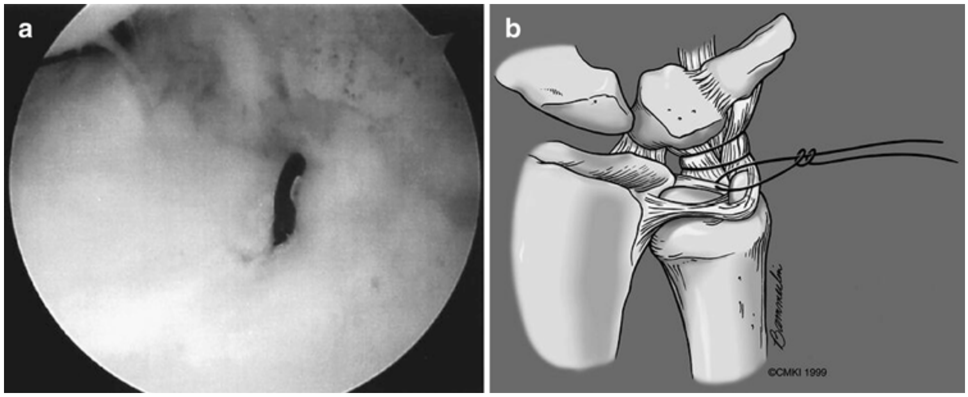


Fig. 12.8 (**a**) The ulnar capsular tension suture is in placed. The suture is passed through the ulnar capsule and through the palmar aspect of the peripheral edge of the TFCC. (**b**) Line drawing of the two plication sutures and the prestyloid and TFCC sutures [**c**: With permission from The Christine M. Kleinert Institute for Hand and Microsurgery, Inc.]

Fig. 12.9 Pin placement. The viewing portal is in the midcarpal space during arthroscopic reduction and pinning of the lunatotriquetral joint. A needle has been placed into the midcarpal space to act as a guide to K-wire placement. Two to three K-wires are placed

Postoperative Care

Initially, after surgery the patient is place in a long arm splint with the elbow flexed at 90°, the forearm in neutral rotation and the wrist in neutral flexion and extension. At approximately 1 week after surgery, a Muenster cast is applied, with the forearm and wrist in neutral rotation and flexion, respectively. At approximately 6 weeks after surgery, the K-wires are removed. A removable Muenster cast is used for an additional 2 weeks to allow daily gentle flexion, extension, pronation, and supination within a painless arc of motion. Eight weeks after surgery, strengthening exercises are instituted and work hardening can begin slowly over 8–24 weeks postoperatively.

Results

In a case series, we looked at a group of 21 patients without ulnar impaction and included seven patients with workman's compensation claims and four patients who sustained injury during sport. All patients complained of ulnar sided wrist pain, which was invariably increased by use of the wrist and the mean time between the onset of symptoms and treatment was 2.5 years (range, 1 week to 5.5 years). 17 patients recalled a specific injury (hyperextension 12, twisting 2, unknown 3) and four noted a gradual onset of symptoms. Three patients had additional significant injuries to the affected extremity: elbow dislocation, humeral shaft fracture, and anterior shoulder dislocation.

The patients were uniformly tender over the lunotriquetral joint. Provocative tests for lunotriquetral instability were specifically positive in nine and for TFCC in six. Crepitus was produced with pronosupination or ulnar deviation in ten patients. A VISI instability pattern was not present. The average ingo Mayo wrist score was 50 and increased to an outgo score of 88 at a mean of 3.1 years after surgery with 19/21 patients having excellent and good results and two with fair results. The average postoperative score for the nine workman's compensation claimants or litigants were slightly lower than the overall group. Three patients had complications including prolonged tenderness along the extensor carpi ulnaris and one patient had persistent neuritis of the dorsal branches of the ulnar nerve.

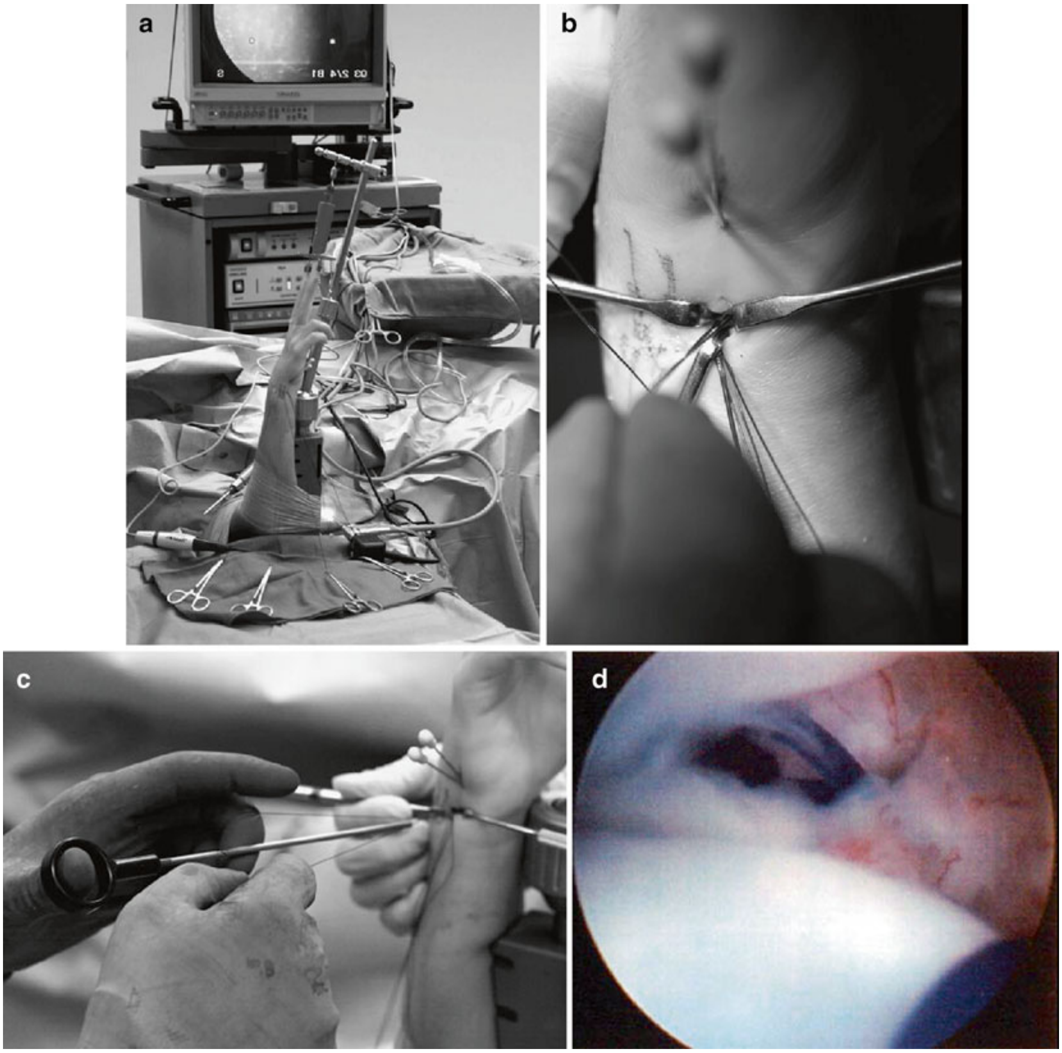


Fig. 12.10 (**a**) The sutures and K-wires are in place. Traction is taken off the wrist and the forearm is maintained in neutral rotation. (**b**) Retractors can be used to retract soft tissue and protect the ulnar nerve sensory branches. (**c**) A knot passer can be used to pass sequential half hitches. (**d**) The sutures are seen entering the radiocarpal joint. The knot is seen adjacent to the disc-triquetral ligament

Conclusion

Symptomatic lunotriquetral interosseous ligament tears have been managed in a variety ways including arthroscopic debridement, ligamentous repair, and intercarpal arthrodesis. Ligamentous repair or grafting requires an extensile approach and lunotriquetral joint fusion limits flexion and extension and radioulnar deviation by 14 % and 25 %, respectively, [28]. Arthroscopic ulnocarpal ligament plication in addition to LT joint reduction and stabilization is designed to augment the volar aspect of the LT joint.

Arthroscopic evaluation with soft tissue plication with percutaneous lunotriquetral pinning improved comfort and function. Suture plication of the ulnocarpal ligaments which shortens their length to act as a checkrein to excessive lunotriquetral motion and prestyloid recess tightening which increases tension in the ulnar DRUJ capsule are goals similar to ulnar shortening procedures.

References

1. Kulick M, Chen C, Swearingen P. Determining the diagnostic accuracy of wrist arthroscopy. Toronto, ON: Annual meeting of the American Society for Surgery of the Hand; 1990.
2. Palmer C, Murray P, Snearly W. The mechanism of ulnar sided perilunate instability of the wrist. Toronto, ON: Annual meeting of the American Society for Surgery of the Hand; 1998.
3. Horii E, Gacias-Elias M, An K, et al. A kinematic study of lunatotriquetral dislocations. J Hand Surg Am. 1991;16A:355.
4. Viegas S, Peterson P, et al. Ulnar-sided perilunate instability: An anatomic and biomechanical study. J Hand Surg Am. 1990;15A:268.

5. Trumble T, Bour C, Smith R, et al. Kinematics of the ulnar carpus to the volar intercalated segment instability pattern. J Hand Surg Am. 1990;15A:384.
6. Reagan D, Linscheid R, Dobyns J. Lunatotriquetral sprains. J Hand Surg Am. 1984;9A:502–14.
7. Kleinman W. Physical examination of lunatotriquetral joint. Am Soc Surg Hand Corr Newsletter. 1985;51:74.
8. Kleinman W. Long-term study of chronic scapho-lunate instability treated by scapho-trapezio-trapezoid arthodesis. J Hand Surg Am. 1989;14A:429.
9. Palmer A, Werner F. The triangular fibrocartilage complex of the wrist: anatomy and function. J Hand Surg Am. 1981;6:153.
10. Palmer A. Triangular fibrocartilage complex lesions: a classification. J Hand Surg Am. 1989;14A:594.
11. Palmer A, Glisson R, Werner F. Ulnar variance determination. J Hand Surg Am. 1982;7:376.
12. Gilula L. Posteroanterior wrist radiography: importance of arm positioning. J Hand Surg Am. 1987;12A:504–8.
13. Hulten O. Uber anatomische variationen der hand-Gelenkknochen. Acta Radiol. 1928;9:155.
14. Steyers C, Blair W. Measuring ulnar variance: a comparison of techniques. J Hand Surg Am. 1989;14A:607.
15. Gilula L. Carpal injuries: analytic approach and case exercises. AJR Am J Roentgenol. 1979;133:503–17.
16. Bednar J, Osterman A. Carpal instability: evaluation and treatment. J Am Acad Orthop Surg. 1993;1:10–7.
17. Cooney W, Dobyns J, Linscheid R. Arthroscopy of the wrist: anatomy and classification of carpal instability. Arthroscopy. 1990;6:113–40.
18. Mayfield J. Patterns of injury to carpal ligaments: a spectrum. Clin Orthop. 1984;187:36.
19. Werner F, Palmer A, Fortino M, et al. Force transmission through the distal ulna: effect of ulnar variance, lunate fossa angulation, and radial and palmar tilt of the distal radius. J Hand Surg Am. 1992;17A:423.
20. Melone Jr C, Nathan R. Traumatic disruption of the triangular fibrocartilage complex, pathoanatomy. Clin Orthop. 1992; 275:65–73.
21. Green D. Carpal dislocation and instabilities. In: Green D, editor. Operative hand surgery. New York, NY: Churchill Livingston; 1988. p. 878–9.
22. Palmer A, Werner F. Biomechanics of the distal radioulnar joint. Clin Orthop. 1984;187:26.
23. Garcias-Elias M, Domenech-Mateu J. The articular disc of the wrist: limits and relations. Acta Anat. 1987;128:51.
24. Johnson R, Carrera G. Chronic capitolunate instability. J Bone Joint Surg. 1986;68A:1164–76.
25. Viegas S, Wagner K, Patterson R, et al. Medial (hamate) facet of the lunate. J Hand Surg Am. 1990;15A:564–71.
26. Pin P, Young V, Gilula L, et al. Management of chronic lunatotriquetral ligament tears. J Hand Surg Am. 1989;14A:77–83.
27. Osterman A, Sidman G. The role of arthroscopy in the treatment of lunatotriquetral ligament injuries. Hand Clin. 1995;11: 41–50.
28. Seradge H, Sterbank P, Seradge E, et al. Segmental motion of the proximal carpal row: their global effect on the wrist motion. J Hand Surg Am. 1990;15A:236–9.

Arthroscopic Management of Dorsal Capsular Lesions

13

David J. Slutsky

Introduction

Various authors have cast light on the importance of the dorsal radiocarpal ligament (DRCL) in maintaining carpal stability [1–4]. Tears of the DRCL have been linked to the development of both volar and dorsal intercalated segmental instabilities and may be implicated in the development of midcarpal instability [5–7]. In most series, the DRCL is overlooked during the typical arthroscopic examination of the wrist. It is hard to visualize a DRCL tear through the standard dorsal wrist arthroscopy portals since the torn edge of the DRCL tends to float up against the arthroscope while viewing through the 3,4 portal and 4,5 portals, which makes both identification and repair of the DRCL tear cumbersome. It can be seen obliquely through the 1,2, or 6R portals but visualization of the DRCL across the radiocarpal joint may be laborious in a tight or small wrist, especially if synovitis is present. Wrist arthroscopy through a volar radial portal (VR) is the ideal way to assess the dorsal radiocarpal ligament due to the straight line of sight [8, 9].

Anatomy/Kinematics

The dorsal radiocarpal ligament is an extracapsular ligament on the dorsum of the wrist. It originates on Lister's tubercle and moves obliquely in a distal and ulnar direction to attach to the tubercle of the triquetrum. Its radial fibers attach to the lunate and lunotriquetral interosseous ligament [10]. The dorsal intercarpal (DIC) ligament originates from the triquetrum and extends radially to attach onto the lunate, the dorsal groove of the scaphoid, and then the trapezium. Viegas et al. have observed that the lateral V configuration of the DRCL and the DIC function as a dorsal radioscaphoid ligament. It can vary its length by changing the angle between the two arms while maintaining its stabilizing effect on the scapholunate joint during wrist flexion and extension [11]. This would require changes in length far greater than any single fixed ligament could accomplish. Elsaidi and Ruch demonstrated the importance of the DRCL on scaphoid kinematics through a series of sectioning studies [12]. They sequentially divided the radioscaphocapitate, long radiolunate, radioscapholunate, and short radiolunate ligaments. They next divided the central and proximal SLIL, then the dorsal SLIL and finally the dorsal capsule insertion on the scaphoid. There was no appreciable change in the radiographic appearance of this wrist. When the DRCL was then divided, a dorsal intercalated segmental instability (DISI) deformity occurred. In a biomechanical study using 24 cadaver arms, Short et al. determined that the SLIL is the primary stabilizer of the scapholunate articulation and that the DRCL, the dorsal intercarpal (DIC) the scaphotrapezial (ST) ligaments and the radioscaphocapitate (RSC) ligaments are secondary stabilizers [13]. They found that dividing the DIC or the ST ligaments alone followed by 1,000 cycles of wrist flexion-extension and radial-ulnar deviation had no effect on scaphoid and lunate kinematics. Dividing the DRCL alone did cause increased lunate radial deviation when the wrist was in maximum flexion. Dividing the SLIL after any of the ligaments tested produced increased scaphoid flexion and ulnar deviation while the lunate extended. They also hypothesized that cyclic motion appears to cause further deterioration in carpal kinematics due to plastic deformation in the remaining structures that stabilize the scapholunate.

The DRCL tear described in this chapter consists of a detachment of the epiligamentous portion of the ligament. In cases where a dorsal capsulotomy was performed the dorsal part of the ligament was always intact. I believe that the pain secondary to a DRCL tear represents an impingement phenomenon of the torn DRCL which is caught between the radius and lunate during wrist motion, and that an arthroscopic

D.J. Slutsky, M.D. (✉)
The Hand and Wrist Institute,
2808 Columbia Street, Torrance, CA 90503, USA
e-mail: d-slutsky@msn.com

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*,
DOI 10.1007/978-1-4614-1596-1_13, © Springer Science+Business Media New York 2015

repair does not necessarily restore normal wrist kinematics—but there is no biomechanical data to support either theory.

Indications

An arthroscopic repair is indicated for an isolated DRCL tear, which often leads to resolution of the wrist pain. The role of a DRCL repair when associated with other wrist pathology is not well defined.

Contraindications

It is unlikely that performing a DRCL repair when there are two or more intracarpal lesions significantly improves the outcome since the results are inconsistent and appear to be largely determined by the treatment of the associated wrist pathology.

Surgical Technique

The procedure is done under tourniquet control with the arm in 10–15 lb of traction. The operator is seated on the volar aspect of the arm. A volar radial (VR) portal is established by making a 2 cm longitudinal incision is made in the proximal wrist crease exposing the flexor carpi radialis (FCR) tendon sheath. The sheath is divided and the FCR tendon is retracted ulnarly. The radiocarpal joint space is identified with a 22G needle. A blunt trochar and cannula are introduced through the floor of the FCR sheath, which overlies the interligamentous sulcus between the radioscaphocapitate ligament and the long radiolunate ligament. A 2.7 mm, 30° arthroscope is inserted through the cannula. The procedure may be done dry but it is easier to see the torn edges of the DRCL with fluid irrigation. The DRCL is seen just radial to the 3,4 portal, underneath the lunate (Fig. 13.1). The dorsal capsule may often appear redundant and can protrude into the joint but when a DRCL tear is present the frayed ligamentous fibers can be seen (Fig. 13.2). In longstanding tears the distal edge of the DRCL becomes rounded (Fig. 13.3). It is helpful to insert a 3 mm hook probe through the 3,4 portal for orientation. The DRCL tear can then be pulled into the joint with the probe which differentiates it from redundant dorsal capsule (Fig. 13.4a, b). The repair is performed by inserting a 22G spinal needle through either the 3,4 or 4,5 portal. A 2-0 absorbable suture is threaded through the spinal needle and retrieved with a grasper or suture snare inserted through the other portal (Fig. 13.5a–c). A curved hemostat is used to pull either end of the suture underneath the extensor tendons, and the knot is tied either at the 3,4 or 4,5 portal. One suture is usually sufficient although an additional suture may be added as necessary to pull the torn edge of the DRCL up against the dorsal capsule. If the plicating suture does not capture the DRCL tear, the needle can be used to spear the distal edge of the DRCL tear which is then plicated up against the dorsal capsule (Fig. 13.6a–c). The DRCL tear can be seen from the 6R portal (Fig. 13.7) but the obliquity of the view makes this type of repair method arduous.

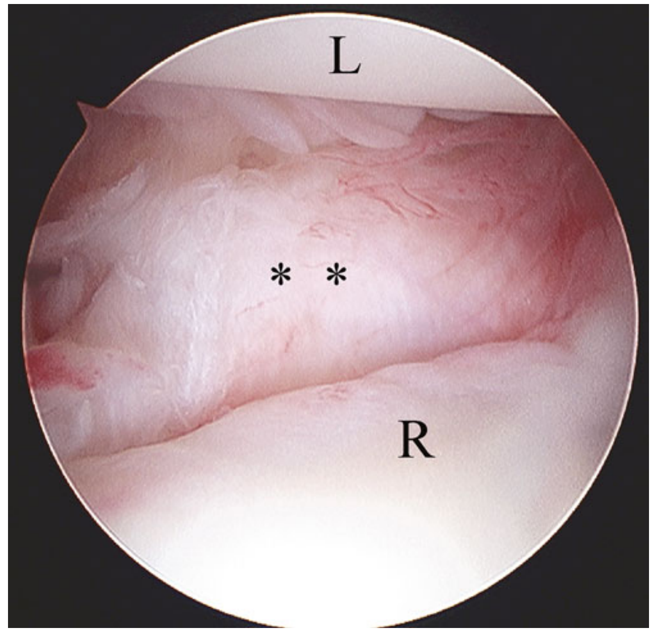


Fig. 13.1 Normal DRCL (*asterisk*) as seen from the VR portal. *L* lunate, *R* radius

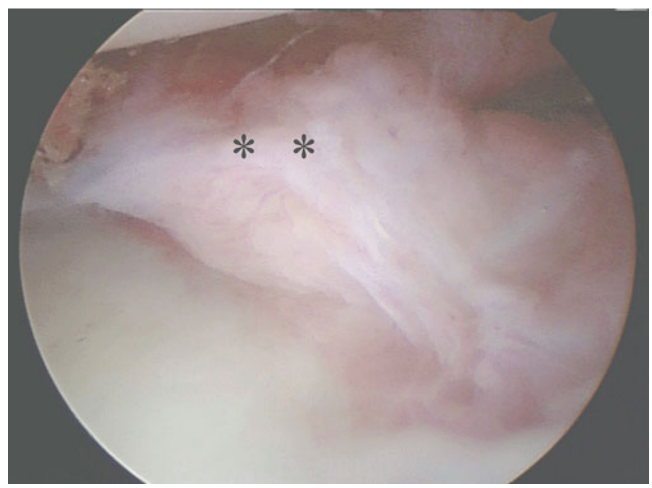


Fig. 13.2 DRCL tear. Note the torn fibers of the distal edge [8]

Following the repair the patient is placed in a below elbow splint with the wrist in neutral rotation. Finger motion and edema control are instituted immediately. At the first postoperative visit the sutures are removed and the patient is placed in a below-elbow cast for a total of 4 weeks, followed by wrist mobilization.

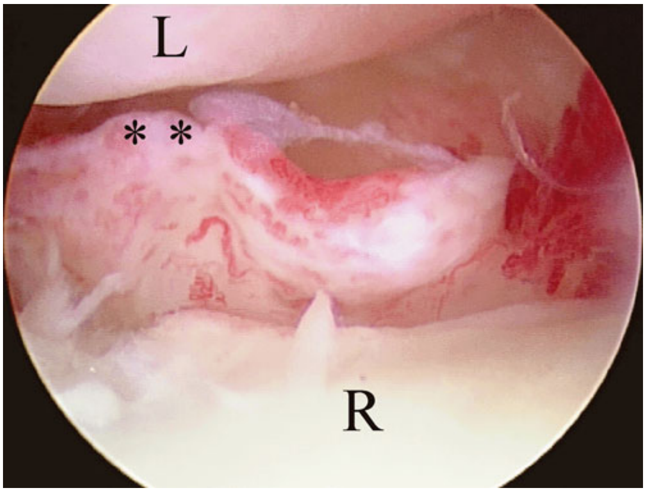


Fig. 13.3 Chronic DRCL tear with rounded edges (*asterisk*). *L* lunate, *R* radius

Outcomes

A retrospective chart review of 21 patients who underwent a DRCL repair was published in 2005 [14, 15]. None of the wrists showed a static carpal instability pattern on X-ray. A preoperative MRI was performed by the referring physician in six patients. Preoperative arthrograms were performed as a part of the diagnostic work up for wrist pain in 20 patients. None of the DRCL tears in this series were identified with preoperative arthrography or MRI. A preoperative MRI in one patient with a DRCL tear was misinterpreted as representing a dorsal wrist ganglion. There were 6 men and 16 women. The average patient age was 40 years (range, 25–62 years). All patients failed a trial of conservative treatment with wrist immobilization, cortisone injections, and work restrictions. The average length of conservative treatment was

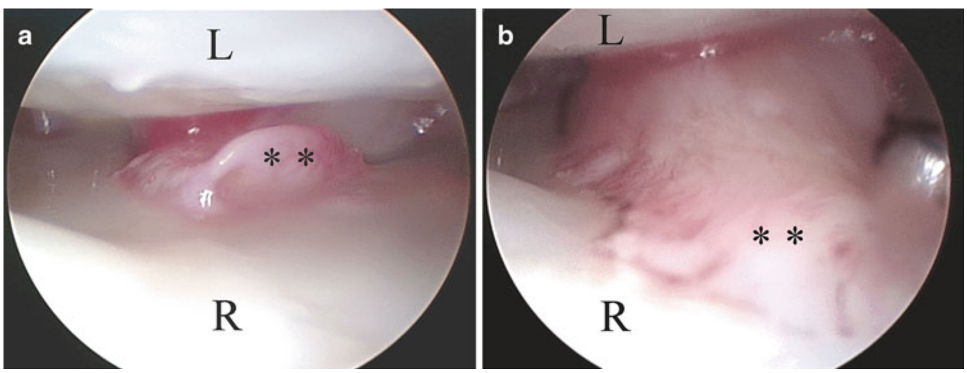


Fig. 13.4 (**a**) Under dry arthroscopy the DRCL tear appears small and unimpressive (*asterisk*). *L* lunate, *R* radius. (**b**) A hook probe is used to pull the DRCL tear (*asterisk*) into the joint, demonstrating the large amount of tissue that can impinge between the radius and lunate

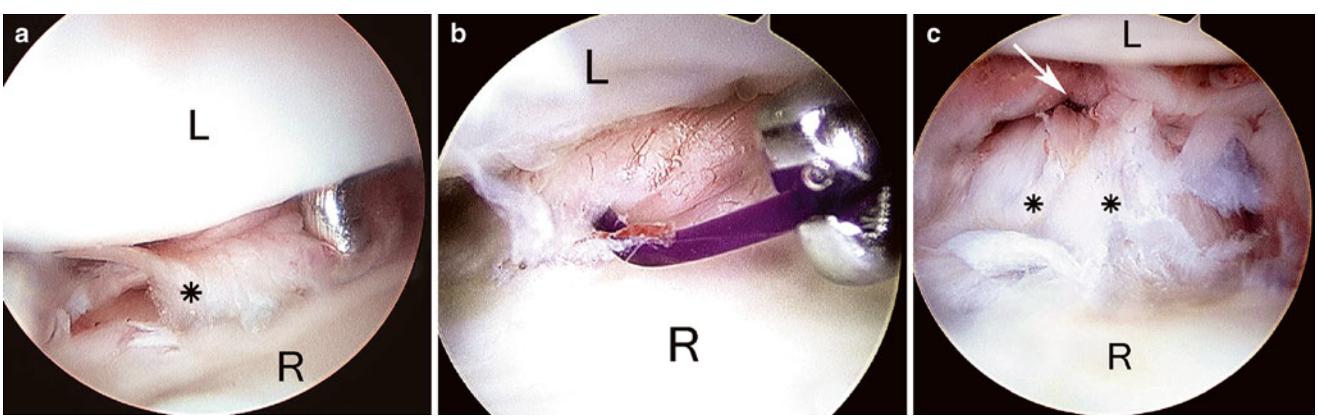


Fig. 13.5 (**a**) Arthroscopic view of DRCL tear (*asterisk*) from the VR portal. *L* lunate, *R* radius. (**b**) A 2-0 suture has been inserted through a spinal needle in the 4,5 portal and is being retrieved with forceps in the 3,4 portal. (**c**) Completed repair. Note how the DRCL tear (*asterisk*) has been plicated up against the dorsal capsule (*arrow*)

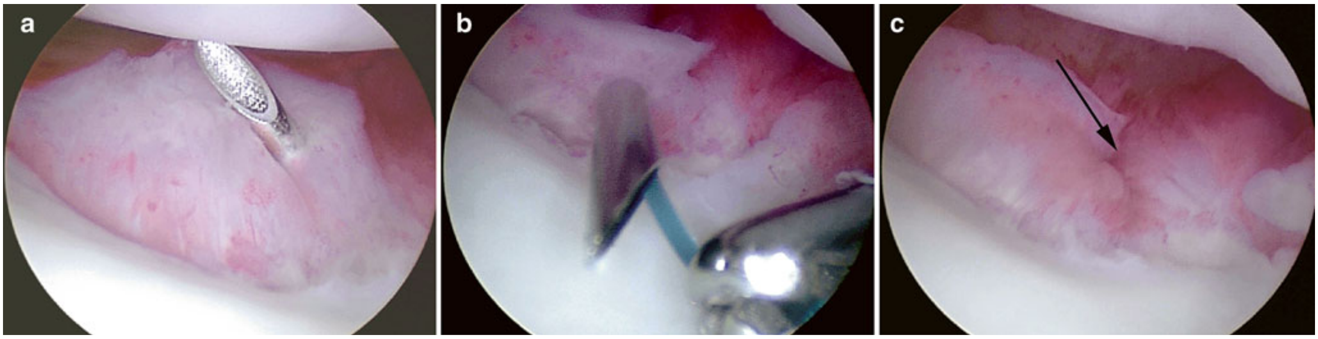


Fig. 13.6 (**a**) a 22G spinal has been inserted through the midsubstance of the DRCL tear. (**b**) A 2-0 suture has been inserted through the spinal needle and is being retrieved with forceps in the 3,4 portal. (**c**) Completed repair (*arrow*)

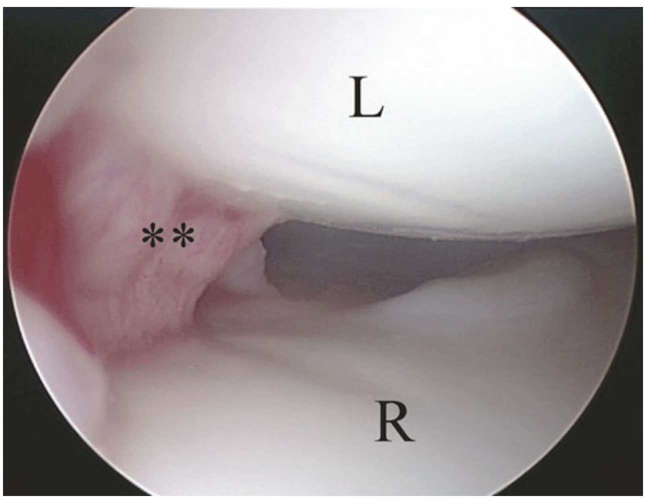


Fig. 13.7 Oblique view of a DRCL tear from the 6R portal

7 months. The time interval between injury and surgical intervention averaged 25 months (range, 8–53 months).

At the time of arthroscopy, five patients were found to have an isolated DRCL tear that was solely responsible for their wrist pain. The remaining patients had additional ligamentous pathology. A dorsal capsulodesis was performed in seven patients as the primary treatment for the SLIL instability/tear. Thirteen patients underwent an arthroscopic DRCL ligament repair ± thermal shrinkage (repair = 5, repair + shrinkage = 6, shrinkage = 2). Ten of these patients underwent ancillary procedures for treatment of the coexisting wrist pathology. Lunotriquetral ligament tears were treated with debridement ± pinning. Triangular fibrocartilage tears were debrided or repaired. Scapholunate ligament tears/instability were treated with capsulodesis ± open repair. One patient had generalized arthrofibrosis which precluded a DRCL repair. Concomitant nerve entrapment was a common finding which was treated at the same time.

The average duration of the follow-up period was 16 months (range, 7–41 months), with one patient lost to follow-up at 4 weeks. Pain was graded as none, mild, moderate, and severe. Wrist extension, wrist flexion, radial deviation, ulnar deviation, and grip strength were assessed. Wrist range of motion was compared with presurgical values. Grip strength was compared with the contralateral side at follow-up evaluation.

The five patients who underwent an isolated DRCL repair were satisfied with the outcome of surgery and would repeat the surgery again because it improved their symptoms. All five patients graded their pain as none or mild. None of these patients were taking pain medications. All returned to their previous occupations without restriction. Their wrist motion was unchanged as compared to the preoperative status. Grip strengths were 90–130 % of the opposite side.

The patients with coexisting pathology had variable outcomes that were largely influenced by the treatment of the associate pathology. It was not possible to separate out the effect of the DRCL repair. At the latest review, 64 patients had undergone arthroscopy for the investigation and treatment of refractory wrist pain. Thirty-five patients were found to have DRCL tears, for an overall incidence of 55 %. As such it is prudent that the arthroscopist is diligent in recognizing and treating this condition. Ongoing research into the ideal method of treatment of these combined injuries however is still needed.

Arthroscopic Wrist Ganglionectomy

Osterman et al. pioneered the arthroscopic resection of dorsal wrist ganglia and reported on 150 procedures with only

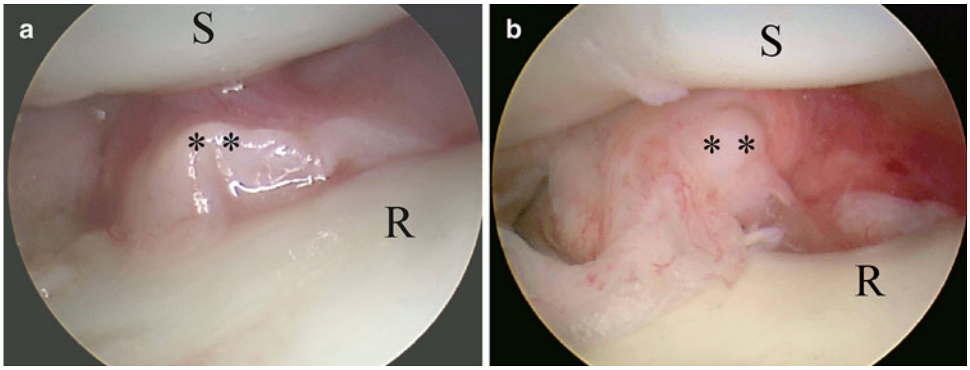


Fig. 13.8 (**a**) View of a dorsal wrist ganglion (*asterisk*) under dry arthroscopy from the VR portal. The appearance can mimic that of a DRCL tear but the ganglion overlies the 3,4 portal and is radial to the DRCL. *S* scaphoid, *R* radius (**b**) Under fluid irrigation the globular structure of the ganglion (*asterisk*) is evident. *S* scaphoid, *R* radius

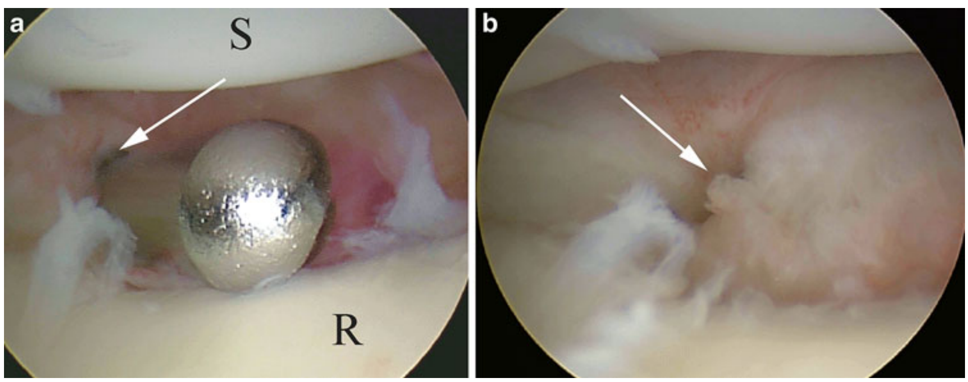


Fig. 13.9 (**a**) View of a shaver from the VR portal which has been introduced through the stalk of the ganglion (*arrow*) which overlies the 3,4 portal. (**b**) Capsular defect (*asterisk*) after resection of the ganglion

one recurrence [16]. Volar wrist ganglia that originate from the radiocarpal joint are amenable to arthroscopic resection, but those that arise from the scaphotrapezialtrapezoidal joint are not.

Indications

The indication for arthroscopic removal of a dorsal ganglion is similar to those for an open method. An ideal indication is when patients have concomitant wrist pain and a positive scaphoid shift test where evaluation of any associated SLIL instability is desirable. The occult ganglion that is entirely intracapsular and cannot be visualized during open surgery is another indication. Preoperative X-rays should be performed to rule out intraosseous communication or other carpal pathology. It is important to ensure the lesion is in fact a ganglion either with transillumination, an MRI or needle aspiration.

Contraindications

Previous scarring in the area due to previous injury or surgery for recurrence may distort the anatomy and make it difficult to establish the portals.

Surgical Technique

Since the ganglion overlies the 3,4 portal, it is the author's preference to view the ganglion through the VR portal, which provides a direct line of sight and allows one to rule out a tear of the DRCL (Fig. 13.8a, b). Alternatively, the 1,2, or 6-R portal can be used. A shaver is then introduced into the ganglion through the 3,4 portal to perforate the ganglion and resect the stalk (Fig. 13.9a, b). The intra articular ganglion is completely debrided along with a 1 cm area of surrounding dorsal capsule. The extensor

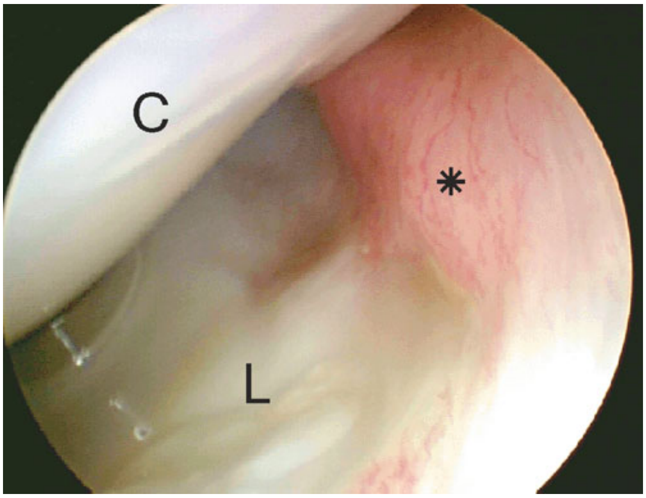


Fig. 13.10 Oblique view from the midcarpal radial portal of a ganglion in the midcarpal joint. *C* capitate, *L* lunate

tendons may be visible through the defect. Midcarpal arthroscopy should be performed to debride any midcarpal extension of the ganglion and to assess the status of the SL and LT joints (Fig. 13.10).

Postoperatively the wrist is splinted for 1 week for comfort followed by protected range of motion. Loss of wrist flexion following dorsal ganglia excision can be treated with dynamic splinting at 6–8 weeks.

Outcomes

Rizzo and coauthors performed an arthroscopic resection of 41 dorsal ganglia. At 2 years, patients demonstrated improved wrist motion and grip strength, excellent pain relief, and only two recurrences [17]. Good results are not invariable in patients with associated intracarpal pathology however. Povlsen and Peckett noted an abnormal scapholunate joint in 10/16 patients and an abnormal lunotriquetral joint in 2/16 patients. At a 5-year follow-up only one patient remained pain free [18]. Edwards and Johansen [19] examined 55 patients with dorsal wrist ganglia following an arthroscopic resection. The ganglion arose from the radiocarpal joint alone in 11 patients and extended into the midcarpal joint in 29 cases. In two patients it arose exclusively from the midcarpal joint. The preoperative Disabilities of the Arm, Shoulder, and Hand scores improved from 14.2 to 1.7. At a 24-month follow-up all patients demonstrated motion to within 5° of preoperative measurements, and there were no recurrences.

References

1. Short WH, Werner FW, Green JK, Weiner MM, Masaoka S. The effect of sectioning the dorsal radiocarpal ligament and insertion of a pressure sensor into the radiocarpal joint on scaphoid and lunate kinematics. J Hand Surg Am. 2002;27:68–76.
2. Mitsuyasu H, Patterson RM, Shah MA, et al. The role of the dorsal intercarpal ligament in dynamic and static scapholunate instability. J Hand Surg Am. 2004;29:279–88.
3. Viegas SF, Yamaguchi S, Boyd NL, Patterson RM. The dorsal ligaments of the wrist: anatomy, mechanical properties, and function. J Hand Surg Am. 1999;24:456–68.
4. Ruch DS, Smith BP. Arthroscopic and open management of dynamic scaphoid instability. Orthop Clin North Am. 2001;32:233–40. vii.
5. Viegas SF, Patterson RM, Peterson PD, et al. Ulnar-sided perilunate instability: an anatomic and biomechanic study. J Hand Surg Am. 1990;15:268–78.
6. Moritomo H, Viegas SF, Elder KW, et al. Scaphoid nonunions: a 3-dimensional analysis of patterns of deformity. J Hand Surg Am. 2000;25A:520–8.
7. Horii E, Garcia-Elias M, An KN, et al. A kinematic study of lunotriquetral dissociations. J Hand Surg Am. 1991;16:355–62.
8. Slutsky DJ. Arthroscopic repair of dorsal radiocarpal ligament tears. Arthroscopy. 2002;18:E49.
9. Slutsky D. Arthroscopic repair of Dorsoradiocarpal ligament tears. J Arthrosc Related Surg. 2005;21:1486e1–86e8.
10. Slutsky DJ. Management of dorsoradiocarpal ligament repairs. J Am Soc Surg Hand. 2005;5:167–74.
11. Slutsky DJ. Wrist arthroscopy through a volar radial portal. Arthroscopy. 2002;18:624–30.
12. Slutsky DJ. Volar portals in wrist arthroscopy. J Am Soc Surg Hand. 2002;2:225–32.
13. Slutsky DJ. Clinical applications of volar portals in wrist arthroscopy. Tech Hand Up Extrem Surg. 2004;8:229–38.
14. Elsaidi GA, Ruch DS, Kuzma GR, Smith BP. Dorsal wrist ligament insertions stabilize the scapholunate interval: cadaver study. Clin Orthop Relat Res. 2004;425:152–7.
15. Short WH, Werner FW, Green JK, Sutton LG, Brutus JP. Biomechanical evaluation of the ligamentous stabilizers of the scaphoid and lunate: part III. J Hand Surg Am. 2007;32:297–309.
16. Osterman AL, Raphael J. Arthroscopic resection of dorsal ganglion of the wrist. Hand Clin. 1995;11:7–12.
17. Rizzo M, Berger RA, Steinmann SP, Bishop AT. Arthroscopic resection in the management of dorsal wrist ganglions: results with a minimum 2-year follow-up period. J Hand Surg Am. 2004;29:59–62.
18. Povlsen B, Tavakkolizadeh A. Outcome of surgery in patients with painful dorsal wrist ganglia and arthroscopic confirmed ligament injury: a five-year follow-up. Hand Surg. 2004;9:171–3.
19. Edwards SG, Johansen JA. Prospective outcomes and associations of wrist ganglion cysts resected arthroscopically. J Hand Surg Am. 2009;34(3):395–400.

14 Arthroscopic Arthrolysis

Duncan Thomas McGuire, Riccardo Luchetti, Andrea Atzei, and Gregory Ian Bain

Introduction

Wrist stiffness is a multifactorial condition that is debilitating for those whom it affects. The etiology may be classified as either intra-articular or extra articular. Intra-articular and capsular injuries as well as prolonged immobilization may stimulate arthrofibrosis. This may be seen after conservative and surgical management of injuries (Table 14.1) [1, 2].

Conservative treatment with physiotherapy and splinting is the treatment of choice. Surgery is reserved for those cases refractory to conservative treatment. Arthroscopic treatment of arthrofibrosis of the knee, shoulder, and elbow is well established and commonly used.

Frequently, incorrect or incomplete reduction of a distal radius fracture is the cause of a stiff and painful wrist. Intra-articular and extra-articular malunions need to be corrected with osteotomies to restore normal anatomy and alignment of the articular surface of the distal radius [3]. Following distal radius fractures, two main conditions can contribute to painful limitation of ROM: (1) capsular contracture with intra-articular adhesions (most commonly), and (2) radiocarpal impingement caused by either malunion of fractures involving the dorsal rim of the distal radius (Figs. 14.1 and 14.2) or an increase in volar tilt of the distal radius articular surface. The two conditions can sometimes coexist and must be treated at the same time. It is important to note the rehabilitation protocol for the various surgical procedures that may need to be performed. Any procedure that would involve postoperative immobilization such as ligament reconstructions must be avoided. Immediate mobilization following surgery is mandatory.

Other potential causes of wrist pain and stiffness include neuroma of the posterior interosseous nerve (PIN), extensor and/or flexor tendons adhesions, and chronic regional pain syndrome (CRPS).

Traditionally, wrist manipulation under anesthesia (MUA) is commonly used when the rehabilitation regime has failed to improve wrist ROM. However, this procedure can be detrimental by causing traumatic ligamentous injuries, chondral or osteochondral damage (especially in cases with dorsal radiocarpal (RC) impingement) or even fractures. Surgical arthrolysis is a gentler and more controlled option that can be performed via open or arthroscopy surgery [4, 5]. This is already a successful treatment option in other joints [6–8].

Arthroscopic arthrolysis of the wrist allows the surgeon to treat the RC and intercarpal joints, whilst minimizing the risk of secondary damage to other articulations, and at the same time permitting immediate postoperative mobilization [9–15].

Technique

Traditional RC portals are used for arthroscopic arthrolysis of the wrist. Two volar portals (radial and ulnar) may also be used for the RC and ulno-carpal (UC) joint [6]. The distal radioulnar joint (DRUJ) may also be involved in the pathological process, and may also be debrided arthroscopically. The midcarpal (MC) joint is rarely involved; however, if it is affected, traditional MC portals are used.

Arthrolysis may be performed using a variety of instruments (Table 14.2). Dry arthroscopy is utilized more fre-

D.T. McGuire, MBCHB, FC (Orth) (SA), MMed (✉)
Department of Orthopaedic Surgery,
Groote Schuur Hospital,
Cape Town, 7705, South Africa
e-mail: duncan.mcguire@gmail.com

R. Luchetti, MD
Private activity, Rimini Hand & Rehabilitation Center,
Rimini, Italy

A. Atzei, MD
Fenice HSRT Hand Surgery and Rehabilitation Team,
Centro di Medicina, Treviso, Italy

G.I. Bain, MBBS, FRACS, FA (Orth) A, PhD
Upper Limb Surgeon, Professor of Upper Limb and Research,
Department of Orthopaedic Surgery, Flinders University of South
Australia, Flinders Drive, Bedford Park, 5042,
South Australia, Australia
e-mail: greg@gregbain.com.au

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*,
DOI 10.1007/978-1-4614-1596-1_14, © Springer Science+Business Media New York 2015

Table 14.1 Possible causes of secondary wrist stiffness (extra- and/or intra-articular)

Posttrauma	Postsurgery
1. Fracture	1. Dorsal wrist ganglia
2. Fracture-dislocation	2. Treatment of scaphoid fractures or nonunion
3. Dislocation	3. Inter-carpal arthrodeses
4. Ligament injuries	4. Ligament reconstruction
	5. Proximal row carpectomy
• Prolonged immobilization	

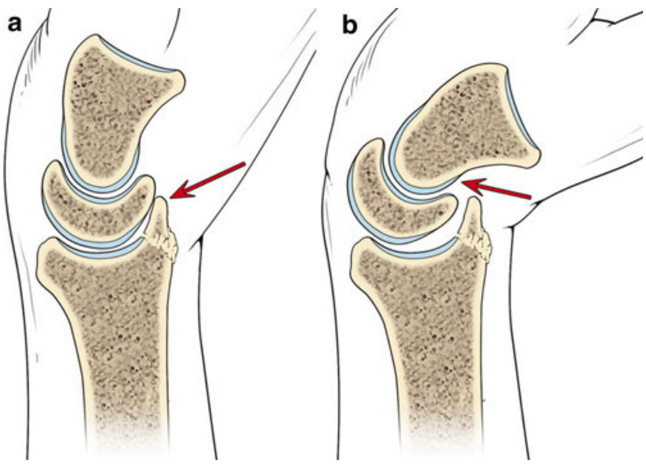


Fig. 14.1 Drawing showing malunion of the dorsal rim of the distal radius following fracture (**a**). Note the impingement between the dorsal rim and the carpus (**b**)

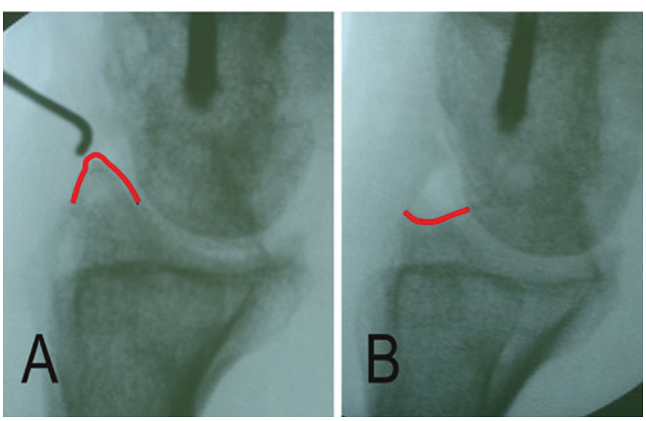


Fig. 14.2 Lateral radiograph of a wrist showing dorsal impingement (*arrow*) of the distal radius following malunion of a fracture. (**a**) Before and (**b**) after arthroscopic debridement of dorsal rim [Courtesy of Francisco del Piñal]

quently for this condition as it has the benefit of avoiding fluid extravasation into the soft tissues [16, 17].

Articular distraction is obtained using the traditional vertical position with counter-traction at the elbow of about 3 kg. Occasionally the articular distraction is not sufficient enough to permit the use of a 2.7 mm scope even when more

Table 14.2 Instruments for arthroscopic arthrolysis

Motor powered
• Full radius blade
• Cutter Blade/Incisor
• Razor cut blade
• Barrel abrader
Suction punch
Mini-scalpel (banana blade)
Laser
Radiofrequency
Dissector and scalpel

traction weight is applied. In these cases a 1.9 mm scope is recommended.

Although arthroscopy starts at the level of the RC joint, the MC joint should always be assessed. When there is a loss of pronation and supination, arthrolysis of the DRUJ should also be performed.

In the most difficult cases, it is impossible to recognize the normal arthroscopic anatomy of the wrist due to the presence of fibrosis that completely encloses the joint space. Difficulties could be encountered in performing triangulation with the instruments. Synovitis, fibrosis, and adhesions that obstruct the visual field, must be resected with caution, ensuring that no damage occurs to the surrounding structures. Obviously, the surgeon's surgical ability is of utmost importance here.

Radiocarpal Joint

All the portals (1-2, 3-4, 4-5, 6R, and 6U) may be used, including the volar ones, if needed. Inflow is permitted through the scope. Outflow by 6U portal or none. When dry arthroscopy is used, the trocar inflow portal is left open permitting the entrance of air as the shaver is used with constant aspiration. This allows removal of synovial fluid, blood, and debris. Furthermore, a 5 cc syringe can be used to inject fluid in order to wash the joint debris and blood, which is then removed by the suction of the shaver. Only when the radiofrequency instrument is used, does fluid become necessary. Once the radiofrequency is no longer required, it is possible to return to dry arthroscopy by using the shaver to aspirate fluid and debris in the joint.

The procedure is divided into two steps to permit a better understanding of the technique.

Step One: Fibrosis and Fibrotic Band Resection

Arthroscopic arthrolysis always starts from the radial side of the RC joint (Fig. 14.3). The starting portal is usually the 3-4 and the 1-2 is used as a working portal, however, portals are switched frequently.

Adhesions are initially removed from the radial side of the joint using the shaver (full radius: 2.9 mm, aggressive or

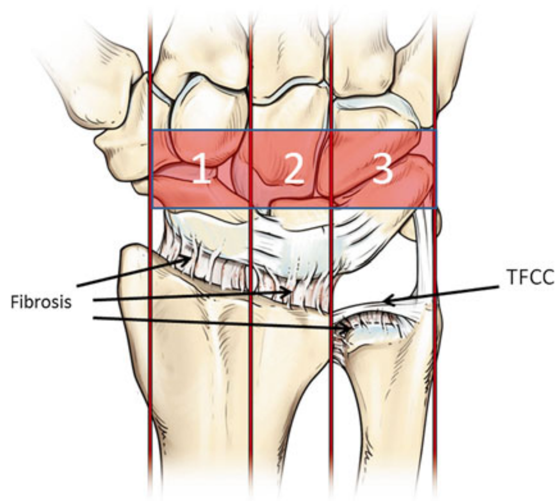


Fig. 14.3 Drawing showing the division of the radiocarpal joint into three parts. The proper radiocarpal joint is divided into two parts by a *longitudinal line* passing through the scapholunate joint. The ulnocarpal joint is separated from the radiocarpal joint by a *longitudinal line* through the medial border of the radius at the sigmoid notch. The ulnocarpal joint is rarely involved. In this drawing fibrosis is located in the radiocarpal joint, the DRUJ and under the TFCC ligament

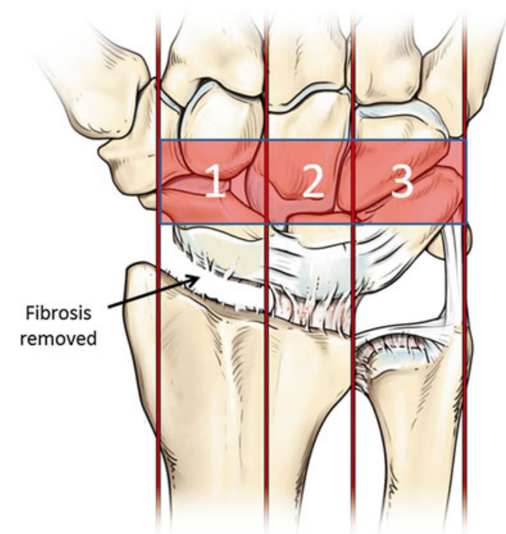


Fig. 14.4 Drawing showing division of the radiocarpal joint into three parts, where fibrosis in the radial side has been removed (step 1)

incisor: 3.2 mm) and radiofrequency instruments. However, not infrequently, difficulties are encountered in triangulation due to intense intra-articular fibrosis. In these circumstances, it is better to switch the scope from the 3-4 portal to the 1-2 portal and use the 3-4 portal as the working portal. The 1-2 portal is established with an outside-in technique using a needle. A longitudinal skin incision is made and blunt dissection with a mosquito forceps is performed to gain access to the joint. Shaving should only be started after ensuring that the full radius is turned towards the scope and not to the articular surface. As the intra-articular vision improves, the resection of fibrosis becomes easier.

Once fibrosis is completely removed from the radial side of the RC joint, the arthroscopic procedure is shifted to the ulnar side (Fig. 14.4). The scope is introduced through the 3-4 portal and the shaver through the 6R. Visualization of the shaver is frequently limited by the presence of the fibrotic band. Traditionally the fibrotic band [14] is localized between the scapho-lunate (SL) ligament and the ridge between the scaphoid and lunate facet of the distal radius (Figs. 14.5 and 14.6). It may be partial or complete. When it is complete, it divides the radio-carpal joint into two separate spaces. The fibrotic band may be incised using a small dissector introduced via the 6R portal in the direction of the scope. The band is carefully detached from the articular surface using the dissector. The fibrotic band may then be resected using a basket forceps or a shaver from the 6R portal (Fig. 14.7). To obtain a complete resection of the band, instruments must be switched from the 6R to 3-4 portal and scope from 3-4 to 6R. Radiofrequency instruments may also be used to resect

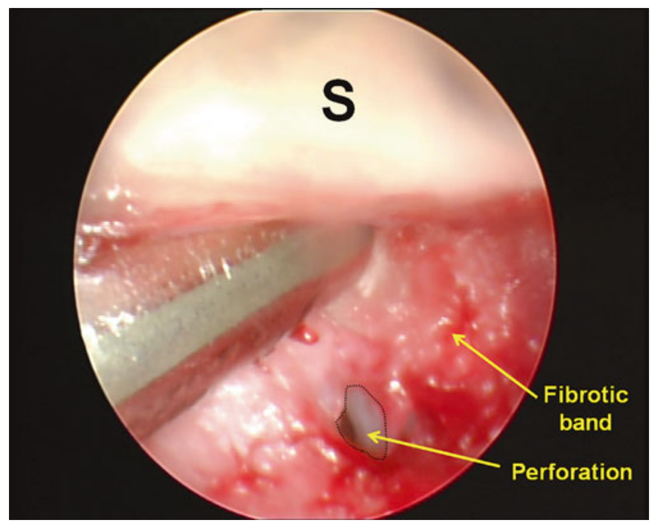


Fig. 14.5 Arthroscopic view of the fibrotic band that has resulted in a virtually complete separation of the radiocarpal joint in two compartments. A shaver is being used to excise the fibrotic band (*S*—scaphoid)

the fibrotic bands. Multiple fibrotic bands may be encountered in a joint with osteochondral damage to the articular surface of the distal radius (Fig. 14.8), with all of them originating from the defect.

Resection of this intra-articular fibrosis is often sufficient to improve passive wrist ROM. However, on occasion this fibrosis may be much more complex making arthrolysis much more difficult. Rarely these bands may ossify and form an osteofibrotic band, and with progression may result in an ankylosis of the RC joint (Fig. 14.9). In this situation it is very difficult to remove the band and may sometimes be impossible. Resection of these osteofibrotic bands may not

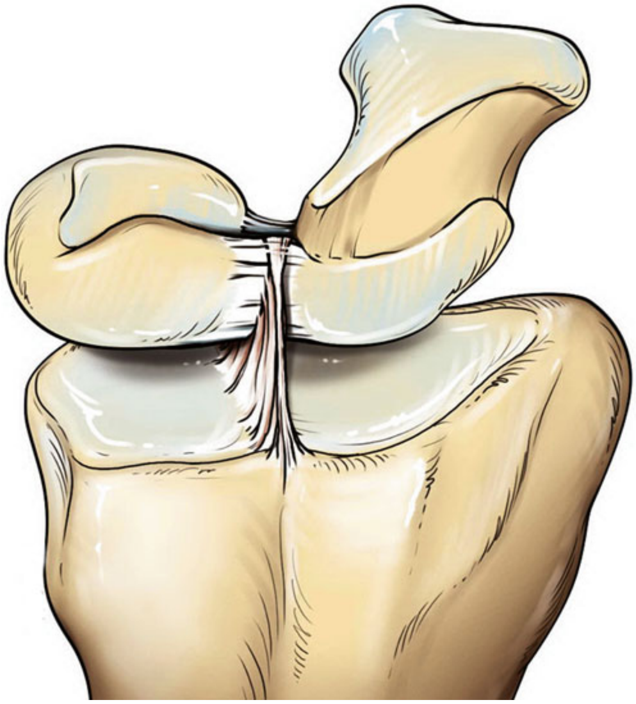


Fig. 14.6 Drawing showing the location of the fibrotic band

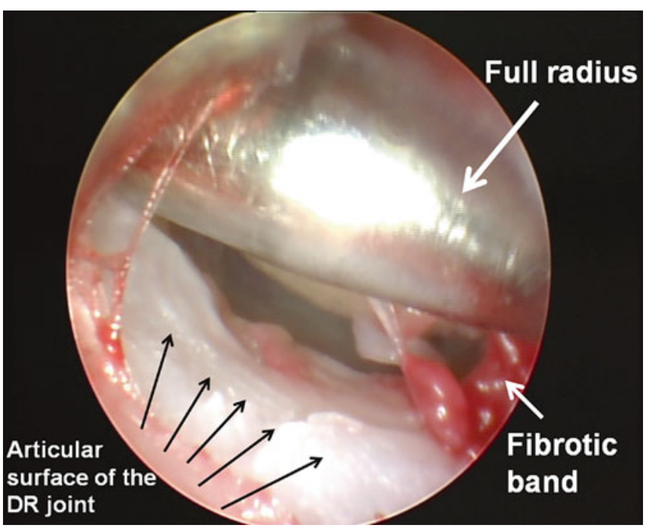


Fig. 14.7 Arthroscopic view of the wrist joint after fibrotic band resection. Note the irregularity of the articular surface of the distal radius due to a previous fracture

be indicated if it will cause an osteochondral defect that would then result in persistence of pain and recurrent formation of the bands.

When fibrosis in the ulnar side of the RC joint has been completely excised, the procedure continues into the ulnocarpal joint (Fig. 14.10). This part of the wrist joint is rarely affected by fibrosis, and arthroscopy is often diagnostic only. Occasionally, peripheral TFCC tears may be found, however,

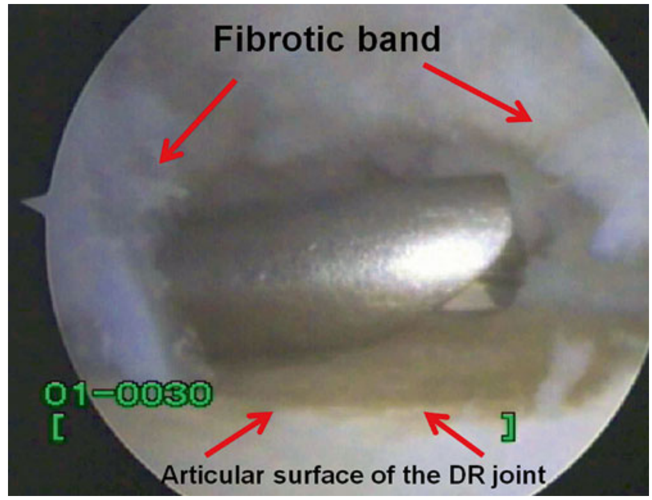


Fig. 14.8 Cartilage damage to the articular surface of the distal radius becomes evident after resection of the fibrosis

Fig. 14.9 X-ray of a wrist showing an ankylosis of the radio-lunate joint due to progression of an osteofibrotic band

the treatment these should be limited to a debridement in order to avoid the need for postoperative immobilization.

Before moving to the second step of the procedure, it is mandatory to evaluate the wrist ROM (Fig. 14.11). This should be performed out of traction.

Step Two: Volar and Dorsal Capsule Resection

Depending on the ROM obtained after step one, the volar and/or dorsal capsule and RC ligaments may need to be released. A mini-scalpel, such as a banana blade for peripheral nerve surgery, or micro-scalpel for ocular surgery is used. Radiofrequency instruments may also be used. Volar capsulotomy is easier than dorsal because the structures are immediately in the field of vision when viewing from the dorsal arthroscopy portals. Initially, the shaver is used to debride the intra-articular portion of the volar ligaments in order to see the entrance point of the mini-scalpel. Once inside the joint the surgeon addresses each affected ligament (Fig. 14.12). Often this is made difficult by articular incongruity, making it impossible to reach all areas of the capsule. This may be made easier by smoothing off the articular steps using a shaver (burr) that helps in reaching the volar capsule. It is much easier to cut the radial side of the capsule from the 1-2 portal with the scope in the 3-4 portal.

Radioscaphocapitate and radiolunate ligaments are resected at their base and the procedure continues through to the ulnar side (Fig. 14.13). The ulnar side of the volar capsule is released through the 6R portal (scope in 3-4). Identification of the volar ulnar limit of the distal radius permits the surgeon to stop the ligament dissection at this point to prevent resec-

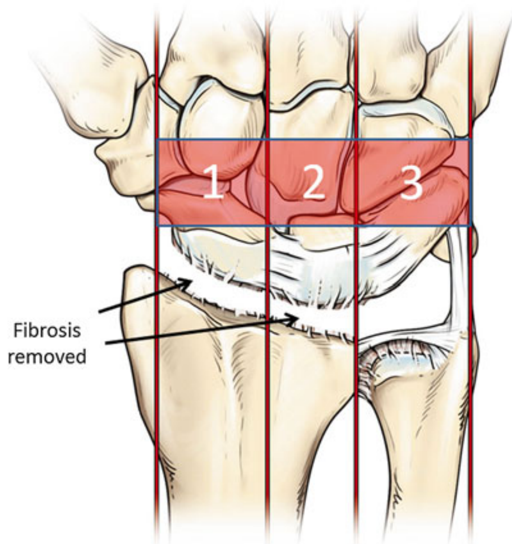


Fig. 14.10 Drawing showing complete resection of fibrosis in the radiocarpal joint

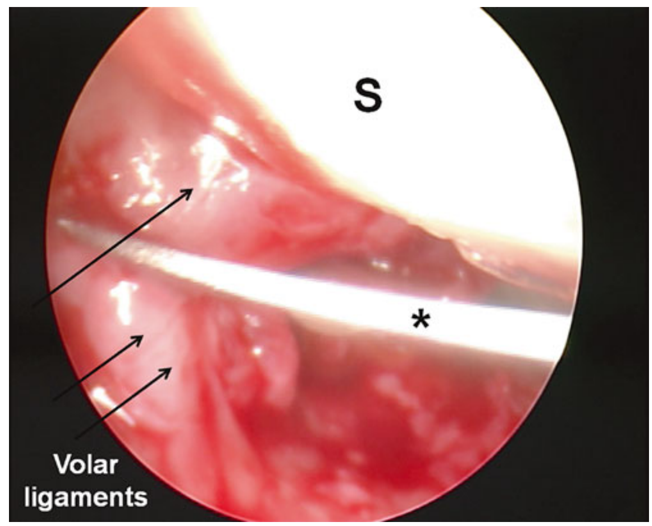


Fig. 14.12 Sectioning of the volar capsule using a miniscalpel (*) (*S*—scaphoid)

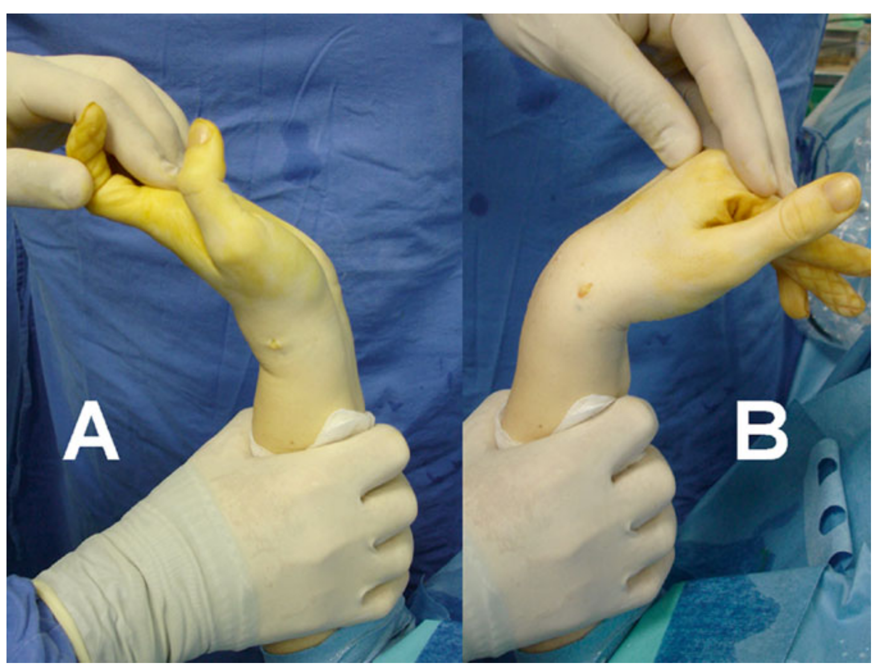


Fig. 14.11 Wrist ROM evaluation after step one of the arthroscopic arthrolysis procedure

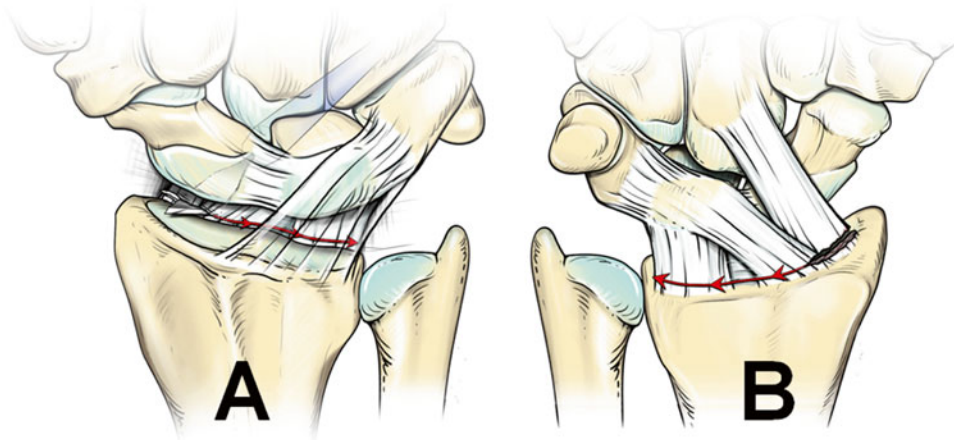


Fig. 14.13 Drawing illustrating the site of sectioning of the volar capsule and ligaments of the wrist (*red arrows*)

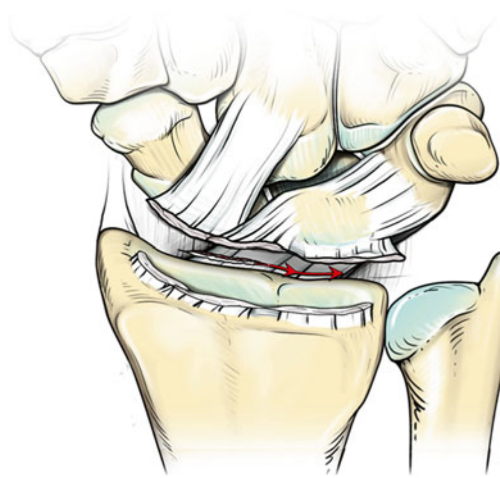


Fig. 14.14 Drawing illustrating the site of section of the dorsal capsule and ligaments (*red arrows*)

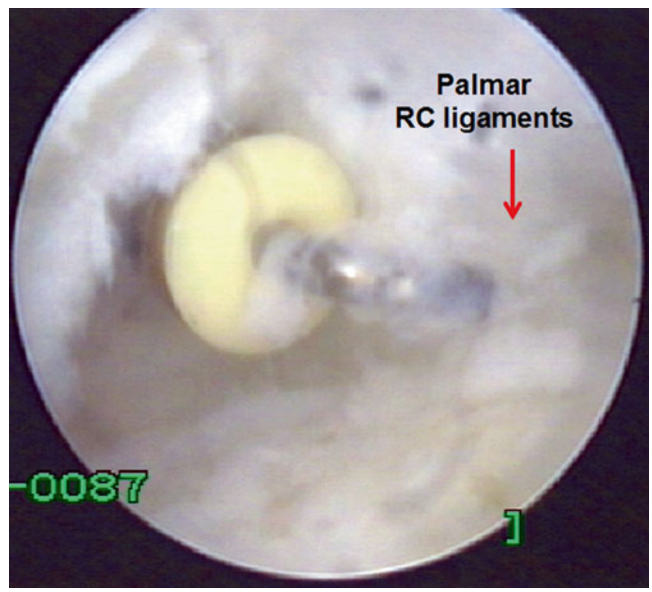


Fig. 14.15 Use of a hook tip of a radiofrequency device to section the dorsal capsule. Care should be taken to avoid injury to the structures dorsal to the capsule

tion of the volar UC ligament. At this point traction is removed, and a gentle manipulation is performed.

Traction is now re-applied and the procedure continues with resection of the dorsal wrist capsule (Fig. 14.14). This is performed with the scope through the 1-2 portal and the instruments through the 6R portal. The dorsal central part of the capsule is sectioned first. By switching the scope to the 6R portal, the capsule can be further resected by introducing the instruments through the 1-2 portal. The intra-articular position of the 3-4 portal is located and from this point the resection of the capsule starts by using a mini-scalpel, shaver, or radiofrequency with a hook tip (Fig. 14.15). The radial part of the capsule is easily resected through the 1-2 portal with the scope in the 6R portal. The ulnar part of the dorsal capsule contains the strong dorsal radiocarpal ligament. Here, the procedure becomes more difficult due to the firm consistency of this ligament. In this case, a volar radial portal may be used [18–20]. Bain et al. have described a safe method to resect the dorsal capsule with minimal risk to the extensor tendons [21, 22]. This technique involved the use of an intracapsular nylon tape that is used as a retractor to pull the extensor tendons out of harms way (Fig. 14.16).

It is very important to remember that the volar UC ligaments and dorsal capsule of the UC joint must not be resected (Fig. 14.17). The dorsal capsule of the UC joint is without a proper ligament but is reinforced by the floor of the ECU tendon sheath. The two volar UC ligaments are the ulno-lunate and the ulno-triquetral ligament. Moritomo et al. showed that

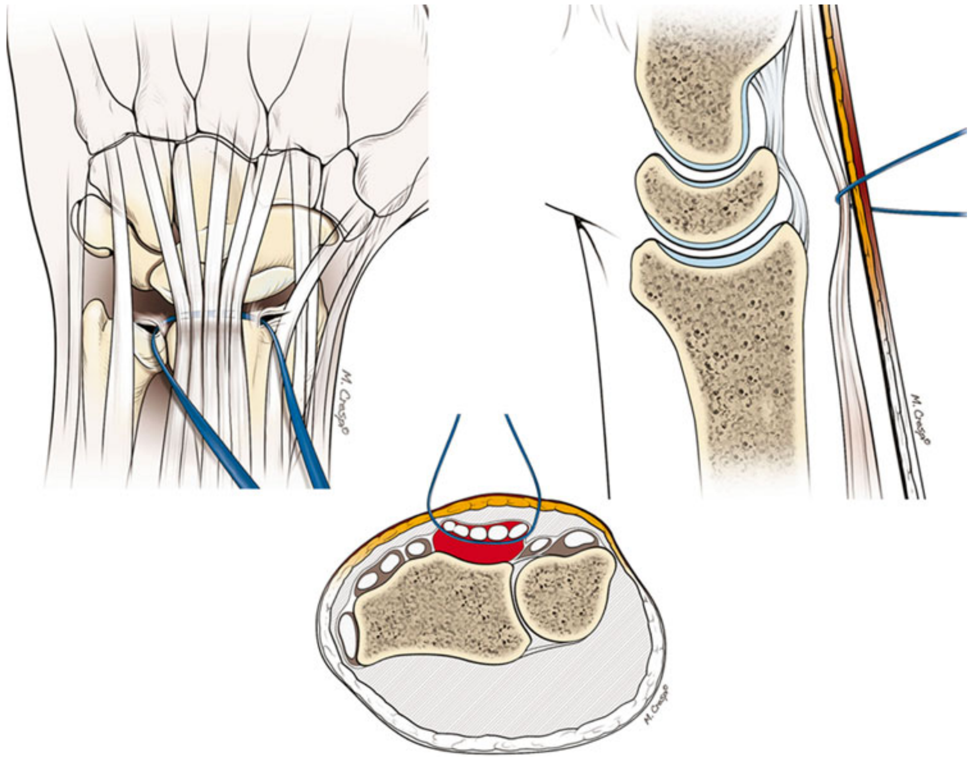


Fig. 14.16 Drawings illustrating the use of nylon tape to retract the extensor tendons during dorsal wrist capsule resection

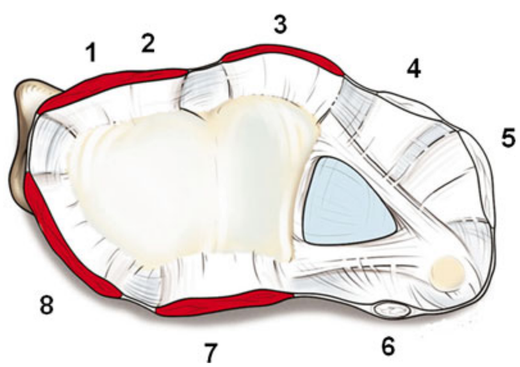


Fig. 14.17 Schematic drawing showing the extrinsic ligaments of the radiocarpal joint. (*1*) Radioscaphocapitate (*2*) Long radiolunate (*3*) Short radiolunate (*4*) Ulnolunate (*5*) Ulnotriquetral (*6*) ECU tendon (*7*) Dorsal radiocarpal (*8*) Dorsal capsule. The ligaments (*1–2–3–7*) that can be sectioned during the arthroscopic volar and dorsal capsulotomy are shown in *red* (according to Verhellen and Bain [15]). The ulnocarpal ligaments (*4* and *5*) must be preserved

the volar UC ligaments insert into the volar aspect of the TFCC ligament and both run proximally attaching to the ulnar head [23]. He demonstrated that a TFCC detachment produces both DRUJ and UC instability. Viegas reported that section of the radioscaphocapitate and radiolunate ligaments does not lead to significant ulnar translation of the carpus, and that either the volar ulnar ligament or the dorsal ulnar ligament complex alone can prevent ulnar translation [24]. The arthroscopic capsulotomy leaves the volar ulnar ligament and dorsal ulnar ligament complex intact.

Resection of a portion of the dorsal rim of the distal radius is mandatory when wrist extension is limited due to dorsal radiocarpal impingement secondary to malunion of a distal radius fracture (Fig. 14.1). This may be performed arthroscopically and improves wrist extension. After dorsal capsule resection the dorsal rim of the distal radius is resected by using a burr of 2.9–3.2 mm introduced through the 6R or 1-2 portal. Sometimes a volar radial portal is used but the ulnar-most side of the dorsal rim cannot be completely reached due to the carpal bones even if wrist distraction is increased. Therefore, the ulnar-most side of the dorsal rim of the distal radius is resected mostly through the 6R portal.

Ancillary Procedures

During arthroscopy one may identify other occult articular, DRUJ, and carpal bone problems. Some of these may be treated during the same procedure but others may need to be treated later due to different rehabilitation programs, in order to avoid postoperative immobilization.

Small articular steps (<1 mm) of the distal radius may be addressed (Fig. 14.18). A burr of 2.9–3.2 mm is used at 500 revolutions per second introduced through the 6R portal with the scope in the 3-4 or 1-2 portal. Larger steps can also be

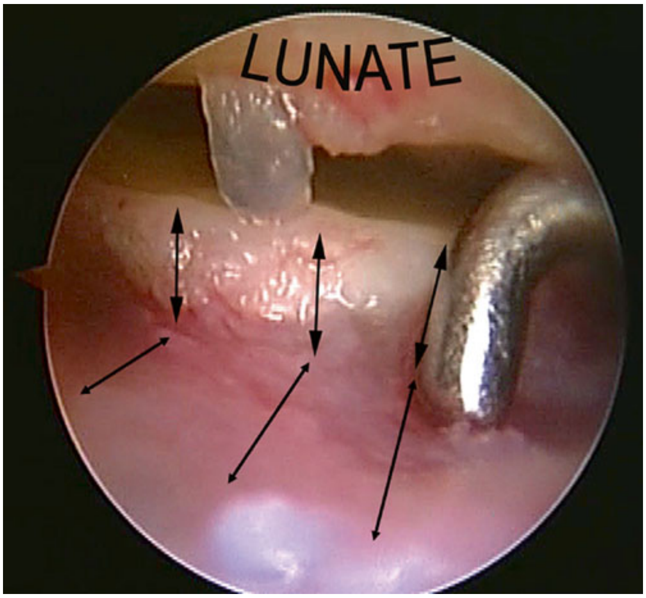


Fig. 14.18 Arthroscopic view showing an articular step of the distal radius that became evident during arthrolysis [Courtesy of Francisco del Piñal]

treated but this often results in fibrotic band recurrences and ongoing wrist pain.

TFCC central tears are debrided: the flap is removed and the edges are resected. TFCC peripheral lesions or foveal detachments must be treated later because of the necessity for postoperative immobilization. Positive ulnar variance may be treated with arthroscopic wafer resection. Loose bodies, an extremely rare occurrence, should be removed if they are found.

This concludes the RC arthroscopy and at this point the ROM should be assessed before proceeding to the MC joint. Traction is temporarily removed and passive wrist ROM is evaluated.

Midcarpal Joint

If there is no appreciable change in passive wrist ROM after the RC arthrolysis, a MC arthroscopy should be carried out. The approach for this articulation is via the two portals (RMC and UMC) but if needed, more portals can be used (scapho-trapezio-trapezoid (STT) and triquetro-hamate (TH)). Arthroscopy of this joint is much easier to perform and synovitis is the most frequently found pathology. It is usually localized at the level of the STT and TH joints. Commonly, one tends to see cartilage degeneration between the capitate and hamate. This may well be responsible for wrist pain. Debridement of the MC joint is performed and may improve pain and ROM. MC joint arthroscopy does not require any ligament resection.

Dorsal radio-midcarpal impingement is suspected when wrist extension is limited and painful, with the pain localized to the capitate, with radiographs demonstrating deformity of the dorsal rim of the radius. The degree of chondral damage to the capitate due to impingement may be assessed. After a synovectomy and debridement, a burr is used to remove excess bone from the dorsum of the neck of the capitate to facilitate acceptance of the remodeled dorsal rim of the distal radius during wrist extension. The procedure is similar to that performed in the elbow for humeral-olecranon impingement in which osteophytes on the tip of the olecranon and the olecranon fossa are arthroscopically removed.

Distal Radioulnar Joint

A prerequisite to ensure a good outcome for the DRUJ, is the preservation of a normal articular surface (sigmoid notch and ulnar head). Malunion of the sigmoid notch due to fracture of the ulna aspect of the distal radius should be treated by osteotomy if there are no signs of arthritis [3]. Salvage procedures are recommended for DRUJ incongruity with secondary arthritis of the joint.

Arthroscopy of the DRUJ is difficult. It is very unusual to have good visibility in the DRUJ even in normal conditions. Stiffness of this joint is due to capsular contraction, intra-articular fibrosis, and synovitis, which makes arthroscopy more difficult.

DRUJ arthroscopy is performed through distal and proximal portals. The scope is introduced in the proximal portal and the instruments in the distal portal. Normally, fibrosis does not permit any visualization. Fluid is constantly used to try to expand the joint and improve visualization. Once visualization is achieved and the tips of the instruments are seen, fibrosis is progressively removed using a full radius or aggressive resector.

From an arthroscopic point of view the DRUJ comprises two spaces (Fig. 14.19), that between the TFCC ligament and the ulna head, and the other between the ulna head and the radius (sigmoid notch). In posttraumatic conditions, both spaces are involved. Fibrosis under the TFCC precludes any visualization by arthroscopy, and in the absence of a central perforation of the TFCC, good visualization is difficult. In these cases we suggest introducing a blunt dissector between the TFCC and the ulnar head, and gently dissecting the adhesions. It can also be done using an arthroscopic shaver through the traditional DRUJ portals or just below the 6U portal (direct foveal portal) or lateral to the 6U portal. Fibrosis can be completely removed through these portals (Fig. 14.20) and it is also possible to perform a wafer resection.

The second space, lying between the ulnar head and radius in the sigmoid notch, is affected by contraction of the volar

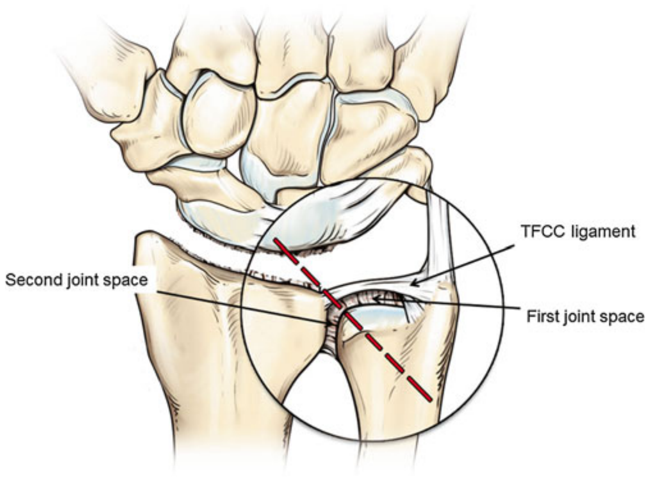


Fig. 14.19 Drawing showing the localization of fibrosis in the DRUJ. This joint is divided into two parts for the sake of the arthroscopic procedure

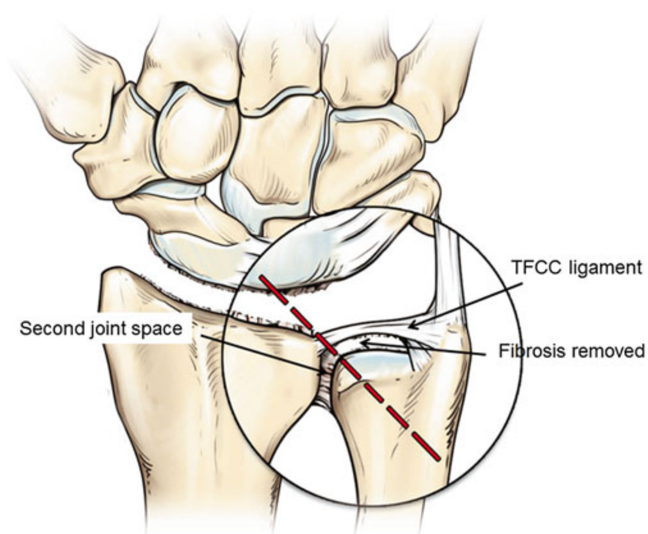


Fig. 14.20 Drawing showing removal of the fibrosis under the TFCC

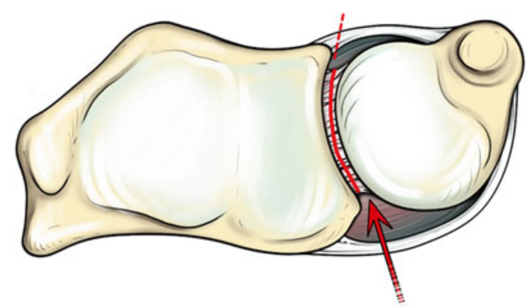


Fig. 14.21 Drawing showing an axial view of the DRUJ. Dorsal and volar capsules are sectioned (*red arrows* and *red line*)

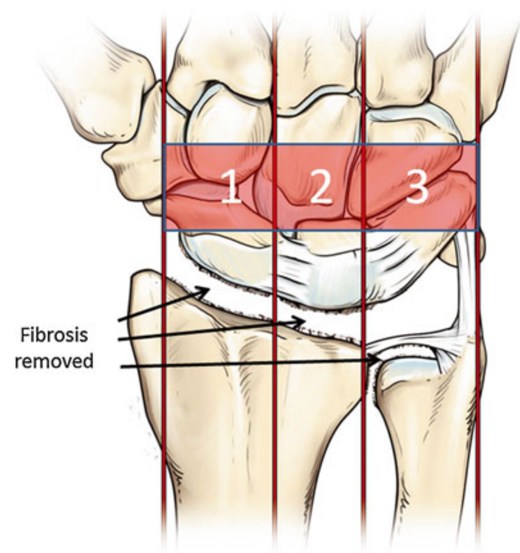


Fig. 14.22 Drawing showing complete removal of fibrosis in the DRUJ and radiocarpal joint

and dorsal capsule, causing a restriction in pronation and supination. Arthroscopic arthrolysis of this space starts with the scope in the distal portal and instruments in the proximal portal. It is difficult to visualize the tip of the instrument introduced in the DRUJ proximal portal. The dorsal and the volar capsule must be detached and/or resected (Fig. 14.21). Volar capsulectomy would improve the supination, and dorsal capsulectomy the pronation. To improve the visualization and speed of this last part of the procedure, a curved dissector is introduced into the joint from the proximal portal. By passing from dorsal to volar it is possible to detach the ligament from the sigmoid notch (Fig. 14.22). The volar and the dorsal parts of the TFCC ligament must not be detached from the bony origin (radius and ulnar fovea). If this happens DRUJ instability will follow. The articular surface of the ulna head and sigmoid notch must not be damaged, either. Dry arthroscopy is rarely used for the DRUJ. Finally, out of the traction, gentle pronation, and supination maneuvers are performed to evaluate the improvement in ROM.

Postoperative Rehabilitation

Rehabilitation is started immediately after surgery [25]. Routine analgesics are used for postoperative pain control. Active and passive pronation–supination and flexion–extension exercises are performed, gradually increasing the passive mobilizing force, under the guidance of a therapist.

Return to work is delayed up to 3 months as per the work requirements of the patient. A volar wrist splint is used for protection while performing heavy activities. Endurance and strengthening exercises using isokinetic and isotonic rehabilitation equipment can be initiated 1 month after surgery under the strict supervision of a physical therapist. The patient protocol is individualized depending on strength requirements for each individual patient and their job requirements [25].

Discussion

Arthroscopic wrist arthrolysis is a difficult and time-consuming procedure. Occasionally the technique requires mini-open surgery or conversion to an open procedure to obtain the best result. This is particularly true for the DRUJ where resection of the volar and dorsal capsule is difficult to perform arthroscopically. However, arthroscopic arthrolysis is a suitable and effective surgical option for the treatment of wrist stiffness after trauma or surgery. It is a safe and minimally invasive procedure and allows the surgeon to identify the intra-articular pathology.

Comparison between published series regarding the improvement of wrist ROM after arthroscopic wrist arthrolysis is reported in Table 14.3. All series showed a significant improvement in wrist ROM.

Arthroscopy may identify associated lesions that contribute to the patient's pain. Loose bodies, arthrofibrosis, radiocarpal septae, arthritis, partial, or complete tears of the inter-carpal ligaments and TFCC, and articular incongruity that may not have been evident on radiographs or MRI may also be identified arthroscopically. This is one of the advantages of performing this procedure arthroscopically [26, 27]. Moreover, it is often possible to treat all the pathologies at the same time, thereby improving outcomes.

Conversion to open surgery is only indicated when it is necessary to surgically treat the DRUJ and when difficulty is encountered during arthroscopy. Other surgical procedures may be performed at the same time to treat associated pathologies, such as carpal tunnel syndrome and partial or total wrist denervation.

Table 14.3 Comparison between studies in literature

	Cases	F-up	Pre-op	Post-op
Publications	No.	Months	Flex/ext (mean degrees)	Flex/ext (mean degrees)
Pederzini, Luchetti et al. (1991)	5	10	44/40	54/60
Verhellen and Bain (2000)	5	6	17/10	47/50
Osterman and Culp (2000)	20	32	9/15	42/58
Luchetti et al. (2001)/(2007)	19	32	46/38	54/53
Hattori et al. (2004)	11	unsure	29/47	42/56

Based on our experience, we suggest that TFCC tears type 1B or a complete tear of the SL ligament must not be treated simultaneously with arthrolysis since they require prolonged postoperative immobilization and the rehabilitation protocol is contrary to that of arthrolysis. Therefore, before arthroscopy it is important to discuss with the patient, the surgical procedure indicated, based on a thorough clinical evaluation and to plan the optimal timing of the surgery, since it is mandatory that the wrist is mobilized and that the patient initiates rehabilitation immediately after an arthroscopic arthrolysis procedure.

One must remember that if there is an underlying SL ligament tear, in addition to the presence of wrist stiffness, the surgeon may not be able to obtain a good result by performing an arthroscopic arthrolysis. The injury to this ligament is often concealed by the wrist stiffness and only after wrist arthrolysis has been performed, will instability due to ligament injury be manifested. The improvement in pain and ROM that is obtained following wrist arthrolysis may be inconsistent.

It may be seen that an intra-operative increase in wrist flexion–extension ROM is followed by a temporary decrease soon after surgery, but is regained over time. On the contrary, pronation–supination improvement that has been obtained during surgery is almost always maintained postoperatively [5].

DRUJ (pronation–supination) stiffness is more frequently encountered than RC stiffness, and may be isolated or in conjunction with RC joint stiffness. When DRUJ stiffness is isolated, ROM recovery after surgery is easier to obtain than when it is associated with RC stiffness, and this improvement is maintained.

Failures and Complications

Unfortunately, it may happen that the surgeon is unable to perform a wrist arthroscopic arthrolysis due to the presence of an osteofibrotic band (RC septum) that is too thick and dense and obstructs the field of view. This may result in a radio-lunate ankylosis (Fig. 14.19). These are the types of cases that should not be treated arthroscopically since they tend to end up with residual wrist stiffness.

Radiographs may not demonstrate all of the pathology, and when the surgeon sees a preserved joint space, they tend to be eager to perform an arthroscopic arthrolysis. Unfortunately, the underlying difficulties become quite evident during the surgery, and if one is able to perform the wrist arthrolysis, they have to first detach the adherent bands and the osteofibrotic band in order to improve the visual field and ultimately, ROM. At the same time osteochondral lesions may become evident. In these cases, even if a proper physical therapy protocol is followed, it is quite common that fibrotic bands reform and result in partial or complete RC ankylosis.

Extra-articular wrist stiffness due to CRPS is a difficult problem to manage. In these cases, wrist arthrolysis must be performed with release of extra-articular soft tissue adhesions. Surgery in these cases must be planned with extreme caution since the root of the wrist stiffness is much more complex than just a localized articular dysfunction.

When the patient reports that wrist pain has recurred or never completely disappeared after surgery, the surgeon should take note that there can still be an underlying articular pathology that has not been diagnosed. Often the pain can be due to intrinsic ligament tears (scapholunate or lunotriquetral) not been identified pre or intra-operatively.

The surgeon should exercise caution with the use of intra-articular instruments that can cause osteochondral damage or ligament injury, which may manifest postoperatively in the form of pain or instability.

References

1. Altissimi M, Rinonapoli E. Le rigidità del polso e della mano. Inquadramento clinico, valutazione diagnostica e indicazioni terapeutiche. Giornale Italiano di Ortopedia e Traumatologia. 1995;21(3):187–92. suppl, LXXX Congresso SIOT.
2. Luchetti R, Atzei A, Fairplay T. Arthroscopic wrist arthrolysis after wrist fracture. Arthroscopy. 2007;23:255–60.
3. del Piñal F, Garcia-Bernal FJ, Delgado J, Sanmartin M, Regalado J, Cerezal L. Correction of malunited intra-articular distal radius fractures with an inside-out osteotomy technique. J Hand Surg. 2006;31A:1029–34.
4. af Ekenstam FW. Capsulotomy of the distal radio-ulnar joint. Scand J Plast Surg. 1988;22:169–71.
5. Pederzini L, Luchetti R, Montagna G, Alfarano M, Soragni O. Trattamento artroscopico delle rigidità di polso. Il Ginocchio. 1991;XI–XII:1–13.
6. Jones GS, Savoie FH. Arthroscopic capsular release of flexion contractures of the elbow. Arthroscopy. 1993;9:277–83.
7. Warner JJ, Answorth A, Marsh PH, Wong P. Arthroscopic release for chronic, refractory adhesive capsulitis of the shoulder. J Bone Joint Surg. 1995;78A:1808–16.
8. Warner JJ, Allen AA, Marks PH, Wong P. Arthroscopic release of post-operative capsular contracture of the shoulder. J Bone Joint Surg. 1996;79A:1151–8.
9. Bain GI, Verhellen R, Pederzini L. Procedure artroscopiche capsulari del polso. In: Pederzini L, editor. Artroscopia di Polso. Milano: Springer; 1999. p. 123–8.
10. Luchetti R, Atzei A. Artrolisi artroscopica nelle rigidità post-traumatiche. In: Luchetti R, Atzei A, editors. Artroscopia di Polso. Fidenza: Mattioli 1885; 2001. p. 67–71.
11. Luchetti R, Atzei A, Fairplay T. Wrist arthrolysis. In: Geissler WB, editor. Wrist arthroscopy. New York, NY: Springer; 2004. p. 145–54.
12. Luchetti R, Atzei A, Mustapha B. Arthroscopic wrist arthrolysis. Atlas Hand Clin. 2001;6:371–87.
13. Luchetti R, Atzei A, Papini-Zorli I. Arthroscopic wrist arthrolysis. Chir Main. 2006;25:S244–53.
14. Osterman AL, Culp RW, Bednar JM. The arthroscopic release of wrist contractures. Scientific Paper Session A1, ASSH Annual Meeting, Boston. NO. 2000
15. Verhellen R, Bain GI. Arthroscopic capsular release for contracture of the wrist. Arthroscopy. 2000;16:106–10.
16. Atzei A, Luchetti R, Sgarbossa A, Carità E, Llusa M. Set-up, portals and normal exploration in wrist arthroscopy. Chir Main. 2006; 25:S131–44.
17. del Piñal F, Garcìa-Bernal FJ, Pisani D, Regalado J, Ayala H, Studer A. Dry arthroscopy of the wrist. Surgical technique. J Hand Surg. 2007;32A:119–23.
18. Doi K, Hattori Y, Otsuka K, Abe Y, Yamamoto H. Intra-articular fractures of the distal aspect of the radius: arthroscopically assisted reduction compared with open reduction and internal fixation. J Bone Joint Surg. 1999;81A:1093–110.
19. Slutsky DJ. Wrist arthroscopy through a volar radial portal. Arthroscopy. 2002;18:624–30.
20. Tham S, Coleman S, Gilpin D. An anterior portal for wrist arthroscopy. Anatomical study and case reports. J Hand Surg. 1999;24B: 445–7.
21. Bain GI, Munt J, Bergman J. Arthroscopic dorsal capsular release in the wrist: a new technique. Tech Hand Up Extrem Surg. 2008; 12:191–4.
22. Bain GI, Munt J, Turner PC. New advances in wrist arthroscopy. Arthroscopy. 2008;24:355–67.
23. Moritomo H, Murase T, Arimitsu S, Oka K, Yoshikawa H, Sugamoto K. Change in the length of the ulnocarpal ligaments during radiocarpal motion: possible impact on triangular fibrocartilage complex foveal tears. J Hand Surg. 2008;33A:1278–86.
24. Viegas SF, Patterson RM, Eng M, Ward K. Extrinsic wrist ligaments in the pathomechanics of ulnar translation instability. J Hand Surg Am. 1995;20:312–8.
25. Travaglia-Fairplay T. Valutazione ergonomica dell'ambiente industriale e sua applicazione per screening di pre-assunzione e riabilitazione work-hardening. In: Bazzini G, editor. Nuovi approcci alla riabilitazione industriale. Pavia: Fondazione Clinica del Lavoro Edizioni; 1993. p. 33–48.
26. Cerofolini E, Luchetti R, Pederzini L, Soragni O, Colombini R, D'Alimonte P, Romagnoli R. MRI Evaluation of triangular fibrocartilage complex tears in the wrist: comparison with arthrography and arthroscopy. J Comput Assist Tomogr. 1990;14:963–7.
27. Zlatkin MB, Chao PC, Osterman AL, Schnall MD, Dalinka MK, Kressel HY. Chronic wrist pain: evaluation with high-resolution MR imaging. Radiology. 1989;173(3):723–9.

Wrist Arthritis: Arthroscopic Techniques of Synovectomy, Abrasion Chondroplasty, Radial Styloidectomy, and Proximal Row Carpectomy of the Wrist

15

Kevin D. Plancher, Michael L. Mangonon, and Stephanie C. Petterson

Introduction

In the eyes of most people, the wrist is a single joint connecting the forearm and the hand. To the surgeon, we know that the wrist is a more intricate entity than our eyes can see. Thus treatment of such a complex structure is not easily undertaken and the limitations caused by a loss of wrist function due to arthritis can greatly change the daily lives of patients.

With the introduction of arthroscopy, orthopedic and hand surgeons have reinvented old techniques to provide the same gold standard care using minimally invasive means. Wrist arthroscopy has become an important tool for the examination and treatment of intra-articular abnormalities. Some procedures are enhanced and more successful using arthroscopy than traditional open techniques. Innovations such as new portals and smaller arthroscopes have led to the expansion of arthroscopic procedures [1–3].

Arthroscopy of the wrist is most useful as a diagnostic tool to examine the joint articular surfaces, diagnose degenerative triangular fibrocartilage lesions, and perform synovial biopsy. It can also be used as a therapeutic modality to remove loose bodies and debride the wrist for early-stage arthritis.

Early results for arthroscopic synovectomy demonstrated reduced pain and swelling and improved joint function [4–6]. It was shown that the effectiveness of this treatment was dependent on the preoperative level of activity as well as the underlying cause of the disease. Arthroscopic synovectomy may be effective in delaying more complex procedures such as arthrodesis or total wrist arthroplasty in select cases [7]. With abrasion chondroplasty of the wrist, it is known that "repair" (Type I) fibrocartilage which replaces articular cartilage allows for defects to be re-contoured, as demonstrated in several animal models [8, 9]. Abrasion chondroplasty has been found to be effective in patients with proximal pole hamate arthrosis and radiocarpal arthrosis, with positive results obtained [10–12]. Radial styloidectomy has been shown to be a suitable alternative for treatment of arthritis of the wrist when a patient does not want to undergo more complex procedures such as a proximal row carpectomy (PRC) or a partial or complete fusion. It is a target-specific procedure with excellent outcomes. Finally, when needed due to severity of the arthritis, PRC is a good salvage procedure, and when performed arthroscopically the soft tissue envelope and capsular ligaments of the wrist are preserved, making this a more desirable option [13]. This review will discuss the indications and techniques for arthroscopic synovectomy, abrasion chondroplasty, radial styloidectomy, and proximal row carpectomy.

Anatomy

Fifteen bones form connections from the end of the forearm to the hand including the radius, ulna, eight carpal bones, and five metacarpals. The carpal bones are grouped in two rows across the wrist. Beginning with the thumb side of the wrist, the proximal row of carpal bones is made up of the scaphoid, lunate, and triquetrum. The distal row is made up of the trapezium, trapezoid, capitate, hamate, and pisiform.

The radiocarpal joint is the primary joint of the wrist formed by the articulations between the radius and the proximal row of carpal bones. The primary motion that occurs at the radiocarpal joint is wrist flexion and extension. The distal radioulnar joint, the articulation between the ulnar head and the ulnar notch of the radius, allows for rotary movements of supination and pronation. The intercarpal joints are small synovial joints that create the transverse arch of the wrist, which is concave on the palmar side. The intercarpal joints, namely the scaphoid–capitate joint and the lunate–capitate

K.D. Plancher, M.D. (✉) • M.L. Mangonon, D.O.
Plancher Orthopaedics & Sports Medicine,
1160 Park Avenue, New York, NY 10128, USA
e-mail: kplancher@plancherortho.com

S.C. Petterson, M.P.T., Ph.D.
Research Department, Orthopaedic Foundation,
Stamford, CT, USA

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*,
DOI 10.1007/978-1-4614-1596-1_15, © Springer Science+Business Media New York 2015

joint, contribute to the total range of motion of the wrist [14]. When the wrist flexes, the transverse arch deepens and when the wrist is extended the transverse arch flattens. Radial and ulnar deviations occur primarily through the midcarpal joints with a smaller contribution from the radiocarpal joint [15].

The intricate set of ligaments surrounding the bones of the wrist provides stability to the osseous structures and aid in maintaining alignment during wrist movements. The ligaments on the palmar side are stronger than the stabilizing ligaments on the dorsal side. The triangular fibrocartilage complex (TFCC) is the major stabilizer of the distal radioulnar joint (DRUJ). It also improves the gliding motion of the wrist. Housed within the TFCC is an articular disc which serves to distribute forces across this part of the wrist. Medial and lateral wrist stability are provided by the ulnar and radial collateral ligaments which connect the ulna and radius, respectively, to the carpal bones. The palmar radiocarpal ligament stabilizes the radius and carpals on the palmar side and limits excessive wrist extension, whereas, the dorsal radiocarpal ligament stabilizes the radius and carpals on the dorsal side and limits excessive wrist flexion. The intrinsic dorsal and palmar midcarpal ligaments stabilize the proximal and distal rows of carpal bones and the intrinsic interosseous ligaments stabilize the individual intercarpal joints. Lastly, the accessory, transverse carpal ligament supports the transverse carpal arch.

The articular surfaces of the wrist bones are covered with a white, shiny material known as articular cartilage. Articular cartilage aids in facilitation of joint motion between two joint surfaces. Articular cartilage can be up to ¼-inch thick in the large, weight-bearing joints, and is thinner in joints such as the wrist that do not support as much weight. Its rubbery consistency contributes to its function as a shock absorber. In the wrist, articular cartilage covers a much larger surface area due to the many joint surfaces involved.

Physiology

Osteoarthritis (OA) is a complex cascade of events leading to degeneration of articular cartilage, which may be accelerated with injury or trauma. Chronic injuries of the scapholunate ligament and in scaphoid nonunions are often initiated with OA of the radial styloid, which then progresses to the radiocarpal and capitolunate joints, and finally results in collapse of the capitate into the scapholunate interval [16].

Matrix metalloproteinases and proinflammatory cytokines (e.g. interleukin-1) have been found to be important mediators of cartilage destruction in patients with primary OA. Interleukin-1 increases the synthesis of matrix metalloproteinases and thereby plays an important role in OA. During the initial stages of OA, the superficial layers of the articular cartilage fibrillate and crack. As degeneration progresses, deep layers become involved, resulting in erosions that produce bare subchondral bone. Denatured type II collagen is found in abundance in OA articular cartilage, with decreased water content and decreased ratio of chondroitin sulfate to keratin sulfate constituents.

Rheumatoid arthritis (RA) is a progressive inflammatory disease characterized by synovitis and joint destruction. Synovial cell proliferation results in pannus formation and fibrosis, which in turn results in erosion of cartilage and bone. Cytokines, prostanoids, and proteolytic enzymes mediate this process. A cell-mediated immune response to an unidentified antigen appears essential in the pathogenesis of RA. Proinflammatory cytokines, such as interleukin-1 and tumor necrosis factor alpha, and T-cell initiation are the central mediators in RA.

In gouty arthritis, allantoin, the enzyme uricase that breaks down uric acid into a more soluble product, is deficient and leads to tissue deposition of crystalline forms of uric acid. Hyperuricemia is a risk factor for the development of gout; however, hyperuricemia does not implicate the development of gout and acute gouty arthritis can occur in the presence of normal serum uric acid concentrations. Gout appears as crystal deposition on the scapholunate and lunotriquetral ligaments when viewed arthroscopically [17].

Secondary OA may emerge as a result of injury to the ligamentous stabilizers. Loss of joint stability contributes to loss of coupled motion in the wrist, abnormal wrist mechanics, and altered joint reaction and loading forces. This process produces degeneration of the articular cartilage, resulting in radiocarpal arthritis, selective intercarpal arthritis, or pancarpal arthritis, depending on the nature and extent of the initial injury and subsequent healing.

Scaphoid fractures, in particular, can result in OA by three different mechanisms:

1. *Nonunion*. A nonunion fracture leads to abnormal movement between the bone fragments. Consequently, the normal distribution of forces across the wrist is altered and can result in early degeneration of the radioscaphoid joint if not treated properly.
2. *Malunion*. Malunion fractures may reduce the height of the scaphoid and restrict the range of motion in one or more planes. Altered range of motion can cause increased strain and lead to OA changes over time.
3. *Avascular Necrosis*. Scaphoid fractures resulting in avascular necrosis of the proximal pole can lead to collapse and degeneration of the radioscaphoid joint. Progression to the lunate and then the entire wrist is also possible.

Regardless of the type of arthritis in question, the main reason for symptoms is the underlying inflammatory processes. Knowledge of the underlying disease process will allow for directed treatment to resolve symptoms and minimize the chance of further disease progression.

Patient Evaluation

History

With proper history, one can elicit certain "historical" facts that can aid in the diagnosis of wrist arthritis. Symptoms typically emerge gradually over time and often do not involve an acute injury. The most commonly reported complaint is pain throughout the arc of motion which is aggravated at extremes of motion. Pain is often improved with rest and gradually worsens with length of activity. As the disease worsens, the functional range of motion of the wrist decreases and in severe cases patients may experience a complete loss of movement.

Physical Examination

Physical deformity is a key feature of wrist arthritis, particularly in RA. Patients with RA may exhibit enlargement of the wrist and metacarpophalangeal joints as well as subluxation of the radiocarpal and inferior radioulnar joints. They may also have enlargement of the proximal interphalangeal joints (Bouchard's nodes); however, Boutchard's nodes are more commonly found in patients with OA as are Heberden's nodes, which are an enlargement of the distal interphalangeal joints of the hand.

Classically in RA, wrist deformity begins with wrist radial deviation and resultant ulnar head prominence and progresses to supination and ulnar translation of the carpus and volar subluxation of the radiocarpal joint. Since the mobility of the wrist dictates hand function, wrist position influences the strength for gripping heavy objects. Swelling of the wrist is also a common manifestation of RA due to synovial thickening. If left untreated, the synovitis can lead to tendon weakening rupture and collapse resulting in the aforementioned characteristic deformities.

Palpation of the wrist would reveal crepitus with motion, capsular edema dorsally without any fluctuance, and localized tenderness. Due to the wrist acting as a stabilizer of the hand for function, pain and deformity can result in decreased grip strength. Wrist deformity and instability reduce support for the hand to grasp, thus impairing fine motor movements. Loss of wrist extension due to stiffness will also hinder the ability to properly evaluate for the tenodesis effect (passive flexion of the digits with passive wrist extension and passive extension of the digits with passive wrist flexion) during examination.

Diagnostic Imaging

Plain radiographs are the mainstay and most accurate modality for imaging and diagnosing arthritis. Radiographs should not be a substitute for the physician's clinical examination. Radiographs may only show the picture in the late stages of disease when bone tissue is already affected [18] and findings are not always indicative of symptoms [19]. Appropriate radiographic workup can provide insight into areas of localized pain in the wrist.

Using the typical wrist views, including zero posteroanterior, zero lateral, oblique, ulnar and radial deviation, and grip, a good evaluation series of the wrist can be obtained (Fig. 15.1). Findings that lead to the diagnosis of arthritis include reduction in articular height, sclerosis, osteophyte formation, bone erosions, intra-articular calcifications, and joint deformity.

We believe that magnetic resonance imaging (MRI) with an appropriate clinical history has a high sensitivity and specificity for imaging articular cartilage when confirmed by arthroscopic findings and clinical correlations. However, others refute the role of MRI as a diagnostic tool. Haims and colleagues concluded that wrist MRI (41 indirect MR arthrograms and 45 unenhanced [nonarthrographic] MR images) is not adequately sensitive or accurate for diagnosing cartilage defects in the distal radius, scaphoid, lunate, or triquetrum, as demonstrated compared to arthroscopic findings [20]. This was also supported by Multimer et al. who demonstrated that MRI and arthroscopy are not correlated and therefore arthroscopy continues to have a role in the diagnosis of an arthritic wrist [21]. While true for the radiologist that sees a rare MRI of the wrist, a trained muscuoloskeletal radiologist well-versed in wrist anatomy can be enormously helpful in treatment planning with an accurate read of the cartilage status of the wrist.

In cases of synovitis and ulnar-sided pathology, MRI remains a strong indicator for which areas need to be addressed with the arthroscope to treat successfully. Signs of synovitis, enhancement with bone erosion-like changes, and of bone marrow edema are strong indicators of an evolving arthritic disease process [22, 23].

MRI is also a sensitive method for excluding the diagnosis of early avascular necrosis and for evaluating the extent to which fibrocartilaginous repair tissue has formed postoperatively. These post-microfracture or cartilage repair procedures have been utilized to look at knee pathology post-surgery, and we have established the same protocols for wrist defects [20, 24].

Treatment Options

Conservative Management

Nonoperative measures for wrist arthritis are typically the first line of defense and are primarily aimed at relieving pain in the wrist. Rest in the form of splinting with removable thermoplastic splints constructed by a certified hand therapist may be useful during periods of exacerbation. The wrist is

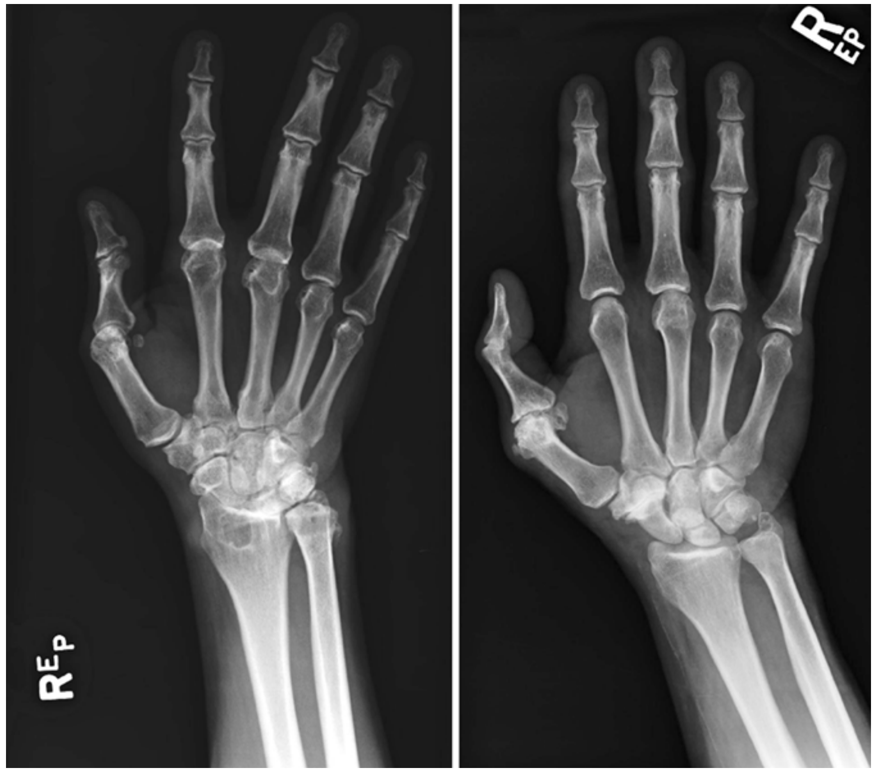


Fig. 15.1 Wrist radiographs demonstrating wrist arthritis. (*left*) scapholunate advanced collapse (SLAC) Wrist Stage III/IV with stylo-scaphoid arthritis, radiocarpal arthritis, and joint space narrowing of the capitolunate junction. (*right*) scaphotrapeziotrapezoidal (STT) arthritis with joint space narrowing and sclerotic changes

usually maintained in neutral or slight dorsiflexion, the functional position of the wrist. While providing pain relief, the disadvantages of splinting include stiffness and wrist weakness as a result of overuse or prolonged immobilization which should always be avoided. Therefore, splinting should be used in conjunction with alternative therapies such as exercise and occupational hand therapy.

Pharmacologic management should also be used during inflammatory periods to control pain and swelling. For patients with inflammatory arthritis, nonsteroidal anti-inflammatory drugs (NSAIDs) are indicated to assist in controlling inflammation and reducing synovitis. Topical NSAIDs have become increasingly popular in recent years to control acute and chronic symptoms. These eliminate the adverse, systemic complications associated with prolonged, oral NSAID use. Topical formulations can be compounded with ingredients such as muscle relaxants, calcium-channel blockers, anesthetics, and GABA-receptor blockers to provide a broader coverage of symptoms. Anti-rheumatic medications, including systemic steroids, methotrexate, and anti-tumor necrosis factor, are indicated for patients with RA and Allopurinol, a xanthine oxidase inhibitor, may be useful in patients with gouty arthritis of the wrist.

Steroid injections, with or without local anesthetic into the joint, may also be performed. Methylprednisolone acetate injection into the wrist can play a role in treating degenerate triangular fibrocartilage. Local steroid injections using a 1½″, 25- or 27-gauge needle when combined with local anesthetic may provide both a diagnostic and therapeutic effect. The effect of steroid injections are transient and therefore repeat injections may be needed. However, repeat injections should be used sparingly (our recommended maximum is two) due to the associated risk of soft tissue weakening and thinning of the cartilage in an already compromised joint.

Surgical Management

When conservative options have failed, arthroscopic intervention may be a viable option for some patients. Indications for the surgical management are dependent on the severity and the extent of wrist arthritis. MRI in conjunction with clinical assessment of the patient aids surgical decision-making. Arthroscopic procedures are more favorable compared to their parent open procedures due to less joint capsule and ligament damage. In general, arthroscopic procedures are safe procedures with no major complications being reported [25–27].

In the earliest stages, when the problems are mainly caused by carpal instability (i.e. pre-arthritic stage), the aim of the surgery is to restore the anatomic position and to correct the carpal instability to prevent degeneration. In the intermediate stages, when the patient has well-established arthritis but a well-preserved range of motion, no proven standard treatment has been established. The available options are geared toward less invasive procedures with fewer complexities such as synovectomy, abrasion chondroplasty, radial styloidectomy, and proximal row carpectomy via arthroscopic techniques. In the late stages of arthritis, a partial or total wrist arthrodesis, a PRC, or a total wrist arthroplasty may be contemplated. Patients with severe dorsal tenosynovitis have weakened tendons and are not usually candidates for arthroscopy due to the risk of tendon injury when establishing portals.

Arthroscopic synovectomy has become a well-described procedure. Aggressive arthroscopic debridement, including radial styloidectomy and partial resection of the scaphoid, has been reported. Resection of the lunate in patients with Kienböck's disease may also be performed arthroscopically. In the DRUJ, arthroscopy can be used for debridement of the TFCC and for a modified Darrach procedure that involves distal ulna resection. Arthroscopic reconstructive procedures have been described for repair of the lunate-triquetrum ligament and ulnocarpal ligament complex, as well as for capsular placation. More recently, arthroscopy has seen increased use for the removal of single or multiple bones in the proximal carpal row and for partial wrist fusions, procedures that are traditionally performed using open techniques.

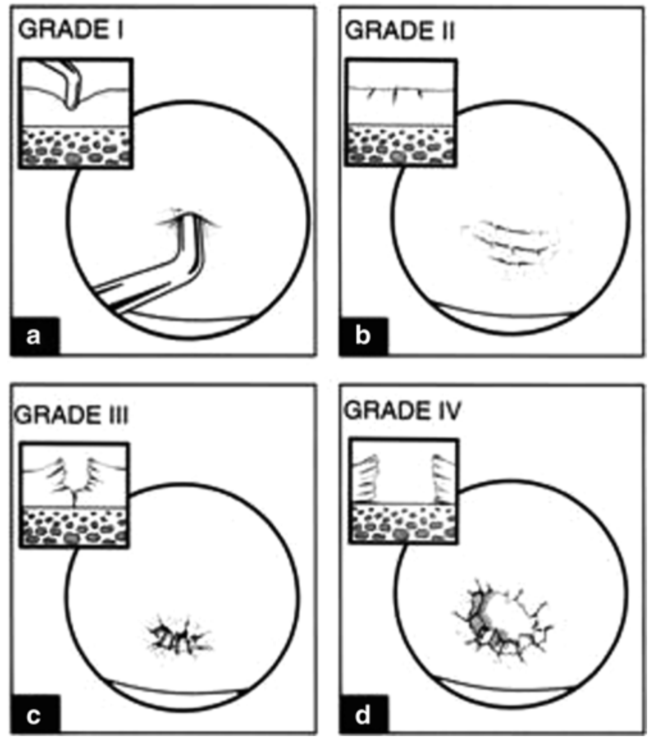


Fig. 15.2 The Outerbridge classification of articular cartilage lesions: Grade 0: Normal Cartilage, (**a**) Grade I: Superficial Softening, (**b**) Grade II: Fibrillation, (**c**) Grade III: Fissuring, (**d**) Grade IV: Loss of all Cartilage Layers and Exposure of Subchondral Bone

Arthroscopic Synovectomy

Arthroscopic synovectomy provides effective treatment of patients with RA, juvenile RA, systemic lupus erythematosus (SLE), and post-infectious arthritis when conservative measures have failed [4–6, 27]. Patients with posttraumatic joint contractures and septic arthritis of the wrist after failed systemic antibiotics and lavage also benefit from arthroscopic synovectomy. Patients requiring more extensive, open wrist procedures would not be an ideal candidate for arthroscopic synovectomy. The goal of the procedure is to decrease pain and improve joint function by excising the inflamed synovium and thereby removing or eliminating the effusion and inflammatory substrate.

The protocol for arthroscopic synovectomy in patients with RA was established by Adolfsson [4]. Indications include persistent joint symptoms following a 6 month course of pharmacologic treatment and the presence of radiographic changes of grade 0, I, or II according to the staging system by Larsen and colleagues [28]. Synovectomy for RA is indicated in the early stages of development when complete synovectomy is more feasible and has been shown to slow and even halt the progression of the disease [6, 29]. It allows for significant improvement in pain, joint motion, inflammatory markers, and disability score [5].

In noninflammatory disease, the Outerbridge classification system, originally developed for patients with chondromalacia patellae, is used (Fig. 15.2) [30]. Patients with early presentation of SLE or reactive arthritis (bacterial or viral) and those with OA with nominal radiographic changes and florid synovitis are also considered good candidates for wrist synovectomy. Patients after intra-articular fractures or multiple previous wrist interventions also benefit from capsular release, removal of adhesions, and synovectomy.

Arthroscopic Abrasion Chondroplasty

Chondral defects are a common source of occult pain. Fibrocartilage forms in locations of disrupted subchondral bone (Outerbridge grade IV). Abrasion and drill chondroplasty take advantage of this phenomenon and are used to fill articular defects with the goals of reducing mechanical symptoms and minimizing intra-articular debris by smoothing out the chondral lesions [9, 24, 30].

Abrasion chondroplasty is effective in patients with proximal pole hamate arthrosis, a cause of ulnar-sided wrist pain when loaded during ulnar deviation. Lunate morphology plays a key role in this condition. Patients with a type II lunate defect have a particularly positive outcome. The type II lunate and its medial facet during contact loading of the proximal pole of the hamate can lead to arthritis, with a reported occurrence in 44 % of type II lunates but only 2 % in type I lunates [11, 31–37]. In cases of advanced arthrosis and an Outerbridge grade IV lesion, we follow the recommendation of Yao and coworkers—excision of the proximal pole [31]. Abrasion arthroplasty is contraindicated for patients with active rheumatoid disease, those who are medically unfit, and patients with active infections not located in the wrist.

Also, with ulnar-sided wrist pain, it is common for patients to have concomitant injuries that also require treatment (e.g. TFCC tears, lunotriquetral interosseous ligament tears, ulnar impaction, and radial-sided pathology). When synovitis is noted on the ulnar side of the wrist, a TFCC injury is almost always noted in the absence of any other structural problem.

Arthroscopic Radial Styloidectomy

Radial styloid arthritis as a result of scapholunate advanced collapse (SLAC), scaphoid nonunion advanced collapse (SNAC), Kienböck's disease, or impingement after scaphotrapeziotrapezoidal (STT) fusion, PRC, or four-corner fusion is the primary indication for radial styloidectomy. Arthroscopic intervention is indicated and highly effective when a PRC or fusion is not yet indicated or when patients are not ready to undergo a more extensive procedure. Arthroscopic radial styloidectomy ensures preservation of the volar ligaments, which provide radial stability of the wrist and enhance precision when determining the appropriate amount of styloid to be removed [31].

Arthroscopic Proximal Row Carpectomy

PRC has long been considered a salvage procedure of wrist arthritis because of its association with decreased range of motion, decreased strength, and progression of arthritis. Recent studies have shown its reliability to be equal to that of the four-corner fusion, which has been a well-established standard of treatment [38]. Arthroscopic PRC thus can be viewed as beneficial over the open technique because it does not require capsulotomy, does not disrupt the stabilizing ligaments, and allows for early mobilization [13]. PRC is contraindicated in the presence of arthritis at the head of the capitate or in the lunate fossa of the radius.

General Technique and Instrumentation for Arthrscopy of the Wrist

The preferred method of anesthesia in patients with arthritic changes is general or regional anesthesia. The patient is positioned supine on the operating table with the shoulder along the edge of the table. A tourniquet is placed above the elbow and inflated to 250 mmHg. The shoulder is abducted 70–90°, and finger traps from an articulating arm attached to the operating table suspend the forearm vertically. We routinely use the long and index fingers; however, all the digits may be placed in the finger traps to distribute the traction load particularly for patients with rheumatoid arthritis whose skin is delicate. A traction force of approximately 10–15 lb is applied to help open the joint and improve access during the surgical procedure (Fig. 15.3). In addition, a sling with 7–10 lb of weight is placed over the tourniquet to provide downward counter-traction and distraction of the wrist joint.

Following patient set-up, the wrist is thoroughly examined, and relevant anatomical landmarks are palpated. The arthroscopic wrist portals are described in Table 15.1. The 3-4 portal is established in the soft spot, 1 cm distal to Lister's tubercle (Fig. 15.4). To minimize the risk of articular cartilage damage, a 22-gauge needle is first inserted and angled 10° volar to be parallel to the radiocarpal joint surface. The wrist is then distended with 5–7 mL of saline solution. When insufflation does not occur, this sign indicates a torn TFCC. A vertical stab incision is made with a No. 15 scalpel blade through the dermis only and then a blunt trocar is introduced into the joint. To maintain orientation, the thumb is kept on Lister's tubercle until the arthroscope is introduced. Inflow of lactated Ringer's solution is gravity-fed (i.e. no pump required).

Subsequent portals are made using an outside-in technique. A needle is introduced into the joint first to establish these portals. Introduction of the needle should be distal to

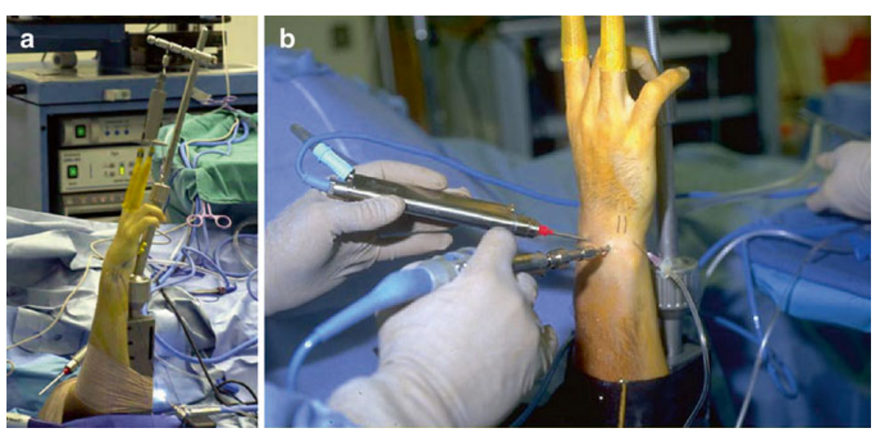


Fig. 15.3 (**a**) Wrist arthroscopy set up. Note the index and long fingers are placed in finger traps. 10–15 lb of traction is applied to allow for better access and mobility inside the wrist joint. (**b**) Wrist arthroscopy setup with instrumentation. Note arthroscope and instruments can be interchanged between portals to obtain the proper vantage point

Table 15.1 Arthroscopic wrist portals: technique and comments

Portal	Technique	Comment
Dorsal		
1-2	Inserted in the extreme dorsum of the snuffbox just radial to the EPL tendon to avoid the radial artery.	Provides access to the radial styloid, scaphoid, lunate, and articular surface of the distal radius.
3-4	The portal is 1-cm distal to Lister's tubercle between the tendons of the third and fourth compartment.	Primary working portal. Gives a wide range of movement and view.
4-5	Between the common extensor fourth compartment and EDQ in the fifth compartment.	Alternative to the 6R portal.
6R	Located distal to the ulna head and radial to the ECU tendon. Established under direct vision of the arthroscope by use of a needle. Avoids damage to the TFCC.	Primary working portal.
6U	Established under direct visualization similar to the 6R portal. Blunt dissection is always used to avoid the dorsal branches of the ulnar nerve.	6U and 6R portals allow visualization back toward the radial side and access to the ulnar-sided structures.
MCR	The portal is created 1-cm distal to the 3-4 portal.	Allows instrument access to the ulnar midcarpal joint.
MCU	The portal is created 1-cm distal to the 4-5 portal.	Allows instrument access to the radial midcarpal joint.

EPL extensor pollicis longus, *EDQ* extensor digiti quinti proprius, *6R* 6-radial, *ECU* extensor carpi ulnaris, *TFCC* triangular fibrocartilage complex, *6U* 6-ulnar, *MCR* mid-carpal radial, *MCU* mid-carpal ulnar

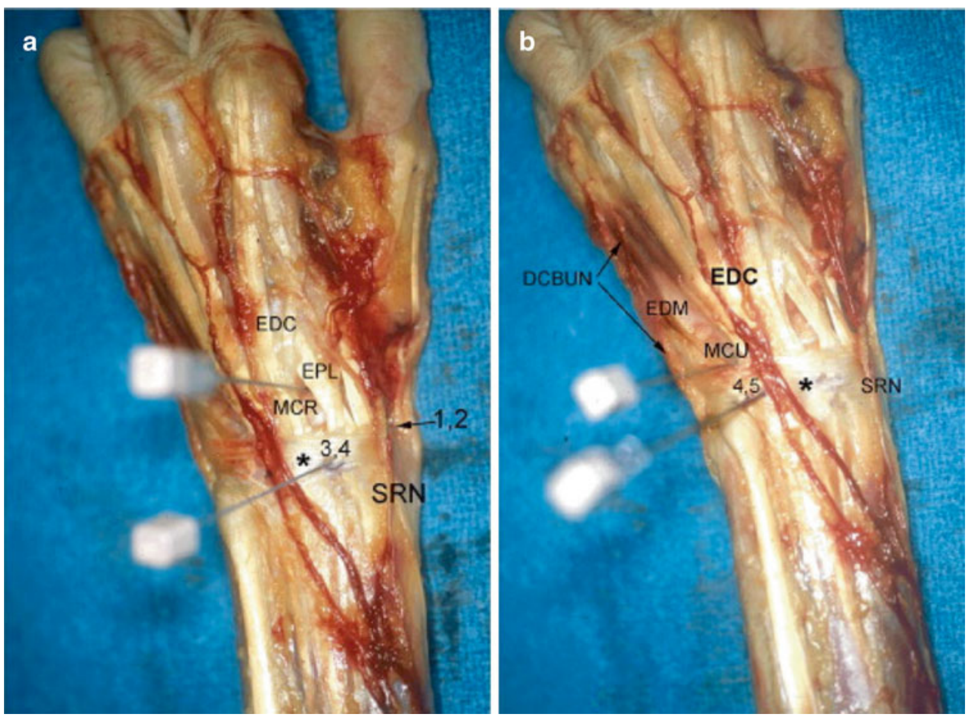


Fig. 15.4 Dorsal portal anatomy. (**a**) Cadaver dissection of the dorsal aspect of a left wrist, demonstrating the relative positions of the dorsoradial portals. (**b**) Relative positions of the dorsoulnar portals. *EPL* extensor pollicus longus, *asterisk* Lister's tubercle, *EDC* extensor digitorum communis, *EDM* extensor digiti minimi, *DCBUN* dorsal cutaneous branch of the ulnar nerve, *MCU* midcarpal ulnar portal, *SRN* superficial radial nerve, *MCR* midcarpal radial portal

the TFCC and either radial to the extensor carpi ulnaris tendon or ulnar to the common extensor tendons. Both the 4-5 and 6-R portals can be used for a radiocarpal portal. The 4-5 or 6-R portals are identified by use of transillumination. A 2.5-mm arthroscope is used with a 30° viewing angle. A short bridge arthroscope (lever arm of 100 mm) allows better control. The 6-U portal can be used when necessary but caution to the dorsal sensory branch of the ulnar nerve is taken.

Arthroscopic Synovectomy

To perform an arthroscopic synovectomy, a 2.5-mm diameter, 30° arthroscope is inserted through the 3-4, 4-5, or 6-R working portals for the radiocarpal joint. The 6-U portal is used for outflow. The radial and ulnar midcarpal portals are used to access the midcarpal joint. Efficiency and speed are important to decrease wrist swelling. In cases of severe STT arthritis, a separate STT portal can be established to provide better access and visualization of the joint.

Fig. 15.5 The rotator shaver is used to perform the synovectomy and remove all the fibrillated cartilage

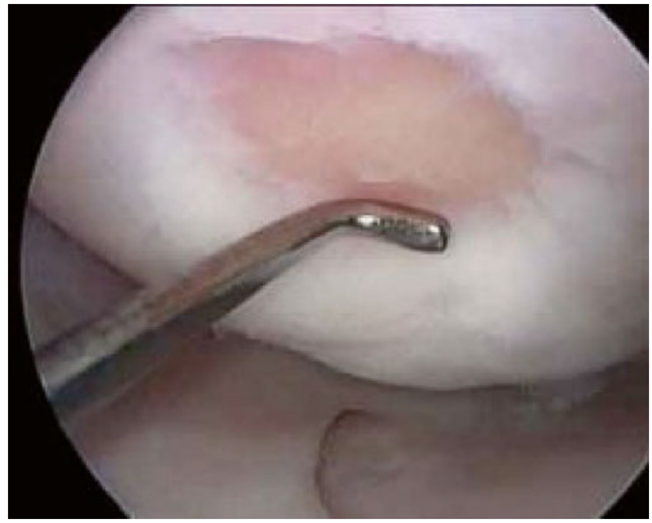


Fig. 15.6 Chondral lesion is debrided and ready for chondroplasty

A motorized shaver system with a 3.5-mm diameter synovial resector blade and 3.5-mm flexible shaver is used to remove the inflamed tissue (Fig. 15.5). We routinely use thermoregulation, which aids in decreasing bleeding. Great care must be taken to avoid touching the articular surfaces. Flow must be maintained within the wrist joint when using thermoregulation to avoid heat buildup.

It is important to inspect the radial styloid, the radioscapholunate and radioscaphocapitate ligaments, ulnar pre-styloid recess, and the dorsoulnar region underneath the extensor carpi ulnaris subsheath. Midcarpal space synovitis is often found along the dorsoulnar region, volarly underneath the capitohamate joint, and in the STT joint. Inspection of the DRUJ can be performed through a central defect in the horizontal portion of the TFCC and synovectomy can be carried out through the 6-R portal. In circumstances where there is no central defect in the TFCC, a separate DRUJ portal immediately proximal to the TFCC can be used for shaving while viewing through the radiocarpal joint.

Incisions are closed with Dermabond and augmented with Steri-Strips or with subcuticular Monocryl. A light dressing is placed with a volar short arm splint and is used for approximately 7–10 days. Patients return for a wound check and suture removal at 2 weeks postoperatively. Immediate wrist motion with a certified hand therapist and home exercise program is encouraged. Patients are instructed to avoid vigorous activity for 6 weeks.

Complications of arthroscopic synovectomy are similar to those of any arthroscopic procedure. When making a skin incision for the 6-U portal, the surgeon must use caution to avoid laceration or a painful neuroma of the dorsal sensory branch of the ulnar nerve. Meticulous care must be used at all times to avoid chondral damage to the articular surfaces. Blunt dissection, direct visualization, and transillumination are used to minimize the risk of injury to tendons and vessels.

Results of arthroscopic synovectomy for wrist arthritis are favorable. A 2012 study by Chung et al. of 21 patients with rheumatoid arthritis in the wrist demonstrated arthroscopic synovectomy following failed conservative management resulted in improved pain, joint motion, inflammatory markers and decreased disability at an average of 30 months [5]. None of the study patients were taking long-term pain medications at the latest follow-up. Similarly, Adolfsson and colleagues reported improved wrist arc of motion from 69.5° to 90° and an 87 % increase in grip strength in 18 wrists 6 months following arthroscopic synovectomy [25]. A second study by the same group reported similar increase in wrist arc of motion and improved pain in 24 wrists at an average of 3.8 years following surgery [26]. Therefore, arthroscopic synovectomy should be considered as an option for patients with mild to moderate stages of arthritis as an effective treatment to decrease pain and improve functional status in patients with arthritis [39, 40].

Arthroscopic Abrasion Chondroplasty

Radiocarpal arthritis treated with abrasion chondroplasty follows the same principles that have been described by Steadman and coworkers for the knee [12]. Working portals in the wrist and instrumentation set up are established as previously described for arthroscopic synovectomy. During the diagnostic arthroscopy, loose bodies are removed and areas of focal chondral damage are identified. Specially designed awls (2.5 and 3.5 mm) are used to make multiple perforations, or microfractures, into the subchondral bone plate (Fig. 15.6). Perforations are made as close together as possible, approximately 1–2 mm apart, but not so close that one breaks into another (Fig. 15.7). The integrity of the subchondral bone plate should be maintained. The released marrow elements (i.e. mesenchymal stem cells, growth

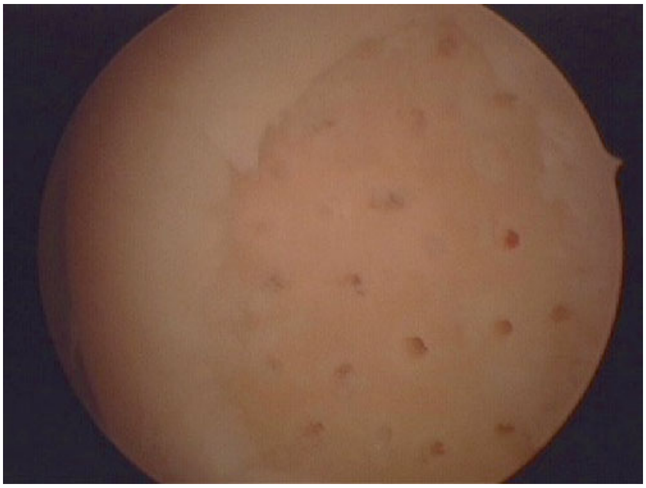


Fig. 15.7 Microfractures created in the subchondral bone 1–2 mm apart using specially designed awls

factors, and other healing proteins) form a surgically induced superclot that provides an enriched environment for new tissue formation [12].

Dressings and closure are carried out as previously described for arthroscopic synovectomy. Early range of motion is recommended with a continuous passive motion device to avoid postoperative complications such as stiffness. Rehabilitation is crucial to optimize the results of the surgery.

Arthroscopic Radial Styloidectomy

Athroscopic radial styloidectomy enhances visualization to ensure complete resection of the arthritic portion of the styloid without sacrificing the ligamentous support of the wrist. This is best done with a short oblique osteotomy [31].

A small 3.5-mm burr is used by entering the 1-2 portal. The diameter of the burr is a good benchmark to gauge the amount of styloid to be removed; ideally this is less than 4 mm. An 18-gauge needle can be introduced into the bone to mark the end point of the styloid resection. Fluoroscopy is used for verification. Following excision of the styloid, a shaver is used to remove debris and loose bodies from the wrist joint (Figs. 15.8 and 15.9). Wounds are closed as previously described. Postoperative management includes the use of a short arm splint. Protected motion is initiated immediately to avoid stiffness.

Complications of radial styloidectomy include incomplete resection, loss of radial support, and excessive resection. Excessive resection can lead to the loss of the radioscaphocapitate and long radiolunate ligaments yielding subsequent instability and eventual ulnar translocation of the carpus.

A report of three patients with scaphoid nonunion fracture and associated avascular necrosis that underwent arthroscopic resection of the distal pole of the scaphoid and radial styloidectomy showed complete relief of pain and improved wrist range of motion [41]. Patient reported satisfaction was also high and a 28-point improvement of the Modified Mayo Wrist Score was also reported. Postoperative x-rays did not reveal progression of degeneration; however, the capitolunate angle increased 10°. Long-term outcome studies are needed to determine any possible chronic sequelae of this procedure.

Fig. 15.8 Radiocarpal arthritis secondary to a scaphoid nonunion fracture (SNAC wrist). Note the penciling of the radial styloid which is pathoneumonic of this condition

Fig. 15.9 Radial styloidectomy performed. Note that approximately 4 mm were removed off the radial styloid decompressing the articular surface of the scaphoid and the radius

Arthroscopic Proximal Row Carpectomy

For arthroscopic proximal row carpectomy, a fluoroscopy unit is used and placed in a horizontal position. Diagnostic radiocarpal and midcarpal arthroscopy is initially performed.

The midcarpal portals are used for the arthroscopic PRC. A small joint arthroscopic burr or shaver is inserted into a midcarpal radial (MCR) portal and the scope into the midcarpal ulnar (MCU) portal. A burr is first used to decorticate the medial corner of the scaphoid at the midcarpal scapholunate joint. Once an adequate portion of the corner of the scaphoid is removed, the MCR portal is slightly enlarged and a 4.0-mm hooded burr is used to remove the remaining scaphoid moving ulnar to radial and distal to proximal. The portals are then switched and the hooded burr is inserted into the MCU portal. Excision of the lunate and triquetrium are performed sequentially moving radial to ulnar and distal to proximal. Facilitation of removal may be performed through the MCR portal while viewing through the STT portal. Once the proximal pole is completely excised, a fine synovial rongeur may be used under direct visualization to remove any remaining bone or cartilage adherent to the capsule. If significant impingement of the radial styloid with the trapezium is encountered, arthroscopic styloidectomy is also performed. Portals are then closed with Monocryl. Early motion is initiated postoperatively [13].

Complications of arthroscopic PRC include damage to the articular surfaces of the capitate or lunate fossa on the radius during instrumentation, disruption of the volar extrinsic ligaments, and nerve damage to the dorsal and ulnar sensory branches [38, 42].

Weiss et al. reported 2-year outcomes of 16 patients following arthroscopic PRC. The investigators reported favorable results including improved wrist range of motion and improved grip strength. Patients achieved 80 % of the grip strength and 80 % of wrist range of motion compared to their contralateral side at final follow-up and 81 % of patients returned to the previous employment. While long-term data at 15 years post-PRC in one study suggests poor patient satisfaction with progression of degenerative changes, and persistent pain follow PRC [43], we have not had the same experience. The senior surgeon, KDP, has found great success to return athletes to the field for golf and tennis at 20 years. We agree caution should be used for this procedure especially in high demand, manual labor populations (e.g. firefighters) and in persons younger than 35 years of age [44].

Pearls and Pitfalls

Pearls

- When using the traction device, ensure at least 15 lb of traction to help visualization in an already compromised joint space.
- Remove all loose bodies in the radial carpal and mid carpal joints.
- When performing the microfracture or chondroplasty, use commercially available picks, and separate holes to avoid defects. Remove the calcified layer with a curette.
- Versatile use of the many portal options can facilitate visualization of the complete wrist.

Pitfalls

- Place the arthroscope with a blunt trocar to avoid penetration to the articular cartilage.
- Avoid ligament injury by understanding the wrist anatomy.
- Avoid debridement and resection of the radial styloid below the level of the radial scaphocapitate ligament; failure to do so can lead to instability of the wrist.
- Avoid damage to the chondral surfaces on the head of the capitate or in the lunate fossa on the radius during arthroscopic PRC.

References

1. Ekman EF, Pochling GG. Principles of arthroscopy and wrist arthroscopy equipment. Hand Clin. 1994;10:557–66.
2. Gupta R, Bozentka DJ, Osterman AL. Wrist arthroscopy: principles and clinical applications. J Am Acad Orthop Surg. 2001;9:200–9.
3. Wolf JM, Dukas A, Pensak M. Advances in wrist arthroscopy. J Am Acad Orthop Surg. 2012;20:725–34.
4. Adolfsson L. Arthroscopic synovectomy in wrist arthritis. Hand Clin. 2005;21:527–30.
5. Chung CY, Yen CH, Yip ML, Koo SC, Lao WN. Arthroscopic synovectomy for rheumatoid wrists and elbows. J Orthop Surg (Hong Kong). 2012;20:219–23.
6. Adolfsson L. Arthroscopic synovectomy of the wrist. Hand Clin. 2011;27:395–9.
7. Feldkamp G. Possibilities of wrist arthroscopy. Even for patients with arthritis? Z Rheumatol. 2008;67:478–84.
8. Altman RD, Kates J, Chun LE, et al. Preliminary observations of chondral abrasion in a canine model. Ann Rheum Dis. 1992;51:1056–62.
9. Kuo AC, Rodrigo JJ, Reddi AH, Curtiss S, Grotkopp E, Chiu M. Microfracture and bone morphogenetic protein 7 (BMP-7) synergistically stimulate articular cartilage repair. Osteoarthritis Cartilage. 2006;14:1126–35.
10. Steadman JR, Biggs KK, Rodrigo JJ, et al. Outcomes of microfractures for traumatic chondral defects of the knee: average 11-year follow-up. Arthroscopy. 2003;19:477–84.
11. Harley BJ, Werner FW, Boles SD, Palmer AK. Arthroscopic resection of arthrosis of the proximal hamate: a clinical and biomechanical study. J Hand Surg Am. 2004;29:661–7.
12. Steadman JR, Rodkey WG, Rodrigo JJ. Microfracture: surgical technique and rehabilitation to treat chondral defects. Clin Orthop Relat Res. 2001;391(Suppl):S362–9.
13. Weiss ND, Molina RA, Gwin S. Arthroscopic proximal row carpectomy. J Hand Surg Am. 2011;36:577–82.
14. Seradge H, Owens W, Seradge E. The effect of intercarpal joint motion on wrist motion: are there key joints? An in vitro study. Orthopedics. 1995;18(8):727–32.
15. Kaufmann R, Pfaeffle J, Blankenhorn B, Stabile K, Robertson D, Goitz R. Kinematics of the midcarpal and radiocarpal joints in radioulnar deviation: an in vitro study. J Hand Surg Am. 2005;30(5):937–42.
16. Watson HK, Ballet FL. The SLAC wrist: scapholunate advanced collapse pattern of degenerative arthritis. J Hand Surg Am. 1984;9(3):358–65.
17. Wilczynski MC, Gelberman RH, Adams A, Goldfarb CA. Arthroscopic findings in gout of the wrist. J Hand Surg Am. 2009;34:244–50.

18. Sankowski AJ, Lebkowska UM, Cwikla J, Walecka I, Walecki J. The comparison of efficacy of different imaging techniques (conventional radiology, ultrasonography, magnetic resonance) in assessment of wrist joints and metacarpophalangeal joints in patients with psoriatic arthritis. Pol J Radiol. 2013;78:18–29.
19. Feydy A, Pluot E, Guerini H, Drape JL. Role of imaging in spine, hand, and wrist osteoarthritis. Rheum Dis Clin North Am. 2009;35:605–49.
20. Haims AH, Moore AE, Schweizer ME, et al. MRI in the diagnosis of cartilage injury in the wrist. AJR Am J Roentgenol. 2001;182:1267–70.
21. Mutimer J, Geen J, Field J. Comparison of MRI and wrist arthroscopy for assessment of wrist cartilage. J Hand Surg Eur Vol. 2008;33:380–2.
22. Ejbjerg B, Narvestad E, Rostrup E, Szkudlarek M, Jacobsen S, Thomsen HS, Ostergaard M. Magnetic resonance imaging of wrist and finger joints in healthy subjects occasionally shows changes resembling erosions and synovitis as seen in rheumatoid arthritis. Arthritis Rheum. 2004;50:1097–106.
23. Kosta PE, Voulgari PV, Zikou AK, Drosos AA. Argyropoulou MI. Arthritis Res Ther. 2011;9:R84.
24. Amrami KK, Askan KS, Pagnano MW, Sundaram M. Radiologic case study. Abrasion chondroplasty mimicking avascular necrosis. Orthopedics. 2002;25(1018):1107–8.
25. Adolfsson L, Nylander G. Arthroscopic synovectomy of the rheumatoid wrist. J Hand Surg Br. 1993;18:92–6.
26. Adolfsson L, Frisen M. Arthroscopic synovectomy of the rheumatoid wrist. A 3.8 year follow-up. J Hand Surg Br. 1997;22:711–3.
27. Park MJ, Ahn JH, Kang JS. Arthroscopic synovectomy of the wrist in rheumatoid arthritis. J Bone Joint Surg Br. 2003;85:1011–5.
28. Larsen A, Dale K, Eek M. Radiographic evaluation of rheumatoid arthritis and related conditions by standard reference films. Acta Radiol Diagn (Stockholm). 1977;18:481–91.
29. Carl HD, Swoboda B. Effectiveness of arthroscopic synovectomy in rheumatoid arthritis. Z Rheumatol. 2008;67:485–90.
30. Outerbridge R. The etiology of chondromalacia patellae. J Bone Joint Surg Br. 1961;43:752–7.
31. Yao J, Osterman AL. Arthroscopic techniques for wrist arthritis (radial styloidectomy and proximal pole hamate excisions). Hand Clin. 2005;21:519–26.
32. Nakamura K, Patterson RM, Moritomo H, Viegas SF. Type I versus type II lunates: ligament anatomy and presence of arthrosis. J Hand Surg Am. 2001;26:428–36.
33. Nakamura K, Beppu M, Patterson RM, et al. Motion analysis in two dimensions of radial-ulnar deviation of type I versus type II lunates. J Hand Surg Am. 2000;25:877–88.
34. Malik AM, Schweitzer ME, Culp RW, et al. MR imaging of the type II lunate bone: frequency, extent, and associated findings. AJR Am J Roentgenol. 1999;173:335–8.
35. Dautel G, Merle M. Chondral lesions of the midcarpal joint. Arthroscopy. 1997;13:97–102.
36. Viegas SF, Wagner K, Partterson R, Peterson P. Medial (hamate) facet of the lunate. J Hand Surg Am. 1990;15:564–71.
37. Viegas SF. The lunatohamate articulation of the midcarpal joint. Arthroscopy. 1990;6:5–10.
38. Atik TL, Baratz ME. The role of arthroscopy in wrist arthritis. Hand Clin. 1999;15:489–94.
39. Kim SJ, Jung KA, Kim JM, Kwun JD, Kang HJ. Arthroscopic synovectomy in wrists with advanced rheumatoid arthritis. Clin Orthop Relat Res. 2006;449:262–6.
40. Kim SM, Park MJ, Kang HJ, Choi YL, Lee JJ. The role of arthroscopic synovectomy in patients with undifferentiated chronic monoarthritis of the wrist. J Bone Joint Surg Br. 2012;94(3):353–8.
41. Ruch DS, Chang DS, Poehling GG. The arthroscopic treatment of avascular necrosis of the proximal pole following scaphoid nonunion. Arthroscopy. 1998;14(7):747–52.
42. Wall LB, Stern PJ. Proximal row carpectomy. Hand Clin. 2013;29:69–78.
43. Ali MH, Rizzo M, Shin AY, Moran SL. Long-term outcomes of proximal row carpectomy: a minimum of 15-year follow-up. Hand (N Y). 2012;7(1):72–8.
44. Diao E, Andrews A, Beall M. Proximal row carpectomy. Hand Clin. 2005;21(4):553–9.

Arthroscopic Proximal Row Carpectomy

16

Noah D. Weiss and Aaron H. Stern

Abbreviations

APRC	Arthroscopic proximal row carpectomy
PRC	Proximal row carpectomy
SLAC	Scapholunate advanced collapse
SNAC	Scaphoid nonunion
MCR	Midcarpal radial portal
MCU	Midcarpal ulnar portal
STT	Scaphotrapezial trapezoid portal
CRPS	Chronic regional pain syndrome

Historical Perspective

Proximal row carpectomy is a well-recognized treatment option to treat a variety of degenerative and posttraumatic conditions of the wrist, including progressive carpal collapse, scaphoid nonunion, Kienbock's avascular necrosis of the lunate, and posttraumatic radioscaphoid arthritis [1].

Proximal row carpectomy (PRC) involves the excision of the entire proximal row of the carpus (the scaphoid, lunate, and triquetrum), so that the majority of radiocarpal motion takes place between the head of the capitate and the lunate fossa of the distal radius [2]. The removal of the proximal carpal row clearly alters the normal kinematics of the wrist, simplifying the radiocarpal articulation into a "sloppy hinge" joint [3, 4]. This change in wrist kinematics necessitates a loss of range of motion, shortening of the height of the carpus, and an incongruent radiocapitate joint. This procedure, along with the four-corner fusion, has long been considered a "salvage" procedure because of the concern for permanent loss of motion, consistent loss of grip strength, possible progression of degenerative arthritis, and unreliable outcomes [5].

Recent outcome studies [6–8], however, have consistently shown that the PRC is a reliable procedure with high patient satisfaction, good pain relief, reasonable long-term outcomes, and a relatively low rate of complications. Multiple studies have consistently produced results demonstrating retention of approximately 75 % of grip strength and range of motion [7, 8]. The incidence of late arthritis appears to be low [8]. PRC permits some degree of both radial-ulnar deviation and dorsal-ulnar translation, which may help dissipate the load across the radio-capitate joint, decreasing the expected wear of this new incongruous joint, and improving the long-term durability of the procedure.

While long-term results between the PRC and four-corner fusion are very similar [9], the PRC typically does not require long-term immobilization, and there are fewer complications than the four-corner fusion, with no need for subsequent hardware removal, and zero risk of nonunion.

Until recently, the PRC has been described only as an open procedure performed through a dorsal wrist arthrotomy, dividing (and repairing) the wrist capsule and dorsal ligaments [10]. Patients are typically immobilized for several weeks postoperatively to allow for soft-tissue healing. Recently, an all-arthroscopic proximal row carpectomy (APRC) has been described [11] with results equal to, or exceeding, those results from previously published studies on the open technique. With an arthroscopic PRC an open capsulotomy is avoided and dorsal capsular ligaments are spared, potentially allowing for increased postoperative stability of the wrist. Less soft-tissue disruption also allows for earlier postoperative motion, less postoperative pain and scarring, and potentially increased motion.

Indications and Contraindications

The indications for the arthroscopic proximal row carpectomy are the same as those for the open technique. These include patients with disabling wrist pain, not relieved by other conservative measures. Common diagnoses treated

N.D. Weiss, M.D. (✉) • A.H. Stern, B.A.
Weiss Orthopaedics, 357 Perkins St., Sonoma, CA 95476, USA
e-mail: nweiss@weissortho.com

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*,
DOI 10.1007/978-1-4614-1596-1_16, © Springer Science+Business Media New York 2015

with the PRC include carpal instability, scapholunate advanced collapse (SLAC), scaphoid nonunion (SNAC), Kienbock's disease, and radioscaphoid arthritis. Good-quality cartilage on both the head of the capitate and on the lunate fossa of the distal radius is essential, as this will be the new radiocarpal articulation.

Contraindications include arthrosis on either the head of the capitate or lunate fossa, preexisting ulnar translocation of the carpus, and possibly rheumatoid arthritis [12, 13]. We have successfully performed this operation on patients with Ehlers-Danlos syndrome, and hypermobility or ligamentous laxity does not appear to be a contraindication.

Surgical Technique

The patient is placed in a supine position. The involved wrist is secured to a standard wrist arthroscopy tower, with 5 kg of longitudinal traction applied throughout the procedure. Good access to the dorsum of the wrist is essential, and adequate radiographic visualization of the wrist with the fluoroscopy arm in the horizontal position should be confirmed prior to draping of the patient. A well-padded tourniquet is always applied preoperatively as a precaution, although the tourniquet is inflated at the discretion of the surgeon. Standard small-joint arthroscopy instruments (arthroscope, shaver, probe) are used. In addition, the large-joint shaver with a 4.0 m bur and fine synovial rongeurs should be available.

Routine radiocarpal portals (3/4, 4/5, 6R, 6U) and midcarpal portals (MCR, MCU, and STT) are established. Standard radiocarpal and midcarpal arthroscopy is performed, and additional procedures (debridement, synovectomy, etc.) are performed as necessary. Adequate articular cartilage of the lunate fossa of the distal radius and of the head of the capitate should be confirmed, as significant arthritic changes would be a contraindication to continuing with APRC.

After diagnostic and operative radiocarpal arthroscopy, the APRC is then performed exclusively through the midcarpal portals, including the scaphotrapezial trapezoid portal (STT). With the arthroscope placed ulnarly in the midcarpal ulnar portal (MCU), the small-joint arthroscopic shaver or bur is introduced into the midcarpal joint through the midcarpal radial portal (MCR). At all times, great care should be taken to avoid any articular injury to the head of the capitate, which is at risk throughout the procedure. The hood of the bur and shaver should always be directed at the head of the capitate to avoid articular cartilage injury. The small shaver or bur is then used to remove the ulnar distal corner of the scaphoid at the scapholunate joint (Fig. 16.1). Once an adequate portion of the distal ulnar scaphoid is removed, the MCR portal is slightly enlarged, and the large shaver with a 4.0 hooded bur is introduced into the MCR portal. The use of the larger bur facilitates more rapid removal of bone.

With the arthroscope in the ulnar viewing (MCU) portal, the scaphoid is excised with the bur, moving from ulnar to radial, and distal to proximal. The bur is then typically placed more radially in the STT portal to remove the distal pole of the scaphoid. Under direct arthroscopic visualization, a fine synovial rongeur is useful to remove small fragments of bone or cartilage that remain adherent to capsule (Fig. 16.2). Complete excision of the distal pole of the scaphoid is left to the discretion of the surgeon (Fig. 16.3).

Following scaphoid excision, the arthroscope is then placed in the STT portal. With the arthroscope placed radially, and viewing ulnarly, the bur is placed in an enlarged MCR portal. The lunate is then excised with the bur, now working radial to ulnar, and distal to proximal (Fig. 16.4). Great care should be taken when removing the proximal layer of articular cartilage of the lunate, but traction usually creates a safe space above the distal radius. Again, the use of fine synovial rongeurs facilitates removal of small fragments of bone and cartilage that remain adherent to the capsule.

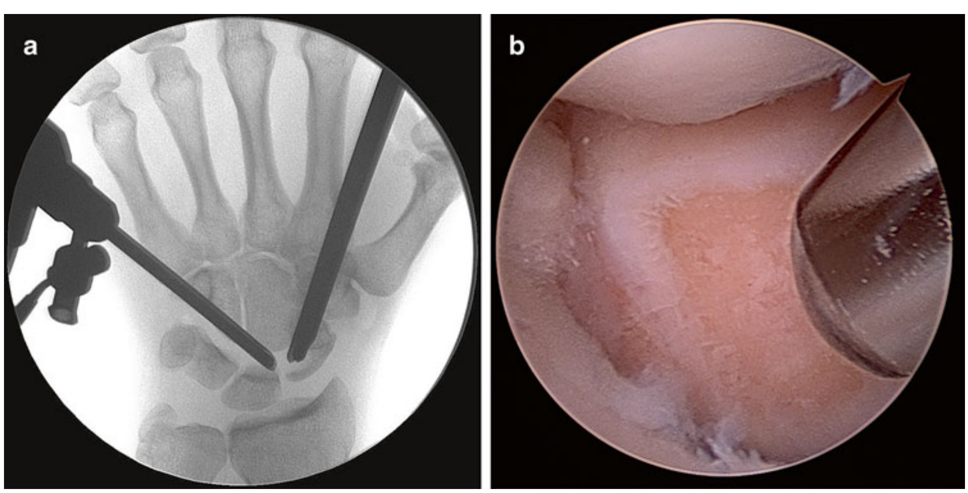


Fig. 16.1 Fluoroscopic (**a**) and arthroscopic (**b**) imaging of the wrist during the excision of the scaphoid

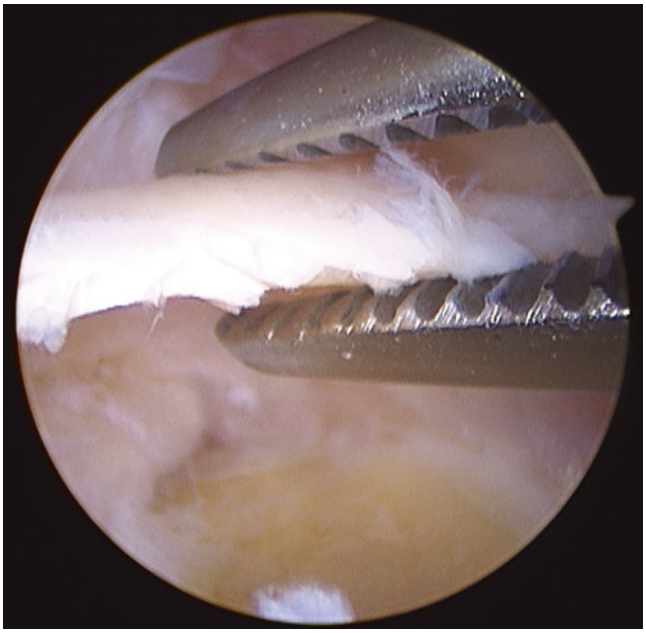


Fig. 16.2 Arthroscopic imaging of bone fragment excision using a fine synovial rongeur

Fig. 16.3 A fluoroscopic image of the wrist following the scaphoid excision

Following removal of the lunate, the arthroscope is moved to the MCR portal, the bur is placed in the MCU portal, and the triquetrum is excised. Confirmation of a complete APRC is made with fluoroscopy (Fig. 16.5).

The limb is then taken out of traction, and the radiocapitate joint is reduced. Seating of the head of the capitate in the lunate fossa of the radius is confirmed both arthroscopically and with fluoroscopy (Fig. 16.6). Range of motion of the wrist under fluoroscopy will confirm stability, and also reveal occasional radial styloid impingement, which can be treated with arthroscopic radial styloidectomy (performed with the bur in the 1/2 portal).

Postoperatively, the wrist is injected with bupivacaine, and a bulky dressing and volar splint are applied, allowing for immediate finger range of motion. The patient is seen in the office 2 days postoperatively, when the bandage is removed, and a removable volar splint is applied for comfort. Early active and passive range of motion of the wrist is encouraged, and return to activity is within the limits of patient comfort. Formal hand therapy is prescribed on an individual basis as needed.

Complications

There are several potential complications that exist when performing the arthroscopic proximal row carpectomy. As with any wrist arthroscopy, sensory nerve injury during portal placement is a concern, and the portals must be developed by careful skin incision, blunt dissection down to the capsule, and careful introduction of a blunt trochar into the joint. When expanding the midcarpal portals to allow the introduction of the large joint bur, the portals must similarly be enlarged using careful technique. With the APRC, it is essential to avoid injury to either the head of the capitate or the lunate fossa of the distal radius, and the hood of the bur should be directed towards those surfaces at all times. Careful fluoroscopic evaluation of the wrist is important at the end of the procedure to confirm a complete proximal row carpectomy. While it may be desirable to leave the distal pole of the scaphoid, occasionally fragments of bone remain adherent to the dorsal capsule, and may not be seen arthroscopically.

Results

Review of our first 35 patients, with an average of 33-month (minimum of 1 year) follow-up, was recently performed. There were no surgical complications, and no patient required conversion to an open procedure. There were no instances of radiocarpal subluxation, despite immediate mobilization. One patient did subsequently progress to radiocarpal arthritis, and one patient developed chronic regional pain syndrome (CRPS) type 2. The average length of surgery was 61 min. Patients retained an average of 78 % of the flexion/extension arc of the wrist, and 70 % of radial and ulnar deviation. Grip strength averaged 83 % of the contralateral wrist, and patient satisfaction was high (94 % satisfied or very satisfied).

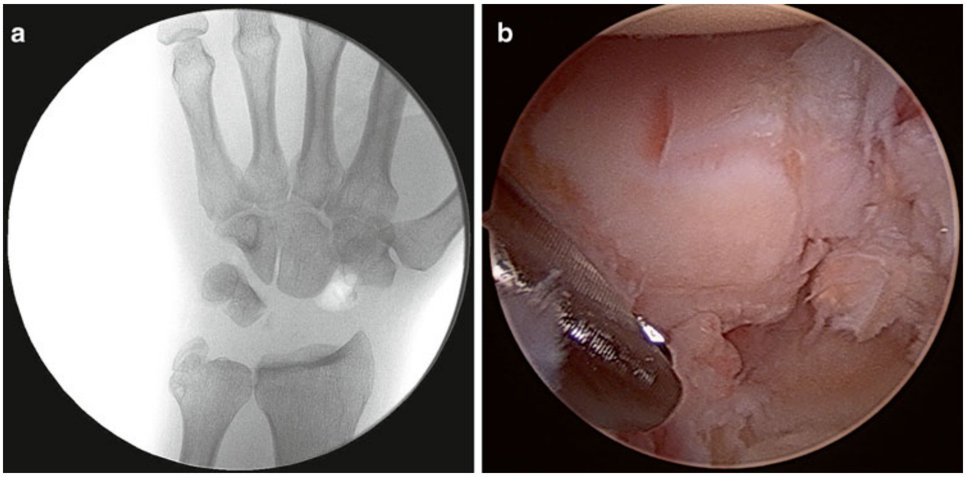


Fig. 16.4 Fluoroscopic (**a**) and arthroscopic (**b**) imaging of the wrist following removal of the lunate

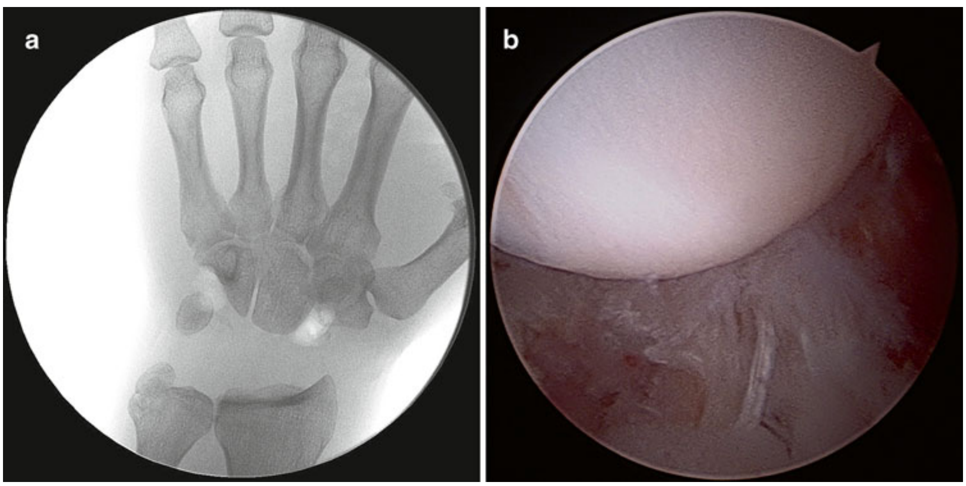


Fig. 16.5 Fluoroscopic (**a**) and arthroscopic (**b**) imaging of the wrist following complete arthroscopic proximal row carpectomy while the wrist is in traction

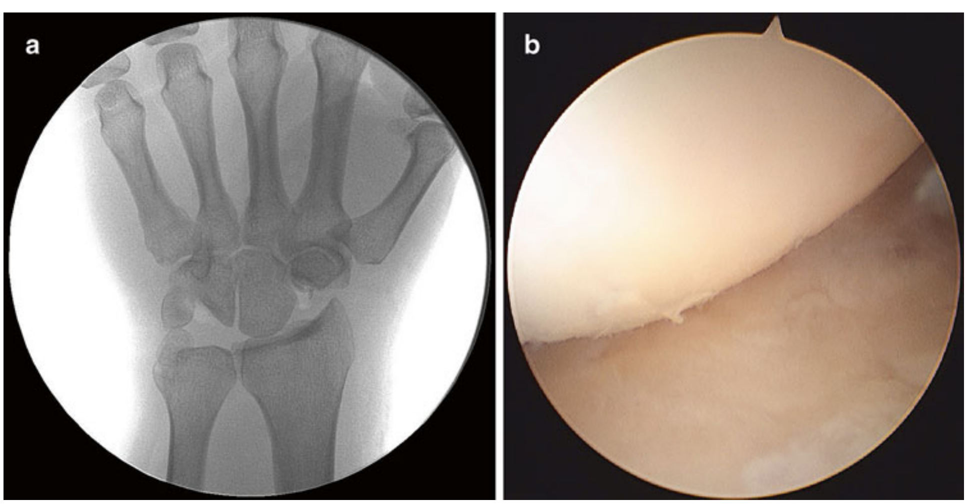


Fig. 16.6 Fluoroscopic (**a**) and arthroscopic (**b**) imaging of the newly formed wrist joint after the wrist is released from traction

Advantages

The APRC has been shown to have several potential advantages over the open procedure with few disadvantages, and provides results that are similar to the open procedure, with maintenance of reasonable range of motion and strength, and high patient satisfaction. By preserving the dorsal capsular ligaments, there is potentially improved postoperative motion. As in other joints, the advantages of arthroscopic surgery over an open arthrotomy include less postoperative pain, decreased scarring, less soft-tissue damage, no unsightly scars, and often earlier range of motion leading to a quicker recovery. Additionally, this arthroscopic procedure allows for optimum evaluation of the wrist joint, and the identification and treatment of other pathologies.

Conclusion

Arthroscopic proximal row carpectomy is a reproducible and effective new arthroscopic procedure that compares favorably to the established open technique. The APRC can be accomplished in a reasonable amount of surgical time, with routine small-joint and large-joint arthroscopic instrumentation. Arthroscopic proximal row carpectomy patients have similar long-term objective strength and possibly improved range of motion as well as high subjective satisfaction when compared to open proximal row carpectomy patients. It is a technically complex procedure, but one that can be performed relatively quickly and successfully using standard arthroscopic techniques and equipment. Patients may be mobilized immediately, and the APRC provides many of the benefits typically associated with arthroscopic surgery such as less scarring and less trauma to the area without any identifiable drawbacks.

References

1. Richou J, Chuinard C, Moineau G, Hanouz N, Hu W, Le Nen D. Proximal row carpectomy: long-term results. Chir Main. 2010;29:10–5.
2. Stamm TT. Excision of the proximal row of the carpus. Proc R Soc Med. 1944;38:74–5.
3. Sobczak S, Rotsaert R, Vancabeke M, Jan SV, Salvia P, Feipel V. Effects of proximal row carpectomy on wrist biomechanics: a cadaveric study. Clin Biomech (Bristol, Avon). 2011;26:718–24.
4. Blankenhorn BD, Pfaeffle HJ, Tang P, Robertson D, Imbriglia J, Goitz RJ. Carpal kinematics after proximal row carpectomy. J Hand Surg. 2007;32A:37–46.
5. Neviaser RJ. On resection of the proximal carpal row. Clin Orthop Relat Res. 1986;202:12–5.
6. Vanhove W, De Vil J, Van Seymortier P, Boone B, Verdonk R. Proximal row carpectomy versus four-corner arthrodesis as a treatment for SLAC (scapholunate advanced collapse) wrist. J Hand Surg. 2008;33B:118–25.
7. Croog AS, Stern PJ. Proximal row carpectomy for advanced Kienbock's disease: average 10-year follow-up. J Hand Surg. 2008; 33A:1122–30.
8. DiDonna ML, Kiefhaber TR, Stern PJ. Proximal row carpectomy: study with a minimum of ten years of follow-up. J Bone Joint Surg. 2004;86A:2359–65.
9. Bisneto ENF, Freitas MC, de Paula EJL, Mattar R, Zumiotti AV. Comparison between proximal row carpectomy and four-corner fusion for treating osteoarthrosis following carpal trauma: a prospective randomized study. Clinics. 2011;66:51–5.
10. Wall LB, Stern PJ. Proximal row carpectomy. Hand Clin. 2013; 29:69–78.
11. Weiss ND, Molina RA, Gwin S. Arthroscopic proximal row carpectomy. J Hand Surg. 2011;36A:577–82.
12. Culp RW, McGuigan FX, Turner MA, et al. Proximal row carpectomy: a multicenter study. J Hand Surg. 1993;18A:19–25.
13. Ferlic DC, Clayton ML, Mills MF. Proximal row carpectomy: review of rheumatoid and non-rheumatoid wrists. J Hand Surg Am. 1991;16A:420–4.

Arthroscopic Partial Wrist Fusion

17

Pak-cheong Ho

Introduction

Partial wrist fusion or limited carpal fusion is considered as a motion preserving salvage procedure for multiple painful wrist conditions. It is a good alternative particularly for those patients who would prefer a mobile functional wrist rather than a solid total wrist fusion [1]. The wrist is consisted of multiple bony linkages from the forearm to the metacarpus via the carpal bones and this anatomical peculiarity offers an opportunity to allow fusion of the painful segments of the wrist while preserving motion in the other unaffected segments. It also helps to halt any predictable mechanical collapse of the carpal column and maintain carpal height in the carpal instability conditions due to failure of the ligament constraint or loss of the bony integrity such as in scaphoid nonunion and Kienbock disease.

A wide variety of partial wrist fusion has been designed in the past to address problem arising from various parts of the wrist [2–5]. Essentially all carpal bones and intervals can be fused selectively and the resulting motion loss and the biomechanical effect have been studied extensively in laboratory and in the clinical settings [6–11]. The fusion can take place between the radius and the proximal carpal row such as radiolunate fusion and radio-scapho-lunate fusion; between the two carpal rows such as the scapho-trapezio-trapezoid fusion, scapho-capitate fusion, capitolunate fusion, triquetro-hamate fusion, and the four-corner fusion involving the medial carpal bones; and within the proximal carpal row such as scapholunate fusion and luno-triquetral fusion. The operations being described in the literature and commonly in use are open surgery requiring much soft tissue dissection including capsular and ligament incisions around the wrist to expose the carpal intervals. This may lead to iatrogenic stiffness of the joint on top of the mechanical constraint rendered by the selected carpal fusion. The expected loss of motion can be predicted theoretically from the biomechanical models, though in practice the final range of motion retained clinically will also rely on the degree of soft tissue contracture and the amount of compensatory hypermobility of the adjacent mobile segments. Thus it is desirable to minimize surgical insult to soft tissue so as to maximize the motion preservation which is always the interest of both the patients and the surgeons.

Arthroscopic intervention in partial wrist fusion has potential advantages of a minimal surgical damage to the supporting ligaments and the capsular structures of the wrist while allowing an unimpeded view to most articular surfaces of the joints and the important soft tissue elements. This ensures a more accurate staging of the arthritis and facilitates clinical decision making on the most appropriate choice of fusion. The remaining carpal motion can be maximized and postoperative pain reduced which favors rehabilitation. There is also cosmetic benefit with the minimal surgical scar.

The following article describes our pioneer experience in the past 15 years in developing this surgical concept and technique for various clinical conditions.

Indications and Contraindications

The main indication for a partial wrist fusion is the painful arthritic conditions of the wrist which affect part of the articulating system and the patient would like to have adequate pain control as well as preservation of a useful functional arc of motion. This is best indicated in posttraumatic arthritis and osteoarthritis. Common indications include scapholunate advanced collapse (SLAC), scaphoid nonunion advanced collapse (SNAC), Kiënbock disease, post-distal radius fracture radiocarpal joint arthrosis, and scaphotrapeziotrapezoid (STT) arthritis. Chronic painful carpal instabilities with or without secondary arthritic change are also good indications. These include chronic

P.C. Ho, MBBS, FRCS, FHKCOS, FHKAM (ORTHO) (✉)
Department of Orthopaedic & Traumatology, Prince of Wales Hospital, Chinese University of Hong Kong, 30-32 Ngan Shing Street, Shatin, New Territories, Hong Kong SAR, China
e-mail: pcho@ort.cuhk.edu.hk

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*,
DOI 10.1007/978-1-4614-1596-1_17, © Springer Science+Business Media New York 2015

lunotriquetral instability, capitolunate instability, palmar midcarpal instability, and radiocarpal translocation. In inflammatory arthritis such as rheumatoid arthritis and crystal deposition disease, the disease progression should be optimally controlled by the pharmacological mean and should not be at an active proliferative phase. This can avoid a rapid deterioration of the clinical improvement due to a progressive involvement of the un-fused segments of the wrist. Patients with multiple joint involvement of the same upper limb may have stronger desire to preserve motion over the wrist to compensate for the stiffness over the other joints. Arthroscopic version of partial wrist fusion is a particular good option for patient conscious of a surgical scar and would like to have less postoperative pain and a potential faster rehabilitation.

Partial wrist fusion is contraindicated when there is an active ongoing sepsis over the wrist joint, pan-arthritis involving all or most compartments of the wrist, and rapidly progressive inflammatory arthritis at a proliferative stage. Partial wrist fusion is also not a guarantee for pain relief. The potential advantage of partial wrist fusion in preserving a useful arc of motion may be offset by the risks of nonunion or by a continuing pain despite a successful fusion [12]. Nagy and Büchler reviewed a cohort of 15 cases of radioscapholunate fusion and reported a nonunion rate of 27 % [13]. Nearly half of them showed secondary degenerative changes of the midcarpal joint, two of which were progressive. Four patients had continuing symptoms despite a sound radiological union of the partial wrist fusion. Revision total wrist fusion was required in 33 % of cases ultimately. Thus those patients who prefer a more guaranteed outcome on the pain control, do not want multiple surgical procedures, and do not bother a loss of wrist motion may be better candidates for a total wrist fusion. Chronic smoker has higher incidence of nonunion after partial wrist fusion and required more revision surgery to achieve a union. Alternative for pain control treatment such as a wrist denervation can be considered. Total wrist arthroplasty can be considered in the older patients with limited functional demand. Accompanying distal radioulnar joint pathology would not be altered by the partial wrist fusion and needs to be tackled separately or concomitantly. Arthroscopic partial wrist fusions are technically demanding procedures and should not be lightly taken by surgeons without much experience in therapeutic arthroscopy of the wrist. Patients with pre-existing extensor tendon pathology over the wrist region may have higher incidence of tendon complications associated with complex arthroscopic wrist reconstruction procedures. Severe arthrofibrosis, joint contracture, and longstanding carpal collapse or wrist deformity may also pose additional difficulty and risk for the surgeons in using the arthroscopic approach.

Technique

The general principles in all forms of arthroscopic partial wrist fusion should include the following steps:

1. Set up and instrumentation
2. Arthroscopic surveillance for final staging of the disease
3. Cartilage denudation
4. Correction of carpal mal-alignment
5. Provisional fixation of the fusion intervals
6. Augmentation of the fusion segment(s) with bone graft or bone substitute in selected indications
7. Definitive fixation

General Approach

Set Up and Instrumentation

The operation is typically performed under general anesthesia for convenience and patient comfort in harvesting the bone graft if it deems necessary. It can be done under regional anesthesia if bone substitute is employed, or when no bone graft or substitute augmentation is needed. Either injectable or small granule form of the bone substitute is suitable for the purpose. There is a tendency of not using any bone graft or bone substitute augmentation if a rigid fixation device such as cannulated compression screws can be applied to the fusion site, and the fusion surfaces are congruent enough without excessive dead-space. C-arm fluoroscopy should be available in all cases for intraoperative assessment. The list of essential instruments includes a motorized full-radius shaver and burr system of diameters ranging from 2.0 to 3.5 mm, small angled curette and ring curette, 2.5 mm suction punch, radiofrequency thermal ablation system, K wires and small cannulated screw system.

The patient is put in supine position while the operated arm is supported on a hand table. Either side of the iliac crest region is draped for bone graft harvesting depending on the patient's preference. An arm tourniquet is applied but need not be inflated routinely. A tight application of the tourniquet without inflation leads to venous engorgement and can induce more troublesome bleeding. Most of the procedures can be done without the use of a tourniquet. Piñal advocates the use of dry arthroscopy to avoid the problem of swelling and the extravasation of fluid, but the use of tourniquet becomes mandatory throughout the procedure which may take extended time [14]. A vertical traction of 4–6 kgf is applied through plastic finger trap devices to the middle three fingers for joint distraction via a wrist traction tower. We employ continuous saline irrigation and distension of the joint by using a 3 liters bag of normal saline solution suspended at 1–1.5 m above the operating table and instill with

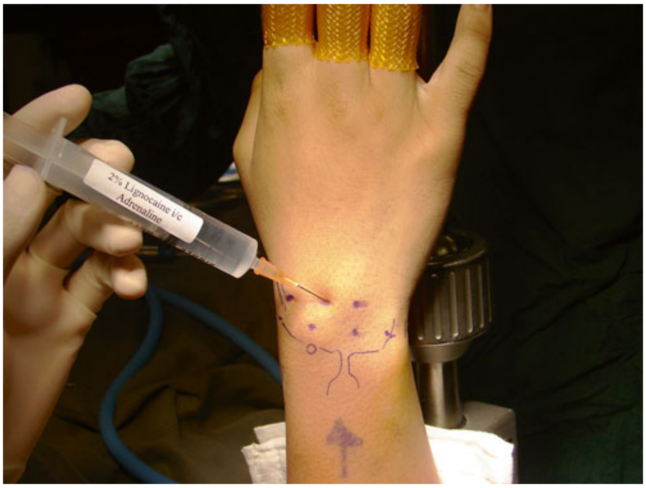


Fig. 17.1 2 % Lignocaine with adrenaline solution in 1:200,000 dilution is injected to portal sites for hemostasis effect

the aid of gravity to maintain a clear arthroscopic view. Infusion pump is not necessarily and is potentially harmful in causing an extravasation of fluid. In wrist arthroscopy, it is mainly the distraction device that keeps the joint opened, not the fluid irrigation like in the shoulder joint.

Arthroscopic Surveillance

We perform routine inspection of both radio-carpal joint through 3/4 portal and midcarpal joint through MCR portal using a 2.7 or 1.9 mm video arthroscope. The aim of the examination is to establish a precise arthroscopic staging of the pathology. Adrenaline solution of 1 in 200,000 dilution is injected to the portal site skin and capsule to reduce bleeding associated with incision [15] (Fig. 17.1). Intra-articular injection is optional and may reduce bleeding associated with the arthroscopic procedures. The outflow is established at 6U portal just volar to the ECU tendon using an 18G needle. In general, all portals should be marked after careful palpation with surgeon's thumb tip and the wrist being distracted on the traction device before saline was injected intra-articularly.

Once the arthroscope is being inserted, particular attention is paid to assess the status of the interosseous ligaments, the degree of synovitis, and the articular cartilage condition of the joints intended to be fused and the other uninvolved joint compartments of the wrist. The latter is essential to determine whether the proposed fusion is appropriate or not. The dorsal rim of the radial styloid is a common site of occurrence of the early SLAC or SNAC wrist arthritic changes and should be assessed in all cases by rotating the 30° forward slanting lens downward to reach the area. The frequently associated localized posttraumatic synovitis in this area may obscure the observation of cartilage condition. The synovial growth needs to be eliminated by using a 2.0 mm shaver or a radiofrequency probe inserted from 4/5 portal. It may be necessary to swap the portal of the arthroscope and instrument in order to obtain a better attacking angle of the instrument for a more efficient synovectomy. The ulnocarpal joint should also be routinely inspected and the status of TFCC ascertained. Any central perforation of the TFCC without peripheral involvement should be debrided of any unstable flap tear at the same operation to avoid possible new source of pain after the definitive index procedure.

The midcarpal joint is approached through the MCR portal. Routinely the STT joint, scaphocapitate joint, capitolunate joint, and triquetrohamate joint are inspected for cartilage lesion and synovitis. The scapholunate and lunotriquetral joint are assessed for stability with a 2 mm probe introduced from the MCU portal. Any instability is graded according to the Geissler classification. Synovial overgrowth should be debrided by using a shaver or radiofrequency probe to adequately expose the underlying cartilage area for assessment of the true extent of chondral damage and subchondral bone exposure. In posttraumatic arthritis, difficulty may be encountered when developing the radial portal at the midcarpal joint due to the intra-articular adhesion and periarticular soft tissue contracture. Under this circumstance, one should not hesitate to shift to the midcarpal ulnar portal where joint space is usually more generous. Once the joint is entered, the other portal can be developed more easily by applying an 18G needle through the skin under direct vision. This greatly helps the localization of any difficult portal. A prerequisite for a successful radio-carpal fusion is a relatively intact articular surface at the midcarpal and STT joints. If significant arthritic change is present, one may need to abandon the planned procedure and consider other salvage option such as total wrist fusion. Two accessory portals may also be recruited during any midcarpal procedure. The triquetrohamate (TH) portal can be located by palpating the tendon of ECU and moving distally until the palpating finger reaches the hamate bone. The portal is then located at the axilla between the ECU tendon and the hamate. It is most useful as an outflow portal. The scapho-trapezial-trapezoid (STT) portal is situated about 1 cm radial and slightly distal to the MCR portal just ulnar to the EPL tendon slightly distal to the MCR portal. The portal is located at the junction between the scaphoid, trapezoid, and trapezium. Care should be taken in avoiding injury to the radial artery which is radial to the EPL tendon.

Cartilage Denudation

The articular surfaces of the joint compartments to be fused are then prepared. The extent and depth of cartilage denudation should be precisely controlled using a 2.9 mm

Fig. 17.2 To have better control of the instrument, the arthroscopic burr is being held near the far end with the surgeon's thumb and index finger, while the middle finger firmly anchors the burr over the skin around the portal site

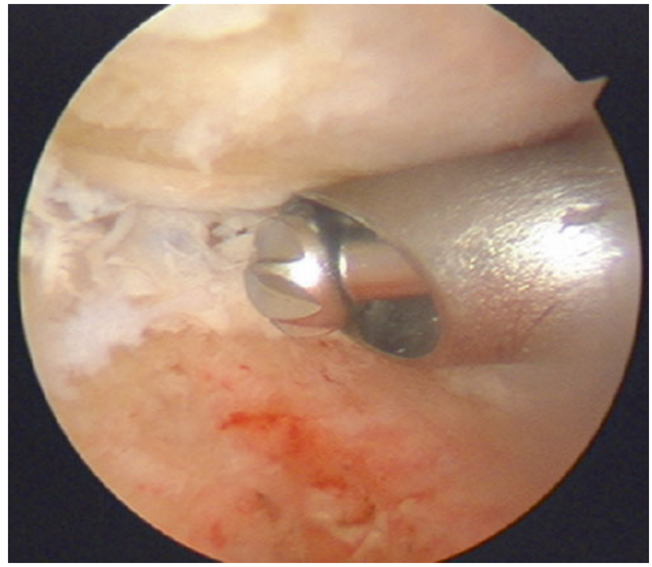


Fig. 17.3 Punctate bleeding can be readily seen from the subchondral bone during burring without the use of tourniquet

arthroscopic burr. In debriding the carpal interval of the same carpal row, such as lunotriquetral or capitohamate interval, a smaller burr such as 2 mm sized should be used to cater for the narrower joint space to avoid excessive cartilage and subchondral bone removal. Either forward or reverse blade rotation mode should be adopted at a speed of 2,000–3,000 rpm. Oscillating mode is not as effective as compared to the unidirectional mode. One should be cautious about the jumping phenomenon when using a burr to attack a particularly sclerotic bone surface. The burr may get caught in the area of hard subchondral bone during the high speed revolution. The resultant force will bounce the burr off the bone and may lead to accidental damage of the articular surface of the surrounding or opposing carpal bones. To have better control of the instrument, the surgeon is recommended to hold the arthroscopic burr near the far end with the surgeon's thumb and index finger, while using the middle finger to firmly anchor the burr over the skin around the portal site (Fig. 17.2). There should be maximal preservation of the subchondral bone so as to maintain carpal height. Burring is completed when the subchondral cancellous bone with healthy punctate bleeding is reached. This phenomenon can be easily observed if a tourniquet is not used during this process (Fig. 17.3). Usually bleeding is limited and can be well controlled with the hydrostatic pressure applied through the irrigation system. If bleeding is profuse, one may further elevate the suspension of the instilling saline bag to increase the hydrostatic pressure, or use the coagulation mode of the radiofrequency apparatus. During the burring process, suction is switched on and off intermittently to remove any accumulated bone debris which may block the visual field. If suction is applied continuously during the burring process, excessive air bubbles drawn in will severely compromise the visibility of the operating site.

Correct Carpal Deformity

DISI deformity is commonly present in many posttraumatic wrist arthritis conditions. It is prudent to correct the deformity as far as possible during the process of partial wrist fusion involving the capitate-lunate joint in order to maximize the motion and to reduce abnormal loading through the lunate fossa. A close reduction can be accomplished by correcting the radio-lunate angle to zero degree using a K wire to transfix the radiolunate joint with the wrist in moderate flexion and slight ulnar deviation (Fig. 17.4). A 1.1 mm K wire is introduced percutaneously through a small stab wound over the distal radius slightly proximal to the sigmoid notch level, aiming at the level between the 3/4 and 4/5 portals. A fine tip hemostat or stitch scissor should be used to dissect bluntly the extensor tendons to avoid iatrogenic injury or tethering of the extensor tendons during the introduction of K wire through the skin. The precise location of the insertion point and insertion angle should be guided by an image intensifier both in the antero-posterior and lateral projection. The K wire should not perforate through the distal cortex of lunate so as to leave

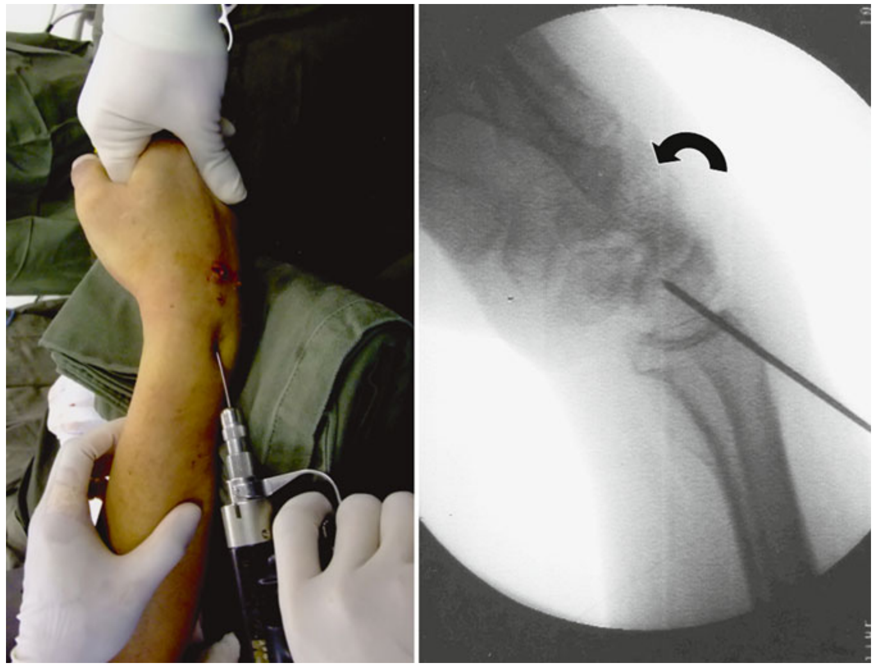


Fig. 17.4 DISI deformity of the lunate can be closely reduced by flexing the wrist and transfixing radiolunate interval at an anatomical alignment before reduction of other carpal bones in relation to lunate

a space at the capitate-lunate joint. Before the final fusion progress, the other carpal bones are realigned manually in relation to proper lunate position.

Provisional Fixation of the Carpal Fusion

The wrist is dislodged from the wrist traction tower and is placed horizontally over a hand table for the provisional fixation. The carpal interval(s) to be fused is temporarily fixed with 1.0 or 1.1 mm K wire percutaneously using a powered driver in an anatomical position as far as possible. Alignment is confirmed with an intraoperative image intensifier. The K wires can be used as definitive fixation device or they can be used as the guide pins for the subsequent conversion into percutaneous cannulated screw fixation. The pins are then withdrawn to free from the joint to be fused while they are maintained in position in the carpal bone or distal radius. Externally the pins should be protected with pin caps to avoid accidental injury to the surgeon's hand in the remaining process. The joint is then ready for grafting with autogenous cancellous bone or bone substitute.

Augmentation of the Fusion Segment(s) with Bone Graft or Bone Substitute

Autogenous bone graft or bone substitute is frequently required to fill up the voids between the articular surfaces to be fused. As the vascularity and the bone quality of the fusing bones are usually adequate, cancellous chip graft from iliac crest may not be essential and there is an increasing role of using bone substitute to reduce the potential donor site morbidity with similar outcome. Both injectable form and small granule form are suitable for the purpose. In order to prevent spillage of the graft inside the joint to the undesirable compartments, special Foley catheter balloon blocking technique has been developed (Fig. 17.5). A French size 6 Foley catheter with a stylet on is introduced through the arthroscopic portal. The tip of the catheter is usually cut short to allow better placement of the balloon. Advancement of the catheter into the joint can be facilitated by grasping the tip of the catheter using a small arthroscopic grasper introduced from a third portal. Once the balloon portion of the catheter is completely inside the joint as monitored through the arthroscope, it can be inflated with saline solution until the joint compartment away from the fusion interval is largely obliterated by the balloon.

Fig. 17.5 Foley catheter blocking technique to avoid spillage of bone graft/substitutes to the uninvolved space

Fig. 17.6 Bone graft is delivered through a cannula with a slightly undersized trocar of flat end such as the bone biopsy trocar into the joint cavity

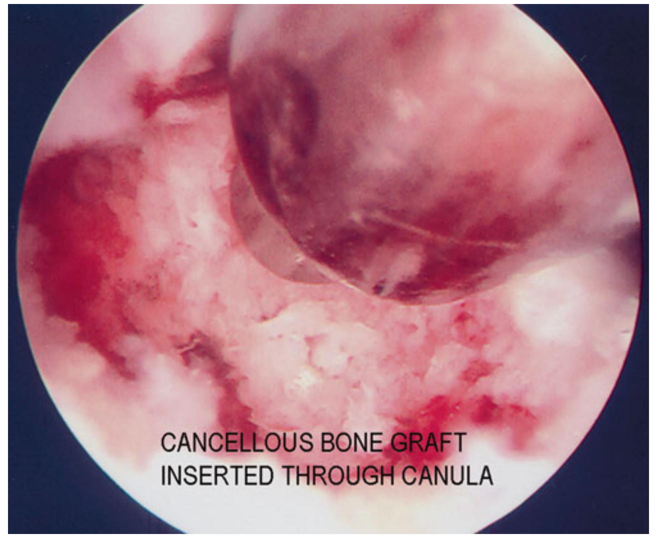


Fig. 17.7 Impaction of graft with blunt trocar at fusion site

The balloon remains inflated during the arthroscopic bone graft process so that redundant cancellous graft or bone substitute will not fall into and be trapped in other compartments not going to be fused. Reducing fluid inflow is also a useful trick to avoid graft spillage.

An arthroscopic cannula is introduced through the appropriate portal directly opposing the fusing surfaces. If autogenous graft is to be used, cancellous bone graft is harvested from the iliac crest using either trephine technique or an open approach through a small incision. The bone graft is then cut into small chips using scissor and delivered through the cannula with a slightly undersized trocar with a flat end such as the bone biopsy trocar into the joint cavity (Fig. 17.6). Trocar with roundish end is not effective enough. Too exact fitting of the trocar in the cannula will cause an easy trapping of bone graft substance between the trocar and cannula wall and may lead to delivery problem. So a slightly undersized trocar is more desirable. The bone graft is impacted with the trocar till satisfactory volume of graft is achieved (Fig. 17.7). This process requires two assistants to execute smoothly. One assistant helps to maintain the position of the arthroscope to provide optimal vision of the fusion site. The operating surgeon controls the arthroscopic cannula and trocar. A second assistant is responsible to deliver the bone graft or bone substitutes into the opening of the cannula in small volume every time. The operating surgeon then drives the bone graft or substitute into the fusion site under directly arthroscopic monitor (Fig. 17.8). The speed of the process can be enhanced by using a cannula of wider bore such as 4.5 or 5 mm so that each time more graft can be accommodated. If injectable bone substitute is to be used, joint irrigation should be ceased and all joint fluid evacuated with suction. A wide bore needle connecting the syringe containing the bone substitute is inserted through appropriate portal to reach the fusion site. Injection of the bone substitute can then be performed under direct vision till the cavity is filled up completely. If necessary, intraoperative fluoroscopy can help to confirm the completeness of the filling process.

Fig. 17.8 With the help of two assistants, the operating surgeon controls the arthroscopic cannula and trocar and drives the bone graft or substitute into the fusion site under direct arthroscopic monitor

Definitive Fixation

The wrist is taken off from the traction tower again and placed in the hand table. Definitive fixation is performed by driving the K wires across the bony interval to be fused and in a correct carpal alignment. If cannulated screw is

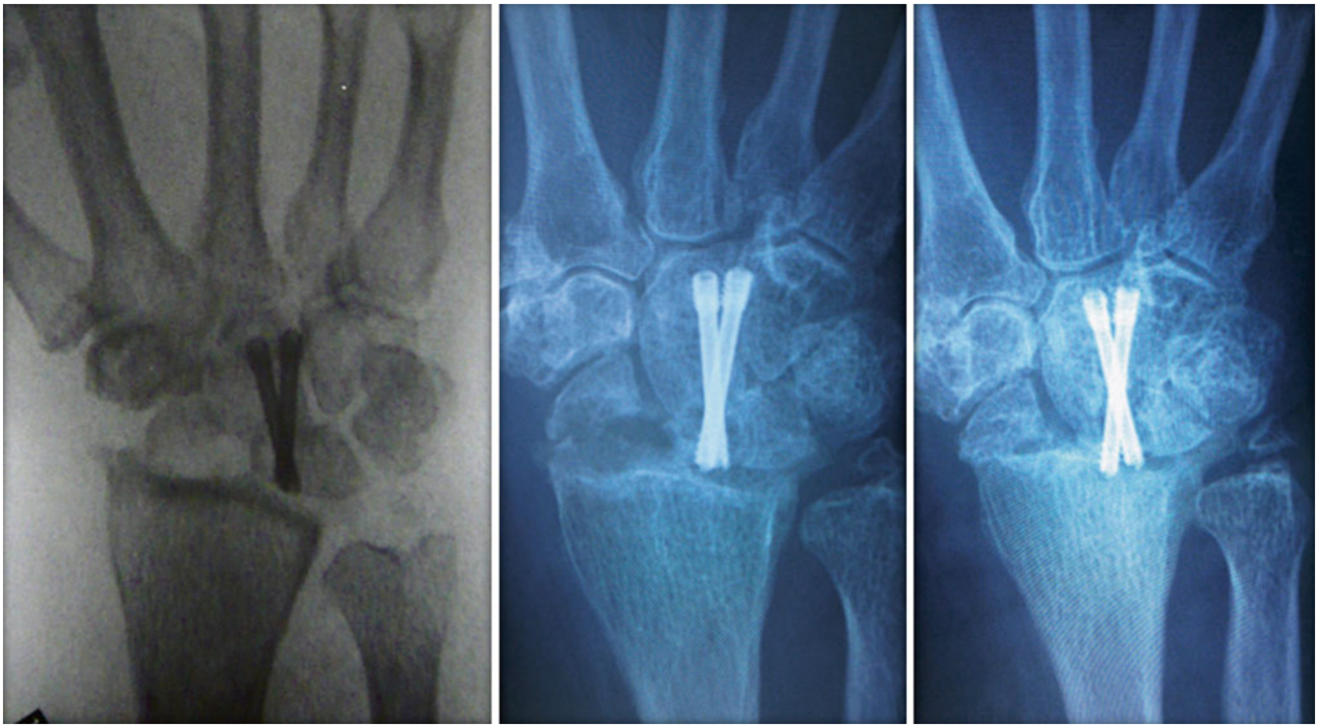


Fig. 17.9 Self-tapping headless screw may protrude into the joint gradually during healing process of the fusion site in old patient with osteopenic bone

preferred, the K wires will then serve as the guide pins. After measuring the length of the screw required, the pin tract is drilled using a cannulated drill bit. Stable internal fixation can then be achieved with compression screw using appropriate percutaneous cannulated screw system, preferably a headless screw system to avoid screw head impingement. The final carpal alignment, screw position, and length should be assessed by using an image intensifier. In older patient with osteoporotic bone, multiple K wires fixation is preferred over screw fixation to avoid hardware problem, such as the protrusion of screw tip into the joint (Fig. 17.9). Percutaneous K wires should be cut short and buried underneath the skin. They are removed under local anesthesia when the bone healing is complete. Exposing pins outside skin may predispose to pin tract infection. The wrist is then immobilized with a plaster slab.

Specific Fusion Technique and Rehabilitation

STT Fusion

STT fusion is commonly indicated in stage 1 or II SLAC wrist, Kienbock disease stage 3a or 3b and STT joint arthritis [16–18]. It is frequently performed together with a radial styloidectomy, which can also be accomplished under an arthroscopic mean. The best indication for arthroscopic STT fusion is STT joint arthritis, with or without association with SLAC wrist. Under such circumstance, there is usually no scaphoid mal-alignment and hence no DISI deformity needed to be correct.

Radiocarpal joint arthroscopy should be routinely performed to look for arthritic changes over the radioscaphoid and radiolunate joints. Arthritic change in the former compartment may make the radial styloidectomy a necessary accompanying procedure while change in the latter compartment may constitute a contraindication of the procedure.

Arthroscopic STT fusion is then performed at the midcarpal joint. The STT portal is often required to provide a direct access to the STT joint. The arthroscope is inserted in the MCR portal and directed towards the STT joint by climbing up the slanting articular surface of the scaphoid over the waist portion opposing the capitate till the scapho-trapezoid-capitate junction is reached. The latter is signified by an inverted Y shaped joint interval which I call it as "Mercedes Benz" sign (Fig. 17.10). In STT arthritis condition, the joint is frequently obliterated by synovial overgrowth and joint debris (Fig. 17.11). They need to be cleared up with a shaver and/or radiofrequency probe before the articular cartilage condition can be verified. The joint space may also be contracted with the periarticular soft tissue fibrosis. Joint entry can be facilitated by using a smaller arthroscope such as 1.9 mm. Sometimes the joint space in the whole radial compartment of the midcarpal joint may be compromised and one should not hesitate to start the joint exploration through the ulnar midcarpal portal, which is always less affected under such circumstances. Nevertheless, joint space usually gets enlarged after a period of joint debridement procedure and manipulation to allow sufficient access for the subsequent grafting procedure with bigger instruments. The arthritic joint surface is then debrided of the remaining articular cartilage till subchondral bone is exposed. Initially the trapezium may be difficult to reach as it is situated in deeper space at the STT joint. As long as the cartilage surface of the distal scaphoid and trapezoid is removed with arthroscopic burr, there is progressively more space for the burr to reach the surface of the trapezium. Due to the relatively tight space, bleeding from bone ends may obscure the operative field and tourniquet may be required to control bleeding at this junction temporarily. The proximal part of the articular surface between the trapezium and trapezoid should also be denuded of cartilage with an arthroscopic burr. However complete take down of the articular surface is probably not necessary as normally the TT joint is very tight and stable.

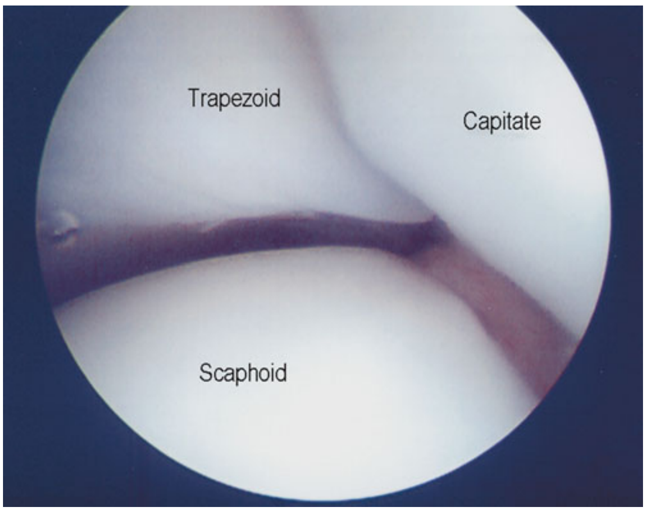


Fig. 17.10 Mercedes Benz sign at junction between capitate, trapezoid, and scaphoid

Once the articular surface for fusion is well prepared, a percutaneous fixation of the STT joint can be performed. Fixation can be in ththe form of K wires transfixing scapho-trapezial, scapho-trapezoid, and trapezio-trapezoid joints. I prefer to employ rigid fixation using a cannulated screw with compression inserted from trapezium to scaphoid percutaneously. Fixation of the scapho-trapezoid and trapezio-trapezoid joints then becomes nonessential. With the hand placed horizontally in hand table, a guide pin is inserted through a small stab wound at junction between base of first metacarpal and the trapezium under an image guidance with the aim towards the proximal pole of the scaphoid (Fig. 17.12). Alignment should be confirmed by at least four radiological views of AP, lateral, semi-supinated AP, and semi-pronated PA view. If scaphoid is abnormally flexed and pronated due to scapholunate instability, a 1.6 mm K wire

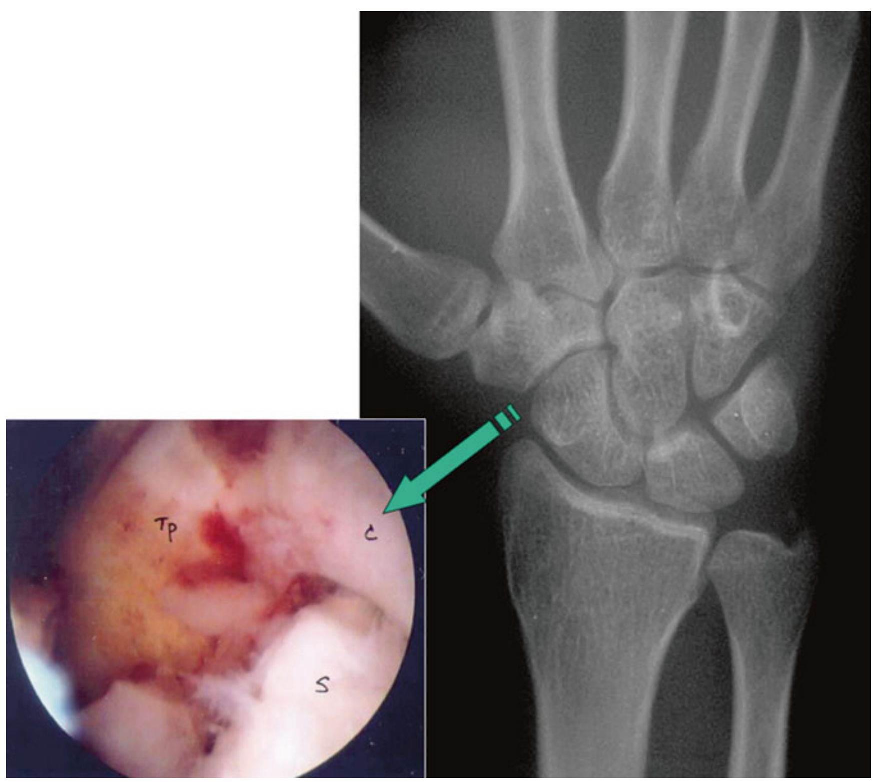


Fig. 17.11 Radiological and arthroscopic view showing typical posttraumatic STT joint arthritis with synovial overgrowth and eburnation at joint surface

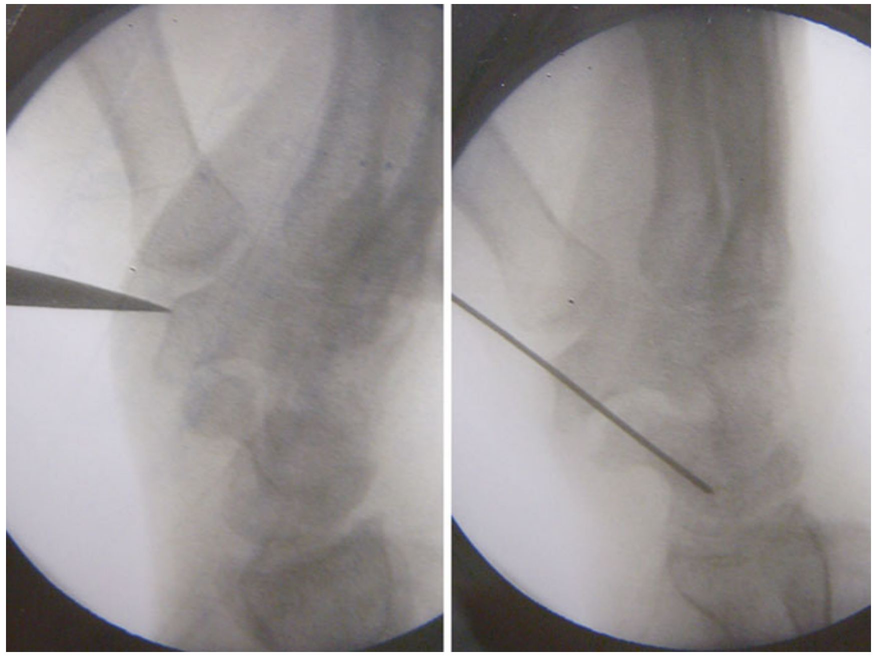


Fig. 17.12 Intra-op X-ray view showing placement of starting awl over the distal tubercle of trapezium and the guide pin insertion across scapho-trapezial joint

can be inserted percutaneously to be used as joystick to correct the alignment of scaphoid. With the arthroscope in MCR portal, a small probe can also be inserted through STT portal to assist the reduction of scaphoid alignment by hooking onto the distal part of the scaphoid to extend and derotate the scaphoid. The K wire inserted through trapezium can then be driven through to reach the proximal scaphoid.

The arthroscope is then inserted again into the joint through MCR portal to verify the position of K wire (Fig. 17.13). If the joint space at STT joint becomes too tight to allow bone grafting through an arthroscopic cannula, the K wire can be withdrawn from the scaphoid but remains attached to the trapezium. Autogenous bone graft or bone substitute can be inserted through a small cannula as described above to fill up the void (Fig. 17.14). The K wire is then driven back into the scaphoid till the subchondral surface of proximal scaphoid is reached. Length of the inserted portion of the K wire is measured. The screw length should be 2 mm short of the measured length to reduce the possibility of perforation of the proximal articular surface of scaphoid. The K wire is then driven further proximally, perforating the proximal pole of scaphoid and exiting outside skin near the 3/4 portal of radiocarpal joint. The tip of the K wire is grabbed with a hemostat. This trick helps to prevent accident pull off of the K wire during subsequent drilling process with the small cannulated drill. The bone is then drilled with a cannulated drill bit and finally the trapezio-scaphoid joint is transfixed with an appropriate cannulated screw with compression for added stability (Fig. 17.15). The guide wire can be removed afterward. Final alignment of the screw should be confirmed using an image intensifier. The midcarpal joint is then surveyed with an arthroscope to check for any spilled out graft material, which should be removed by using a mosquito grasper or flushed out from the canula with saline.

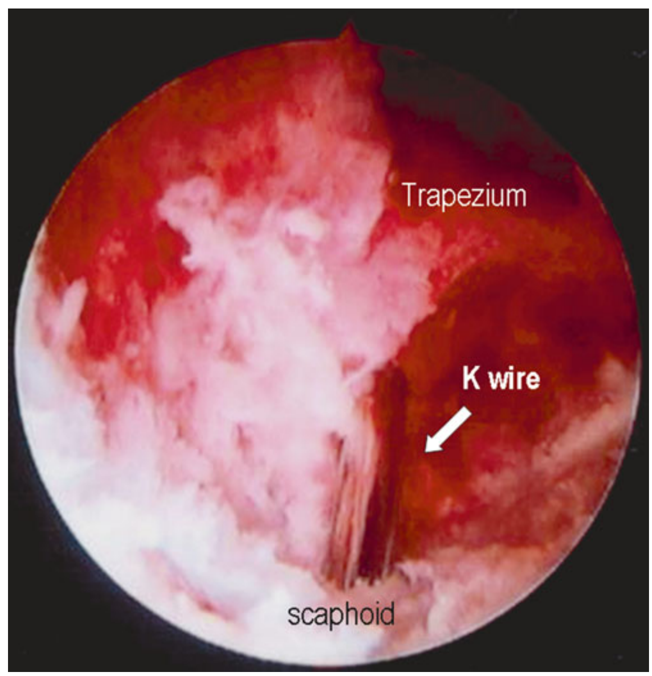


Fig. 17.13 Verification of the guide pin position at the STT joint as viewed through the arthroscope

Wounds are closed with steri-strips and a comfortable bulky dressing is applied supported with a short arm plaster slab. The slab is changed to a removable scaphoid splint after the first week. Active mobilization of the wrist is allowed out

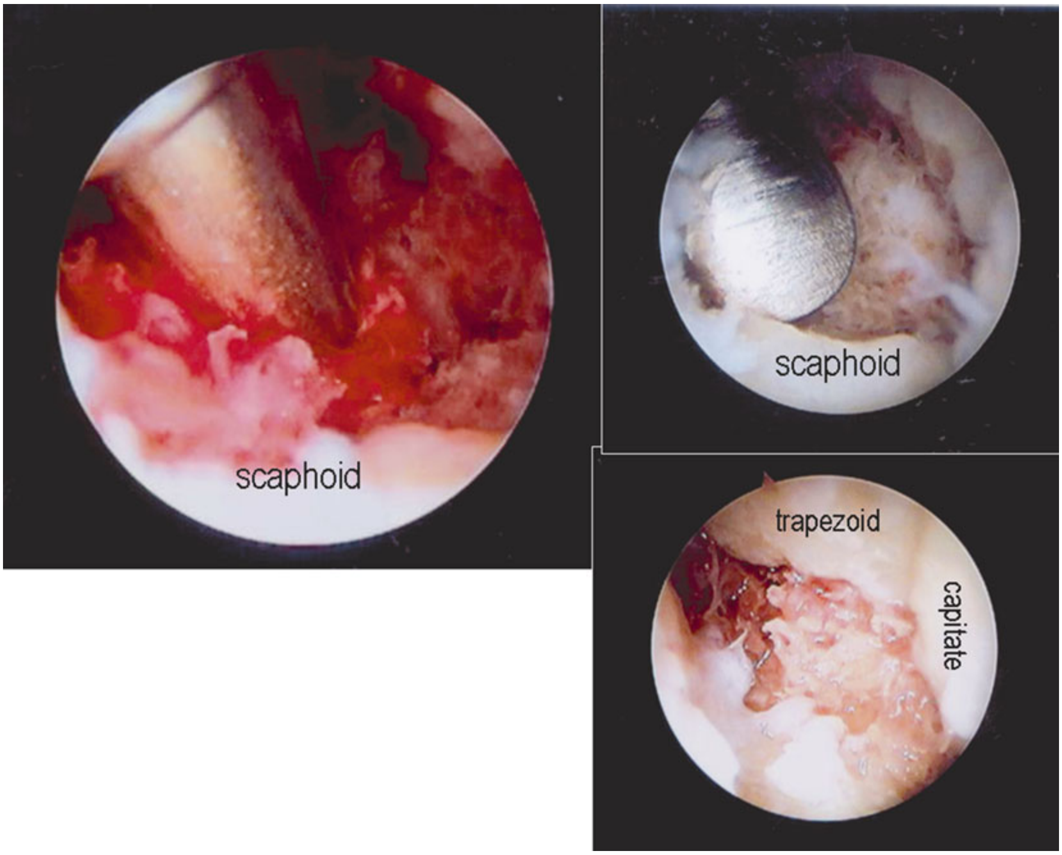


Fig. 17.14 Delivery of autogenous bone graft through cannula to the fusion site, impaction, and final appearance

of splint under supervision of a hand therapist. Passive wrist mobilization and strengthening exercise can be offered when radiological and clinical union is evidenced, usually around 10–12 weeks post-op (Fig. 17.16).

Four Corners Fusion

Four corners fusion is indicated when there is significant peri-scaphoid arthritis in the presence of a relatively intact radio-lunate joint (Fig. 17.17). Under these circumstances, the scaphoid is usually removed surgically as a concomitant procedure with the four corners fusion. Presence of severe arthritic change at the midcarpal joint will exclude the alternative option of proximal row carpectomy and makes the operation a procedure of choice [19, 20]. For pathology that does not involve radioscaphoid arthritis, the indications include midcarpal instability, isolated midcarpal arthritis, or lunotriquetral dissociation with fixed volar intercalated segmental instability alignment of the lunate. When performing four corners fusion in cases without radioscaphoid arthritis, Taleisnik favored scaphoid inclusion [21] and Weiss et al. preferred scaphoid retention [22]. In a cadaveric study carried out by Kobza et al., it was shown that simple four corners fusion with scaphoid retention led to a significant decrease in extension, radial deviation, and ulnar deviation [10]. Four corners fusion with scaphoid excision allowed significantly greater radial deviation but also led to significant increase in radiolunate contact area and the mean contact pressure. However the clinical impact was not known.

We reported four cases of arthroscopic four corners fusion with scaphoidectomy in 2008 [23]. The operation should begin with a surveillance of the radio-carpal joint to confirm an intact radio-lunate articulation and preferably an intact proximal articular surface of triquetrum. Arthroscopic scaphoidectomy is then performed from the midcarpal joint. The operation can be performed without a tourniquet provided that the portal sites and joint space are infiltrated with adrenaline solution in lignocaine. With the arthroscope introduced from the MCU portal, an arthroscopic burr of 2.9 mm is inserted into MCR portal and directed towards the proximal and mid-scaphoid region. The scaphoid is burred at high speed from the articular surface down to the core cancellous bone. Bone debris is removed by intermittently applied suction. To avoid accidental damage of the adjacent articular surfaces to be preserved, a shell of cartilage can be left intact until majority of the cancellous bone is removed. This shell of cartilage can help to separate the burr from the adjacent carpal bone during the burring process

Fig. 17.15 Final wound appearance and progress of radiological changes showing early union at 5 weeks and consolidation over 3 months post-op

(Fig. 17.18). This can be removed piecemeal at the end of the scaphoidectomy procedure by using a small pituitary rongeur or an arthroscopic punch (Fig. 17.19). When taking out the larger piece of bone fragment, it is advisable not to use excessive violence in order to avoid damage to the attaching ligament and soft tissue structure. One trick is to firmly grip on the bone fragment with the small rongeur using both hands while to twist around its own axis and maintain a gentle pulling force. The fragment will gradually lose its connection to the soft tissue and can be delivered smoothly out of the joint. During the delivery process, the surgeon has to maintain a sustained and firm grip on the bony fragment or otherwise it may get lost in the juxta-articular or subcutaneous tissue plane. Under such situation, the surgeon may be forced to enlarge the surgical wound in order to remove the retained bony fragment, which is not desirable (Fig. 17.20). In order to speed up the process, an arthroscopic burr of progressive increase in size such as 3.5 mm and even 4.5 mm can be used when there is more space opened up after part of the scaphoid is removed (Fig. 17.21). The speed of scaphoid excision can often be doubled or even tripled. Alternatively a small osteotome can also be used to break the bone into piecemeal for easier removal. Extreme care has to be exercised during insertion of the larger burr or osteotome to avoid iatrogenic injury to the extensor tendon and cutaneous nerve. The distal few millimeters of the scaphoid can be left in situ so as to preserve the scapho-trapezial ligament. The distal scaphoid tubercle does not normally articulate with the radial styloid and hence its preservation will not cause impingement pain postoperatively.

Once scaphoid is cleared, attention can be paid to the fusion of the midcarpal joint at the four corners region. The arthroscope is now inserted through MCR portal while the MCU portal is reserved for the arthroscopic instruments. The articular surface between the capitate, lunate, triquetrum, and hamate is denuded of cartilage with 2.9 mm burr. The joint surface of the luno-triquetral joint is also burred. I do not routinely burr the articulation between hamate and capitate as the joint is very rigid normally.

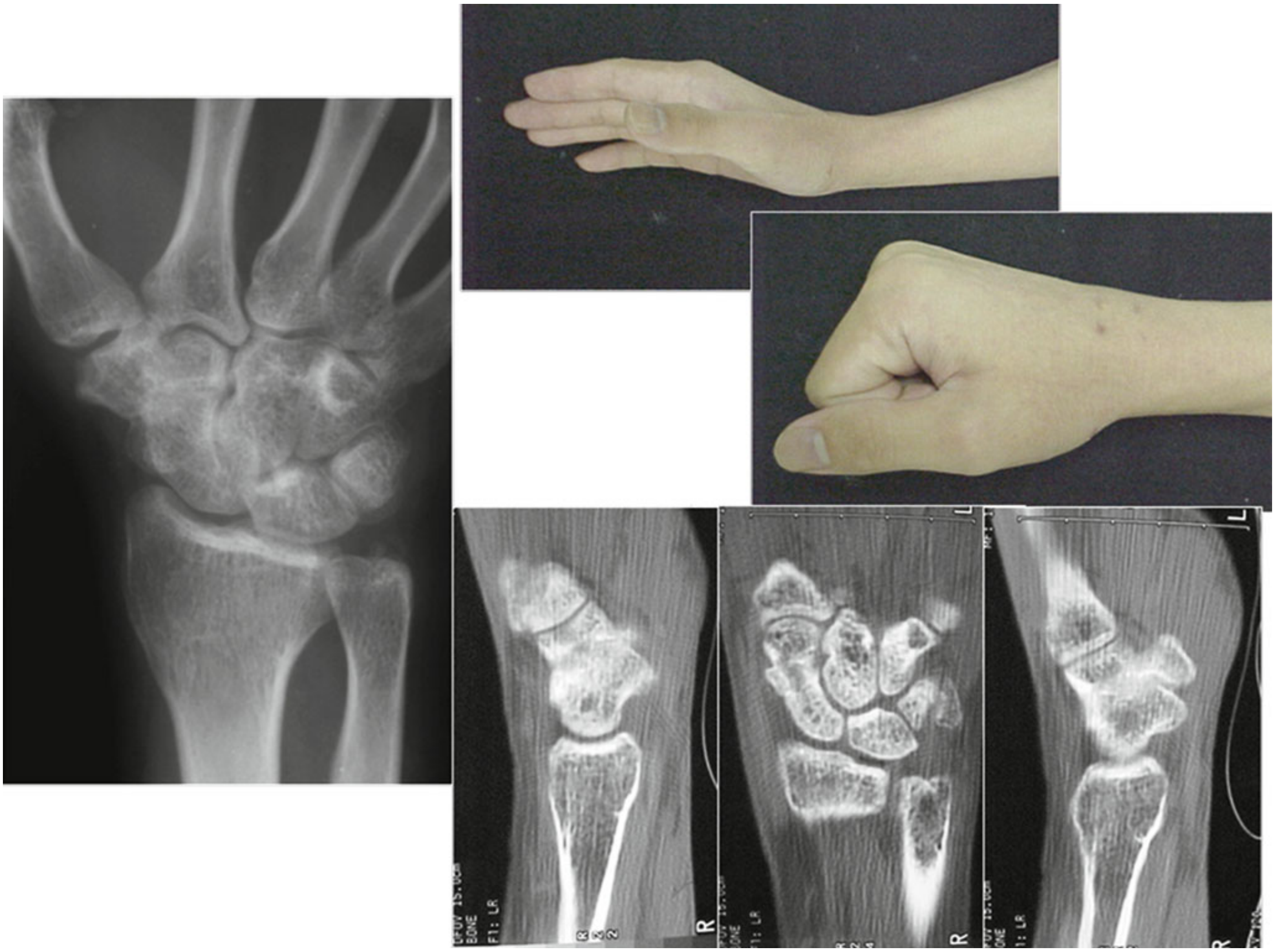


Fig. 17.16 X-ray, CT, and clinical features confirming solid union of the STT joint fusion

After an adequate cartilage destruction, provisional fixation is performed under an image intensifier's guide. If there is significant ulnar translocation and DISI deformity of the lunate and radial subluxation of the capitate off the lunate margin, the lunate is reduced by gentle flexion and radial translation of the wrist so as to restore the normal radio-lunate relationship. The aim is to have at least half of the lunate sitting over the distal radius. The lunate is then fixed to the radius with a percutaneous K wire of 1.1 or 1.6 mm inserted from the distal radius.

The capitate is then reduced by ulnar translation of the wrist so that it sits as much as possible on the distal lunate articular surface (Fig. 17.22). A percutaneous K wire is inserted from the dorsal surface of the capitate at the distal junction with the base of the third metacarpal under an image guide (Fig. 17.23). The mini-stab wound should be bluntly dissected to avoid iatrogenic injury to the extensor tendon. With the help of a lateral projection on the image guide, the K wire is driven across the capitolunate joint to anchor into the lunate. The angle of attack has to be acute enough in order to catch the central part of the lunate to have a better purchase of the bone. It is most crucial to obtain a good surface contact of the capitolunate joint as the key point of the operation is to achieve solid fusion of the CL joint to avoid late collapse of the midcarpal joint and hence loss of the carpal height.

If satisfactory alignment can be achieved, the K wire is withdrawn from lunate while still attaching to the capitate. This is then followed by the bone grafting procedure at the midcarpal joint as described in session before. With the arthroscope held at MCR portal, the cannula can be inserted through the MCU portal for bone graft or substitute delivery. If scaphoidectomy is included, a French size 6 Foley catheter is inserted via the 3/4 portal to completely obliterate the empty space left after the scaphoidectomy procedure. The balloon is inflated while bone graft or substitute is being delivered to the ulnar midcarpal space (Fig. 17.24). The catheter can be removed after the bone grafting procedure, or can be left in situ for a day or two to serve as a surgical drain.

After completion of the bone grafting, the K wire over the capitate is driven back to lunate at the reduced position.

Fig. 17.17 A 47-year-old manual worker with SLAC wrist stage III undergoing arthroscopic scaphoidectomy and four corners fusion at Sept 2000

Length of the K wire inserted is measured. This is followed by drilling of bone with a cannulated drill bit and the final insertion of a headless self-tapping cannulated screw to fix the capitolunate joint. The screw tip should reach no more than 2 mm from the proximal surface of the lunate to avoid screw tip protrusion and iatrogenic damage to the radiolunate articulation. To avoid loss of reduction during the drilling action, an additional K wire can be inserted to the CL interval for temporary fixation. One has to be sure that the screw is completely buried in the capitate so that it will not cause impingement to the extensor tendons. Lateral and oblique X-ray views should demonstrate that the screw does not project beyond the proximal articular surface of the lunate so that no scratching of the articular surface of the distal radius will occur. This can also be checked with a gentle passive movement of the wrist after the fixation procedure, or more definately with an arthroscopic evaluation at the radio-carpal joint. The lunotriquetral joint and the capitohamate joint are then fixed with percutaneous K wires through small stab incisions (Fig. 17.25). If the positions of the K wires are satisfactory, headless screws are inserted from ulnar aspect of the hand to fix the carpal intervals (Fig. 17.26). Structures at risk

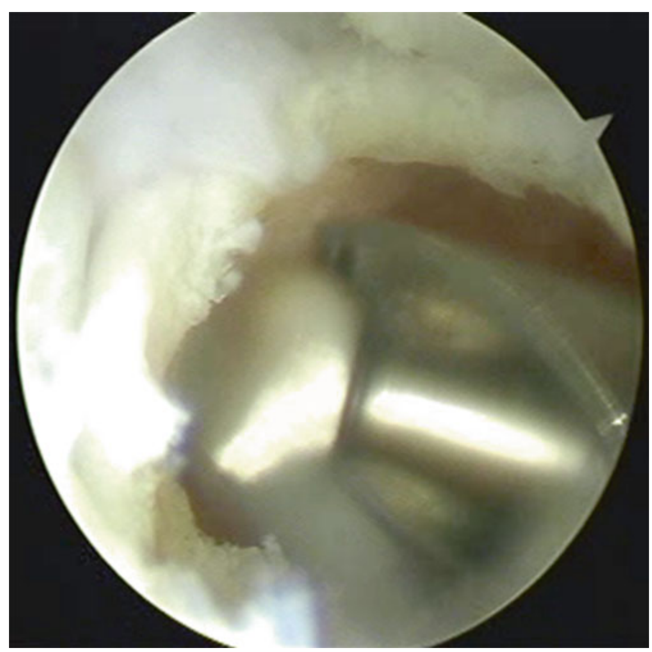


Fig. 17.18 Shell of cartilage left intact during burring of scaphoid to protect other uninvolved articular surface

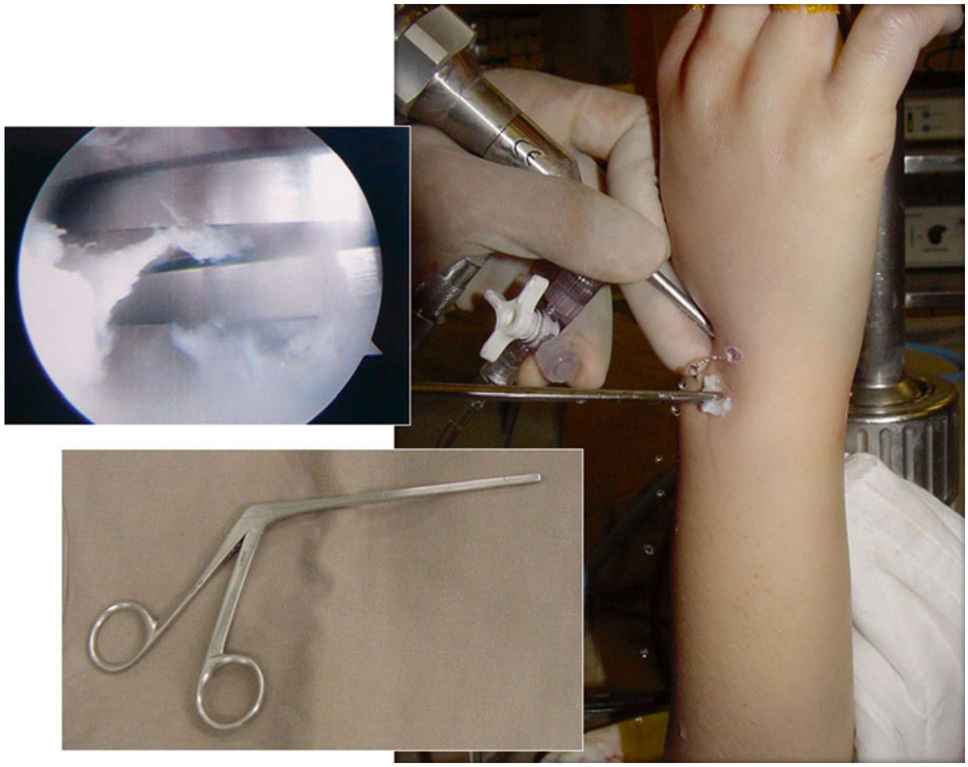


Fig. 17.19 Cartilage shell removed in piecemeal using small pituitary rongeur inserted through portals

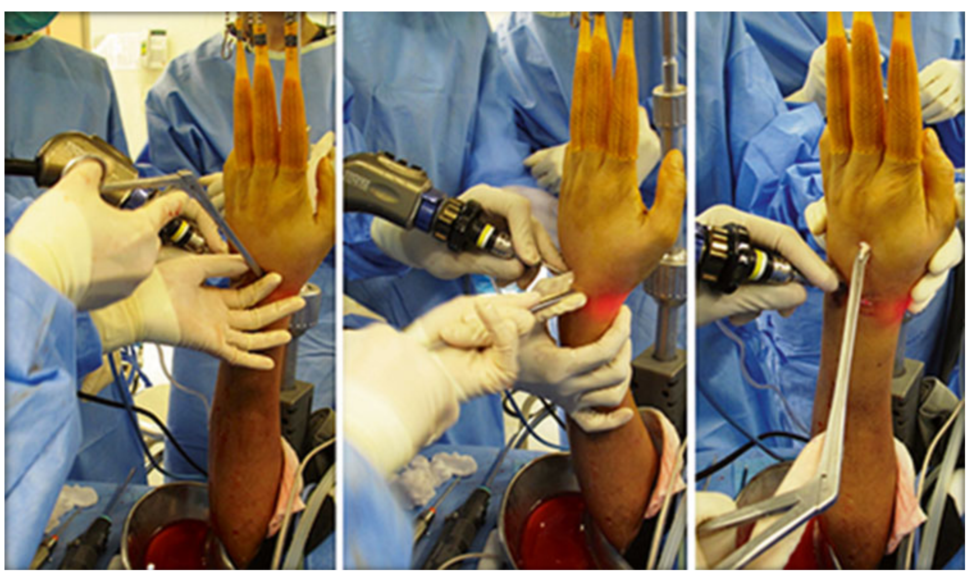


Fig. 17.20 The surgeon firmly grips on the bone fragment with the small rongeur using both hands while to twist around its own axis and maintain a gentle pulling force. The fragment will gradually lose its connection to the soft tissue and can be delivered smoothly out of the joint

include the dorsal branches of ulnar nerve, EDM, and ECU tendons. Blunt dissection of the stab wounds should be a routine before the insertion of guide wire to avoid iatrogenic injury to these important structures. In order to reduce the chance of hitting onto the screw fixing capitolunate joint, the guide wire for capitohamate fusion should aim at the more volar aspect of the capitate, while that of the lunotriquetral fusion should aim at the more dorsal aspect of lunate.

After solid fixation of the four corners bones, any K wire over the radiolunate joint can be left in situ for 2 weeks. The

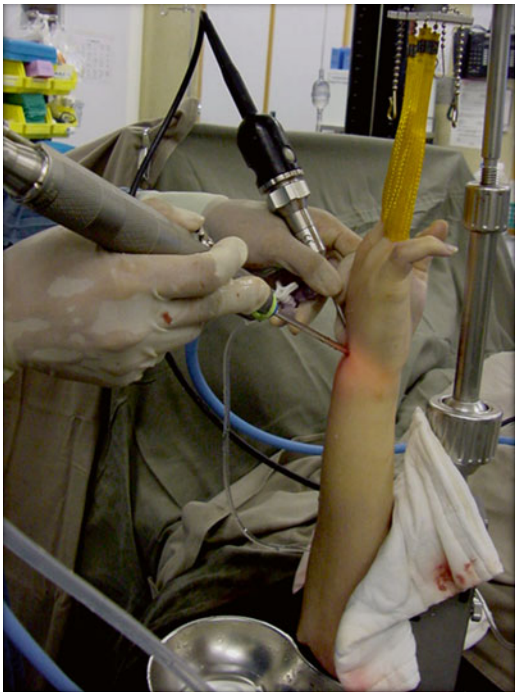


Fig. 17.21 Use of large 4.5 mm arthroscopic burr helps to speed up the burring process

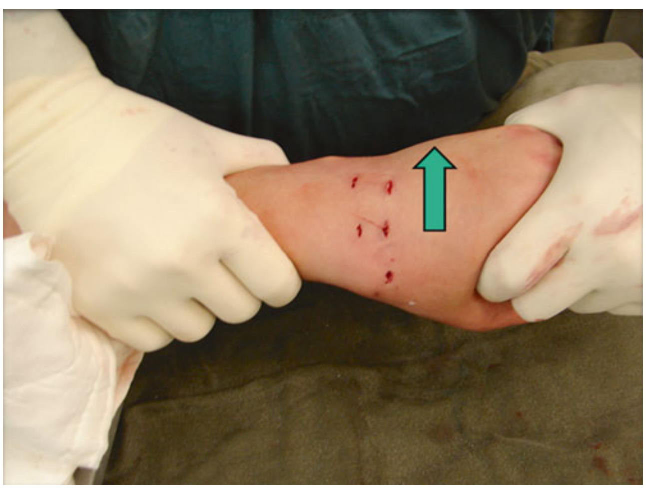


Fig. 17.22 The capitate is reduced by ulnar translation of the wrist so that it sits as much as possible on the distal lunate articular surface

wire end is cut short and bent outside the skin. Wounds are approximated with steri-strips and a comfortable bulky dressing is applied supported with a short arm plaster slab (Fig. 17.27). The plaster slab is changed to a removable wrist splint after the first week. After removal of the K wire over the radiolunate joint, active mobilization of the wrist can be initiated out of splint under the supervision of a hand therapist. Passive wrist mobilization and strengthening exercise can be offered when radiological and clinical union is

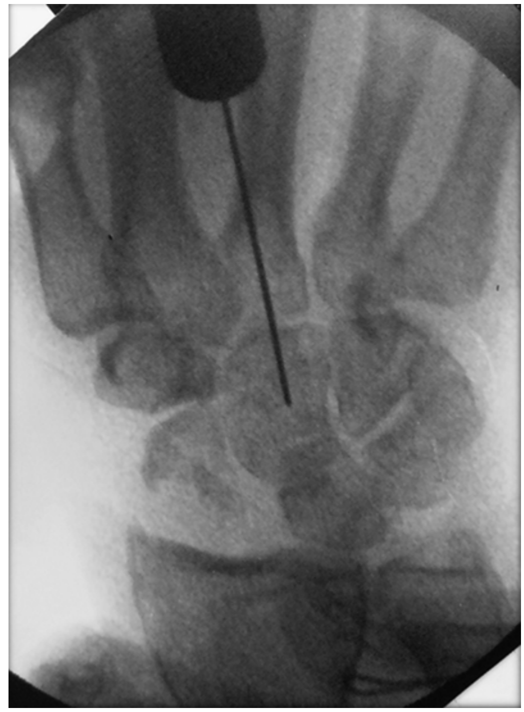


Fig. 17.23 Guide pin inserted through distal capitate to transfix capitolunate joint

evidenced, usually around 10–12 weeks post-op (Figs. 17.28, 17.29, and 17.30).

Capitolunate Fusion

Capitolunate (CL) fusion and scaphoidectomy are now the preferred solution for me in managing stage II or III SLAC or SNAC wrist condition, unless there is concomitant arthritis at the ulnar midcarpal joint. This allows a shorter operating time and preservation of the relatively normal ulnar component of the midcarpal joint, while adequately preventing carpal collapse after the removal of the scaphoid in arthritic condition. CL fusion has historically bad reputation for high nonunion rate due to the limited bony fusion surface and masses. Nevertheless Slade demonstrated a high union and satisfaction rate with an arthroscopic assisted CL fusion, accountable by the minimal invasive method and the rigid percutaneous fixation [24]. The more conservative bone resection also eliminates the potential drawback of triquetral hamate impingement.

The operation begins with a surveillance of the radiocarpal joint to confirm an intact radio-lunate articulation. Arthroscopic scaphoidectomy can then be performed at the midcarpal joint as described before. Once scaphoid is cleared, attention can be paid to the fusion of CL joint. The arthroscope is now inserted through MCR portal while the MCU portal is reserved for arthroscopic instruments. The

Fig. 17.24 A French size 6 Foley catheter is inserted via the 3/4 portal to completely obliterate the empty space left after the scaphoidectomy procedure

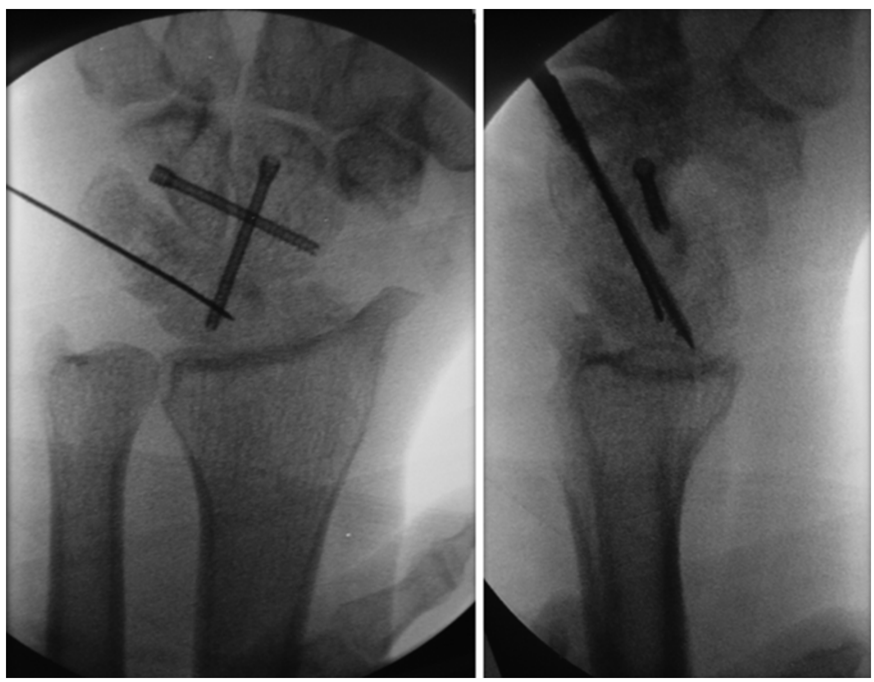


Fig. 17.25 The lunotriquetral joint and the capitohamate joint are fixed with percutaneous K wires

articular surface between the capitate and the lunate is carefully denuded of cartilage with 2.9 mm burr, while those of the triquetrum and hamate should be carefully protected and preserved. For type I lunate, the whole distal articulating surface of the lunate should be debrided. For type II lunate, the typical small ulnar facet need not be debrided as it will not be involved in the fusion process. If the ulnar facet is of considerable size and proportion, one may consider more aggressive flattening of the articular surface by removing the central wedge in between the two facets before attempting the fusion. However the chance of subsequent triquetro-hamate impingement may become higher such that one may consider switching to a formal four corners fusion.

If there is significant ulnar translocation and DISI deformity of the lunate and radial subluxation of the capitate off the lunate margin, the lunate should be reduced and fixed to the radius temporarily as described before.

The wrist is taken off from the wrist tower. A small stab wound is being made over the distal dorsal surface of the capitate at the junction with the radial aspect of the base of third metacarpal (Fig. 17.13). The mini-stab wound should be bluntly dissected to avoid iatrogenic injury to the extensor

Fig. 17.26 Fusion of the four corners bones with percutaneous headless screws

Fig. 17.27 Arthroscopic wounds are closed with steri-strips without stitch

tendon until the bony cortex is reached. With the help of an antero-posterior and lateral projection under an image intensifier, a guide wire of a small cannulated screw system is inserted and driven across the capitate towards lunate and parallel to the radial border of capitate. A small metal awl is helpful to establish the entry point over the capitate prior to the insertion of the guide pin (Fig. 17.31). The angle of attack has to be acute enough with an aim to catch the central part of the lunate to have better purchase of the bone. Before the first guide wire is being fired across the CL joint, the second one should be placed to the ulnar side of the capitate-metacarpal joint. With a second small stab wound over the distal dorsal surface of the capitate at the junction with the ulnar aspect of the base of third metacarpal, the guide wire is driven across the capitate, with an aim to catch the dorsal third of the lunate at the CL junction. The slightly different angle of attack of the two guide pins can avoid crowding of the screws upon final definitive fixation.

With the two pins on the capitate, the capitate is manually reduced to the lunate by ulnar translation of the wrist so that it sits as much as possible on the distal lunate articular surface (Fig. 17.32). The pins are then driven through the lunate until they reach the subchondral surfaces (Fig. 17.33). It is most crucial to obtain good surface contact of the capitolunate joint as the key point of the operation is to achieve a solid fusion of the CL joint to avoid late collapse of the midcarpal joint and hence loss of the carpal height.

In CL fusion, the articular congruency achieved between the capitate and lunate is typically very good. There is no need for added bone graft or substitute. Conversion of the K wires fixation with cannulated screws is then followed as described (Fig. 17.34). Lateral and oblique X-ray views are taken to confirm that no screw should project beyond the proximal articular surface of the lunate (Fig. 17.35). The stability and range of motion of the wrist can be checked under fluoroscopic guidance. Passive finger movement should be checked to confirm no impingement by the screws.

Fig. 17.28 The 47-year-old manual worker with SLAC wrist stage III as shown in Fig. 17.17 undergone arthroscopic scaphoidectomy and four corners fusion showed solid fusion 3 months post-op

Fig. 17.29 Post-op scar condition and range of motion of wrist at 3 months

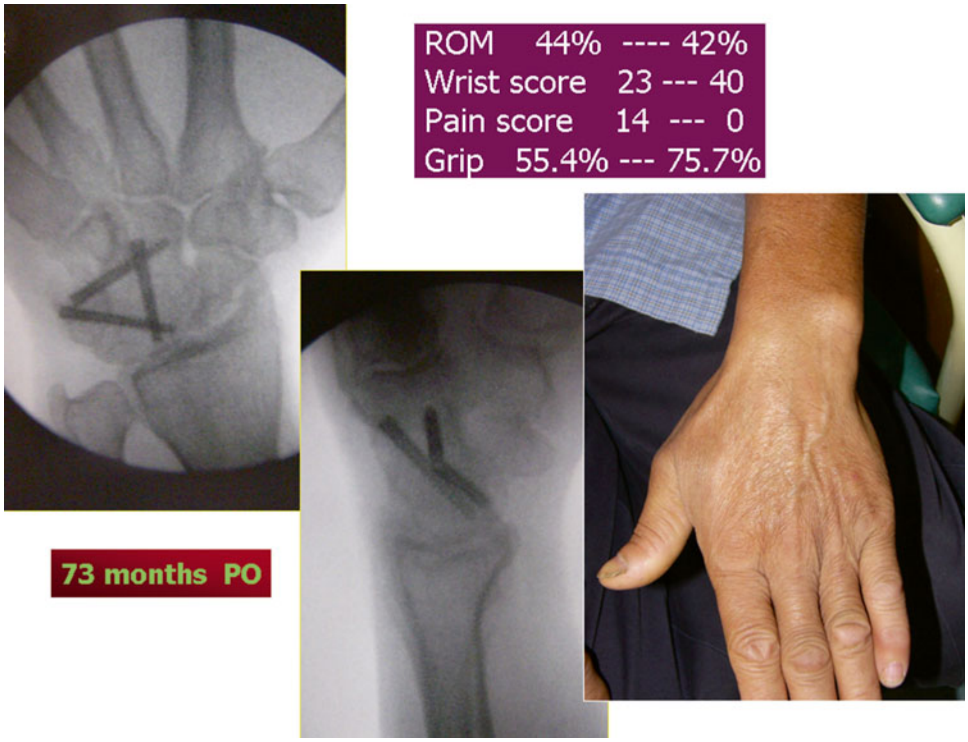


Fig. 17.30 Final follow-up at 73 months post-op: Wrist ROM similar to pre-op (42 % vs. 44 % of opposite wrist), full wrist function score, no pain, grip power increased from 55.4 to 75.7 % of opposite side. Scar was invisible

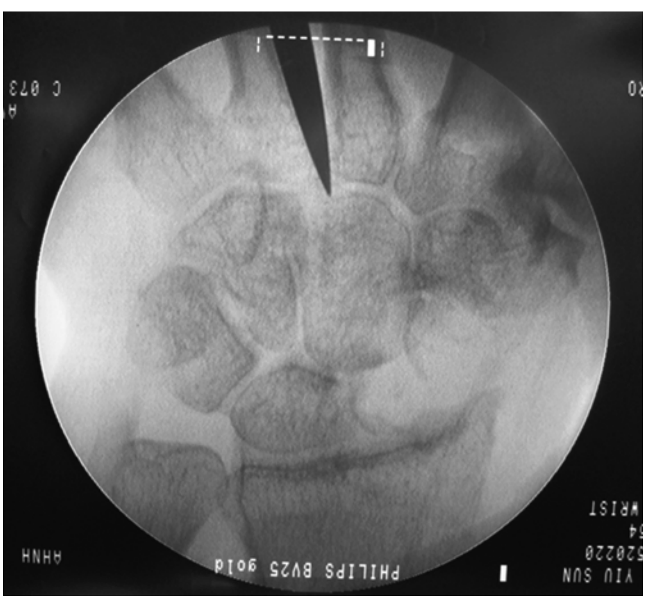


Fig. 17.31 A small metal awl inserted through a stab wound at the ulnar border of the base of the third metacarpal and the capitate to establish an entry point for the guide pin

Fig. 17.32 The wrist is manually ulnar translated to reduce the capitate as much as possible to the distal articular surface of the lunate

Fig. 17.33 Two pins are inserted percutaneously under image intensifier to transfix the capito-lunate joint

Fig. 17.34 Cannulated drill is inserted through the percutaneous pin to prepare track for the cannulated screw

Wounds are then closed with steri-strip and a comfortable bulky dressing is applied supported with a short arm plaster slab. The slab is changed to a removable wrist splint after the first week, when gentle active mobilization of the wrist can be initiated out of splint under supervision of hand therapist. Passive wrist mobilization and strengthening exercise can be offered when radiological and clinical union is evidenced, usually around 8–10 weeks post-op (Figs. 17.36 and 17.37).

Radioscapholunate Fusion

Radioscapholunate fusion is indicated for severe painful post-traumatic arthritis involving the whole radiocarpal joint while the midcarpal joint is relatively preserved [25] (Fig. 17.38). For inflammatory arthritis, the disease should not be at the height of progression and better be adequately controlled with medication [26]. It has been shown that an accompanying distal scaphoidectomy procedure can help to improve midcarpal motion especially on ulnar radial deviation [27]. This can also be accomplished by arthroscopic mean.

A general surveillance of the midcarpal joint to confirm its relative integrity is a prerequisite for a successful radioscapholunate fusion. Arthroscopic distal scaphoidectomy can also be performed at the same time. With the arthroscope placed at the MCU portal, a 2.9 mm burr is inserted into the MCR portal and directed towards the distal scaphoid portion articulating with the trapezoid. Burring of the scaphoid is started at this point towards the distal pole from dorso-ulnar to volar-radial direction. Caution has to be taken to avoid iatrogenic damage to the articular cartilage of trapezoid, trapezium, and capitate. The junction between capitate, scaphoid, and trapezoid forms the landmark of the proximal extent of resection. A shell of cartilage can be left intact until majority of the cancellous bone of the distal scaphoid pole is removed. This shell of cartilage can help to separate the burr from the adjacent carpal bones during the burring process. This can be removed piecemeal at the end of the distal scaphoidectomy procedure by using a small pituitary rongeur or an arthroscopic punch. The STT portal can also be employed to facilitate burring of the most distal part of the scaphoid. At the end of the procedure, there should be a void opposing the trapezium and trapezoid bone, while the waist of scaphoid is preserved and is articulating with capitate. The precise extent of distal scaphoid resection can be checked with intraoperative fluoroscopy (Fig. 17.39).

After the distal scaphoidectomy is complete, the arthroscope can be directed to the radiocarpal joint. The remaining articular cartilage of the radiocarpal joint is denuded. With the arthroscope in 3/4 portal, a 2.9 mm burr is inserted into 4/5 portal and both the lunate fossa and the proximal surface of the lunate are debrided of articular cartilage. The degree of cartilage denudation should be well controlled so that no

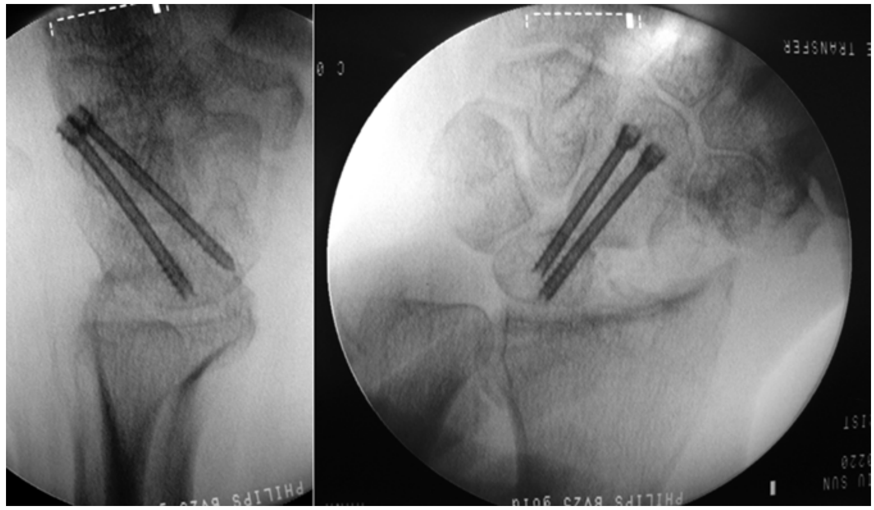


Fig. 17.35 The position of the two headless cannulated screws is being checked radiologically to ensure no violation of the articular surface at the radiolunate joint

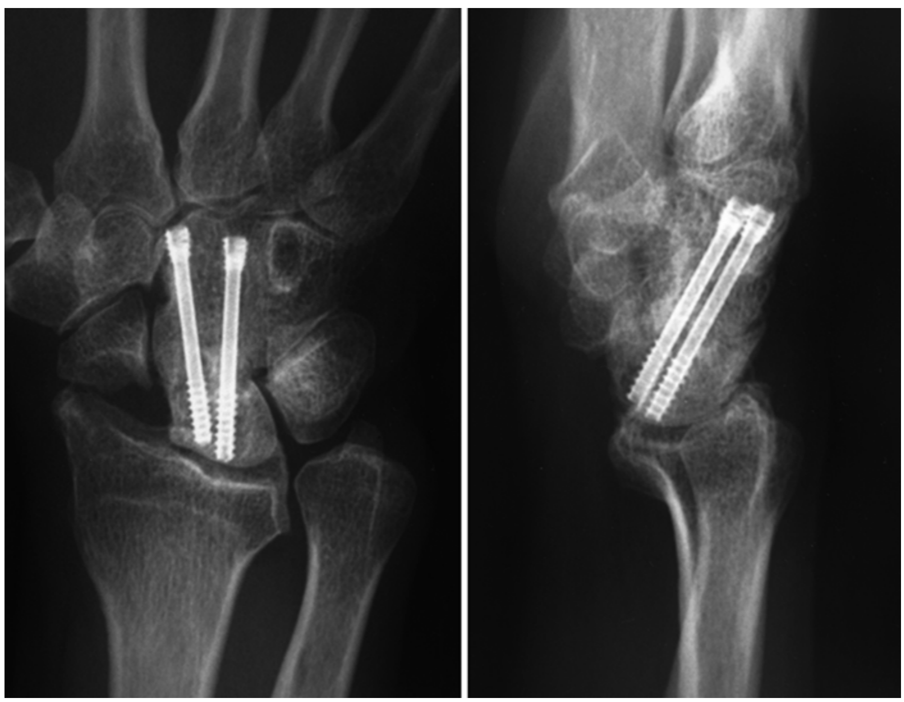


Fig. 17.36 A 55-year-old man with SLAC wrist stage III underwent arthroscopic scaphoidectomy and capitolunate fusion. X-ray at 12 months post-op showed solid fusion and good carpal alignment

excessive subchondral cancellous bone is being removed. Burring is completed when the subchondral bone with healthy punctate bleeding is reached. This phenomenon can be easily observed if tourniquet is not used during this process. Usually bleeding is limited and can easily be controlled with hydrostatic pressure applied through the irrigation system. If bleeding is profuse, one may use the coagulatory role of radiofrequency apparatus. Use of a tourniquet is optional depending on the degree of bleeding. During the burring process, suction can be switched on and off intermittently to remove any accumulated bone debris which may block the visual field. If suction is applied continuously during the burring process, excessive air bubbles drawn in will severely compromise the visibility of the operating site. The portals are then switched so that the burr is introduced from the 3/4 portal to have a better clearance of the articular cartilage of the proximal scaphoid and the scaphoid fossa including the radial styloid area.

After completion of the burring process, the hand is taken off the wrist traction tower and placed horizontally on the operating hand table. An image intensifier is moved in. Percutaneous K wires are inserted from distal radius to transfix the radiolunate and radioscaphoid joint (Fig. 17.40). A small longitudinal incision is made at the distal radius

Fig. 17.37 Clinically the patient got 35° extension and 40° flexion at the wrist. Operative scars were inconspicuous

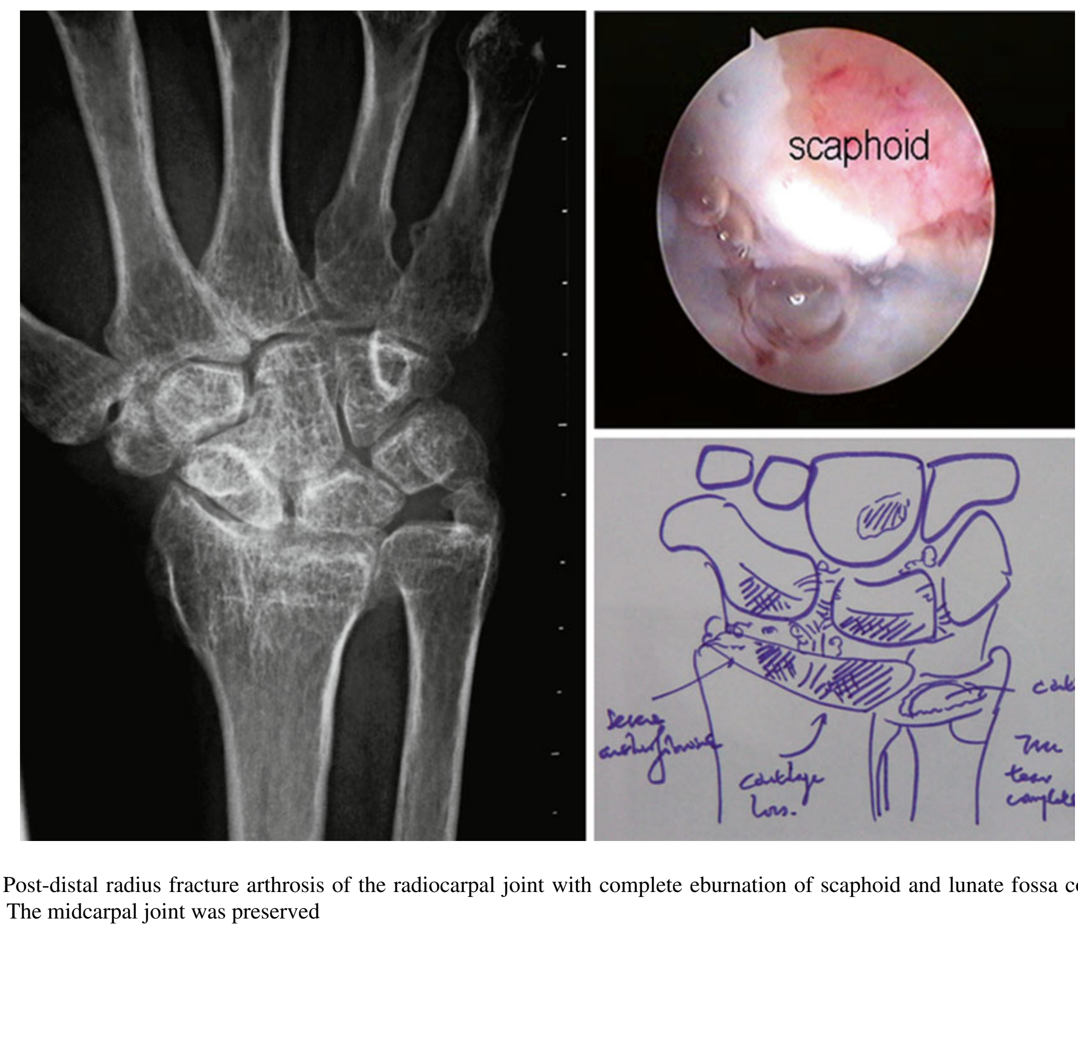


Fig. 17.38 Post-distal radius fracture arthrosis of the radiocarpal joint with complete eburnation of scaphoid and lunate fossa confirmed with arthroscopy. The midcarpal joint was preserved

Fig. 17.39 X-ray showing the extent of distal scaphoidectomy in patient receiving arthroscopic radioscapholunate fusion (*circle of dotted line*)

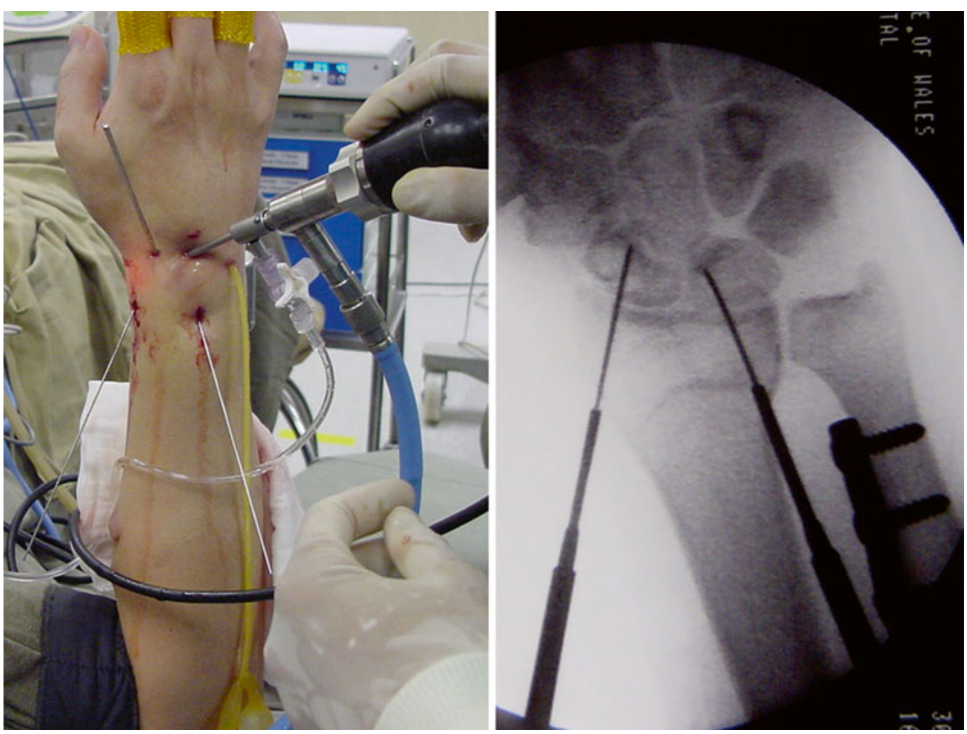


Fig. 17.40 Arthroscope being inserted into the radiocarpal joint after the two percutaneous K wires were back out from the joint

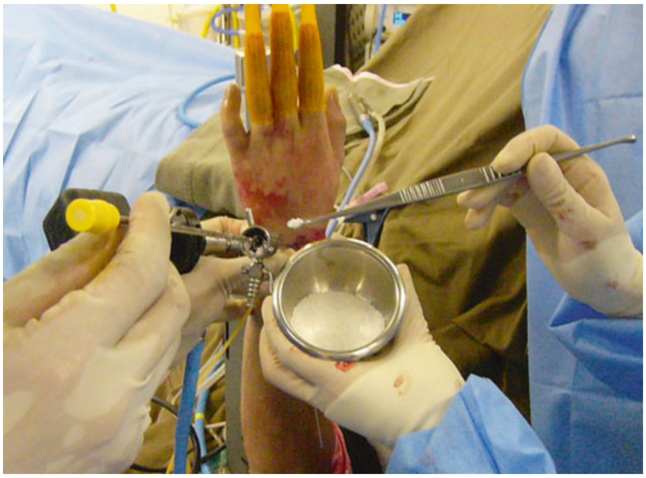


Fig. 17.41 Fine granules of artificial bone substitutes are being inserted into the radiocarpal joint space through a cannula before the definitive bony fixation

about 2 cm proximal to the midpoint between the 3/4 and 4/5 portal. This is corresponding to the direct articulation between radius and lunate. The extensor tendons are bluntly dissected off from the potential wire insertion point using a fine pointed stitch scissor. With the wrist placed in neutral position both in flexion-extension plane and radio-ulnar deviation plane, two 1.1 mm K wires are inserted using a protective sheath one after the other from distal radius to fix the lunate. If small cannulated screw is being used, the guide pin is inserted in the same manner. One or two guide pins are used according to the size of the carpal bone. The two wires should aim at the radial and ulnar border of the lunate so as to have even purchase of the bone. The radiolunate angle should be maintained at zero degree. This requires confirmation using both AP and lateral view of X-ray. On the lateral projection, the wire should target on the anterior horn of the lunate bone. To optimize the bone purchase, the angle of insertion of the K wire should be quite acute at 20–30° with reference to the long axis of the forearm. Another incision is made over the radial styloid at the bare area between the first and second extensor compartment. After careful blunt dissection of the superficial branches of radial nerve, the two K wires or guide wires are inserted in sequence to transfix the distal radius to the scaphoid. After verification of the wire position, they can be back out from the carpal bones while attaching to the distal radius. The protruded ends of the K wire are capped to avoid injury to the surgeon. The wrist is then put back to the wrist traction tower for the arthroscopic grafting procedure.

With arthroscope introduced at 4/5 portal, an arthroscopic cannula is inserted through 3/4 portal to reach the radial side of the scaphoid fossa. Autogenous bone graft or bone substitute can be inserted to fill up the radial side of the radio-scaphoid joint. As the fusion surfaces are usually well vascularized, I prefer the use of bone substitute to reduce

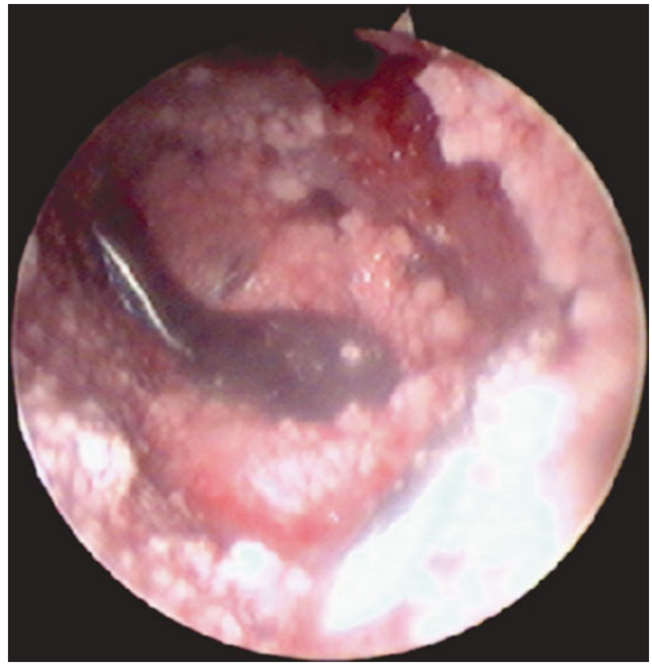


Fig. 17.42 Bone substitute granules are being impacted with a small impacter monitored through the arthroscope

donor site morbidity on the patient (Fig. 17.41). To achieve better vision on the operative field, the tourniquet is inflated at this junction to reduce bleeding inside the joint (Fig. 17.42). When the radio-scaphoid joint is half filled with bone substitute, the arthroscope is switched to 3/4 portal and the cannula is inserted at the 4/5 portal. Grafting process is continued at the radiolunate joint. To prevent spilling of the graft to the ulnocarpal compartment, a size 6 Foley catheter is inserted through the 6R portal and is inflated with saline so as to obliterate the space there.

When the grafting procedure is complete, the hand is again taken off the tower and tourniquet deflated. Under image guide, the K wires are driven back into the carpal bones just short of the articulating surface at the midcarpal joint. For posttraumatic arthritis in the younger patients, I prefer using percutaneous compression screws to enhance fusion rate. After measuring the length of the inserted portion of the K wires, the wire tracks are drilled with cannulated drill bit. Definitive fixation is performed with 3.0 mm cannulated screws with the head firmly anchored over the dorsal cortex of the distal radius. Alternatively a headless cannulated screw system can also be used (Figs. 17.43 and 17.44). X-ray is required to confirm that the thread of the screws should not perforate the midcarpal joint surface to impinge on the distal carpal row. This can also be verified arthroscopically. In osteopenic bone where screw purchase can be suboptimal, the 4 K wires can serve as the definitive mean of fixation (Figs. 17.45, 17.46, and 17.47). They are cut short and buried underneath skin. The wrist should be

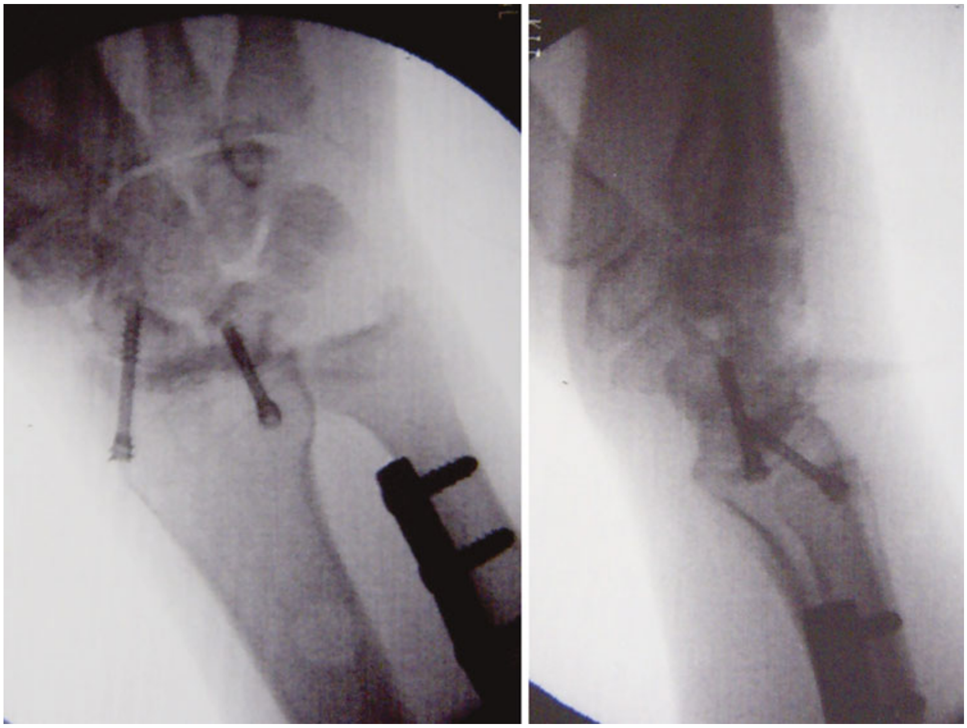


Fig. 17.43 Intra-op X-ray shows the final fixation of radioscapholunate intervals with two percutaneous AO screws. Noted that the ulnar shortening was performed before the indexed procedure

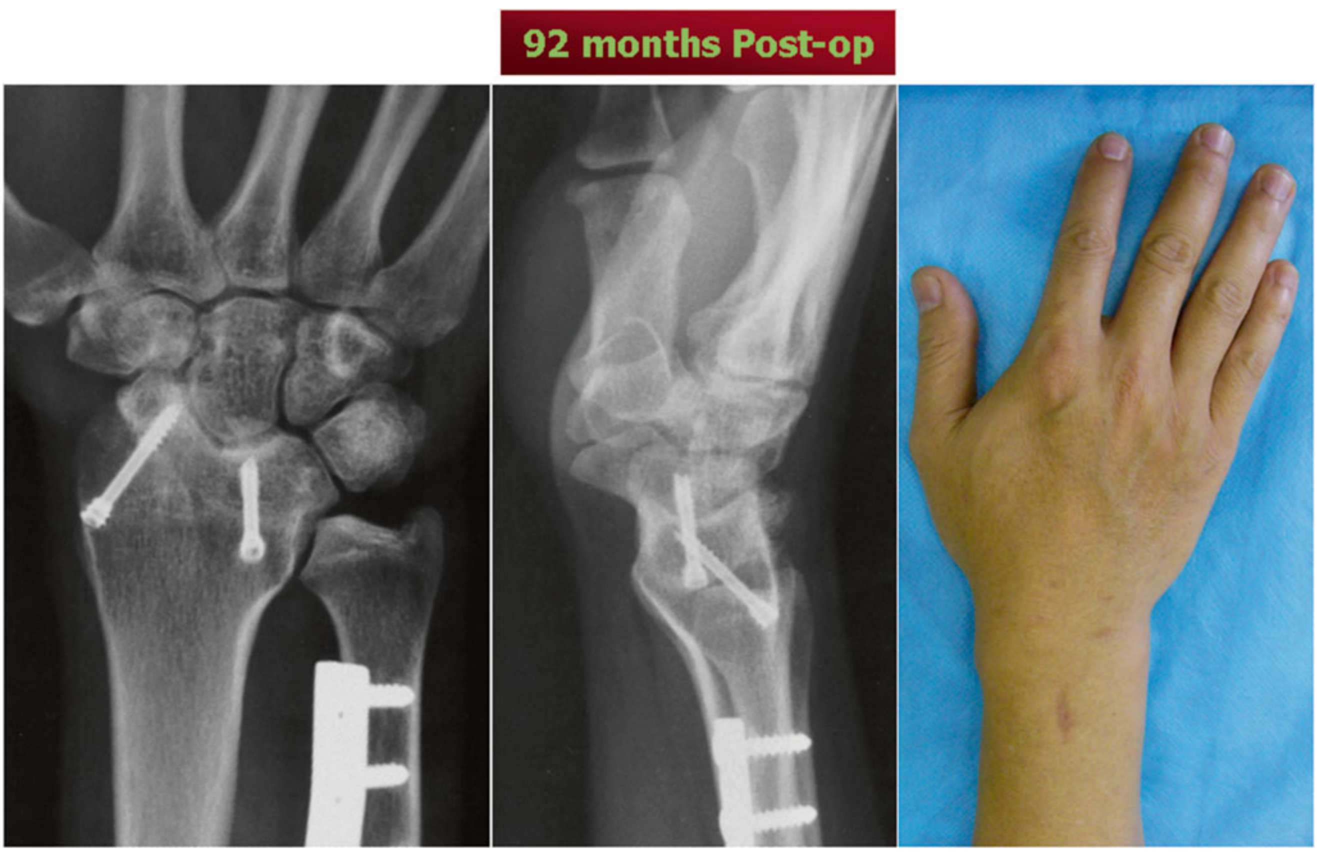


Fig. 17.44 Solid union of radioscapholunate fusion site at 92 months post-op. Surgical scar was minimal

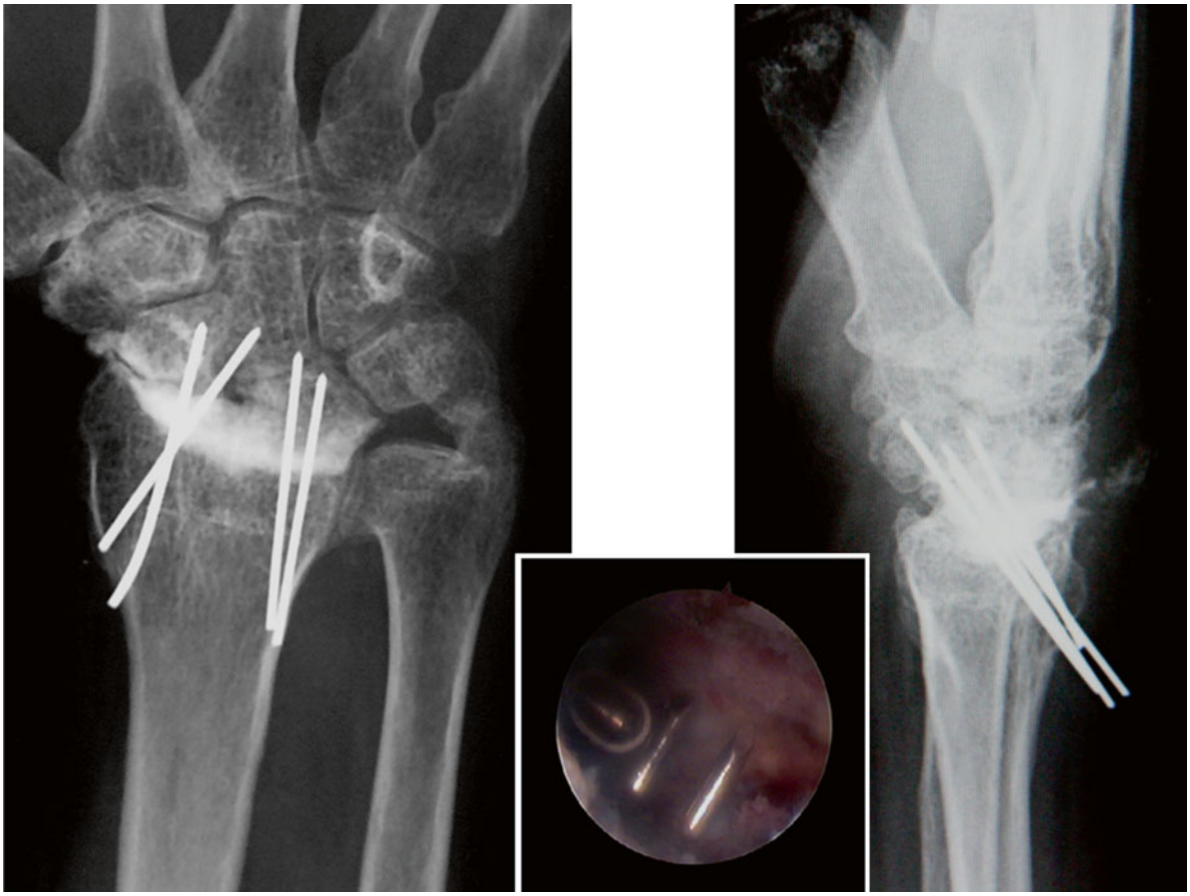


Fig. 17.45 A 51-year-old lady with posttraumatic radiocarpal joint arthrosis for 4 years. Arthroscopic radioscapholunate fusion with 4 K wires and bone substitutes was done. Position of K wires could be verified through arthroscopy at radiocarpal joint

moved gently to confirm the smooth articulation at the midcarpal joint and a stable fixation at the radiocarpal joint. The incision wounds are then opposed with steri-strips or simple stitches. Comfortable compression dressing with a short arm plaster slab is applied. It is changed to a removable wrist splint at 1–2 weeks of time. For K wire fixation cases, active mobilization of the wrist is initiated after the fusion is united radiologically and clinically. The K wires can be removed under local anesthesia through the original skin incisions. For compression screw fixation cases, gentle active wrist mobilization can be started at 2 weeks post-op under supervision. More vigorous mobilization can be performed when radiological and clinical union is achieved.

Radiolunate Fusion

Radiolunate fusion is most commonly utilized in rheumatoid arthritis where there is painful ulnar translocation of the carpus at the radiocarpal joint. In posttraumatic situation, it is indicated when the articular cartilage destruction is confined to the radiolunate joint, such as in post-distal radius die-punch fracture (Fig. 17.48).

The operation is essentially similar to radioscapholunate fusion, except that the radio-scaphoid joint is spared. In addition, distal scaphoidectomy is not necessary. Thus during the burring procedure, the articular surface of the proximal scaphoid and scaphoid fossa should be well protected. During the graft insertion procedure, a second Foley catheter can be inserted at the 1/2 portal to obliterate the space at the radio-scaphoid articulation so as to isolate the space at the RL joint (Fig. 17.49). The arthroscope is placed at the 3/4 portal while bone substitute is delivered to the radiolunate joint through a cannula at the 4/5 portal (Fig. 17.50). The fixation can be accomplished by two K wires or two compression cannulated screws inserted percutaneous from distal radius as described above (Figs. 17.51 and 17.52). In patient with significant ulnar positive variance, an accompanying ulnar shortening osteotomy is performed to unload the ulnocarpal joint as well as to avoid potential ulno-carpal impaction after the radiolunate fusion which may shorten the proximal carpal row. The post-op care and rehabilitation is same as radioscapholunate fusion as described above. However the period of immobilization may need to be extended due to the limited contact area between lunate fossa and proximal lunate. Postoperatively close radiological

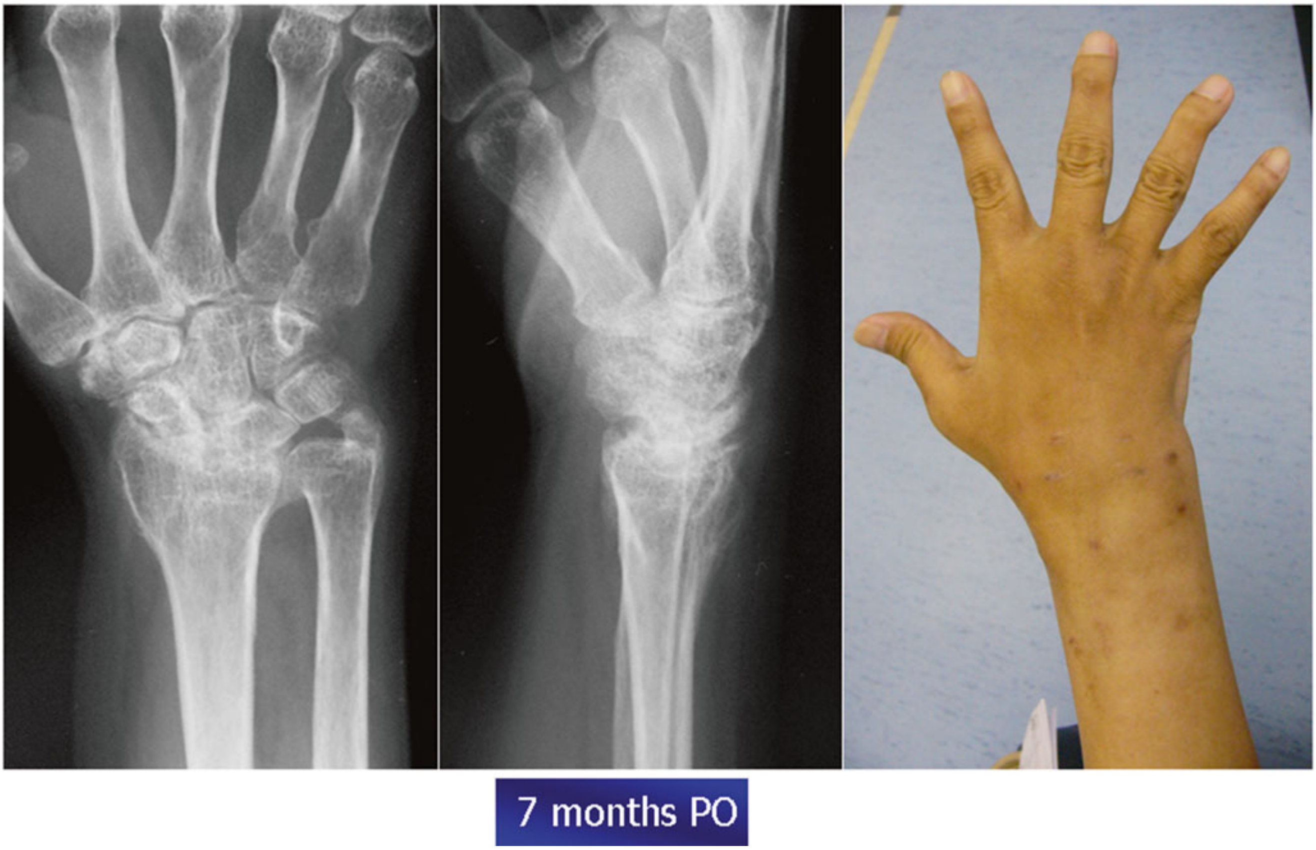


Fig. 17.46 X-ray at 7 months post-op shows good fusion; scars on patients are minimal

Fig. 17.47 Solid radioscapholunate fusion at 88 months post-op. There was also spontaneous luno-triquetral fusion. Midcarpal joint was preserved. Patient had no pain

Fig. 17.48 A 34-year-old man with severe painful post-distal radius fracture arthrosis at radiolunate joint

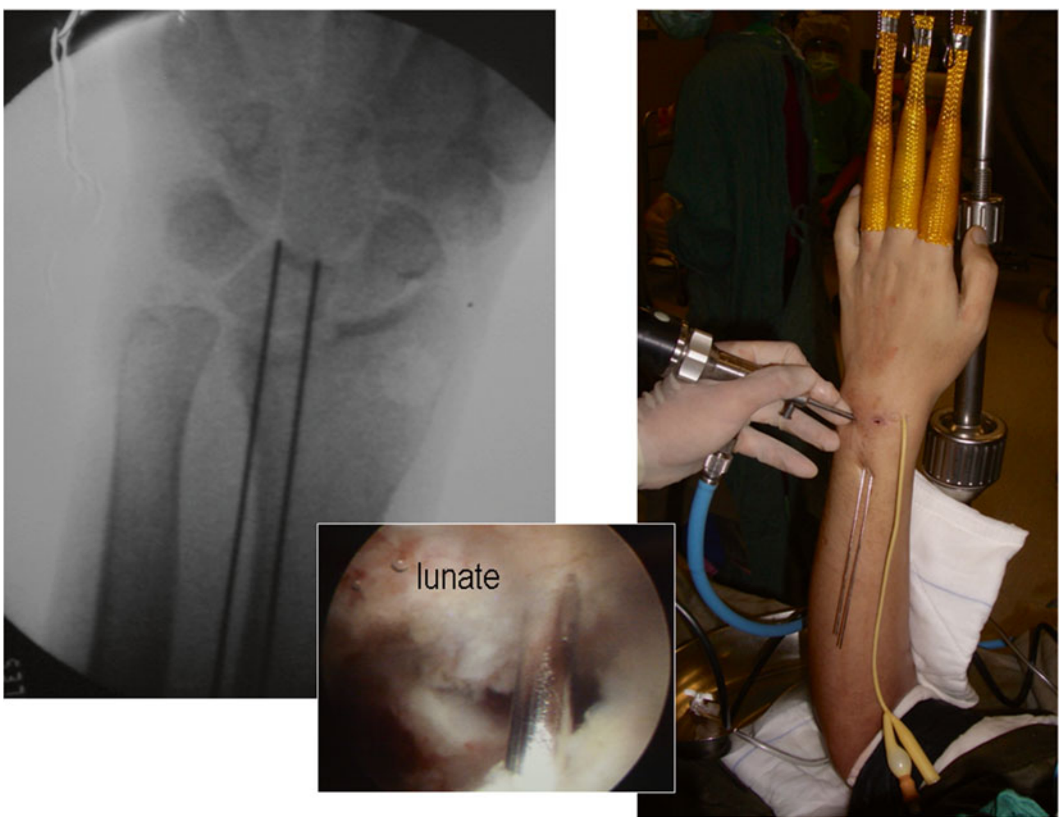


Fig. 17.49 Percutaneous pinning of the radiolunate joint under X-ray and arthroscopic guidance. A Foley catheter had been placed to obliterate the space at the radioscaphoid joint

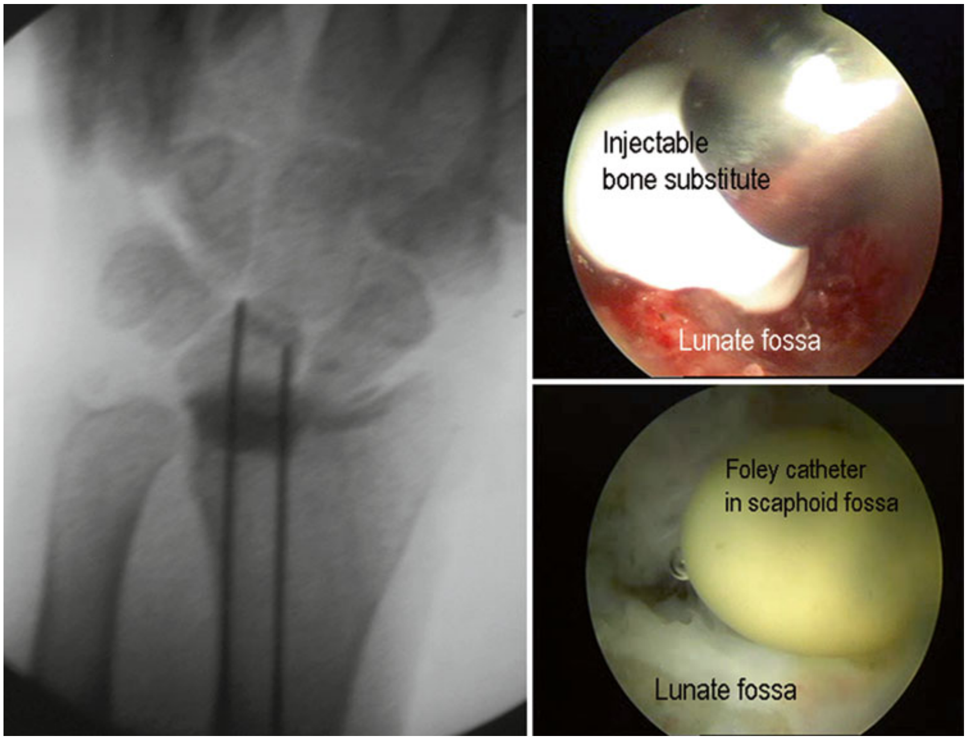


Fig. 17.50 Filling of radiolunate joint space with injectable bone substitute. Spilling of bone substitutes to adjacent space was blocked with inflated Foley catheter

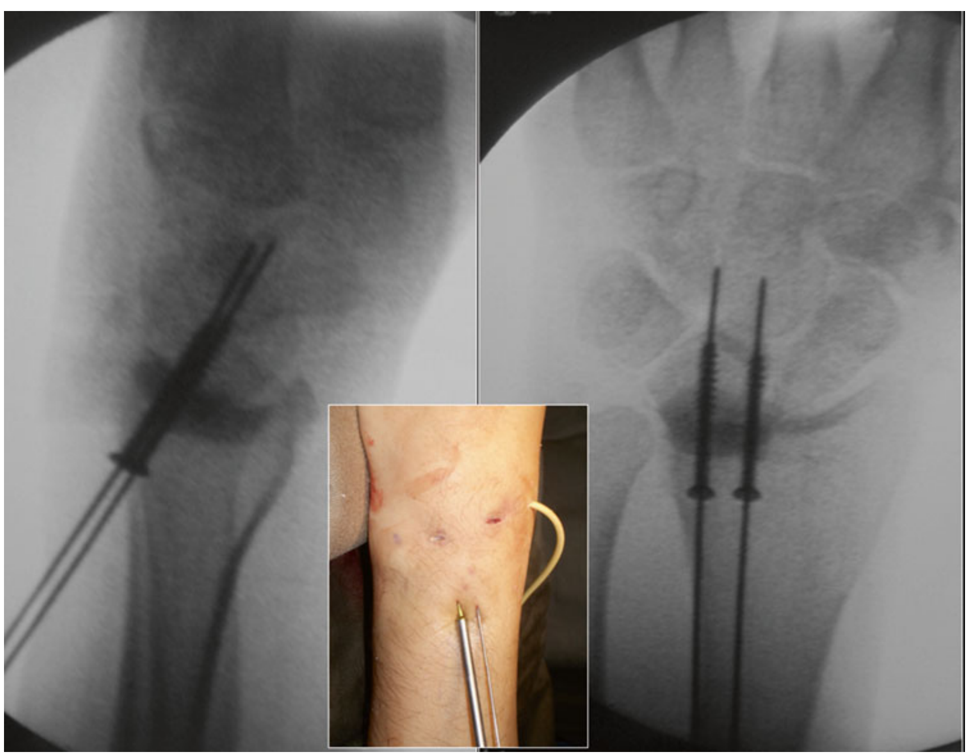


Fig. 17.51 Definitive fixation with two percutaneous AO screws at radiolunate joint

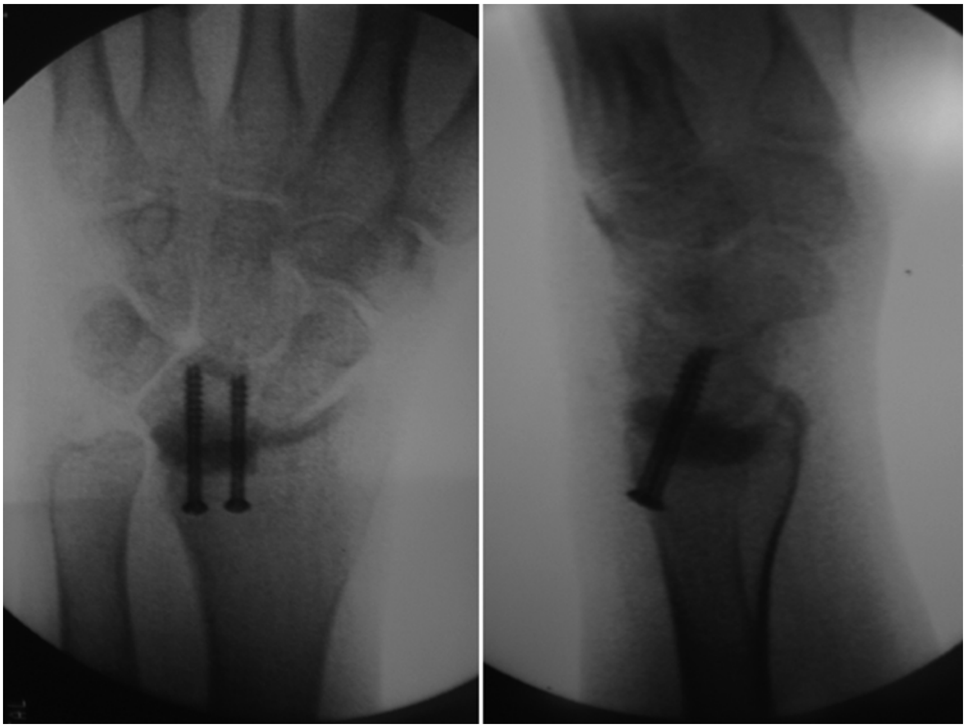


Fig. 17.52 Post-op X-ray appearance of the radiolunate fusion with good capitolunate alignment. Noted that the bone substitutes were well contained at the radiolunate joint

monitoring is essential to determine the pacing of rehabilitation (Figs. 17.53, 17.54, 17.55, 17.56, 17.57, 17.58, 17.59, and 17.60). The author favors the granule form of bone substitute rather than injectable form, though the latter is very convenient for administration through the arthroscopic cannula.

Lunotriquetral Fusion

Lunotriquetral (LT) fusion is indicated for symptomatic chronic LT instability with or without ulnocarpal impaction syndrome [28, 29]. In the latter condition, ulnar shortening osteotomy is often an accompanying procedure to decompress the ulnocarpal joint. In the absence of secondary chondral damage, an alternative option of LT ligament reconstruction can be considered, since failure to unite is common in surgical fusion of the LT joint, according to the literature. In a meta-analysis of the outcome of intercarpal arthrodesis conducted by Siegel et al., the overall reported nonunion rate in 81 patients out of a total of 143 cases of LT fusion by open surgery in seven clinical series was 26 % [6]. Where reported, 46 % of patients has persistent postoperative symptom. Sennwald et al. also found disappointing high rate of pseudarthrosis of 57 % in 23 patients receiving LT fusion [30]. In their open procedures from a dorso-ulnar approach, they recommended the routine use of cortico-cancellous bone graft to enhance union. They cautioned about prolonged rehabilitation with 6 months out of work at best and the significant loss of grip power particularly in male subjects, which might force them to change their job nature.

Arthroscopic fusion of the LT joint can be performed with midcarpal arthroscopic approach (Fig. 17.61). Routine radiocarpal joint arthroscopy is performed to evaluate the status of the TFCC, associated chondral lesions of the ulnar head, proximal lunate and triquetrum, and the LT ligament. If significant chondral lesion is present at the carpal bone surface, ulnar shortening or arthroscopic Wafer procedure should be done in association with the LT fusion procedure.

The arthroscope is then directed to the midcarpal joint. With the arthroscope placed at the MCR portal, a small probe is inserted at the MCU portal to reach the LT joint to confirm instability. This is then replaced by a 2.0 or 2.9 mm arthroscopic burr and debridement of the articular cartilage is performed from distal to proximal direction (Fig. 17.62). Attention should be paid at the dorsal aspect of the joint by rotating the 30° forward slanting lens to a downward position. Difficulty may be encountered in burring this portion as the angle of attack of the burr is frequently restricted by the dorsal soft tissue of the wrist. A small angled curette or ring curette may be useful in removing the cartilage at this area.

When burring is complete, provisional fixation of the LT interval is performed. A small wound is made opposing the ulnar surface of triquetrum and blunt dissection is performed

Fig. 17.53 A 53-year-old lady developed severe radiolunate arthrosis without history of trauma

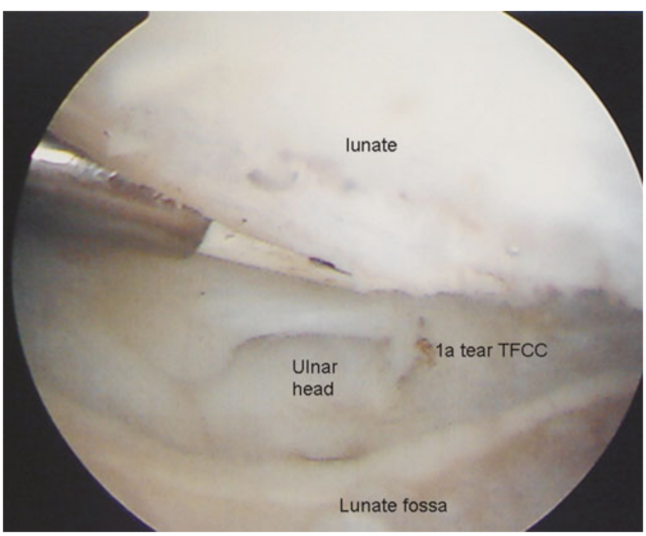


Fig. 17.54 Wrist arthroscopy shows complete eburnation of lunate fossa and proximal lunate, old 1a tear of TFCC with preserved ulnar head cartilage

to free the overlying terminal branch of the dorsal sensory branch of ulnar nerve. Under an image guide, a guide wire is inserted from the triquetrum across the LT joint to reach the lunate bone. The length of the guide wire is measured. Whenever feasible, two parallel guide pins are inserted to aim for two cannulated screws. If alignment is satisfactory, the guide pins are withdrawn from the lunate to free the joint space. The joint gap is then filled with bone graft or bone substitute through a cannula inserted at the MCU portal. The former is preferred as nonunion of the fusion site is notoriously common. This is then followed by percutaneous fixation with compression cannulated screws inserted from the ulnar aspect of the hand. A cannulated drill bit is applied and a compression headless and self-tapping cannulated screw is inserted to compress the fusion site (Fig. 17.63). Preferably two screws should be inserted to obtain maximal stability of the fusion site (Fig. 17.64). Alternatively, a K wire can be used to augment the strength of a single screw fixation if the

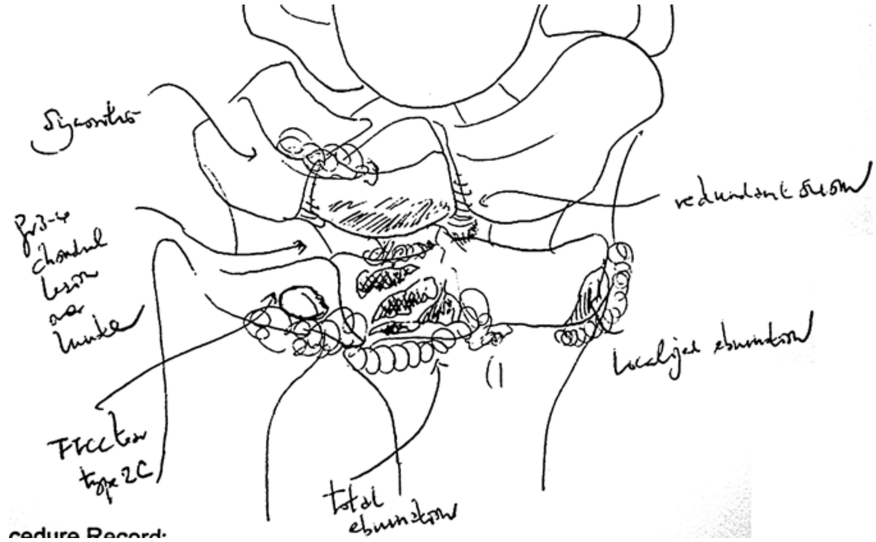


Fig. 17.55 Operative diagram depicts extent of joint pathology. There is associated small osteochondral lesion over scaphoid fossa. The midcarpal joint is normal

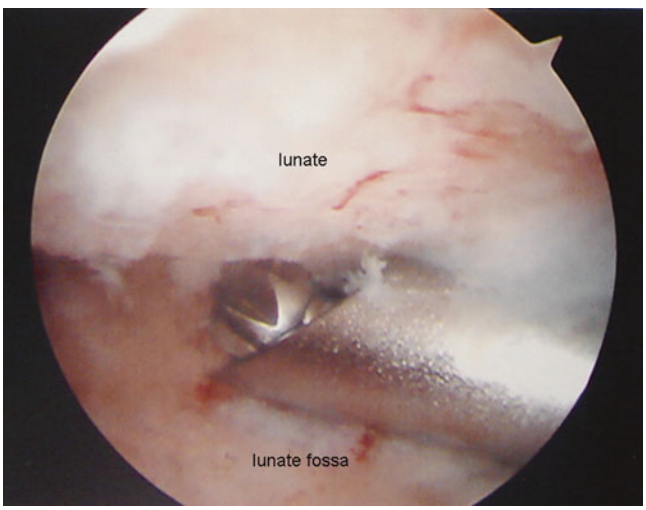


Fig. 17.56 Without tourniquet on, burring of proximal lunate revealed good subchondral punctate bleeding

bone is too small to accommodate two screws. All wounds are closed with steri-strips and a short arm plaster is applied to protect the fusion site until radiological union or stable fibrous union is achieved (Fig. 17.65).

Scaphocapitate Fusion

Scaphocapitate (SC) fusion is indicated in advanced Kienbock disease as a salvage solution [31]. It is best indicated when the lunate has collapsed and the articular surfaces become fragmented, such as in Lichtman stage IIIa or IIIb situation (Figs. 17.66 and 17.67). I routinely removed the lunate since an ischemic bone can be a source of pain in the patient.

Routine surveillance of the radio-carpal joint is required to confirm an intact radio-scaphoid articulation and the damaged articular cartilage of the lunate. When there is a fixed DISI deformity, the radial volar ligament and capsule can be released with the aid of shaver or radiofrequency apparatus to improve the scaphoid extension. Arthroscopic lunate excision is then performed from the midcarpal joint. With the arthroscope introduced from MCR portal, an arthroscopic burr of 2.9 mm is inserted into MCU portal and directed towards the distal surface of the lunate. The lunate is burred at high speed from articular surface down to the core cancellous bone. Bone debris is removed by intermittently applied suction. To avoid accidental damage of the adjacent articular surfaces to be preserved, a shell of cartilage can be left intact until majority of the cancellous bone is removed. This shell of cartilage can help to separate the burr from the adjacent carpal bone during the burring process. This can be removed piecemeal at the end of the lunate excision procedure by using a small pituitary rongeur or an arthroscopic punch. In order to speed up the process, arthroscopic burr of progressive increase in size such as 3.5 mm and even 4.5 mm can be used when there is more space open up after part of the lunate is removed.

Once the lunate is cleared, attention can be paid to the fusion of the scaphocapitate joint. The arthroscope is now inserted through MCU portal while the MCR portal is reserved for arthroscopic instruments. The articular surface between the scaphoid and capitate is denuded of cartilage with 2.9 mm burr with the principle as described before. The articular cartilage at the STT joint area should remain intact.

The wrist is taken off from the wrist tower. A small stab wound is being made at the anatomical snuff box area.

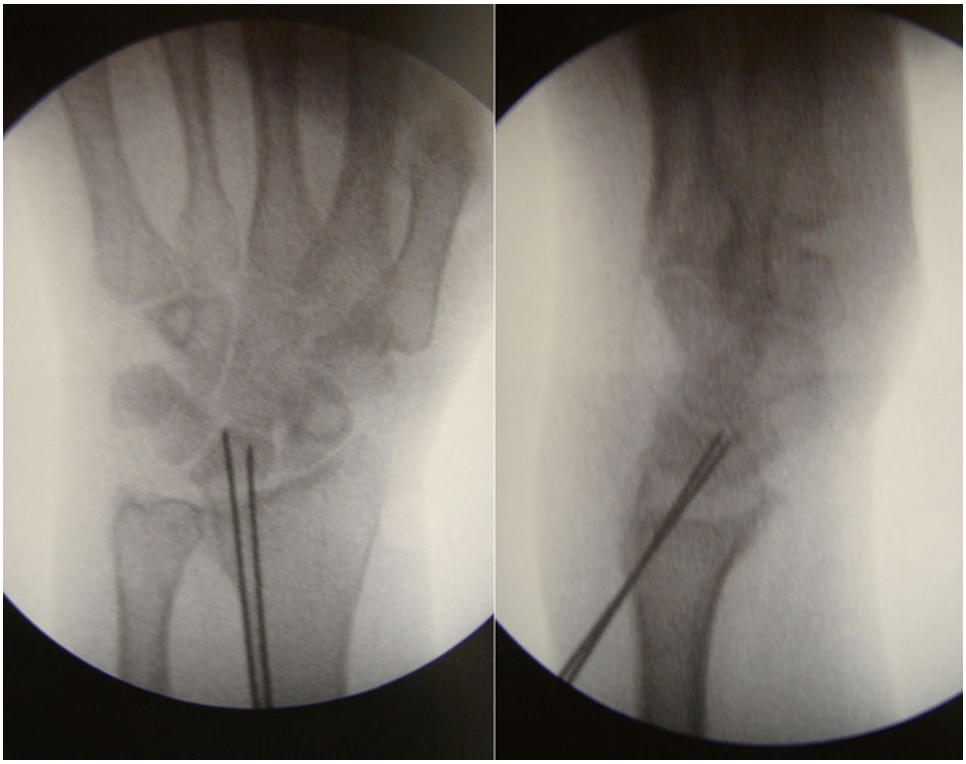


Fig. 17.57 Intraoperative fluoroscopy shows good position of the guide pins across the radiolunate joint

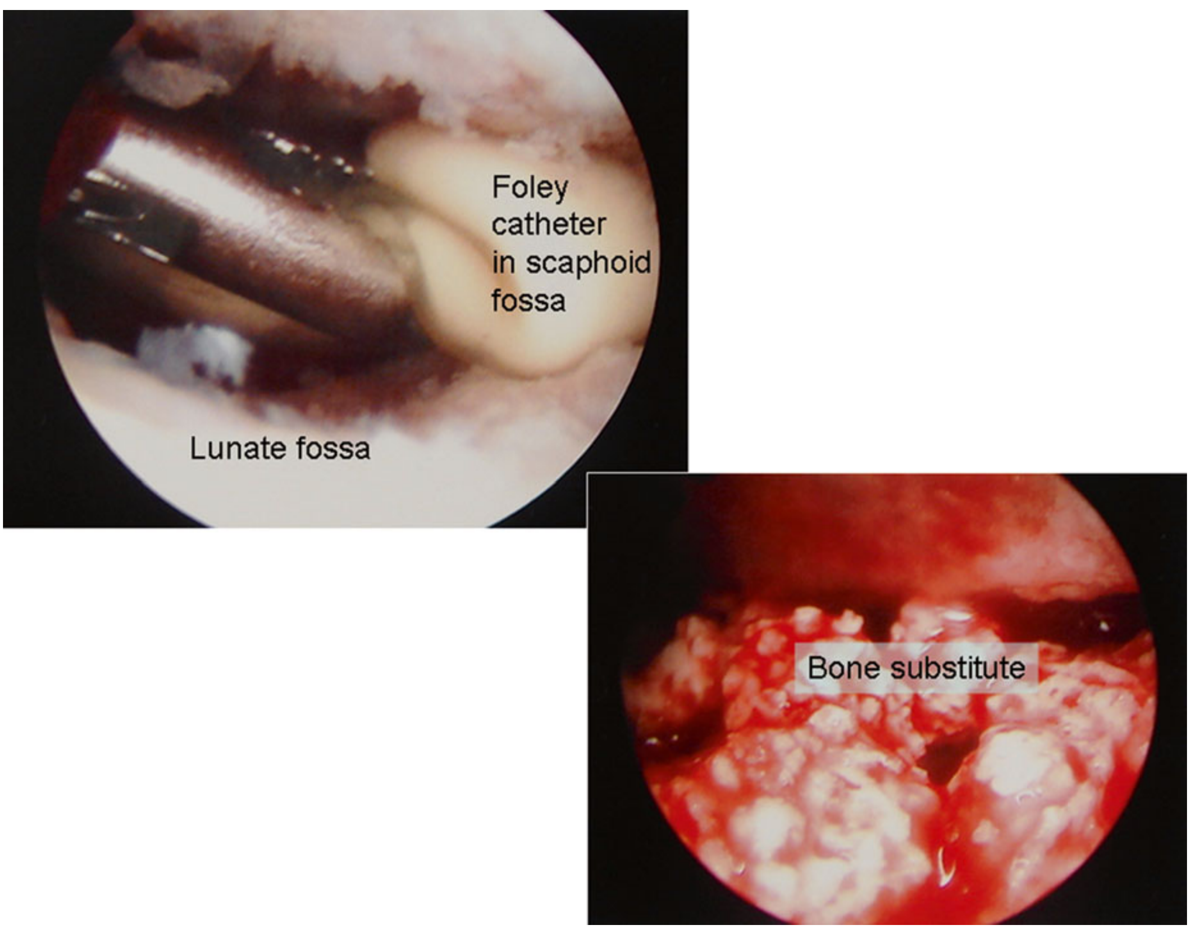


Fig. 17.58 Arthroscopic view showing position of Foley catheter at the scaphoid fossa and granule form of bone substitute at radiolunate joint space

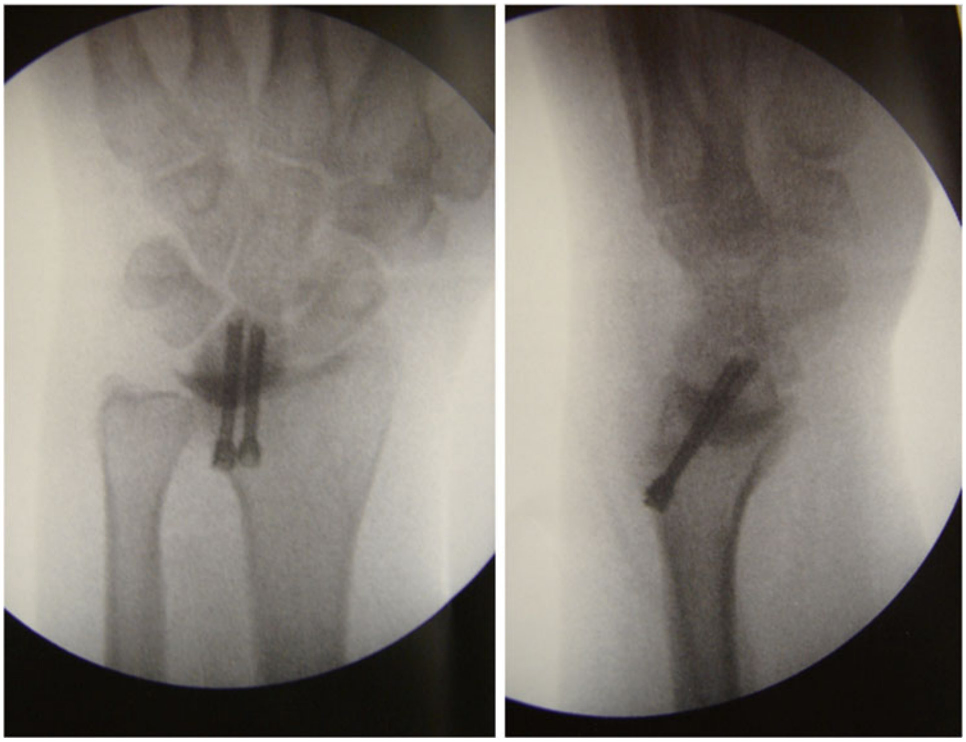


Fig. 17.59 Final definitive fixation of radiolunate joint with two percutaneous bold screws. Noted that both radioscaphoid and ulno-carpal joint were free of bone substitute due to blockage by Foley catheter

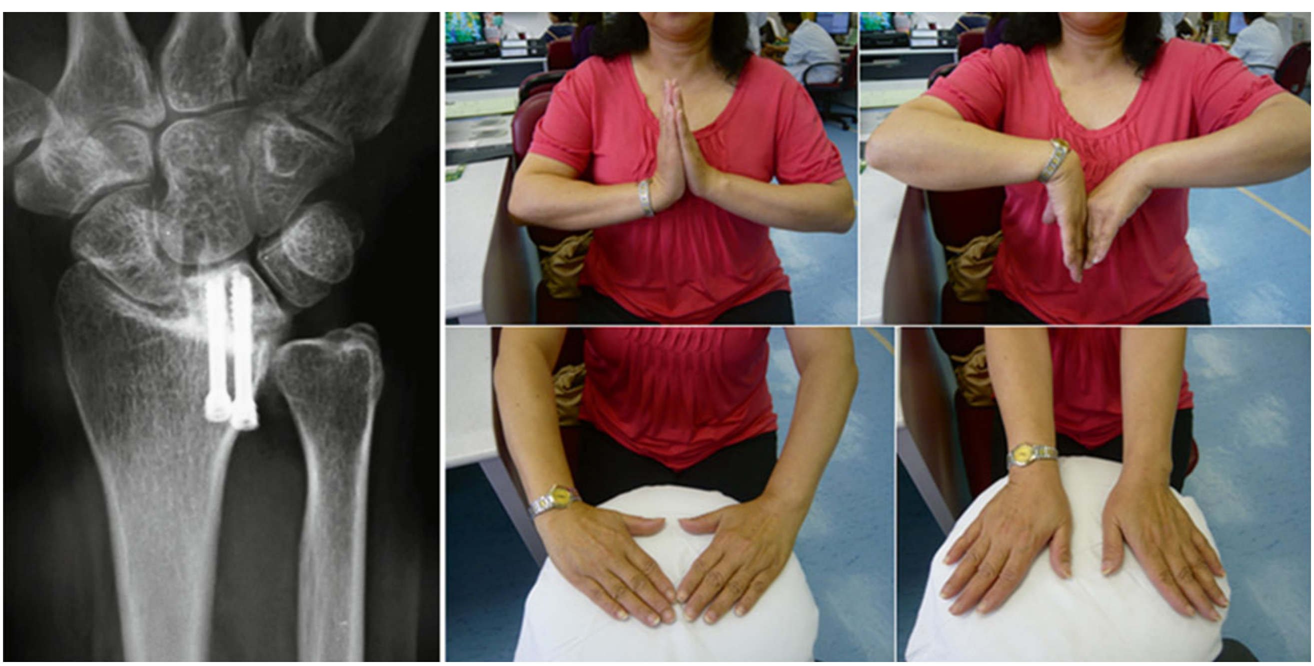


Fig. 17.60 Solid bone union at 6 months post-op and clinical range of motion of the left wrist. Patient was pain free and returned to normal duty as office assistant

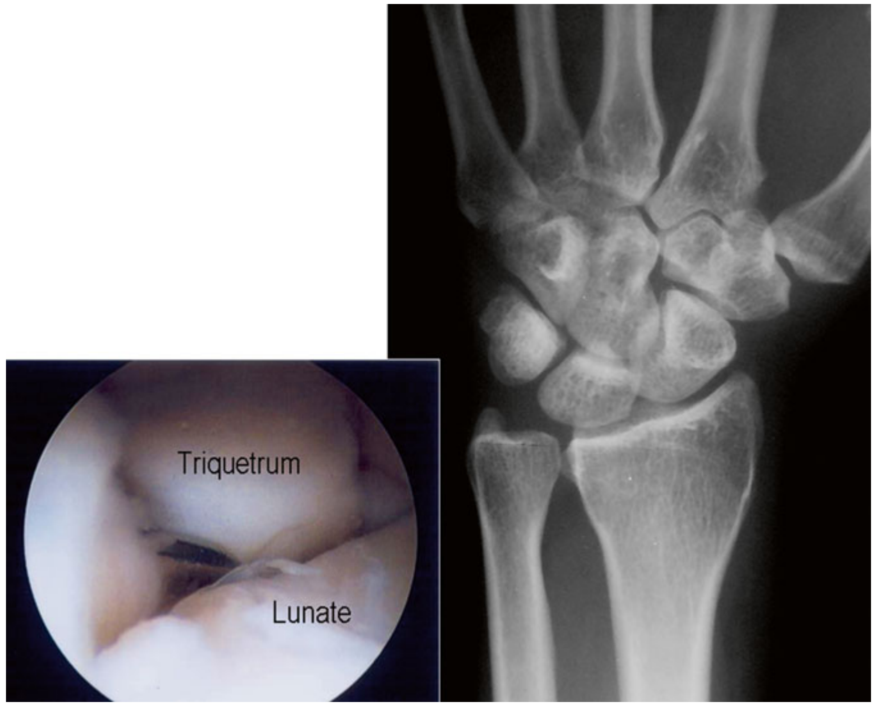


Fig. 17.61 Patient with chronic ulnar wrist pain for 2 years. X-ray reviewed an increased luno-triquetral interval. Arthroscopy confirmed Geissler grade 3 luno-triquetral instability

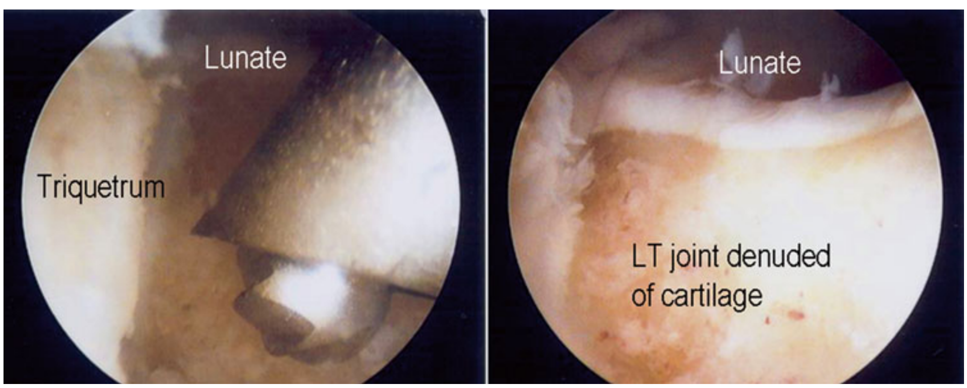


Fig. 17.62 Burring of the luno-triquetral joint before fusion

The mini-stab wound should be bluntly dissected to avoid iatrogenic injury to the radial artery and terminal branches of the radial nerve until the bony cortex of scaphoid is reached. With the help of an antero-posterior and lateral projection under an image intensifier, two guide wires of a small cannulated screw system with adequate space in between are being inserted and driven across the scaphoid towards capitate. To avoid injury to the vessel, the guide pins can be inserted through a metal sheath of a 14G angiocatheter serving as a guide.

In SC fusion, the articular congruency achieved between the scaphoid and the capitate is typically good. The use of bone graft or substitute is optional. Conversion of the K wire fixation with cannulated screws is then followed as described (Fig. 17.68). Stability and range of motion of the wrist can be checked under fluoroscopic guidance.

Wounds are then closed with steri-strips and a comfortable bulky dressing is applied supported with a short arm plaster slab. The slab is changed to a removable wrist splint after the first week, when gentle active mobilization of the wrist can be initiated out of splint under the supervision of a hand therapist (Fig. 17.69). Passive wrist mobilization and strengthening exercise can be offered when radiological and clinical union is evidenced, usually around 8–10 weeks post-op (Figs. 17.70 and 17.71).

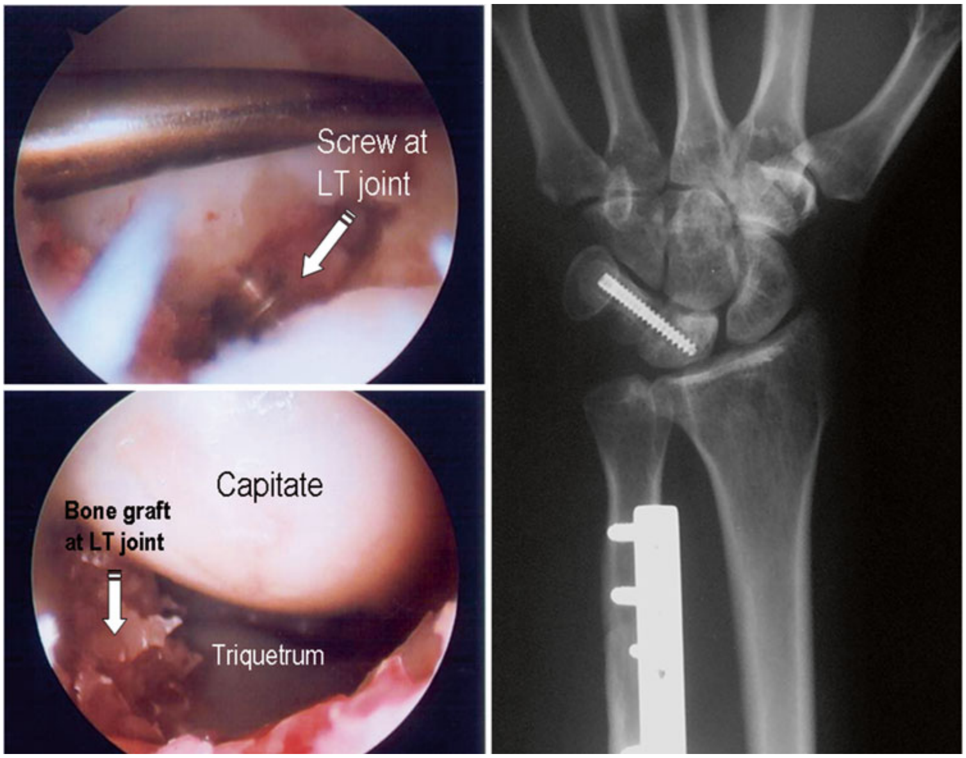


Fig. 17.63 Arthroscopic view of the screw in the luno-triquetral joint, which is eventually covered with arthroscopic bone graft. X-ray shows good fusion position

Fig. 17.64 Another patient with complete LT dissociation treated with arthroscopic LT fusion using two compression screws

Fig. 17.65 Minimal scarring over surgical wounds

Outcome and Complications

From November 1997 to October 2011, we had performed arthroscopic partial wrist fusion in 23 patients, including 19 male and 4 female. The indications were SLAC wrist in six, SNAC wrist in five, chronic LT instability in two, Kienbock disease in three, posttraumatic arthrosis in five, and inflammatory arthritis in two. The average duration of symptom was 34.2 months (range 9–82 months). These procedures included STT fusion in three, scaphoidectomy plus four corners fusion in five, scaphoidectomy plus capitolunate fusion in four, lunatectomy plus scaphocapitate fusion in three, radioscapholunate fusion in four, radiolunate fusion in two, and luno-triquetral fusion in two. The average age of the patients at time of surgery was 42 (range 18–68 years old). Concomitant arthroscopic procedures were performed in four patients and they included radial styloidectomy, TFCC reconstruction with palmaris longus graft, Wafer procedure, and endoscopic carpal tunnel release. Autogenous bone graft was used in nine patients while bone substitute was employed in another nine patients. Radiological union of the fusion site

Fig. 17.66 A 22-year-old male semiprofessional tennis player with right dominant wrist Kienbock disease stage 3b for 5 years

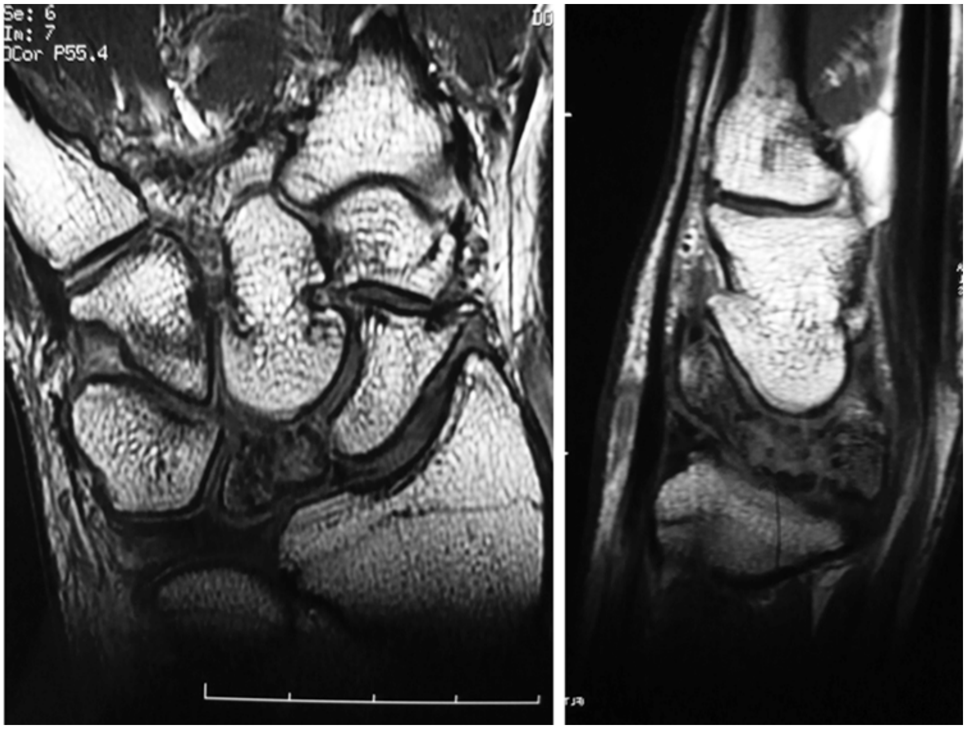


Fig. 17.67 MRI images of the right wrist show severe avascular necrosis and complete fragmentation collapse of the lunate

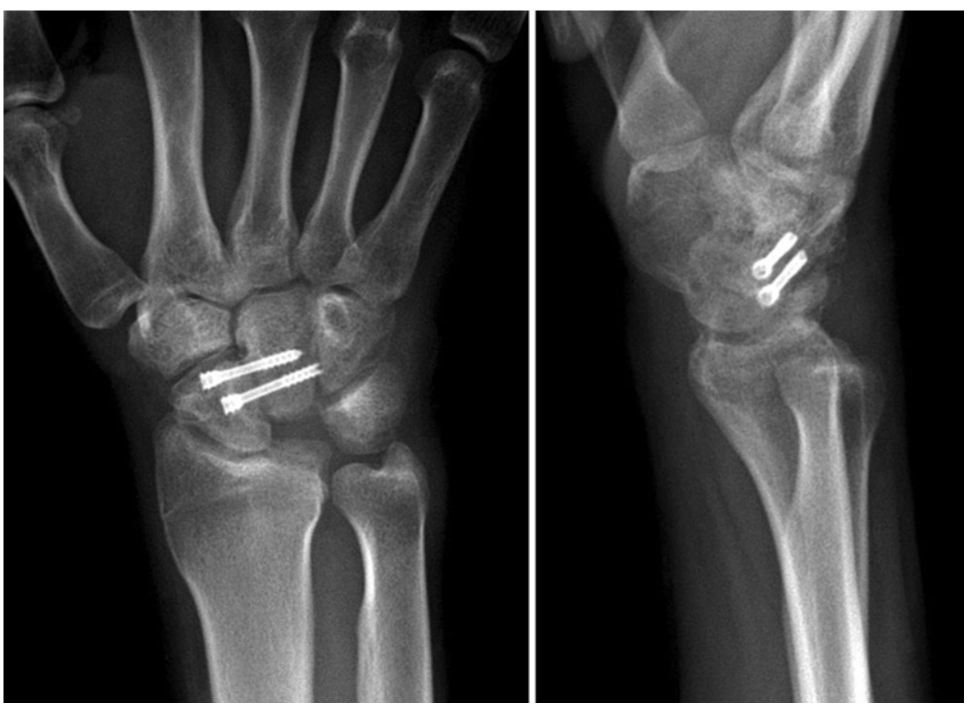


Fig. 17.68 The patient underwent arthroscopic lunate excision and scaphocapitate fusion with two headless cannulated screws augmented with injectable demineralized bone matrix at the fusion interface

was obtained in 19 cases, stable asymptomatic fibrous union in three cases, and definite nonunion requiring revision in one case. Break down of union rate according to the surgical types is shown in Table 17.1.

The median time of radiological union in the united cases was 10 weeks (range 5–50 weeks). The average follow-up time was 59.9 months (range 11–112 months). The three cases of fibrous union remained asymptomatic and no further surgery or treatment was required. It was notable that both cases of LT fusion ended up in fibrous union. Among the bony union cases, three patients had continuing pain and required further treatment including wrist fusion in two and Amandy interposition arthroplasty in one patient. Two patients required a combined anterior and posterior interosseous nerve neurectomy as secondary procedure for complete pain relief. At final follow-up, all except one patient had no pain or minimal residual pain (Figs. 17.72 and 17.73). The case of RL fusion using percutaneous screw fixation and injectable bone substitute failed to heal in 9 months despite optimal internal fixation and was revised successfully with open RL fusion using iliac crest block bone graft and plating. Intraoperatively marked osteolysis was noted at the fusion site though no evidence of infection was obtained. The final outcome was excellent (Figs. 17.74, 17.75, 17.76, 17.77, and 17.78). All arthroscopic surgical scars were almost invisible at the final follow-up and all patients were satisfied with the clinical result.

Fig. 17.69 Right wrist condition at 2 weeks post-op showing minimal swelling and scars

Complications in our small series of 23 patients were limited. Early complication included two cases of pin tract infection which responded to dressing, antibiotic, and early pin removal. There was one case of superficial second degree skin burn due to the use of a high speed burr without a good protective sheath, and one case of delayed union of the radioscapholunate fusion which required 50 weeks to complete the radiological union. One old and osteoporotic patient required removal of the screws at 8 months postoperation due to protrusion of screw threads at the proximal lunate articular surface.

Technically there are potential drawbacks of arthroscopic approach compared to the conventional open techniques. Use of additional bone graft or bone substitute to augment

Fig. 17.70 Solid fusion and excellent aesthetic result at 11 months post-op

Fig. 17.71 Patient retained 45° extension and 55° flexion at the wrist. He resumed competitive tennis sport activities at 6 months post-op

Table 17.1 Break down of union rate according to the surgical types

	Bony union	Fibrous union	Nonunion
STT fusion	2	1	
LT fusion		2	
Scaphoidectomy + four corners fusion	5		
Scaphoidectomy + CL fusion	4		
Lunatectomy + SC fusion	3		
RSL fusion	4		
RL fusion	1		1
Total	19	3	1

Fig. 17.72 A 22-year-old man with 34 months history of chronic SL dissociation. Arthroscopic STT joint fusion was performed on 24.11.1997. Solid radiological union on X-ray and CT scan was seen 24 months post-op

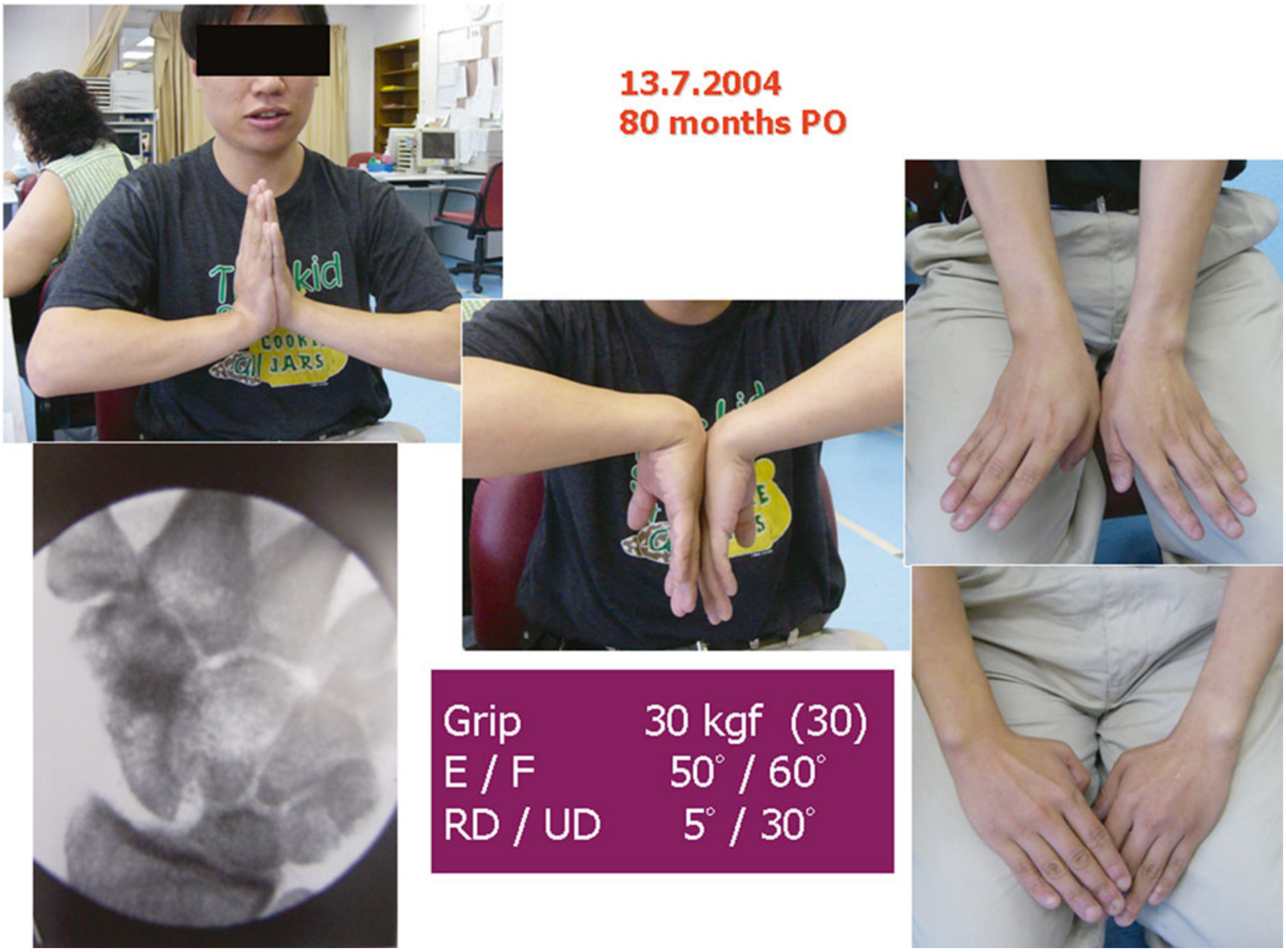


Fig. 17.73 Excellent clinical and radiological outcome at 80 months post-op

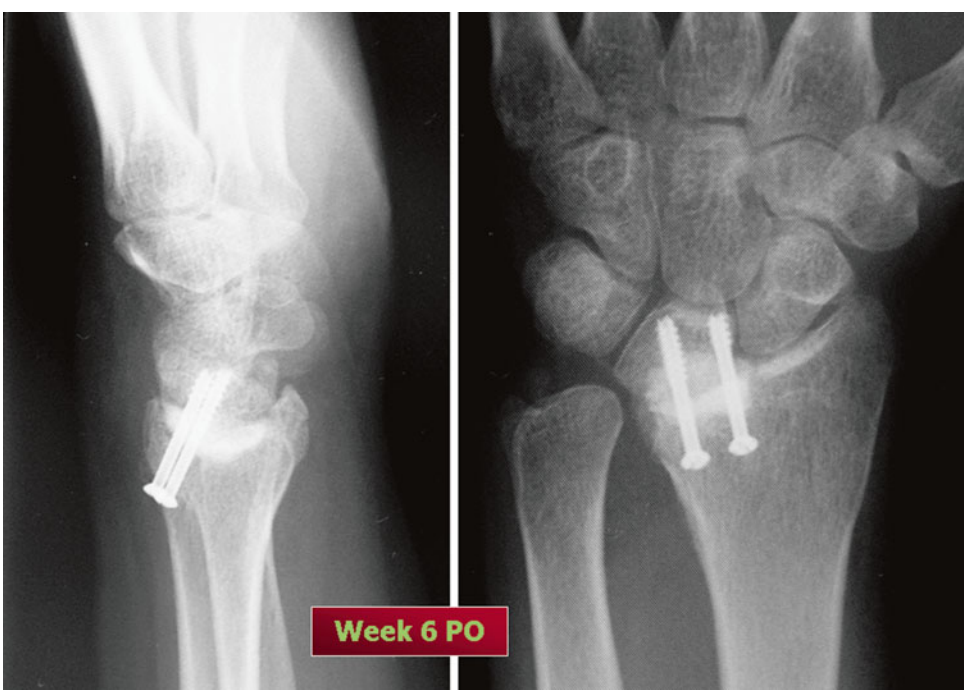


Fig. 17.74 A 31-year-old man with post-distal radius fracture radiolunate arthrosis. Good alignment and fixation of the arthroscopic radiolunate fusion at 6 weeks post-op was shown

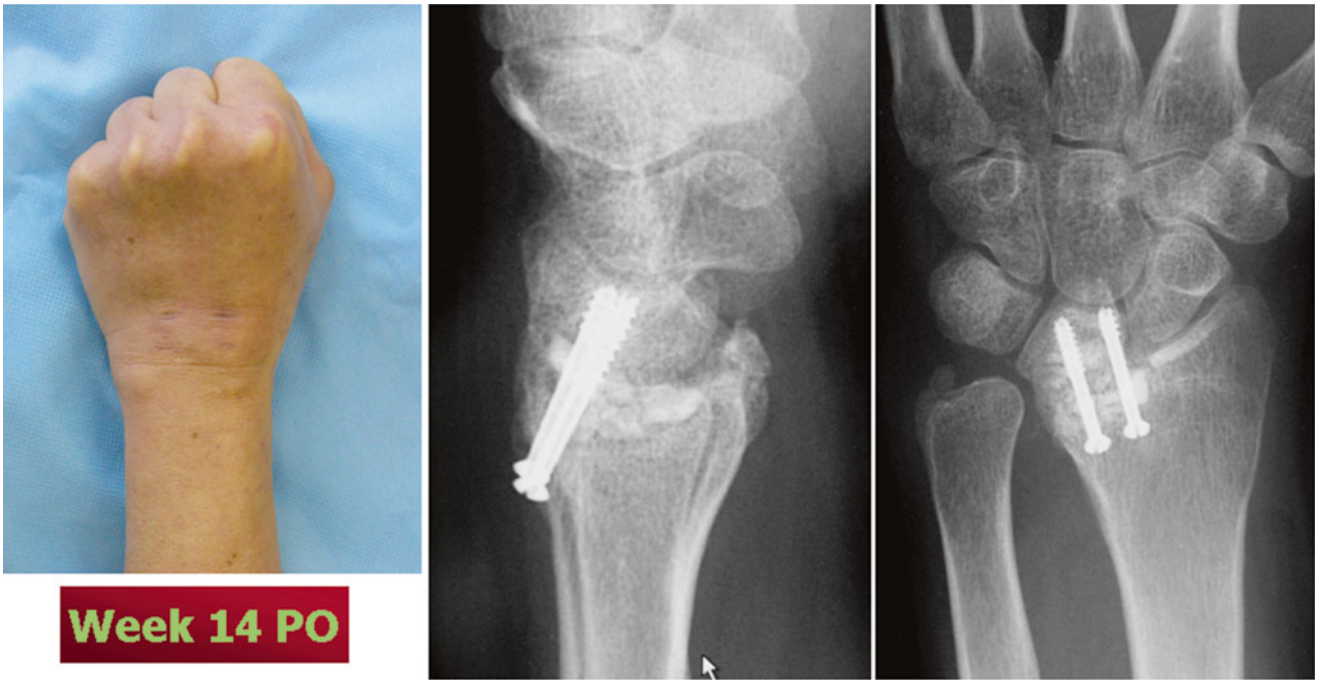


Fig. 17.75 Evidence of early osteolysis of fusion site at 14 weeks post-op

Fig. 17.76 Definite nonunion at 9 months post-op as shown by X-ray and CT scan

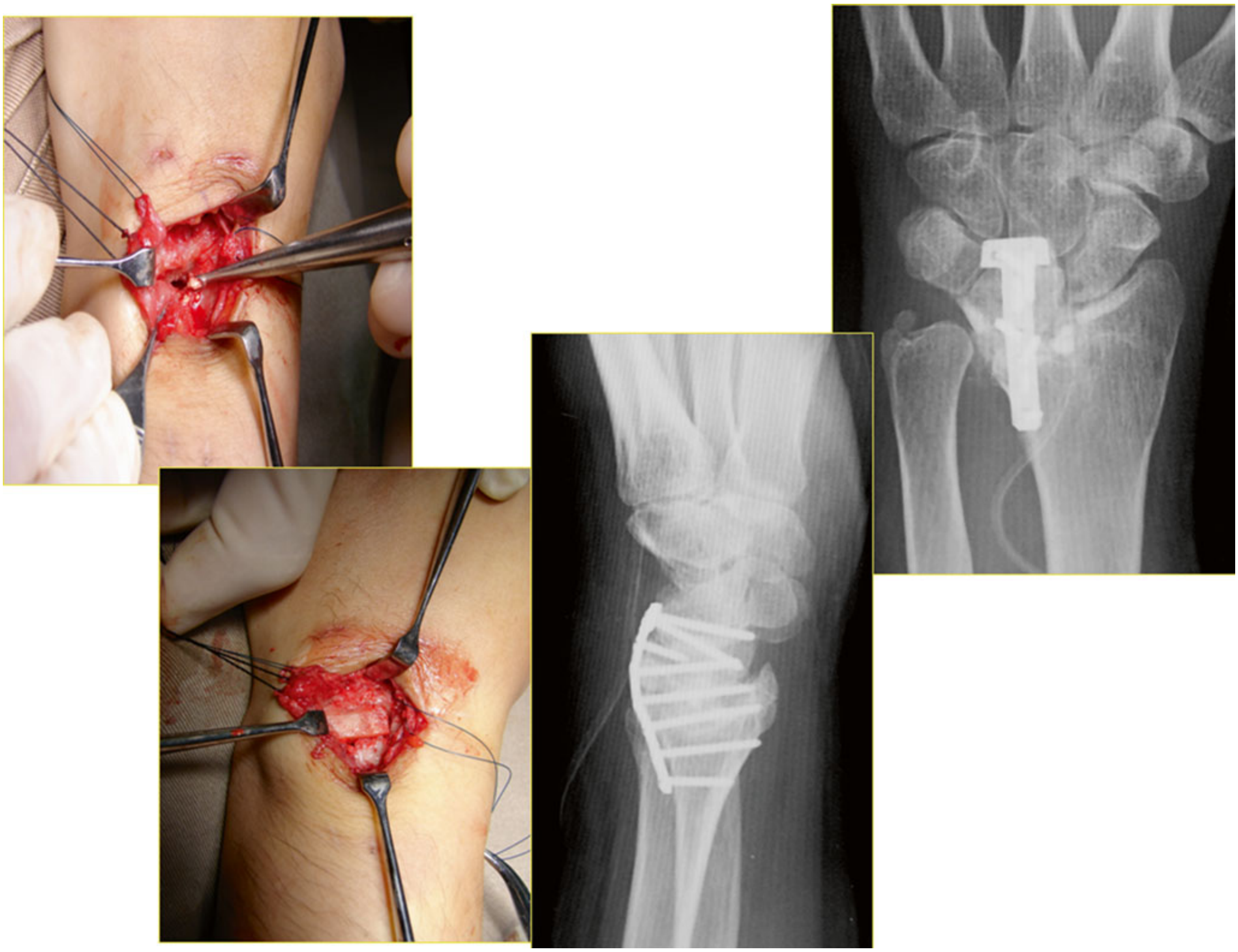


Fig. 17.77 Aseptic nonunion confirmed at revision operation with fusion converted to open iliac crest block bone grafting and plating

Fig. 17.78 Final X-ray at 8.5 years post-op showing no ongoing arthrosis of the wrist

fusion may become mandatory in some cases due to inability to recycle the excised carpal bone as bone graft in situations such as concomitant scaphoidectomy. The small surgical access also limits the choice of use of implant for fixation. K wire or cannulated screw becomes the usual armamentarium. It can be technically demanding and time consuming for those less experienced with small joint arthroscopy. Our average operating time was 185 min. Efficiency of current commercially available instruments can also be one of the limiting factors on the speed of the operation.

In conclusion, arthroscopic partial wrist fusion is a viable option for patients suffering from posttraumatic or nonprogressive wrist arthritis who would like to preserve useful wrist motion with good aesthetic outcome. Union rate is high and complication uncommon. However, it is a technically demanding procedure with steep learning curve. Proper training in small joint arthroscopy and further improvement in design and efficacy of the arthroscopic instruments will be helpful in popularizing the technique.

References

1. Krimmer H, Wiemer P, Kalb K. Comparative outcome assessment of the wrist joint-mediocarpal partial arthrodesis and total arthrodesis. Handchir Mikrochir Plast Chir. 2000;32:369–74.
2. Peterson HA, Lipscomb PR. Intercarpal arthrodesis. Arch Surg. 1967;95:127–34.
3. Hasting DE, Silver RL. Intercarpal arthrodesis in the management of chronic carpal instability after trauma. J Hand Surg Am. 1984; 9:834–40.
4. Minami A, Kato H, Iwasaki N. Limited wrist fusions: comparison of results 22 and 89 months after surgery. J Hand Surg Am. 1999;24:133–7.
5. Tomaino M. Intercarpal fusion for the treatment of scaphoid nonunion. Hand Clin. 2001;17(4):671–86.
6. Siegel LM, Ruby LK. A critical look at intercarpal arthrodesis: review of literature. J Hand Surg Am. 1996;21:717–23.
7. Douglas DP, Peimer CA, Koniuch MP. Motion of the wrist after simulated limited intercarpal arthrodesis: an experimental study. J Bone Joint Surg Am. 1987;69:1413–8.
8. Garcia-Elias M, Cooney WP, An KN. Wrist kinematics after limited intercarpal arthrodesis. J Hand Surg Am. 1989;14A:791–9.
9. Iwasaki N, Genda E, Barrance PJ, et al. Biomechanical analysis of limited intercarpal fusion for the treatment of Kienbock's disease: a three-dimensional theoretical study. J Orthop Res. 1998;16(2):256–63.
10. Kobza PE, Budoff JE, Yeh ML. Management of the scaphoid during four-corner fusion—a cadaveric study. J Hand Surg Am. 2003; 28(6):904–9.
11. Middleton A, MacGregor D, Compson JP. An anatomical database of carpal bone measurements for intercarpal arthrodesis. J Hand Surg Br. 2003;28(4):315–8.
12. Hastings H. Arthrodesis (partial and complete). In: Pederson WC, Wolfe SW, editors. Green's operative hand surgery, vol. 1. 5th ed. Philadelphia: Elsevier; 2005.
13. Nagy L, Büchler U. Long-term results of radioscapholunate fusion following fracture of the distal radius. J Hand Surg Am. 1997; 22B:705–10.
14. del Piñal F. Dry arthroscopy and its applications. Hand Clin. 2011;27:335–45.
15. Ho PC, Lo WN. Arthroscopic resection of volar ganglion of the wrist: a new technique. Arthroscopy. 2003;19(2):218–21.
16. Sauerbier M, Trankle M, Erdmann D. Functional outcome with scaphotrapeziotrapezoid arthrodesis in the treatment of Kienbock's disease stage III. Ann Plast Surg. 2000;44(6): 618–25.
17. Minami A, Kato H, Suenaga N. Scaphotrapeziotrapezoid fusion: long-term follow-up study. J Orthop Sci. 2003;8(3):319–22.
18. Wollstein R, Watson HK. Scaphotrapeziotrapezoid arthrodesis for arthritis. Hand Clin. 2005;21(4):539–43.
19. Sauerbier M, Trankle M. Midcarpal arthrodesis with complete scaphoid excision and interposition bone graft in the treatment of advanced carpal collapse (SNAC/SLAC wrist): operative technique and outcome assessment. J Hand Surg Br. 2000;25(4):341–5.
20. Enna M, Hoepfner P, Weiss AP. Scaphoid excision with four-corner fusion. Hand Clin. 2005;21(4):531–8.
21. Taleisnik J. Subtotal arthrodesis of the wrist joint. Clin Orthop. 1984;187:81–8.
22. Weiss LE, Taras JS, Sweet S, Osterman AL. Lunotriquetral injuries in athletes. Hand Clin. 2000;16:433–8.
23. Ho PC. Arthroscopic partial wrist fusion. Tech Hand Up Extrem Surg. 2008;12:242–65.
24. Slade III JF, Bomback DA. Percutaneous capitolunate arthrodesis using arthroscopic or limited approach. In: Osterman A, Slade III JF, editors. Atlas of the hand clinics: scaphoid injuries, Scaphoid injuries, vol. 8:1. 2003. p. 149–62.
25. Yajima H, Kobata Y, Shigematsu K. Radiocarpal arthrodesis for osteoarthritis following fractures of the distal radius. Hand Surg. 2004;9(2):203–9.
26. Ishikawa H, Murasawa A, Nakazono K. Long-term follow-up study of radiocarpal arthrodesis for the rheumatoid wrist. J Hand Surg Am. 2005;30(4):658–66.
27. Garcia-Elias M, Lluch AL. Resection of the distal scaphoid for scaphotrapeziotrapezoid arthritis. J Hand Surg Br. 1999;24(4): 448–52.
28. Guidera PM, Watson HK, Dwyer TA. Lunotriquetral arthrodesis using cancellous bone graft. J Hand Surg Am. 2001;26(3):422–7.
29. Vandesande W, De Smet L, Van Ransbeeck H. Lunotriquetral arthrodesis, a procedure with a high failure rate. Acta Orthop Belg. 2001;67(4):361–7.
30. Sennwald GR, Fischer M, Mondi P. Lunotriquetral arthrodesis: a controversial procedure. J Hand Surg Br. 1995;20(6):755–60.
31. Pisano SM, Peimer CA, Wheeler DR. Scaphocapitate intercarpal arthrodesis. J Hand Surg Am. 1991;9:501–4.

18 Arthroscopic Management of Distal Radius Fractures

Tommy Lindau and Kerstin Oestreich

List of Abbreviations

AP	Antero-posterior
PA	Postero-anterior
A&E	Acute and emergency
OR	Operating room
FCR	Flexor carpi radialis
TFCC	Triangular fibro-cartilage complex
SL	Scapho-lunate
LT	Luno-triquetral
DRUJ	Distal radio-ulnar joint
ECU	Extensor carpi ulnaris
SC	Scapho-capitate
RSC	Radio-Scapho-Capitate ligament
LRL	Long Radio-Lunate ligament
PDS	Polydioxanone (suture)
DRCL	Dorso-radio-carpal ligament
DICL	Dorsal inter-carpal ligament
OA	Osteoarthritis
SLAC	Scapho-lunate advanced collapse

Introduction

Distal radius fractures are still one of the most common fractures in the twenty-first century. However, we are still not able to fully predict the outcome of the fracture treatment. In fact, there is no scientific evidence for anything we do in the management of distal radius fractures [1]. Certain things, however, are well supported by experience and case series; for instance that restoration of articular congruity is of paramount importance for long-term outcome with articular displacement more than 1 mm as an important predictor of pain [2] and late osteoarthritis (OA) [3]. This is further supported by findings that intra-articular incongruity and residual radial shortening have a strong correlation with poor outcome [4].

Although volar locking plates have improved the accuracy of the extra-articular fixation, the accuracy of the intra-articular reduction remains a challenge. In fact, arthroscopic evaluation is superior compared to fluoroscopy alone, in the assessment of articular step-off as well as the rotation of fractured fragments [5]. Moreover, the functional and radiological outcomes of arthroscopically assisted fixation have been shown to be significantly better than fluoroscopy alone [6, 7]. It is therefore natural that the role of arthroscopy in the management of intra-articular distal radius fractures is gaining increasing popularity due to its ability to address joint incongruity as well as recognition of chondral and ligament injuries as direct and magnified visualisation with a scope allows restoration of joint surfaces with minimal additional morbidity otherwise caused by soft tissue dissection [8–12].

Understanding and Investigating the Fracture

The standard AP (Antero-Posterior), PA (Postero-Anterior) and lateral radiographic views most often give you all necessary information to fully understand the fracture in order to plan treatment.

The fracture pattern is most often better understood with traction views either in the Acute and Emergency (A&E) setting whilst using Chinese finger traps or in the operating room (OR) before the actual operative procedure.

The lateral radiographic view should be assessed for radiocarpal alignment or malalignment. The long axial line through the radius and capitate should cross within the carpus; otherwise it indicates carpal instability [13].

T. Lindau, M.D., Ph.D. (✉)
The Pulvertaft Hand Centre, Royal Derby Hospital, Uttoxeter Road, Derby DE22 3NE, UK
e-mail: tommylindau@hotmail.com

K. Oestreich, M.D., M.Sc.
Department of Plastic Surgery, Birmingham Childrens Hospital, Steelhouse Ln, Birmingham B4 6NH, UK

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*,
DOI 10.1007/978-1-4614-1596-1_18, © Springer Science+Business Media New York 2015

Special articular views, compensating for the radial and dorsal inclination, are important after volar plate fixation to rule out pegs/screws in the joint.

Radiocarpal instability can also be caused by a partial intra-articular fragment, either on the dorsal lunate facet or on the palmar lunate facet of the radius. A very important sign in this respect is that of the 'tear drop' fragment, at the palmar aspect of the lunate facet, which represents the important insertion of the Short Radio-Lunate (SRL) ligament [14]. Not recognising and managing this important fragment will cause radio-carpal subluxation.

A CT scan will give you a better idea of the distribution of the fracture, important fragments such as 'tear-drop' fragments necessary to include in your fixation, involvement of sagittally split fragments as well as incongruency of the sigmoid notch [14]. However, CT scans may occasionally scare the less experienced surgeon due to the extent of a fracture that may look relatively benign on normal x-rays and now presenting as a quite complex exercise. More importantly, the procedure can after a CT scan be more accurately planned!

Indications vs. Experience

- The main reason to consider arthroscopy in the management of distal radius fracture is an intra-articular step-off more than 1 mm after an attempted closed reduction.
- Second, radiological signs suggestive of associated soft tissue injuries, which may be widening of inter-carpal joint spaces. In this respect, radiographic disruption of the carpal arches of the so-called Gilula lines [15]; i.e. the three congruent, concave arches that can be drawn along the proximal and distal carpal rows, strongly suggest inter-carpal ligament injury.
- Third, a widening of the Distal Radio-Ulnar (DRU) joint may be another sign of secondary ligament injuries to the Triangular Fibro-Cartilage Complex (TFCC) that need arthroscopic assessment in the management of the fracture [15–17].

Indications for arthroscopy should be balanced with the surgeon's experience. There are certain relatively simple fractures, such as radial styloid fractures, which will be very reasonable to do even for an inexperienced surgeon. First, it is most often a two-part fracture and second, it may be part of an incomplete greater arch injury according to the Mayfield mechanism, but without the lunate dislocation [18].

For more experienced surgeons, impacted fractures such as the 'die-punch' fracture warrant arthroscopic assessment, reduction and fixation.

For the very experienced surgeon in an expert centre, three or four-part fractures will be the next challenge. Even more complex injuries with high-grade intra-articular comminution the so-called 'explosion fractures' or fractures with associated scaphoid fractures and/or obvious ligament injuries will benefit from direct visualisation and arthroscopic management.

Contraindications

The most obvious contraindication is open fractures, followed by fractures with other soft tissue involvement such as large capsular tears, neurovascular injuries, incipient carpal tunnel syndrome or signs of a compartment syndrome.

The Arthroscopic Procedure: General Principles

The procedure includes a complete treatment of the fracture and its associated injuries. It is most often done as a regional anaesthetic procedure, i.e. an axillary block or ultrasound-guided supraclavicular block with general anaesthetic as an option.

A 2.7 mm 30° angled arthroscope provides adequate view as well as manoeuvrability within the wrist joint. The arthroscopy mobile cart (with a screen, video camera, light source, and electronic documentation system) is positioned at the foot end of the bed. The fluoroscopy unit or C-arm is placed on the same side as the hand table.

The Arthroscopic Procedure: Traction

The intra-operative traction system should allow easy transition between the open procedure and the arthroscopic part. The traction system can either be truly horizontal allowing complete treatment [19] or be a designated traction system for fractures (e.g. Geissler). Alternatively, the traction system can be set either with an overhead traction boom keeping the boom draped but leaving the connection bar sterile. In this fashion, the transition from a horizontal to a vertical position is minimally impaired between the open procedure and need for fluoroscopy to the arthroscopic procedure and need for special instrumentation. Some traction towers may sometimes block the radiographic assessment due to the metal block of the traction device.

The Arthroscopic Procedure: Arthroscopic Setup

After exsanguination of the arm, finger traps are placed on the index and middle fingers. The most commonly used system for arthroscopy keeps the shoulder in 60–90° of abduction with the elbow flexed to 90°. Countertraction of about 4–5 kg traction of the upper arm is applied.

The traction often facilitates reduction of the extra-articular fracture components.

Swelling most often distorts the normal landmarks for the portals. Therefore, surface landmarks for establishing the viewing of 3-4 portal can be approximated by a point on a line extended along the radial side of the middle finger at the level of radial styloid, which is easily palpable. Introduction of a needle and aspiration of blood as part of the hemarthrosis at this point confirms the position in the joint. After distending the joint with saline, a blunt trochar is introduced followed by the 2.7 mm arthroscope. The scope is directed ulnarly to establish the 4-5 or the 6R portal with the help of a percutaneous needle radial to extensor carpi ulnaris (ECU) tendon. Care should be taken to stay distal to the TFCC. A 6-U outflow portal may help lavage the joint. If larger clots or debris are found, a 2.9 mm motorised shaver can be introduced through the 4-5 or 6R working portal to clear the joint from debris and allow a clear view of the joint surface.

The Arthroscopic Procedure: 'Dry' or Wet?

There is a risk of further soft tissue swelling if continuous saline irrigation is used. If so, an elastic dressing is wrapped around the forearm to minimise the risk of extravasation. The use of a 'dry' arthroscopic technique will minimise the risk of these problems, but may make the procedure slightly more cumbersome [20, 21]. It may be difficult to achieve a good intra-articular view with the 'dry' technique due to the intra-articular hemarthrosis [22, 23]. If any debris or blood clot is noted, the joint is irrigated as necessary [21] before continuing with the 'dry' arthroscopy technique. The main medical benefit is to minimise the risk of secondary compartment syndrome. If a 'dry' arthroscopy technique is to be considered, it is recommended to keep the air valve open to permit free circulation of air through the joint. It is also advisable to turn the suction off except when needed.

The Arthroscopic Procedure: Arthroscopic Assessment

Once a clear view has been established, the examination starts by assessing the radio-carpal joint regarding intra-articular congruency and possible need for fine-tuning the provisional reduction. A 2 mm probe inserted through the 4-5 or the 6R portal can help to accurately evaluate the gap and separation and step-off of fragments.

Once the joint reduction has been done, any associated ligament or cartilage injury is assessed. The integrity of the scapho-lunate (SL) ligament, the luno-triquetral (LT) ligament and the TFCC or any other intra-articular pathology is visualised to plan the sequence of surgery.

The Arthroscopic Procedure: Surgical Plan in a Stepwise Manner

The procedure has to be planned depending on the fracture pattern, need for open reduction and internal fixation (ORIF) as well as when the arthroscopic assessment and treatment will take place (Fig. 18.1). Subsequently, radial styloid fractures will not need a volar locking plate. These fractures will start with the arthroscopic procedure as opposed to all other fractures, where the procedure will start with an open volar approach and provisional fixation of the extra-articular component of the fracture followed by arthroscopy (Fig. 18.1).

The Arthroscopic Procedure: Radial Styloid Fracture (Chauffeur's Fracture); a Two-Fragment Fracture

Radial styloid fractures are the first and possibly most important intra-articular fracture to approach with arthroscopy assistance. It is normally a two-fragment fracture so it does not need a volar locking plate and can normally be reduced and fixed with ease. The styloid fragment is often rotated in pronation in relation to the radius.

More importantly, it may also be part of a greater arch trans-styloid perilunate injury as described by Mayfield, but without the lunate dislocation [18]. It may therefore have associated injuries to the lesser or greater arch that can either be detected or ruled out with arthroscopy.

Once the overview assessment has been done and the intra-articular fragments have to be mobilised and reduced, the viewing portal has to be switched to a 4-5 or 6R portal away from the fracture as the scope otherwise will block free mobilisation of the fragment.

The reduction is done either with a probe within the joint or with an elevator through a separate skin incision over the fracture. The displaced fragment is frequently rotated, which is often underestimated. Arthroscopically this is seen with 'inverted' incongruencies dorsally and volarly. It will ease the reduction of the fragment when the forearm is in neutral rotation or supinated with the elbow flexed to neutralise the force of the brachioradialis tendon inserted in this fragment.

Under fluoroscopic guidance, a K-wire is inserted palmar to the first extensor compartment through the tip of the styloid. The fragment is reduced using the K-wire as a joystick and arthroscopic assessment of the reduction before the wire is secured into the radius. A second K-wire is inserted across the fracture to provide rotational stability. Once anatomic reduction is confirmed, either a cannulated or compression screw can be inserted.

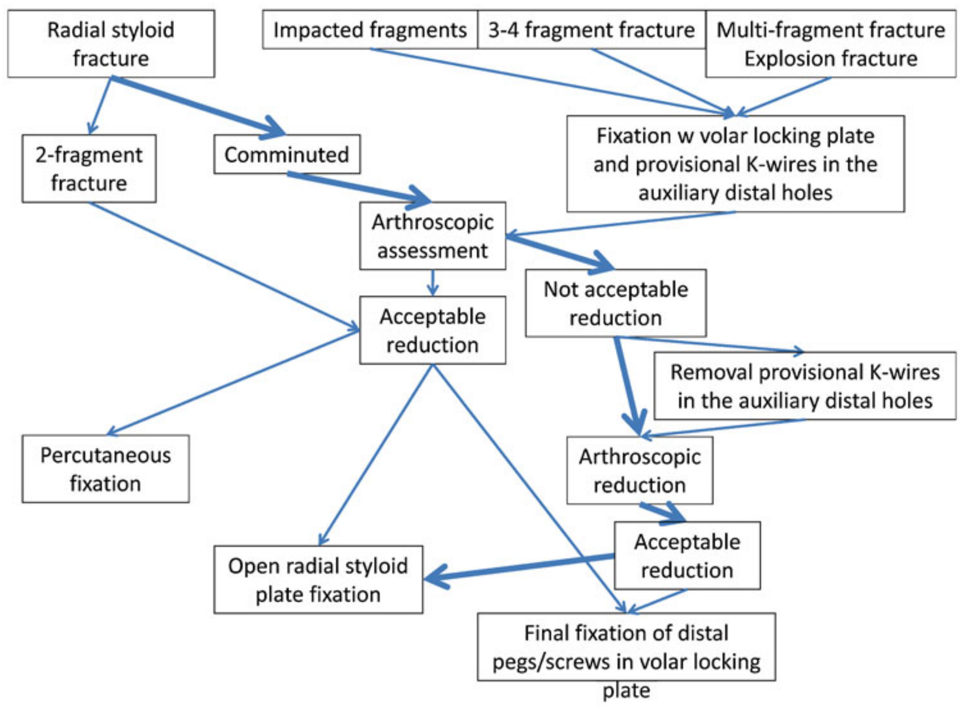


Fig. 18.1 General principles in managing distal radius fracture with arthroscopy assistance in a stepwise fashion. From easier two-fragment fractures managed by the relatively inexperienced surgeon, through three or four-part fractures dealt with by an experienced surgeon. The multi-fragmentary or so-called explosion fractures is for the expert. The fat arrows demonstrate how a comminuted radial styloid fracture moves through the flow chart into a final fragment specific radial styloid plate fixation

The Arthroscopic Procedure: Radial Styloid Fracture; a Two-Fragment Comminuted Fracture

Radial styloid fractures with comminution can be reduced as described above, but single screws will not maintain stability. More commonly, a fragment specific radial styloid plate is used to maintain reduction by buttressing the fracture.

The Arthroscopic Procedure: Impacted, Three to Four Fragment and Explosion Fractures

These fractures are all for the more experienced arthroscopist. The arthroscopic procedure follows a provisional fixation of the extra-articular fracture with a volar locking plate.

The Arthroscopic Procedure: General Surgical Technique for the Volar Locking Plate

The general approach for most surgeons is to reduce and provisionally fix the extra-articular fracture before proceeding with the arthroscopic assessment. The distal radius fracture is most often approached through the flexor carpi radialis (FCR) bed and the volar locking plate is applied and provisionally stabilised by inserting a screw in the elliptical hole in the plate to allow later adjustments. The plate should be positioned to allow the distal row of pegs/screws to lie in the subchondral bone. The metaphyseal fragments are manipulated with traction, compression and manual reduction under direct visualisation as well as fluoroscopic guidance, possibly with the wrist in some flexion. K-wires are applied stabilising the articular fragments to the plate using the auxiliary holes. Once the provisional stabilisation seems adequate, another cortical screw is inserted in the plate to secure its position in order to avoid any secondary displacement.

Special emphasis is directed towards the intermediate column, also called the critical corner to support the important lunate facet.

Once the extra-articular fracture has been provisionally fixed, including provisional fixation of the intra-articular fractures with K-wires in the auxiliary distal holes, the traction system is used for the arthroscopic procedure of either securing the fragments or fine-tuning reduction.

The Arthroscopic Procedure: Post-plating Assessment and Reduction of Impacted and Other Fragments

After provisional reduction of the intra-articular fracture component with the open approach, the accuracy of the intra-articular fracture is assessed arthroscopically.

Occasionally, in simpler cases, the reduction is acceptable and the following part is to sequentially fix the fracture to the distal plate with pegs/screws for a final arthroscopic and fluoroscopic confirmation of a well-reduced fracture.

As a general principle for the arthroscopic reduction, a K-wire is placed centrally in each fragment. Thereafter, depressed fragments are mobilised and elevated through combined manipulation with the probe and/or elevator using a joystick manoeuvre of the K-wire. Thus the fracture fragments are sequentially reduced under arthroscopic control.

1. The first step in the reduction is the realignment of the ulnar border of the radius as it represents a 'double-joint incongruency' both in the sigmoid notch of the DRU joint and in the lunate facet of the radiocarpal joint [24]. Furthermore, it secures the important critical corner of the intermediate column.
2. The arthroscope has to be moved away from the 3-4 to 6R portal to allow free mobilisation of the lunate facet. Elevate a depressed lunate fragment with a probe, which may be further supported proximally with a percutaneous K-wire. If the lunate facet is split into volar and dorsal fragments, then a K-wire in the lunate fragment is used as a joystick to move the related articular fragments. With digital pressure of the surgeon's thumb from the dorsum, the fragments are brought closer to the plate and are provisionally stabilised with a K-wire.
3. Further fragments are added to the 'ulnar platform' by sequentially positioning K-wires from larger to smaller fragments.
4. After all fragments have been provisionally reduced and fixed with K-wires, the realignment of the joint surface is determined arthroscopically and fluoroscopically. Once the joint surface is congruent, two transverse subchondral K-wires can further secure the reduced position.
5. Once this is established the palmar plate is fixed with all distal pegs or screws inserted.
6. Hereafter, arthroscopy and fluoroscopy again confirm a solid fixation and all K-wires are either removed or in selected cases converted into screw fixations, either cannulated or mini-fragment screws.
7. Finally, associated injuries including ligaments and cartilage are assessed and treated if necessary.

The Arthroscopic Procedure: 'Explosion-Type' Fractures

An extreme form of multi-fragmentary fractures has been described as 'explosion-type' fractures [20]. They pose a unique challenge for arthroscopy-assisted fixation even for the expert. Explosion-type fractures are defined as having more than four articular fragments and with a single, free, central osteochondral fragment [20]. The osteochondral fragments, due to the paucity of their attachments, bear a high risk of settling into the metaphyseal void. This can be addressed by inserting the distal row of pegs first, allowing the free osteo-chondral fragment to rest on the supporting pegs and then impact it with an elevator [20]. These complex fractures gain from direct visualisation and accurate reduction, but the surgeon ought to have at least one assistant who preferably should be experienced in arthroscopy-assisted procedures. The procedure otherwise follows the advice given earlier. It should be noted that they can be extremely demanding even for the experienced surgeon and external or internal bridging fixation is a very reasonable treatment option.

The Metaphyseal Void

Multi-fragmentary fractures are almost always associated with shortening of the radius and/or depressed articular fragments that leave a void after reduction. It is therefore important to consider additional treatment of the metaphyseal void at the end of the procedure, by means of bone graft or bone substitution.

The Arthroscopic Procedure: Exceptional Fracture Types

Partial Volar Fragments

Partial volar fractures can be part of a spectrum of complex injuries involving the stabilising radio-carpal ligaments or represent ligament avulsion fractures. They are easily missed and misunderstood. CT is very useful to plan the procedure. Arthroscopy readily detects them and allows not only exact reduction and fixation but also the diagnosis and treatment of associated injuries.

The so-called teardrop is the U-shaped outline of the volar rim of the lunate facet representing the insertion of the Short Radio-Lunate (SRL) ligament [14]. A displaced 'teardrop' fragment will cause radio-carpal instability and can be recognised by an abnormal teardrop angle (75°). The volar 'teardrop' fragment tends to rotate dorsally with traction because of ligamentotaxis due to the strong palmar radio-carpal ligaments. Consequently, they need either open reduction and fixation with a temporary K-wire for 3 weeks, a fragment specific small plate, a fragment specific screw or a fixation with a cannulated screw through a limited palmar approach rather than percutaneous fixation due to the delicate anatomy [25, 26]. Alternatively, by decreasing the traction and simultaneously palmarly flexing the joint the fragments might reduce and they can be pinned from the dorsal aspect of the distal radius or from the palmar aspect through a limited palmar approach [2, 27, 28].

Partial Dorsal Fragments

Partial dorsal articular fractures most often involve the lunate facet. They can be difficult to view from dorsal portals unless either a very radial 1-2 portal or a very ulnar 6R portal is established. A volar portal is a very interesting option, provided that the surgeon is experienced in this approach. A small incision is done between the FCR tendon and the radial artery and with careful blunt technique the palmar capsule is penetrated and the arthroscope is inserted [29, 30].

An option is to use a Wissinger rod technique from dorsal, directing the rod between the Radio-Scapho-Capitate ligament (RSC) and the Long Radio-Lunate ligament (LRL) and gently pushing it towards the palmar skin. A small incision is done over the rod and blunt dissection further secures the portal until the trochar is fitted over the rod palmarly and advanced into the joint.

A single K-wire is inserted into the dorsal fragment under fluoroscopic control and the wrist is palmar flexed. Once the reduction is satisfactory after manipulation under arthroscopic guidance, the wire is advanced further after which a cannulated screw fixes the fragment. If the fragment represents a more complex impacted 'die-punch' injury then an ulnar fragment specific plate may be considered with or without bone graft behind the impacted fragment.

The Importance of Ulnar Styloid Fractures

The importance of ulnar styloid fractures depends on its relationship to the TFCC, thereby either being part of a destabilising injury to the DRU-joint or not. It is therefore not surprising that there are no studies that show any benefits with repair of ulnar styloid fractures [40]. In fact, ulnar styloid fractures are not always associated with TFCC tears [8–10], or late DRU-joint instability [31–33]. Furthermore, there is no relationship between ulnar styloid fractures or non-union and functional outcome [31–33], which has further been shown in cases with plate fixation [34–39].

Clinical experience suggest that ulnar styloid fragments are stable and ulnar styloid fractures at the base have an increased risk of instability [39] particularly if the fracture is displaced more than 2 mm, especially if the displacement is in radial direction [40]. The fracture in those cases can be fixed with any means, or if comminuted be excised and the TFCC reattached to the fovea of the ulnar head.

Closure and After Care

The pronator quadratus muscle is repaired back to cover the volar locking plate before skin closure and a protective plaster slab is applied, which is changed in 48–72 h to a removable splint before commencing mobilisation with the help of the therapy team. In the absence of scientific evidence for benefit of physiotherapy, experience suggests that physiotherapy starts after 6 weeks in order to restore range of motion and progressive wrist and hand strengthening exercises.

In case of a dorsal rim fracture fixation, 3 weeks of extension blocking splint may be required. A sugar-tong splint to prevent forearm rotation is used when the DRU-joint region needs to be protected as in a TFCC repair.

Extended immobilisation is considered if inter-carpal ligaments have been found, with or without further treatment.

Return to heavy activities is withheld for the first 3 months.

Associated Soft Tissue Injuries in Distal Radial Fractures

Arthroscopy has been pivotal in highlighting the high incidence of soft tissue injuries associated with distal radius fracture, which are frequently missed when the fracture is managed by the conventional methods of treatment (Table 18.1) [8–10, 41]. This is not surprising as the radius may be involved in the greater arch mechanism described by Mayfield in perilunate dislocations [18]. This is further emphasised in non-osteoporotic patients as they more often present with intra-articular fractures caused by a severe, high-energy trauma [42, 43]. In contrast, most fractures in osteoporotic patients are extra-articular and sustained by low energy [44].

Arthroscopy has become the gold standard in detecting these injuries in addition to being an adjunct in the management of distal radius fractures.

- Injuries to the TFCC seem to be the most frequent and are found in around ¾ of the fractures (Table 18.1) [8–10, 45].
- The second most frequent ligament injury is to the SL ligament, which is found in between 1/3 and ½ of the cases (Table 18.1) [8–10].

Table 18.1 Injuries associated with distal radius fractures

Study	Number and type	% TFCC injury	% SL injury	% LT injury
Geissler (1996)	60 (intra-articular)	49	32	15
Lindau (1997)	50 (intra- and extra-articular)	78	54	16
Richards (1997)	118 (intra- and extra-articular)	35 (intra) 53 (extra)	21 (intra) 7 (extra)	7 (intra) 13 (extra)
Mehta (2000)	31 (intra-articular)	58	85	61
Hanker (2001)	173 (intra-articular)	61	8	12

- Lunotriquetral (LT) ligament tears are less common and seen in about 1/6 of the fractures [2, 8–10, 45].
- In addition, there have been findings of chondral lesions [8] with a possible long-term development of secondary osteoarthritis [46].

Triangular Fibro-Cartilage Complex (TFCC) Injuries

TFCC injuries are the most common associated intra-articular injuries in distal radius fractures in non-osteoporotic patients (Table 18.1) [8–10]. Cadaveric studies have suggested that in order for an ulnar attachment of TFCC to be compromised, the displacement of the distal radius has to be more than 4 mm of radial shortening, down to 0° of radial inclination and a dorsal tilt of minimum 10° [47].

There has been an accepted understanding for the last 10–15 years that associated peripheral tears to the TFCC will cause instability [31–33] with a subsequent worse outcome [31–33]. However, this has recently been contradicted as only one patient had a stabilising procedure due to painful instability in a 15-year prospective longitudinal outcome study of untreated TFCC tears [48].

In the absence of scientific evidence, there is however clinical experience to support the following advice regarding TFCC treatment in association with distal radius fractures:

- Central perforation tears (Palmer 1A, [49]) are stable and can be debrided to leave smooth edges with a suction punch, a shaver or a radiofrequency probe. Care should be taken to avoid jeopardising the stability provided by the important palmar and dorsal ulno-radial ligaments. This treatment does not change the overall rehabilitation plan.
- Peripheral tears of the TFCC (Palmer 1B [49]) may come with or without associated DRU joint instability. The distal tears may be debrided and possibly sutured back to the capsule and ECU subsheath [50]. The proximal tears cannot be seen at radio-carpal arthroscopy alone, but need reattachment to the fovea of the ulna [50]. The combined tears are diagnosed due to the distal component and should also be reattached [50].
- Reattachment can be done with arthroscopy assistance or with an open technique with similar good outcome [51]. Arthroscopically assisted reattachment is done with two or three 2/0 absorbable (PDS) sutures that are passed through the periphery of the TFCC and fixed to the distal ulna, either through drill holes or with any one of the many varieties of TFCC techniques found in the literature. The repair is protected from supination and pronation for 4 weeks, followed by 2–4 weeks in a short-arm cast.
- Ulnocarpal ligament tears (Palmar 1C [49]) are very rare [8]. A reinsertion technique directly through the palmar approach in line with the exposure of the critical corner in the intermediate column is the simplest option. This repair should be protected for 4 weeks in relation to the rehabilitation for the fracture.
- Radial avulsion tears (Palmar 1D [49]) are uncommon, but may often be associated with a dorso-ulnar fracture fragment. If found in isolation, i.e. true avulsions from the radial insertion site of the ulno-radial ligament, they most likely ought to be reattached [52]. Due to the need for internal fixation of the distal radius fracture, the techniques based on drill holes through the radius are not suitable, but rather with suture anchors with a mini-open approach [53, 54].

Inter-carpal Ligament Injuries

The potential association of inter-carpal ligament injuries to the scapho-lunate (SL) and the luno-triquetral (LT) ligament should be looked upon as part of an incomplete greater arch injury described by Mayfield [18], but without the final dislocation of the lunate. Awareness of this mechanism makes it important to assess these potential associated injuries, where arthroscopic assessment obviously is the best way of detecting and treating them.

The ligament injuries should be classified as partial or complete (Table 18.2).

The ligaments are examined in its dorsal, membranous and palmar portions as well as from the mid-carpal joint where the joint space is assessed regarding widening and

Table 18.2 Arthroscopic classification of scapho-lunate ligament tears according to Geissler [9]

Grade	Radio-carpal joint	Mid-carpal instability	Step-off	Management
1	Haemorrhage of IOL, no attenuation	None	None	Immobilisation
2	Incomplete partial or full substance tear, no attenuation	Slight gap (<3 mm)	Midcarpal only	Arthroscopic reduction and pinning
3	Ligament attenuation incomplete partial or small full substance tear	Probe can be passed between carpal bones	Midcarpal and radiocarpal	Arthroscopic/open reduction and pinning
4	Complete tear	Gross instability, 2.7 mm scope can be passed (drive thru sign)	Midcarpal and radiocarpal	Open reduction and repair

Based on data from reference [9]

Table 18.3 Classification system for interosseous SL and LT ligament injuries and mobility of the joints

Grade	Radio-carpal lig. appearance	Mid-carpal diastasis (mm)	Step-off (mm)
1	Hematoma/distension	0	0
2	As above and/or partial tear	0–1	<2
3	Partial or complete tear	1–2	<2
4	Complete tear	>2	>2

Adapted from Lindau T, Arner M, Hagberg L. Intraarticular lesions in distal fractures of the radius in young adults. A descriptive arthroscopic study in 50 patients. J Hand Surg [Br] 1997; 22:638–43. With permission from Sage Publications

step-off by using a probe with known size (e.g. 1 mm thickness, 2 mm tip length) (Table 18.2) as a template for measurement. The widening and the step-off reflect the degree of the mobility, which is not necessarily a pathological laxity, of the affected inter-carpal joint. If the traction is released, then the assessed joint can be tested, by checking signs of pathological excessive mobility with the arthroscope in the mid-carpal joint. Thus, the inter-carpal ligament injury can be completely classified and graded (Tables 18.2 and 18.3).

Scapho-Lunate (SL) Ligaments Injuries

SL ligament injuries are not only common (50 %) [8] in the presence of distal radius fractures, but if left untreated high grade tears are likely to progress to radiographic SL dissociation [55] and symptomatic wrist instability [55, 56]. In the long term, this will lead to posttraumatic scapho-lunate advanced collapse (SLAC) OA.

It is therefore important to not only detect SL tears but also consider treatment. Arthroscopic reduction and percutaneous pinning is the simplest option with a good outcome in 85 % of the patients if found and treated early [6, 57]. It should be noted that there is no strong evidence (level 1 or 2) for management of these injuries and published recommendations are largely experience based [58].

Grade 1–2 SL Injuries

These can be managed with immobilisation, as most patients are asymptomatic at 1 year [55]. This means that the protocol for mobilisation of the fracture after volar locking plate fixation may have to be changed [58].

Grade 3 and 4 SL Injuries

These injuries are more likely to lead to radiographic dissociation and long-term SLAC if untreated and early treatment is important [55, 59].

Grade 3 can be treated with arthroscopic reduction and K-wire pinning. An incision is made slightly palmar to the anatomical snuffbox while protecting the sensory branches of the radial nerve. K-wires are inserted first into the scaphoid and used as a joystick to achieve arthroscopic reduction, which is assessed from the mid-carpal joint. Once reduction is achieved, the K-wire is advanced into the lunate. An additional K-wire should be inserted into the scapho-capitate (SC) joint [57, 60]. Pins remain for 6 weeks [57, 58].

Grade 4 may in some cases be difficult to reduce arthroscopically and open direct repair may be warranted, followed by protective K-wires as described above. During closure, dorsal capsulodesis is helpful in augmenting the repair, which might lead to long-term reduced palmar flexion. It also seems reasonable to assume that Grade 4 injuries, especially those with dissociation already on the trauma films, probably should be treated with an open repair [58, 61].

Luno-Triquetral (LT) Ligament Injuries

The incidence of LT ligament injuries is less frequent, present in about 1/6 (Table 18.1). There is no evidence that LT tears lead to long-term problems when found associated with distal radius fractures [55].

Stable injuries (Grade 1–3) may need immobilisation, where again the fracture mobilisation rationale has to be reconsidered.

Grade 4 injuries may need arthroscopic debridement of the tear followed by pinning of the joint. K-wires are introduced from a dorso-ulnar approach and after reduction of the LT dissociation with a joystick manoeuvre; the wires are advanced across the joint. Two to three wires are kept for 6 weeks.

Associated Scaphoid Fractures

If a scaphoid fracture is associated with a distal radius fracture, preoperative planning is important for correct operative approach [62].

If the scaphoid fracture is undisplaced, it is fixed percutaneously first to avoid secondary displacement.

In cases of a displaced scaphoid fracture, the radius is generally stabilised first. Fixation of the displaced scaphoid is done through an extension of the volar approach for the volar plate. In proximal pole fractures, a dorsal approach is used and for those cases a dorsal approach to the distal radius fracture is often recommended.

Arthroscopically, the scaphoid fracture is mainly visualised using the radial mid-carpal portal for a better anatomical guidance of the reduction. Fracture reduction is facilitated with a probe introduced through the STT mid-carpal portal, before the K-wire is advanced while confirming the position fluoroscopically. After drilling and tapping, the appropriate screw is advanced with the scope in the 3-4 portal to check that there is no screw prominence.

Chondral Lesions

Acute chondral lesions range from subchondral hematomas, with or without cracks in the cartilage, to avulsed cartilage flakes and finally complete avulsions of the cartilage [8]. There is some evidence that subchondral hematoma can lead to development of early onset of mild, radiographic OA [46].

There is currently no other treatment option than debridement for these injuries. A tempting, but unproven option is the micro-fracture treatment similar to the one applied in the knee. Chondral lesions may, however, if found, lead to changes in treatment in the sense that a comminuted intra-articular fracture might be treated with a primary partial wrist fusion instead of a lengthy attempt of reducing a multi-fragmentary joint surface with loss of cartilage. It will also give the surgeon an awareness of an expected bad outcome. Most importantly, they reflect, together with the associated ligament injuries, the complexity of distal radial fractures, especially in the non-osteoporotic population [42].

Outcomes

There is no scientific evidence that arthroscopy is necessary in the management of distal radius fractures, but there seems to be increasing support regarding the benefit to use arthroscopy in the management of distal radius fractures [48, 63–67]. It seems important to consider arthroscopy as the radiographic displacement may be underestimated [68]. This is important, as improved arthroscopic reduction of the intra-articular step-off to less than 1 mm will reduce the risk of secondary OA [69].

Only one randomised study shows that the arthroscopically treated group had better overall outcome compared to ORIF, with better reduction, grip strength and range of motion than the openly treated group [27]. Their results support the findings of others, where arthroscopically assisted reduction has been found to result in improved joint congruency and yield excellent or good outcomes in about 90 % of the patients [5, 6, 70, 71]. Furthermore, arthroscopically assisted procedures may improve mobility compared to patients undergoing fluoroscopically assisted surgery [72].

There is limited experience in arthroscopically assisted treatment of associated injuries, but TFCC repairs in conjunction with distal radius fixation resulted in a high degree of patient satisfaction and good to excellent clinical outcomes [73].

Summary

The wide spectrum of injury pattern after a fall onto the outstretched hand lies between a sprain, a radial styloid fracture in isolation or with a radial fracture as part of the greater arch injury as part of a complete or incomplete perilunate dislocation mechanism [18]. Today, there is strong evidence that displaced fractures in the non-osteoporotic patient have a high incidence of associated soft tissue injuries, which will affect the long-term outcome, where arthroscopy plays its role to establish the correct diagnosis and facilitate early treatment to optimise the overall outcome of these complex injuries.

The incomplete improved outcomes after volar locking plate fixation and early mobilisation compared to external fixation [74–76] may be explained by the undetected associated injuries only found if arthroscopy is used in conjunction with volar locking plate fixation.

Small joint arthroscopy in the management of distal radius fracture has been available for over 20 years, yet still requires experience and management in expert centres only. It is with thorough understanding of the anatomy, understanding the relevance of individual fragments and associated bony and soft tissue injuries, that the surgeon will be successful in the management of this relatively simple, yet complex fracture.

The advantage of arthroscopically assisted management of distal radius fractures is to improve intra-articular accuracy to less than 1 mm of incongruency and combine this with a complete assessment, management and treatment of associated ligament, TFCC and cartilage injuries. As the intra-articular reduction is assessed at the end of the procedure, inadvertent intra-articular placement of screws from the volar locking plate can be secured. In essence, the surgeon has complete control of all fracture and treatment-related factors in distal radius fractures. It is the authors' firm belief that this will evolve in the future for the benefit of the so far incomplete fracture management and for the benefit of our patients!

References

1. Cochrane library; Handoll H, Elstub L, Elliott J, Gillespie LD, Gillespie WJ, Madhok R. Cochrane Bone, Joint and Muscle Trauma Group. About The Cochrane Collaboration (Cochrane Review Groups (CRGs)); 2008, Issue 4.
2. Mehta JA, Bain GI, Heptinstall RJ. Anatomical reduction of intra-articular fractures of the distal radius. An arthroscopically assisted approach. J Bone Joint Surg Br. 2000;82-B:79–86.
3. Knirk JL, Jupiter JB. Intra-articular fractures of the distal end of the radius in young adults. J Bone Joint Surg Am. 1986;68A:647–59.
4. Trumble TE, Schmitt SR, Vedder NB. Factors affecting functional outcome of displaced intra-articular distal radius fractures. J Hand Surg Am. 1994;19:325–40.
5. Edwards II CC, Haraszti CJ, McGillivary GR. Intra-articular distal radius fractures: arthroscopic assessment of radiographically assisted reduction. J Hand Surg Am. 2001;26:A1036–41.
6. Varitimidis SE, Basdekis GK, Dailiana ZH, Hantes ME, Bargiotas K, Malizos K. Treatment of intra-articular fractures of the distal radius: fluoroscopic or arthroscopic reduction? J Bone Joint Surg Br. 2008;90(6):778–85.
7. Lutsky K, Boyer MI, Steffen JA, Goldfarb CA. Arthroscopic assessment of intra-articular distal radius fractures after open

reduction and internal fixation from a volar approach. J Hand Surg Am. 2008;33(4):476–84.
8. Lindau T, Arner M, Hagberg L. Intraarticular lesions in distal fractures of the radius in young adults. A descriptive arthroscopic study in 50 patients. J Hand Surg Br. 1997;22:638–43.
9. Geissler WB, Freeland AE, Savoie FH, et al. Intracarpal soft-tissue lesions associated with an intra-articular fracture of the distal end of the radius. J Bone Joint Surg Am. 1996;78:357–65.
10. Richards RS, Bennett JD, Roth JH, et al. Arthroscopic diagnosis of intra-articular soft tissue injuries associated with distal radial fractures. J Hand Surg Am. 1997;22:772–6.
11. Cognet JM, Martinache X, Mathoulin C. Arthroscopic management of intra-articular fractures of the distal radius. Chir Main. 2008;27(4):171–9.
12. Guofen C, Doi K, Hattori Y, Kitajima I. Arthroscopically assisted reduction and immobilization of intraarticular fracture of the distal end of the radius: several options of reduction and immobilization. Tech Hand Up Extrem Surg. 2005;9(2):84–90.
13. Lafontaine M, Hardy D, Delince P. Stability assessment of distal radius fractures. Injury. 1989;20:208–10.
14. Medoff R. Essential radiographic evaluation for distal radius fractures. Hand Clin. 2005;21(3):279–88.
15. Gilula LA. Carpal injuries: analytic approach and case exercises. Am J Roentgenol. 1979;133(3):503–17.
16. Bellinghausen HW, Gilula LA, Young LV, et al. Post-traumatic palmar carpal subluxation: report of two cases. J Bone Joint Surg Am. 1983;65:998–1006.
17. Biyani A, Sharma JC. An unusual pattern of radiocarpal injury: brief report. J Bone Joint Surg Br. 1989;71:139.
18. Mayfield JK, Johnson RP, Kilcoyne RF. The ligaments of the human wrist and their functional significance. Anat Rec. 1976;86(3):417–28.
19. Lindau T. Wrist arthroscopy in distal radial fractures using a modified horizontal technique. Arthroscopy. 2001;17(1):1–6.
20. del Piñal F. Treatment of explosion-type distal radius fractures. In: Piñal F, Mathoulin C, Luchetti R, editors. Arthroscopic management of distal radius fractures. New York, NY: Springer; 2010. p. 41–65.
21. del Piñal F. Technical tips for (dry) arthroscopic reduction and internal fixation of distal radius fractures. J Hand Surg Am. 2011;36(10):1694–705.
22. del Piñal F, Garcia-Bernal FJ, Pisani D, Regalado J, Ayala H, Studer A. Dry arthroscopy of the wrist: surgical technique. J Hand Surg Am. 2007;32(1):119–23.
23. Atzei A, Luchetti R, Sgarbossa A, et al. Set up, portals and normal exploration in wrist arthroscopy. [Article in French]. Chir Main. 2006;25(1):S131–44.
24. Lindau T. The role of wrist arthroscopy in distal radial fractures. In: Geissler W, editor. Atlas of the hand clinics, vol. 6, No 2. Amsterdam: Elsevier; 2001. p. 285–306.
25. Fernandez DL, Geissler WB. Treatment of displaced articular fractures of the radius. J Hand Surg Am. 1991;16A:375–84.
26. Fernandez DL, Jupiter JB. Surgical techniques. In: Fractures of the distal radius. A practical approach to management. 2nd ed. New York, NY: Springer; 2002. p. 71–121.
27. Doi K, Hattori Y, Otsuka K, et al. Intra-articular fractures of the distal aspect of the radius: arthroscopically assisted reduction compared with open reduction and internal fixation. J Bone Joint Surg Am. 1999;81:1093–110.
28. Wiesler ER, Chloros GD, Lucas RM, Kuzma GR. Arthroscopic management of volar lunate facet fractures of the distal radius. Tech Hand Up Extrem Surg. 2006;10(3):139–44.
29. Battistella F. Management of simple articular fractures. In: del Piñal F et al., editors. Arthroscopic management of distal radius fractures. Heidelberg: Springer; 2010. p. 27–39.
30. Slutsky DJ. Clinical applications of volar portals in wrist arthroscopy. Tech Hand Up Extrem Surg. 2004;8(4):229–38.
31. Lindau T, Adlercreutz C, Aspenberg P. Peripheral tears of the triangular fibrocartilage complex cause distal radioulnar joint instability after distal radial fractures. J Hand Surg Am. 2000;25:464–8.
32. Lindau T, Hagberg L, Adlercreutz C, et al. Distal radioulnar instability is an independent worsening factor in distal radial fractures. Clin Orthop Relat Res. 2000;376:229–35.
33. Lindau T. Treatment of injuries to the ulnar side of the wrist occurring with distal radius fractures. Hand Clin. 2005;21:417–25.
34. Buijze GA, Ring D. Clinical impact of United versus nonunited fractures of the proximal half of the ulnar styloid following volar plate fixation of the distal radius. J Hand Surg Am. 2010;35(2):223–7.
35. Kim JK, Cho SW. The effects of a displaced dorsal rim fracture on outcomes after volar plate fixation of a distal radius fracture. Injury. 2012;43(2):143–6A.
36. Zenke Y, Sakai A, Oshige T, Moritani S, Nakamura T. The effect of an associated ulnar styloid fracture on the outcome after fixation of a fracture of the distal radius. J Bone Joint Surg Br. 2009;91(1):102–7.
37. Sammer DM, Shah HM, Shauver MJ, Chung KC. The effect of ulnar styloid fractures on patient-rated outcomes after volar locking plating of distal radius fractures. J Hand Surg Am. 2009;34(9):1595–602.
38. Kim JK, Yun YH, Kim DJ, Yun GU. Comparison of united and nonunited fractures of the ulnar styloid following volar-plate fixation of distal radius fractures. Injury. 2011;42(4):371–5.
39. Geissler WB, Fernandez DL, Lamey DM. Distal radioulnar joint injuries associated with fractures of the distal radius. Clin Orthop Relat Res. 1996;327:135–46.
40. Logan A, Lindau T. The management of distal ulnar fractures in adults: a review of the literature and recommendations for treatment. Strategies Trauma Limb Reconstr. 2008;3(2):49–56.
41. Hohendorff B, Eck M, Mühldorfer M, Fodor S, Schmitt R, Prommersberger KJ. Palmar wrist arthroscopy for evaluation of concomitant carpal lesions in operative treatment of distal intraarticular radius fractures. Handchir Mikrochir Plast Chir. 2009;41(5):295–9.
42. Lindau T. Distal radial fractures and effects of associated ligament injuries. Dept of Orthopedics. Lund: University of Lund; 2000. p. 76.
43. Lindau T, Aspenberg P, Arner M, et al. Fractures of the distal forearm in young adults. An epidemiologic description of 341 patients. Acta Orthop Scand. 1999;70:124–28.
44. Schmalholz A. Epidemiology of distal radius fracture in Stockholm 1981–1982. Acta Orthop Scand. 1988;59:701–3.
45. Hanker GJ. Radius fractures in the athlete. Clin Sports Med. 2001;20:189–201.
46. Lindau T, Adlercreutz C, Aspenberg P. Cartilage injuries in distal radial fractures. Acta Orthop Scand. 2003;74(3):327–31.
47. Viegas SF, Pogue DJ, Patterson RM, et al. Effects of radio-ulnar instability on the radio-carpal joint: a biomechanical study. J Hand Surg Am. 1990;15:728–32.
48. Mrkonjic A, Geijer M, Lindau T, Tägil M. The natural course of traumatic triangular fibrocartilage complex tears in distal radial fractures: a 13-15 year follow-up of arthroscopically diagnosed but untreated injuries. J Hand Surg Am. 2012;37(8):1555–60.
49. Palmer AK. Triangular fibrocartilage complex lesions: a classification. J Hand Surg Am. 1989;14A:594–606.
50. Atzei A. New trends in arthroscopic management of type 1-B TFCC injuries with DRUJ instability. J Hand Surg Eur Vol. 2009;34(5):582–91.
51. Anderson ML, Larson AN, Moran SL, Cooney WP, Amrami KK, Berger RA. Clinical comparison of arthroscopic versus open repair of triangular fibrocartilage complex tears. J Hand Surg Am. 2008;33(5):675–82.

52. Morisawa Y, Nakamura T, Tazaki K. Dorsoradial avulsion of the triangular fibrocartilage complex with an avulsion fracture of the sigmoid notch of the radius. J Hand Surg Eur Vol. 2007;32(6):705–8.
53. Fellinger M, Peicha G, Seibert FJ, et al. Radial avulsion of the triangular fibrocartilage complex in acute wrist trauma: a new technique for arthroscopic repair. Arthroscopy. 1997;13:370–4.
54. Sagerman SD, Short W. Arthroscopic repair of radial-sided triangular fibrocartilage complex tears. Arthroscopy. 1996;12(3):339–42.
55. Forward D, Lindau T, Melsom D. Intercarpal ligament injuries associated with fractures of the distal radius. Arthroscopic assessment and 12 month follow-up. J Bone Joint Surg Am. 2007;89(11):2334–40.
56. Tang JB, Shi D, Gu YQ, et al. Can cast immobilization successfully treat scapholunate dissociation associated with distal radius fractures? J Hand Surg Am. 1996;21A:583–90.
57. Whipple TL. The role of arthroscopy in the treatment of scapholunate instability. Hand Clin. 1995;11:37–40.
58. Chennagiri RJR, Lindau T. Assessment of scapholunate instability and review of evidence for management in the absence of arthritis. J Hand Surg Eur Vol. 2013;38(7):727–38.
59. Peicha G, Seibert F, Fellinger M, et al. Midterm results of arthroscopic treatment of scapholunate ligament lesions associated with intra-articular distal radius fractures. Knee Surg Sports Traumatol Arthrosc. 1999;7:327–33.
60. Kuo CE, Wolfe SW. Scapholunate instability: current concepts in diagnosis and management. J Hand Surg Am. 2008;33A:998–1013.
61. Walsh JJ, Berger RA, Cooney WP. Current status of scapholunate interosseous ligament injuries. J Am Acad Orthop Surg. 2002;10(1):32–42.
62. Slade 3rd JF, Taksali S, Safanda J. Combined fractures of the scaphoid and distal radius: a revised treatment rationale using percutaneous and arthroscopic techniques. Hand Clin. 2005;21(3):427–41.
63. Slutsky DJ. Current innovations in wrist arthroscopy. J Hand Surg Am. 2012;37(9):1932–41.
64. Ono H, Katayama T, Furuta K, Suzuki D, Fujitani R, Akahane M. Distal radial fracture arthroscopic intraarticular gap and step-off measurement after open reduction and internal fixation with a volar locked plate. J Orthop Sci. 2012;17(4):443–9.
65. Scheer JH, Adolfsson LE. Patterns of triangular fibrocartilage complex (TFCC) injury associated with severely dorsally displaced extra-articular distal radius fractures. Injury. 2012;43(6):926–32.
66. Levy S, Saddiki R, Normand J, Dehoux E, Harisboure A. Arthroscopic assessment of articular fractures of distal radius osteosyntheses by percutaneous pins. Chir Main. 2011;30(3):218–23.
67. Kamano M, Koshimune M, Kazuki K, Honda Y. Palmar plating for AO/ASIF C3.2 fractures of the distal radius with arthroscopically assisted reduction. Hand Surg. 2005;10(1):71–6.
68. Kordasiewicz B, Podgórski A, Klich M, Michalik D, Chaberek S, Pomianowski S. Arthroscopic assessment of intraarticular distal radius fractures-results of minimally invasive fixation. Ortop Traumatol Rehabil. 2011;13(4):369–86.
69. Cognet JM, Bonnomet F, Ehlinger M, Dujardin C, Kempf JF, Simon P. Arthroscopy-guided treatment of fractures of the distal radius: 16 wrists. Rev Chir Orthop Reparatrice Appar Mot. 2003;89(6):515–23.
70. Herzberg G. Intra-articular fracture of the distal radius: arthroscopic assisted reduction. J Hand Surg. 2010;35A:1517–19.
71. Geissler WB. The role of wrist arthroscopy in intra-articular distal radius fracture management. In: Slutsky DJ, Nagle DJ, editors. Techniques in wrist and hand arthroscopy. Philadelphia: Churchill Livingstone; 2007. p. 151–70.
72. Ruch DS, Vallee J, Poehling GG, Smith BP, Kuzma GR. Arthroscopic reduction versus fluoroscopic reduction in the management of intra-articular distal radius fractures. Arthroscopy. 2004;20(3):225–30.
73. Ruch DS, Yang CC, Smith BP. Results of acute arthroscopically repaired triangular fibrocartilage complex injuries associated with intra-articular distal radius fractures. Arthroscopy. 2003;19(5):511–6.
74. Kapoor H, Agarwal A, Dhaon BK. Displaced intra-articular fractures of distal radius: a comparative evaluation of results following closed reduction, external fixation and open reduction with internal fixation. Injury. 2000;31(2):75–9.
75. Kreder HJ, Hanel DP, Agel J, et al. Indirect reduction and percutaneous fixation versus open reduction and internal fixation for displaced intra-articular fractures of the distal radius: a randomised, controlled trial. J Bone Joint Surg Br. 2005;87(6):829–36.
76. Wright TW, Horodyski M, Smith DW. Functional outcome of unstable distal radius fractures: ORIF with a volar fixed-angle tine plate versus external fixation. J Hand Surg Am. 2005;30(2):289–99.

19 Arthroscopic Management of Scaphoid Fractures and Nonunions

William B. Geissler

Introduction

The scaphoid carpal bone is the most frequently fractured bone in the carpus and accounts for nearly 70 % of all carpal fractures [1]. This fracture typically occurs in young men between the ages of 15 and 30 years and is also a common athletic injury occurring most often in contact sports [2]. It has been estimated that one in 100 college football players will sustain a fracture of the scaphoid in their career [3]. Frequently, a competitive athlete does not report his initial injury and continues to compete and eventually presents to the treating physician after the season is over with a scaphoid nonunion.

Acute nondisplaced fractures of the scaphoid have traditionally been managed with cast immobilization [4, 5]. Nondisplaced scaphoid fractures may heal in 8–12 weeks when immobilized in a short or long-arm cast [4–6]. While cast immobilization is successful in up to 85–90 % of cases, there may be significant cost to the patient with prolonged immobilization [4–6]. Prolonged immobilization may lead to muscle atrophy, joint contracture, disuse osteopenia, and financial hardship. An athlete may not be able to tolerate a lengthy course of immobilization and potentially could lose his scholarship or a worker could lose his employment.

It has been shown that the duration of cast immobilization varies dramatically according to the site of the fracture. A fracture of the scaphoid tubercle may heal within a period of 6 weeks while a fracture of the waist of the scaphoid may require 3 months or longer. Fractures of the proximal pole may take 6 months or longer to heal with a cast because of the vascularity of the scaphoid [7]. It is frequently difficult to truly identify when a fracture of the scaphoid will heal with nonoperative management by plain radiograph alone. Frequently, a CT scan may be required to thoroughly evaluate when a scaphoid is healed and treated non-operatively.

Displaced scaphoids have a reported nonunion rate of up to 50 % [2]. Factors that decrease the prognosis for healing include the amount of displacement, associated carpal instability, and delayed presentation (greater than 4–6 weeks) [1]. Traditionally, acute displaced fractures of the scaphoid, proximal pole fractures, and scaphoid nonunions are managed by open reduction and internal fixation [1, 2, 8–16]. Complications associated with open reduction and internal fixation include avascular necrosis, carpal instability, donor site pain, screw protrusion, infection, and complex regional pain syndrome [4, 17]. In one series, the biggest complication was hypertrophic scarring [2]. Multiple jigs have been designed to assist in open reduction; however, they are frequently difficult to apply and may necessitate further surgical dissection [18].

Wrist arthroscopy has revolutionized the practice of orthopedics allowing the surgeon to examine intra-articular abnormalities of the wrist under magnified and bright light conditions [19]. Whipple was one of the first surgeons to attempt arthroscopic management of scaphoid fractures [19]. His preliminary work set the stage for arthroscopic management of this common carpal fracture by many arthroscopic surgeons.

Arthroscopic stabilization provides direct visualization of the fracture reduction, particularly rotation, and the precise site for screw insertion with limited surgical dissection. This may allow for greater range of motion and early return to competition or employment. Fractures of the scaphoid are best visualized with the arthroscope in the midcarpal space. Fractures of the proximal pole are best seen with the arthroscope in the ulnar midcarpal portal, while fractures of the waist are best visualized with the arthroscope in the radial midcarpal portal. Associated soft tissue injuries may occur with a fracture of the scaphoid can be arthroscopically detected and managed at the same sitting.

Electronic supplementary material: Supplementary material is available in the online version of this chapter at 10.1007/978-1-4614-1596-1_19. Videos can also be accessed at http://www.springerimages.com/videos/978-1-4614-1595-4.

W.B. Geissler, M.D. (✉)
Department of Orthopaedic Surgery and Rehabilitation, University of Mississippi Medical Center, 2500 North State Street, Jackson, MS 39216, USA
e-mail: 3doghill@msn.com

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*, DOI 10.1007/978-1-4614-1596-1_19, © Springer Science+Business Media New York 2015

The indications and techniques of arthroscopic management of acute scaphoid fractures and selected nonunions are described in this chapter.

Diagnostic Imaging

Posterior/anterior and lateral radiographs are mandatory to assess the amount of displacement, angulation and alignment of a scaphoid fracture. Semisupinated and pronated views can provide additional information particularly in fractures of the proximal and distal poles of the scaphoid. It is helpful to place the wrist in ulnar deviation thereby extending the scaphoid in a posterior/anterior view for detection of fracture displacement. A nondisplaced fracture of the scaphoid may not become apparent on radiographs for several weeks post injury. It is important to immobilize the patient who presents with snuffbox tenderness to allow the pain to resolve or until a diagnosis has been confirmed radiographically.

Computer tomography (CT) parallel to the longitudinal axis of the scaphoid is useful to evaluate angulation, displacement, and healing. In this technique, the patient is placed prone with the arm extended overhead and the wrist radial deviated to obtain longitudinal access to the scaphoid. Coronal CT slices are obtained with supination of the forearm to a neutral position. CT evaluation is particularly helpful to determine scaphoid healing with nonoperative management of the scaphoid fracture is chosen. It is particularly important to return a contact athlete back to sports. One advantage of operative fixation is that the screw acts as an internal splint to stabilize the fracture and the exact time to return to competition is less critical compared with nonoperative management.

Treatment

Indications

Arthroscopic fixation may be performed for acute nondisplaced fracture of the scaphoid and for acute displaced fractures which are reducible. It is important in patients that have an acute nondisplaced fracture that the risks and benefits of arthroscopic stabilization compared with cast immobilization be discussed with the patient so that an informed decision can be made by the patient and associated family members. For acute scaphoid fractures that are reducible, the fracture may reduce by a number of techniques including manipulation of the wrist in a traction tower or joysticks inserted into the proximal and distal poles of the scaphoid. The reduction is best viewed with the arthroscope in the midcarpal space.

In addition, arthroscopic visualization of selected scaphoid nonunions may be performed. Slade and Geissler published their radiographic classifications for scaphoid nonunions (Table 19.1) [20]. Type I fractures are the result of a delayed presentation (4–12 weeks) after injury. Delayed presentation has been shown with a high incidence of nonunion. In Type II injuries, a fibrous union is present. A minimal fracture line may be seen on radiographs. It is important to note that the lunate is not rotated and there is no humpback deformity. In Type III injuries, minimal sclerosis is seen at the fracture site. The sclerosis is less than 1 mm in width, and again the lunate is note rotated and no humpback deformity is seen. In Type IV injuries, cystic formation is present at the nonunion site. The cystic formation may be between 1 and 5 mm in width. No humpback deformity or rotation of the lunate is seen on plain radiographs. In Type V injuries, the cystic changes are greater than 5 mm in width, and rotation of the lunate has occurred resulting in humpback deformity. The lunate has rotated to a position of dorsal intercalated segmental instability (DISI). In Type VI injuries, secondary degenerative changes have occurred with peaking of the radial styloid with spurring along the radial border of the scaphoid.

Table 19.1 Slade–Geissler classification of scaphoid nonunions

Type	Description
I	Delayed presentation at 4–12 weeks
II	Fibrous union, minimal fracture line
III	Minimal sclerosis <1 mm
IV	Cystic formation, 1–5 mm
V	Humpback deformity with >5 mm cystic change
VI	Wrist arthrosis

Arthroscopic stabilization of selected scaphoid nonunions is indicated in types I–IV. After a humpback deformity has occurred, arthroscopic stabilization is not recommended and open reduction and internal fixation is required to correct the humpback deformity and DISI rotation of the lunate.

Arthroscopic Techniques

Various arthroscopic assisted and percutaneous techniques for fractures of the scaphoid have been described in the literature [21–32]. Haddad and Goddard popularized the volar approach and the dorsal approach was popularized by Slade and colleagues [24, 26]. Geissler described his arthroscopic technique for viewing exact placement of the guide wire for eventual screw fixation [32].

Volar Percutaneous Approach

Haddad and Goddard popularized the volar percutaneous technique [24]. They recommended placing the patient supine with the thumb suspended in the Chinese finger trap. Placing the thumb under suspension allows ulnar deviation improving access to the distal pole of the scaphoid. A longitudinal 0.5 cm skin incision is made under fluoroscopic guidance over the most distal radial aspect of the scaphoid. Blunt dissection is carried down to expose the distal pole of the scaphoid. It is important to protect the cutaneous nerves as one dissects down to the distal pole of the scaphoid.

A percutaneous guide wire is then introduced into the scaphoid trapezial joint and advanced proximally and dorsally across the fracture site. The guide wire is inserted through a needle which is impaled onto the distal pole of the scaphoid. Using the needle helps to control the angulation of the guide wire. In addition, the bevel of the needle can help further direct the direction of the guide wire. The advantage of their technique by suspending the thumb in traction allows an almost 360° view of the position of the guide wire within the scaphoid. The length of the guide wire within the scaphoid is determined by placing a second guide wire next to the initial one and measuring the difference between the two. It is important when using a headless cannulated screw to use a screw 2–4 mm shorter than what is measured in the volar approach. A drill is inserted through a soft tissue protector and the scaphoid is reamed. A headless cannulated screw is placed over the guide wire. Occasionally, a second guide wire may be helpful to prevent rotation of the fracture fragments while the screw is being inserted.

Haddad and Goddard reported their initial results in a pilot study of 15 patients with acute scaphoid fractures [24]. Union was achieved in all patients in an average of 57 days (range 38–71 days). They found that the range of motion at the union was equal to that of the contralateral limb with their percutaneous technique and grip strength averaged 90 % at 3 months. The patients were able to return to sedentary work within 4 days and to manual work within 5 weeks.

The advantage of their technique is that it is fairly simple and straightforward and requires minimal specialized equipment. The disadvantage of the volar approach is that the screw may be placed slightly oblique to the mid waist fracture line in the scaphoid. The scaphoid is shaped like a cone with the widest part being distally and the smallest more proximally. It is harder to place the cannulated screw in the exact center of the scaphoid with starting at the wider distal pole of the scaphoid compared to the more narrow proximal pole.

Dorsal Percutaneous Approach

Joseph Slade was as pioneer in management of fractures of the scaphoid. He and his coworkers popularized the dorsal percutaneous approach [26, 27]. This technique became very popular because it involved limited surgical dissection and allowed arthroscopic evaluation and reduction of the scaphoid fracture. In his technique, the patient is placed in a supine position on the table with the arm extended. Several towels are placed under the elbow and support the forearm parallel to the floor. The wrist is then flexed and pronated under fluoroscopy until the proximal and distal poles of the scaphoid are aligned to perform a perfect cylinder. Continuous fluoroscopy is recommended as the wrist is flexed to obtain the true ring sign as the proximal and distal poles are aligned.

Under fluoroscopy, a 14-gauge needle is placed percutaneously in the center of the ring sign and parallel to the beam of the fluoroscopic unit. A guide wire is then inserted through the 14-gauge needle and driven across the central axis of the scaphoid from dorsal to volar until the guide wire comes into contact with the distal scaphoid cortex. Position of the guide wire is then evaluated under fluoroscopy in the lateral, posterior/anterior, and oblique planes while the wrist is maintaining flexion. It is important not to extend the wrist at this time as this may bend the guide wire. A second guide wire is then placed parallel to the first so that it touches the proximal pole of the scaphoid to determine the screw length. The difference in length between the two guide wires is measured. It is of vital importance that a screw at least 4 mm shorter is chosen when utilizing Slade's dorsal technique.

Once the screw length is determined, the primary guide wire is advanced volarly through a portion of the trapezium to exit the skin on the volar aspect of the hand. The wire is continued to be advanced volarly until it is flush with the proximal pole of the scaphoid dorsally so the wrist may now be extended.

The wrist is suspended in a traction tower and the radiocarpal and midcarpal spaces may be evaluated arthroscopically. The radiocarpal space is evaluated for any associated soft tissue injuries, and then the arthroscope is placed in the midcarpal space to evaluate the reduction of the scaphoid fracture. If the reduction of the scaphoid fracture is not determined to be satisfactory, the guide wire is continued to be advanced out volarly but yet it is still in the distal pole of the scaphoid. Joysticks may be placed at the proximal and distal poles of the scaphoid to facilitate reduction as viewed with the arthroscope in the midcarpal space. Once anatomic reduction has been obtained with the joysticks, the guide wire is then advanced proximally back into the proximal pole of the scaphoid.

The guide wire is then advanced back out dorsally with the wrist flexed once anatomic restoration of the scaphoid fracture has been obtained. It is important that blunt dissection continues around the guide wire dorsally to minimize risk of soft tissue impalement by the guide wire as it exits back out dorsally by the surrounding extensor tendons. A portion of the guide wire is still left out the volar aspect of the hand so if it breaks, easy access to the broken guide wire is possible. Through a soft tissue protector, the scaphoid is reamed over the guide wire and a headless cannulated screw is placed.

The dorsal approach has several advantages as the screw is inserted down the central axis of the scaphoid most perpendicular to the fracture site. This allows compression directly across the fracture site as compared to possibly more oblique orientation with the volar approach. The concern with the dorsal percutaneous approach is that as the wrist is hyperflexed to obtain the cylinder or ring sign, it may displace the scaphoid fracture creating a humpback deformity, which may be unstable. Reduction of the scaphoid should be evaluated with the arthroscope in the midcarpal space when utilizing this technique. Frequently, it takes a surgeon and a very capable assistant with the Slade technique.

Geissler Technique

The Geissler technique has the advantage of knowing the exact starting point for the guide wire as viewed directly with the arthroscope [33] (Video 19.1). There is no guesswork concerning the insertion point and location of the headless cannulated screw. It is the author's opinion that this technique is simpler than the dorsal percutaneous approach with the ring sign. The wrist is not hyperflexed, which could distract the scaphoid fracture and cause a possible humpback deformity.

The wrist is initially suspended in a wrist traction tower (Acumed, Hillsboro, OR) (Fig. 19.1). The wrist is flexed approximately 20–30° in the tower. The arthroscope is initially placed in the 3–4 portal to evaluate any associated soft tissue injuries and the 6-R portal is made. It is important when making the initial 3–4 portal that if one is to error, error slightly ulnar and proximal. If the 3–4 portal is made too radial or too distal, placement of the guide wire would be difficult. A 14-gauge needle is inserted through the 3–4 portal and the junction of the scapholunate interosseous ligament as it inserts onto the proximal pole of the scaphoid is palpated with the needle as viewed directly with the arthroscope in the 6-R portal (Fig. 19.2). Occasionally, some synovitis from the dorsal capsule may need to be debrided to facilitate visualization of the scapholunate interosseous ligament. It is important that as the needle is inserted through the 3–4 portal that it passes easily into the joint and does not impale through an extensor tendon. The proximal pole of the scaphoid is impaled once the needle is at the junction of the scapholunate interosseous ligament to the scaphoid (Fig. 19.3).

Fig. 19.1 The wrist is suspended in 10 lb of traction in the traction tower (Acumed, Hillsboro, OR). The suspension arm is out to the side, which facilitates arthroscopic and fluoroscopic reduction of fractures

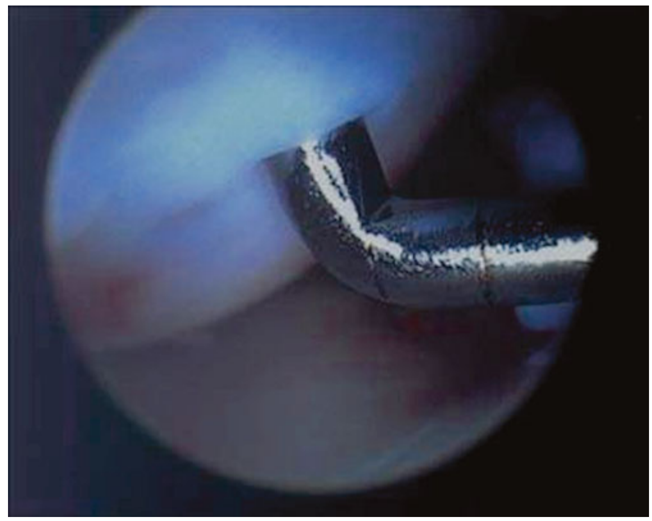


Fig. 19.2 Arthroscopic view with the arthroscope in the 6-R portal. The probe is placed in the 3–4 portal palpating the junction of the scapholunate interosseous ligament to the proximal pole of the scaphoid

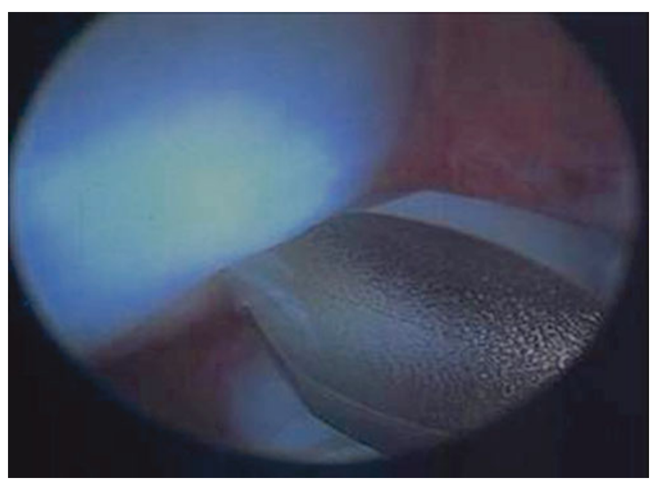


Fig. 19.3 Arthroscopic view with the arthroscope in the 6-R portal with a 14-gauge needle inserted through the 3–4 portal. The needle is palpating the junction of the scapholunate interosseous ligament to the proximal pole of the scaphoid and is impaled into the scaphoid

The wrist traction tower is then flexed and the starting point of the needle is confirmed under fluoroscopic visualization (Fig. 19.4). This technique allows for a consistent starting point of the very proximal pole of the scaphoid. The needle is then simply aimed toward the thumb under fluoroscopy, and a guide wire is placed through the needle down the central axis of the scaphoid to abut the distal pole (Fig. 19.5). The position of the guide wire is easily checked under fluoroscopy in the posterior/anterior, oblique, and lateral planes while rotating the forearm of the traction tower. The fluoroscopic image is not hindered by the support beam of the traction tower as it is off to the side. A second guide wire is then advanced against the proximal pole of the scaphoid and the length of the screw is determined by the difference of the two guide wires. Just as in the Slade technique, a screw at least 4 mm shorter than what is measured is recommended.

The reduction of the scaphoid may be evaluated with the arthroscope in the midcarpal portal. If anatomic reduction is confirmed arthroscopically, the guide wire is then advanced out the volar aspect of the hand. The scaphoid is then reamed with a cannulated reamer and a screw is placed (Figs. 19.6 and 19.7). The position of the screw is then checked in the posterior/anterior, oblique, and lateral planes under fluoroscopy with the wrist stabilized by the traction tower (Fig. 19.8).

It is important to evaluate the wrist both in the radiocarpal and midcarpal spaces after placement of the screw (Fig. 19.9).

Fig. 19.4 The traction tower (Acumed, Hillsboro, OR) is flexed down to verify the starting point of the proximal pole of the scaphoid

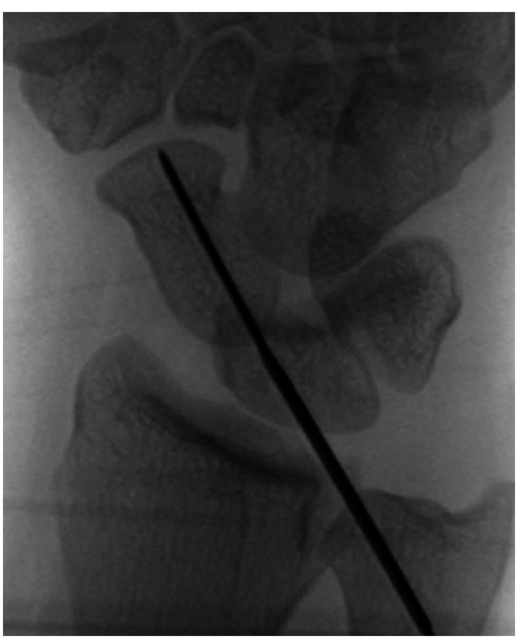


Fig. 19.5 Fluoroscopic view confirming ideal position of the starting point and guide wire through the central axis of the scaphoid fracture

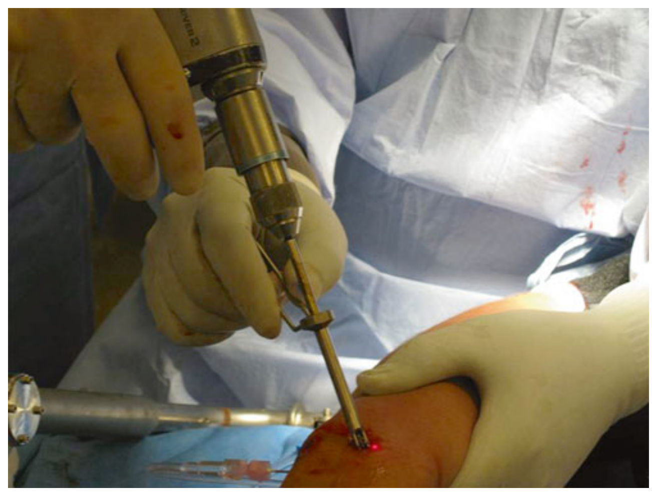


Fig. 19.6 Outside view showing reaming of the scaphoid through a soft tissue protector to protect the extensor tendons

Fig. 19.7 Outside view showing a headless cannulated screw being inserted over the cannulated guide wire stabilizing the fracture of the scaphoid

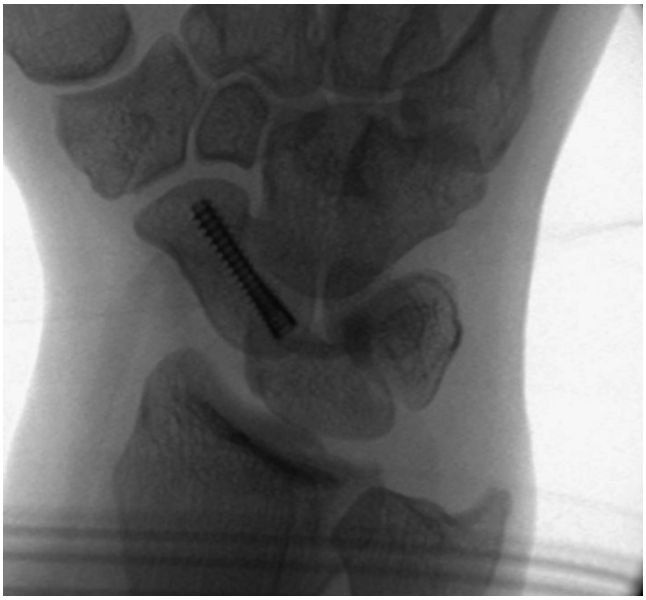


Fig. 19.8 Fluoroscopic oblique view showing ideal position of the headless cannulated screw inserted arthroscopically

Fig. 19.9 Arthroscopic view with the arthroscope in the radial midcarpal portal demonstrating anatomic reduction to the scaphoid fracture

It is particularly important to evaluate the radiocarpal space following screw placement because the screw may look well inserted in the scaphoid under fluoroscopy, but may still be slightly prominent proximally, which could potentially injure the articular cartilage of the scaphoid facet of the distal radius (Fig. 19.10)

Scaphoid Nonunions

Geissler and Slade described their use of Slade's dorsal percutaneous technique in 15 patients with a stable fibrous nonunion of the scaphoid [32]. There were 12 horizontal oblique

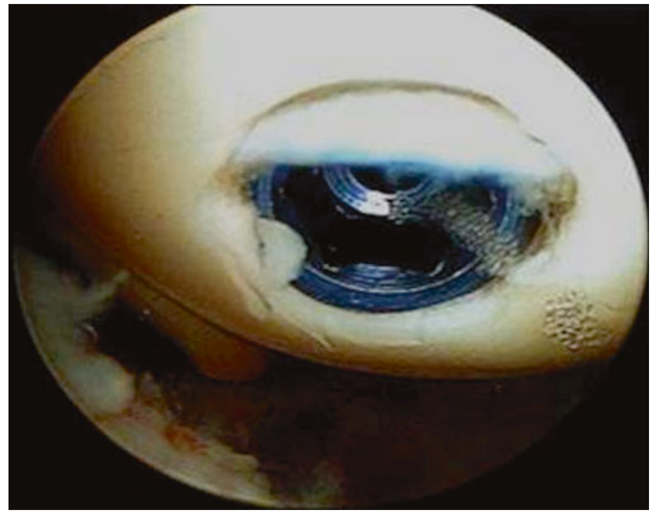


Fig. 19.10 Arthroscopic view with the arthroscope in the 3–4 portal confirming placement of the headless cannulated screw up into the scaphoid so as not to injure the articular cartilage of the distal radius

fractures, two proximal pole fractures, and one transverse fracture in their series. The average time to presentation to surgery was 8 months. All patients underwent percutaneous dorsal fixation with a headless cannulated screw with no bone grafting. Eight of the 15 patients underwent CT evaluation postoperatively to evaluate healing. All patients healed their fractures in an average time of 3 months in their series without any bone grafting. The patients demonstrated excellent range of motion at their final follow-up because of minimal surgical dissection. Utilizing the Mayo modified score, there were 12 of 15 patients who had excellent results. Dorsal percutaneous fixation without bone grafting was recommended in most patients with a stable fibrous nonunion with no signs of humpback deformity of the scaphoid or rotation of the lunate into a DISI position. This study of evaluating patients with Type I through Type III scaphoid nonunions by Slade and Geissler's classification revealed a 100 % success rate of union.

In patients who have a cystic scaphoid nonunion without a humpback deformity or rotation of the lunate, percutaneous cancellous bone grafting or injection of demineralized bone matrix (DBM) may be used. In Geissler's technique, the guide wire is placed as previously described [33]. The scaphoid is reamed through a soft tissue protector. A bone biopsy needle is filled with DBM putty. The needle is placed over the guide wire from dorsal to proximal and inserted into the drill hole directly into the nonunion site. The guide wire is then retracted distally out of the proximal pole of the scaphoid while still remaining into the distal pole of the scaphoid. The DBM is injected through the bone biopsy needle directly into the central hole of the scaphoid until resistance is felt (Fig. 19.11). Following injection of the DBM, the guide wire is advanced back dorsally through the bone

Fig. 19.11 Outside view showing insertion of DBM putty over the cannulated guide wire through a putty pusher into the scaphoid nonunion site

Fig. 19.12 Anterior/posterior radiograph demonstrating a transscaphoid perilunate dislocation

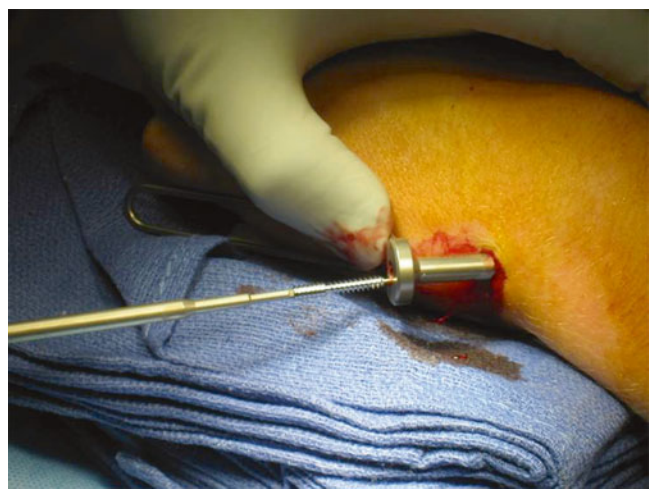


Fig. 19.13 Outside view showing placement of a SLIC screw (Acumed, Hillsboro, OR) placement across the lunotriquetral interval for a complete tear of the lunotriquetral osseous ligament

biopsy needle from volar to dorsal. In this manner, the guide wire passed back through the original reamed tract of the proximal pole of the scaphoid out dorsally. The bone biopsy needle is then removed, and the headless cannulated screw is placed over the guide wire.

Geissler reported his results of using 1 cc of DBM putty for cystic scaphoid nonunions of the scaphoid [33]. There were 15 patients in his series that were classified by the Slade and Geissler classification Type IV. Fourteen of 15 patients healed their cystic scaphoid nonunions utilizing this technique. Arthroscopic evaluation of the wrist from both the radiocarpal and midcarpal spaces showed no extravasation of the DBM into the joint.

Discussion

While cast immobilization of an acute nondisplaced fracture of the scaphoid is effective, there are certain disadvantages including muscle atrophy, joint contracture, and stiffness. Fractures or the scaphoid are common athletic injuries occurring especially in young men [34, 35]. Most nondisplaced acute fractures of the scaphoid have been reported to heal with nonunion rates of 10–15 %. However, union rates of 100 % for acute fractures of the scaphoid managed by percutaneous arthroscopic assisted fixation have been consistently reported in the literature [19–22].

Arthroscopic fixation of acute scaphoid fractures has several advantages. This can allow the patient to return quickly to the work force or to competition. Arthroscopic fixation allows for secure stabilization through limited surgical dissection, which may result in improved range of motion. Recently, the author has been working on stabilization of transscaphoid perilunar dislocations all arthroscopically without Kirschner wires and starting early range of motion (Figs. 19.12, 19.13, 19.14, 19.15, and 19.16). Early results have been very encouraging. In addition, arthroscopic fixation allows for the management of associated soft tissue injuries which may occur with a fracture of the scaphoid (Figs. 19.17, 19.18, and 19.19).

Arthroscopic fixation has also been shown to be beneficial in treating scaphoid nonunions Type I through Type IV with the classification scheme of Slade and Geissler [36]. In patients with a stable fibrous nonunion, stabilization with a

Fig. 19.14 Fluoroscopic view confirming ideal position of the SLIC screw across the injured lunotriquetral interval. Following this, the scaphoid fracture will be arthroscopically stabilized

Fig. 19.15 Following stabilization of the LT interval, the traction tower (Acumed, Hillsboro, OR) is being flexed to confirm the ideal starting point of the guide wire for the scaphoid fracture

screw alone has been shown to be effective. In patients with cystic changes, arthroscopic stabilization and percutaneous injection of DBM or percutaneous cancellous bone grafting is an effective option [33].

Arthroscopic fixation limits the guess work concerning the exact location of the starting point of a guide wire and cannulated screw as compared to previously described percutaneous fluoroscopic techniques. The ideal starting point is at the most proximal pole of the scaphoid at the junction of

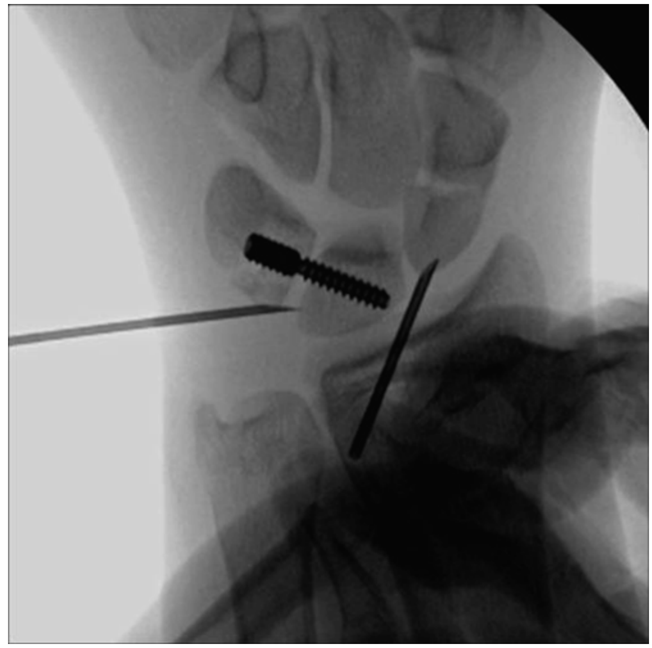


Fig. 19.16 Fluoroscopic view demonstrating the ideal starting point for the guide wire to stabilize the cannulated screw

Fig. 19.17 Fluoroscopic view showing stabilization both to the LT interval and scaphoid fracture and the perilunate dislocation. This patient will be started on immediate range of motion as no Kirschner wires were utilized, which can hamper rehabilitation

the scapholunate interosseous ligament. It is very reproducible and easily confirmed under fluoroscopy without hyperflexion of the wrist causing a potential humpback

Fig. 19.18 Radiograph showing a great arc injury to the wrist involving the distal radius, scaphoid, capitate, and lunotriquetral interval

Fig. 19.19 Fluoroscopic view following arthroscopic reduction of the distal radius fracture, scaphoid fracture, and SLIC screw placement (Acumed, Hillsboro, OR) of the lunotriquetral interval. The capitate fracture was stabilized percutaneously

deformity of the scaphoid. Dorsal insertion of the screw enables central placement down the axis of the scaphoid as compared to oblique orientation through the volar approach.

It is important to remember that these two techniques are not indicated for those patients who have severe humpback deformity, which is not correctable, or for those patients who have advanced arthrosis of the radiocarpal joint (SNAC) [37].

References

1. Gelberman RH, Wolock BS, Siegel DB. Current concepts review: fractures and nonunions of the carpal scaphoid. J Bone Joint Surg. 1989;71A:1560–5.
2. Cooney WP, Dobyns JH, Linscheid RL. Fractures of the scaphoid: a rational approach to management. Clin Orthop. 1980;149:90–7.
3. Rettig AC, Ryan RO, Stone JA. Epidemiology of hand injuries in sports. In: Strickland JW, Rettig AC, editors. Hand injuries in athletes. Philadelphia, PA: WB Saunders; 1992. p. 37–48.
4. Gellman H, Caputo RJ, Carter V, et al. Comparison of short and long thumb spica casts for non-displaced fractures of the carpal scaphoid. J Bone Joint Surg. 1989;71A:354–7.
5. Kaneshiro SA, Failla JM, Tashman S. Scaphoid fracture displacement with forearm rotation in a short arm thumb spica cast. J Hand Surg. 1989;71:354–7.
6. Skirven T, Trope J. Complications of immobilization. Hand Clin. 1994;10:53–61.
7. Gelberman RH, Menon J. The vascularity of the scaphoid bone. J Hand Surg. 1980;5:508–13.
8. Rettig AC, Weidenbener EJ, Gloyeske R. Alternative management of mid-third scaphoid fractures in the athlete. Am J Sports Med. 1994;22:711–4.
9. DeMaagd RL, Engber WD. Retrograde Herbert screw fixation for treatment of proximal pole scaphoid nonunions. J Hand Surg. 1989;14:996–1003.
10. Filan SL, Herbert TJ. Herbert screw fixation of scaphoid fractures. J Bone Joint Surg. 1996;78:519–29.
11. Herbert TJ, Fisher WE. Management of the fractured scaphoid using a new bone screw. J Bone Joint Surg. 1984;66:114–23.
12. O'Brien L, Herbert TJ. Internal fixation of acute scaphoid fractures: a new approach to treatment. Aust NZ J Surg. 1985;55:387–9.
13. Rettig ME, Raskin KB. Retrograde compression screw fixation of acute proximal pole scaphoid fractures. J Hand Surg. 1999; 24:1206–10.
14. Russe O. Fracture of the carpal navicular: diagnosis, nonoperative treatment and operative treatment. J Bone Joint Surg. 1960;42A:759.
15. Toby EB, Butler TE, McCormack TJ, et al. A comparison of fixation screws for the scaphoid during application of cyclic bending loads. J Bone Joint Surg. 1997;79:1190–7.
16. Trumble TE, Clarke T, Kreder HJ. Nonunion of the scaphoid: treatment with cannulated screws compared with treatment with Herbert screws. J Bone Joint Surg. 1996;78:1829–37.
17. Garcia-Elias M, Vall A, Salo JM, et al. Carpal alignment after different surgical approaches to the scaphoid: a comparative study. J Hand Surg. 1988;13:604–12.
18. Adams BD, Blair WF, Regan DS, et al. Technical factors related to Herbert screw fixation. J Bone Joint Surg. 1988;13:893–9.
19. Whipple TL. The role of arthroscopy in the treatment of intraarticular wrist fractures. Hand Clin. 1995;11:13–8.
20. Geissler WB. Arthroscopic assisted fixation of fractures of the scaphoid. Atlas Hand Clin. 2003;8:37–56.
21. Geissler WB, Hammit MD. Arthroscopic aided fixation of scaphoid fractures. Hand Clin. 2001;17:575–88.
22. Slade JF, Merrell GA, Geissler WB. Fixation of acute and selected nonunion scaphoid fractures. In: Geissler WB, editor. Wrist arthroscopy. New York, NY: Springer; 2005. p. 112–24.

23. Cosio MQ, Camp RA. Percutaneous pinning of symptomatic scaphoid nonunions. J Hand Surg. 1986;11:350–5.
24. Haddad FS, Goddard NJ. Acute percutaneous scaphoid fixation: a pilot study. J Bone Joint Surg. 1998;80:95–9.
25. Shin A, Bond A, McBride M, et al. Acute screw fixation versus cast immobilization for stable scaphoid fractures: a prospective randomized study. Presented at American Society Surgery for the Hand, Seattle, October 5–7, 2000.
26. Slade III JF, Grauer JN, Mahoney JD. Arthroscopic reduction and percutaneous fixation of scaphoid fractures with a novel dorsal technique. Orthop Clin North Am. 2000;30:247–61.
27. Slade III JF, Jaskwhich J. Percutaneous fixation of scaphoid fractures. Hand Clin. 2001;17:553–74.
28. Taras JS, Sweet S, Shum W, et al. Percutaneous and arthroscopic screw fixation of scaphoid fractures in the athlete. Hand Clin. 1999;15:467–73.
29. Slade III JF, Grauer JN. Dorsal percutaneous repair of scaphoid fractures with arthroscopic guidance. Atlas Hand Clin. 2001;6:307–23.
30. Wozasek GE, Moser KD. Percutaneous screw fixation of fractures of the scaphoid. J Bone Joint Surg. 1991;73:138–42.
31. Kamineni S, Lavy CBD. Percutaneous fixation of scaphoid fractures: an anatomic study. J Hand Surg. 1999;24:85–8.
32. Geissler WB, Slade JF. Arthroscopic fixation of scaphoid nonunions without bone grafting. Presented American Society Surgery of the Hand, Phoenix, AZ, September 2002.
33. Geissler WB. Arthroscopic fixation of cystic scaphoid nonunions with DBM. Presented American Association Hand Surgery, Tucson, AZ, January 2006.
34. Geissler WB. Carpal fractures in athletes. Clin Sports Med. 2001;20:167–88.
35. Rettig AC, Kollias SC. Internal fixation of acute stable scaphoid fractures in the athlete. Am J Sports Med. 1996;24:182–6.
36. Geissler WB. Wrist arthroscopy. New York, NY: Springer; 2005.
37. Fernandez DL. Anterior bone grafting and conventional lag screw fixation to treat scaphoid nonunions. J Hand Surg. 1990;15A:140–7.

Arthroscopic Assessment and Management of Kienböck's Disease

20

Duncan Thomas McGuire and Gregory Ian Bain

Introduction

Kienböck's disease is a debilitating condition resulting in avascular necrosis of the lunate. First described over 100 years ago by Robert Kienböck, the disease was initially thought to be caused by repetitive trauma to the wrist [1]. To this day the precise etiology remains uncertain, although the theory that it is caused by a disruption of the blood supply to the lunate is well accepted. The exact cause of this disruption is unknown, although there are certain associated factors that have been identified.

Cadaveric studies have brought attention to the variable blood supply to the lunate [2]. The lunate receives its blood supply from vessels entering dorsally and volarly. In certain instances the number of vessels entering the lunate may be fewer, possibly predisposing certain individuals to avascular necrosis of the lunate. Another theory postulates that increased venous pressure and disruption of venous outflow may be an etiological factor [3]. It is not clear however if this increased pressure contributes to the disease or is a secondary result of the disease.

The disease is more common in males, between the ages of 20 and 40 years. It often affects the dominant hand and is associated with negative ulnar variance. Patients typically present with wrist pain, swelling, restricted range of motion and difficulty performing activities of daily living. For those patients who fail to improve with nonoperative modalities, surgical treatment is offered.

Historically, the radiological classification of Kienböck's disease developed by Lichtman et al. [4] has been used to classify the disease (Table 20.1), although its reliability has been shown to be poor [5]. To improve the reliability of the classification, Goldfarb et al. proposed a modification to the classification system in which stage 3B was defined as a radioscaphoid angle greater than 60° [5]. This classification system is based on radiographic assessment and so does not take into consideration the condition of the cartilaginous articular surface.

Arthroscopy provides direct visualization of the articular cartilage and allows assessment of the radiocarpal and midcarpal joints. The disparity between radiographic and arthroscopic assessment has been highlighted by Ribak, who reported that plain radiographs correlated poorly with arthroscopic findings [6]. This was reinforced by Bain and Begg, who reported that it was not uncommon for plain radiographs to underscore the severity of the articular involvement identified with arthroscopy [7].

The Role of Wrist Arthroscopy

In 1999 Menth-Chiari et al. first described the use of wrist arthroscopy for the treatment of Kienböck's disease [8]. Their model was to use arthroscopy to assess the articular surfaces, to debride the necrotic lunate and perform a limited synovectomy. In their study all patients were either Lichtman grade IIIA or IIIB, and all experienced relief of their painful mechanical symptoms.

Wrist arthroscopy has become a valuable assessment and primary treatment tool in the treatment of Kienböck's disease. The authors use arthroscopy to perform the initial debridement and to identify the nonfunctional joints to tailor the surgical reconstruction to the anatomic findings [7]. This system uses direct visual assessment of the articulations of the lunate and a probe to assess the degree of softening of the articular surfaces. Correlating this arthroscopic assessment with traditional investigations helps the clinician make better-informed management decisions. The advantage is that functional joint surfaces determine treatment.

D.T. McGuire, M.B.C.H.B., F.C.S.
G.I. Bain, M.B.B.S., F.R.A.C.S. (✉)
Department of Orthopaedic surgery, Royal Adelaide Hospital, 196 Melbourne Street, North Adelaide, Adelaide, SA 5006, Australia
e-mail: greg@gregbain.com.au

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*, DOI 10.1007/978-1-4614-1596-1_20, © Springer Science+Business Media New York 2015

Table 20.1 Lichtman classification of Kienböck's disease

Stage 1	Normal radiographs. Signal intensity changes on MRI scan
Stage 2	Sclerosis of the lunate on radiographs; Fracture lines may be seen, but no collapse
Stage 3	Collapse of the lunate articular surface.
Stage 3A	Normal carpal alignment and height.
Stage 3B	Abnormal carpal alignment. Fixed scaphoid rotation, proximal capitate migration, and loss of carpal height.
Stage 4	Collapse of the lunate associated with radiocarpal or midcarpal arthritis

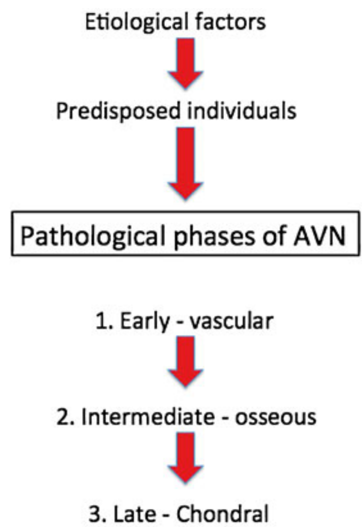


Fig. 20.1 The pathological phases of Kienböck's disease showing the association between the vascular, osseous, and chondral phases [Reprinted from Bain GI, Durrant A. An articular-based approach to Kienböck avascular necrosis of the lunate. Tech Hand Up Extrem Surg. 2011;15(1):41–7. With permission Wolters Kluwer Health]

Arthroscopic Technique

Wrist arthroscopy is performed using the standard technique. The patient is placed supine with their arm on an arm board. A tourniquet is used. Traction is applied from a tower mounted on the opposite side of the bed, and the arm is suspended using finger traps. A counter traction weight of 4 kg is attached to a sling and draped over the tourniquet on the patient's upper arm. Standard 3/4, 6R and midcarpal portals are used.

The articular surface of the lunate is examined from the radiocarpal and the midcarpal joint. The articular surface is probed. If there is a subchondral fracture, then the cartilage will be soft, indicating a floating articular surface. The articular surfaces of the lunate facet of the distal radius and the head of the capitate are also inspected and probed. Fracture of the lunate may be identified and any loose bodies are removed. Synovitis is identified. If no further surgery is planned the joint is debrided.

Pathological Phases of Kienböck's Disease

Avascular necrosis of the lunate consists of three pathological phases: vascular (early), osseous (intermediate), and chondral (late) [9] (Fig. 20.1).

Early Vascular

Changes in the lunate commence with ischemia, subsequent necrosis and revascularization. MRI and bone scan are of value in interpreting the vascular changes.

Intermediate Osseous

Lichtman has described this phase well over the last 36 years. CT scan is of value and it demonstrates well the detail of the osseous changes [10]. The initial radiological changes are of sclerosis, followed by subchondral collapse. Multiple faults or plates occur in the trabeculae and when the formation of these outstrips the repair, the blood supply may be disrupted and result in bone necrosis [11]. It has been shown that the trabecular structure of lunates affected by Kienböck's disease is different from that of normal lunates. The trabeculations are denser and thicker, whereas the surface area and volume are lower [12] (Fig. 20.2a).

It is the authors' opinion that the subchondral bone plate is likely to be the critical part of the process of avascular necrosis, and that its survival is the key to the prognosis of articular cartilage, lunate, and the wrist. The normal lunate has longitudinal trabeculae that give axial support and prevent collapse of the bone during loading. As a result of the avascular necrosis, the trabeculae collapse and this leads to loss of height of the lunate and shortening of the carpus. In addition to the longitudinal collapse, shear fractures may occur with normal physiological loads, and with more advanced disease fractures occur through the proximal subchondral bone plate (Fig. 20.2b–d).

Late Chondral

The articular cartilage is often soft and can be indented, giving the impression that the articular surface has a false floor. The chondral changes will be described in more detail in the classification below.

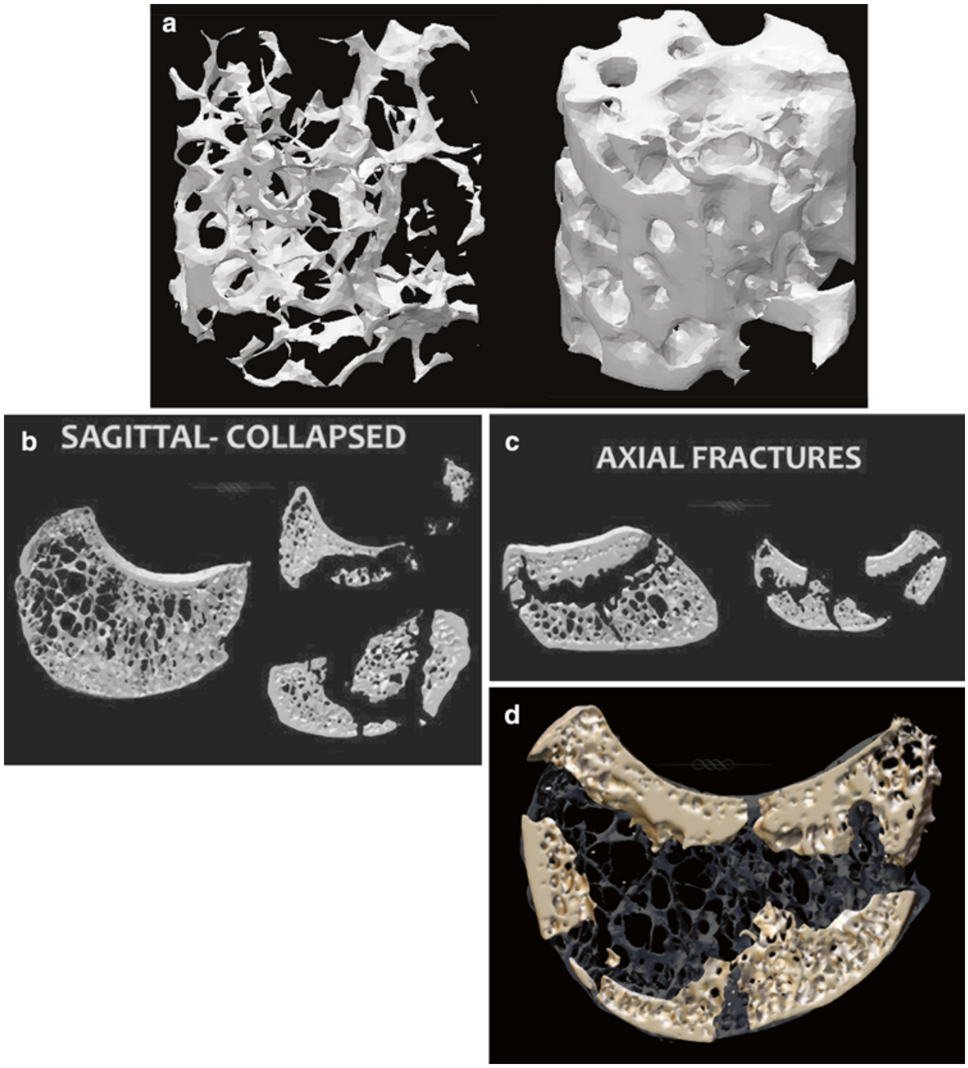


Fig. 20.2 (**a**) Micro CT scan of normal bone on the *left*, and bone from a lunate affected by Kienböck's disease on the *right*. Note how the avascular, necrotic bone has larger, thicker trabeculae and is denser. (**b**) Sagittal micro CT images showing a normal lunate on the *left* and necrotic, collapsed lunates with multiple fractures on the *right*. (**c**) Sagittal micro CT images of avascular lunates with multiple fractures. The lunate on the *left* has a shear fracture in the axial plane. The fracture line has occurred at the junction between the hard bone of the subchondral bone plate and the weakened cancellous bone in the center. (**d**) Micro CT scan of the fragmented avascular lunate superimposed on a micro CT of a normal lunate. The bone of the hard subchondral bone plate is still present but there is loss of the longitudinal trabeculae, which leads to collapse and carpal shortening [Courtesy of Dr. Gregory Ian Bain]

Arthroscopic Classification

Bain and Begg first described their arthroscopic classification in 2006 [7]. This is based on the number of nonfunctional articular surfaces. The authors defined a normal articular surface as having a normal glistening appearance or minor fibrillation, with normal hard subchondral bone on probing. A nonfunctional articular surface is defined as having any one of the following: extensive fibrillation, fissuring, localized or extensive articular loss, a floating articular surface, or fracture. The number of nonfunctional articular surfaces determines the grade.

The authors observed a consistent pattern of changes in the lunate. This was based on MRI, plain radiographs and arthroscopy. The changes always first occurred on the proximal articular surface of the lunate. The more severe cases would develop a subchondral fracture and these would have secondary chondral changes in the lunate facet of the radius. Involvement of the distal articular surface of the lunate was rare, except if a coronal fracture extended through to the surface, or in late cases. The classification was based on these observations (Fig. 20.3).

Grade 0

All articular surfaces are functional.

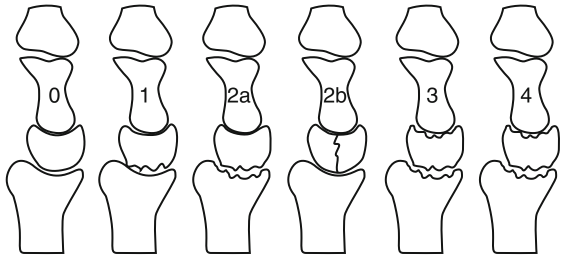


Fig. 20.3 The Bain and Begg arthroscopic classification of Kienböck's disease. The number of nonfunctional articular surfaces determines the grade. The grading system assists the surgeon to determine the best surgical option, based on the pathoanatomical findings. Although the classification was established based on arthroscopic findings, the grading can be determined based on imaging modalities [Reprinted from Bain GI, Durrant A. An articular-based approach to Kienböck avascular necrosis of the lunate. Tech Hand Up Extrem Surg. 2011;15(1):41–7. With permission Wolters Kluwer Health]

Grade 1

One nonfunctional articular surface—usually the proximal articular surface of the lunate.

Grade 2

Two nonfunctional articular surfaces. Divided into types A and B.

- Grade 2A: The proximal lunate and the lunate facet of the radius.
- Grade 2B: Proximal articular surface of the lunate, and distal articular surface of the lunate.

Grade 3

Three nonfunctional articular surfaces—the lunate facet of the radius, proximal and distal articular surfaces of the lunate, with a preserved head of capitate.

Grade 4

All four articular surfaces are nonfunctional.

The authors have noted the following observations [9]:

- The degree of synovitis correlates with the degree of articular damage
- The severity of articular changes are underestimated by plain radiographs
- Findings at arthroscopy commonly change the initial treatment plan
- In certain cases the articular cartilage envelope remains intact with collapse of the subchondral bone plate. This is an important subgroup where the lunate has probably revascularized. In these patients, particularly if they are young, conservative treatment may be considered, as there is potential to heal and stabilize.

Table 20.2 Patient summary from Tatebe et al. [13]

Bain and Begg classification	
Grade	Number of cases
Grade 0	2
Grade 1	14
Grade 2	22
Grade 2A	9
Grade 2B	13
Grade 3	18
Grade 4	1

Adapted from Tatebe M, Hirata H, Shinohara T, Yamamoto M, Okui N, Kurimoto S, Imaeda T. Arthroscopic findings of Kienböck's disease. J Orthop Sci. 2011;16(6):745–8. With permission from Springer Verlag

Tatebe et al. performed a retrospective review of 57 patients with Kienböck's disease who had undergone wrist arthroscopy [13]. Each case was classified using the Bain and Begg classification and the number of cases of each grade is summarized in Table 20.2. They found that the number of articular surfaces involved did not correlate with either the Lichtman radiographic stage or the duration from onset to surgery. They did note a correlation between the number of nonfunctional articular surfaces and older age of the patient. Their conclusions were that the proximal articular surface of the lunate is usually affected, and that older patients had more nonfunctional articular surfaces.

Imaging modalities other than arthroscopy may be used to assess the articular cartilage. As the resolution of MRI continues to improve it may become a suitable standard to assess the articular surfaces prior to reconstructive surgery (Fig. 20.4). CT scans may demonstrate bone on bone articulations, which implies loss of cartilage and a nonfunctional articular surface (Fig. 20.5).

Articular Based Approach to Treatment

Traditionally, Kienböck's disease has been managed based on the radiological osseous findings as defined by the Lichtman classification. However, the extent of the disease may be better understood after arthroscopy, and so the authors have used an articular based approach to determine surgical treatment. At arthroscopy, functional and nonfunctional articular surfaces are identified and the Bain and Begg Classification determined. The principles of surgical treatment are to remove the nonfunctional surfaces, and to leave the carpus articulating with functional articular surfaces, while maintaining a functional range of motion.

When discussing treatment options with the patient, the options of operative and nonoperative management should be offered. It would be common to start with conservative

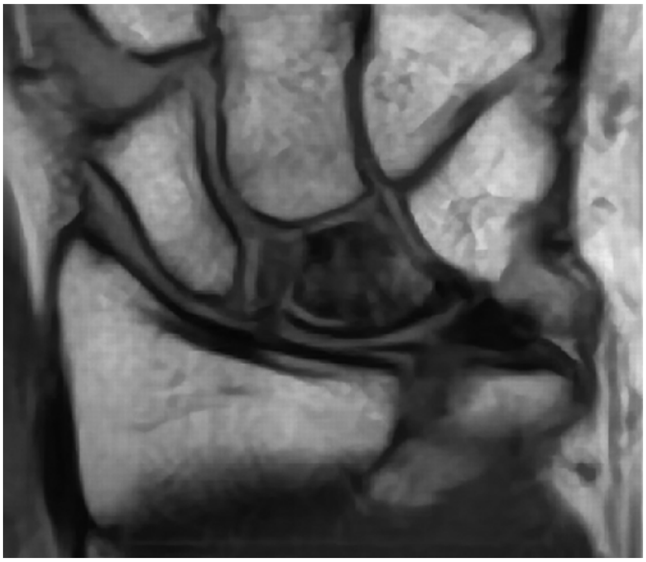


Fig. 20.4 MRI scan showing the lunate with fragmentation and a subchondral fracture extending distally. The articular cartilage has some irregularity. At this stage the resolution of the articular cartilage is not really sufficient to recommend treatment and therefore, arthroscopy is essential to identify the integrity of the articular surface [Reprinted from Bain GI, Durrant A. An articular-based approach to Kienböck avascular necrosis of the lunate. Tech Hand Up Extrem Surg. 2011;15(1):41–7. With permission Wolters Kluwer Health]

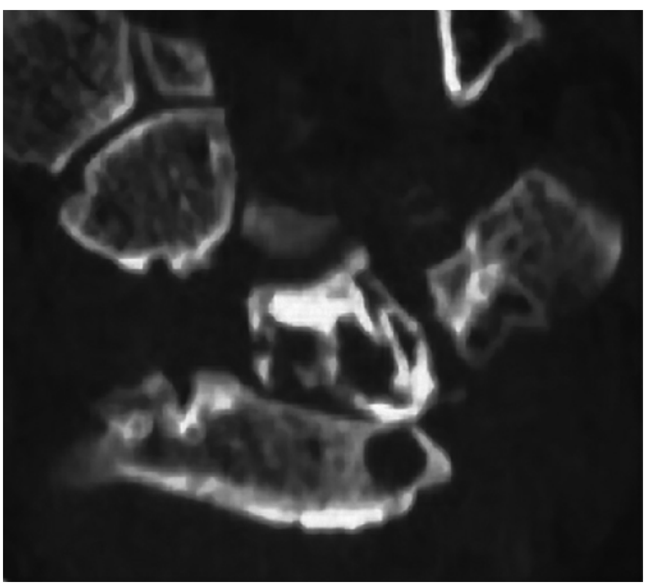


Fig. 20.5 CT scan of the wrist showing sclerosis and fragmentation of the lunate. The bone on bone appearance with complete loss of joint space indicates that there must be full thickness loss of the articular cartilage of the lunate and lunate facet. Arthroscopy will be of value to assess the midcarpal joint involvement before determining the best surgical reconstructive procedure [Reprinted from Bain GI, Durrant A. An articular-based approach to Kienböck avascular necrosis of the lunate. Tech Hand Up Extrem Surg. 2011;15(1):41–7. With permission Wolters Kluwer Health]

treatment using a wrist splint and activity modification. If the patient elects to proceed with surgery the authors provide informed consent for the arthroscopy and the reconstruction procedure.

The authors consent the patient for the arthroscopy and the reconstruction procedure. The option of an arthroscopy without a reconstructive procedure is also discussed. An isolated arthroscopy and debridement is usually performed in those patients with Grade 0, or in patients with very advanced disease who do not want a full wrist fusion (Grade 4).

Grade 0

All articular surfaces are functional. An arthroscopic debridement and synovectomy is performed. Further treatment may involve an unloading procedure, revascularization, core decompression, or bone grafting.

An unloading procedure is performed extra-articularly. In the presence of negative ulnar variance a radial shortening osteotomy is performed. For neutral or positive ulnar variance, a capitate shortening procedure can be performed.

A revascularization procedure or an arthroscopic decompression may also be considered. Arthroscopic core decompression has been described for this phase of the disease [14]. It is recommended only for patients with neutral or positive ulnar variance, who have grade 0 disease (Fig. 20.6).

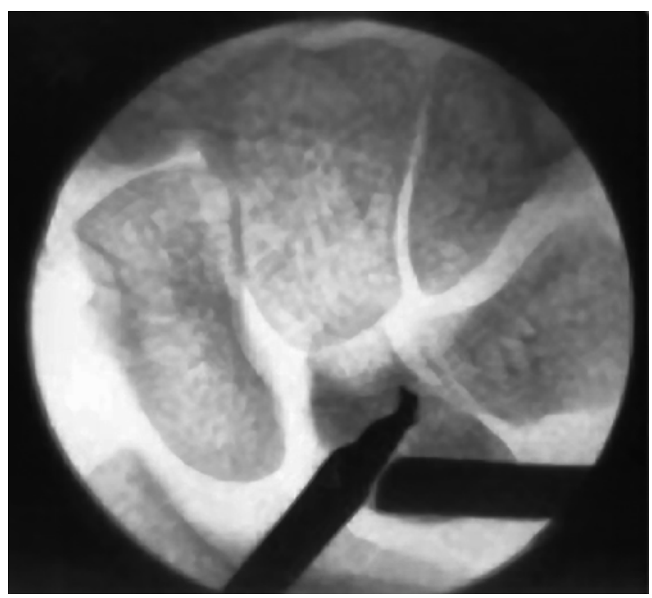


Fig. 20.6 Arthroscopic core decompression of the lunate under fluoroscopic guidance in a patient with an arthroscopic grade 0 Kienböck's disease [Reprinted from Bain GI, Durrant A. An articular-based approach to Kienböck avascular necrosis of the lunate. Tech Hand Up Extrem Surg. 2011;15(1):41–7. With permission Wolters Kluwer Health]

Bone grafting of the necrotic lunate may be performed and this may be done as an arthroscopic procedure. In a technique described by Pegoli et al., the lunate is drilled at a site near the dorsal insertion of the lunotriquetral ligament after it has been confirmed that the articular cartilage is uninvolved [15]. The necrotic lunate is debrided with a motorized shaver. Osteoscopy is then performed by inserting the scope into the lunate bone to confirm adequate debridement [7]. Cancellous bone graft is harvested from the volar surface of the distal radius and inserted into the lunate through a trocar.

Grade 1

These patients have a nonfunctional proximal lunate articular surface. Treatment involves either a proximal row carpectomy (PRC) or a radioscapholunate (RSL) fusion.

Grade 2A

The proximal articular surface of the lunate and the lunate fossa are both nonfunctional. A RSL fusion removes both nonfunctional articular surfaces and enables the wrist to articulate through the normal midcarpal joint. The head of the capitate and distal lunate articular surface are uninvolved.

Grade 2B

The proximal and distal articular surfaces of the lunate are nonfunctional. This usually occurs when there is a coronal or sagittal fracture of the lunate extending between the radiocarpal and midcarpal joints. The articular surfaces of the lunate fossa of the radius and the head of the capitate are normal. A PRC is the treatment of choice. More complex procedures such as internal fixation or vascularized bone grafting tend to have poor results [7, 16].

Grade 3

Three articular surfaces are nonfunctional. Most likely it will be the capitate articular surface, which remains functional. This usually requires a salvage procedure such as a total wrist fusion or arthroplasty. An alternative option is a resurfacing hemiarthroplasty of the distal radius that would articulate with the head of the capitate. However, the results of this procedure are not yet established (Fig. 20.7).

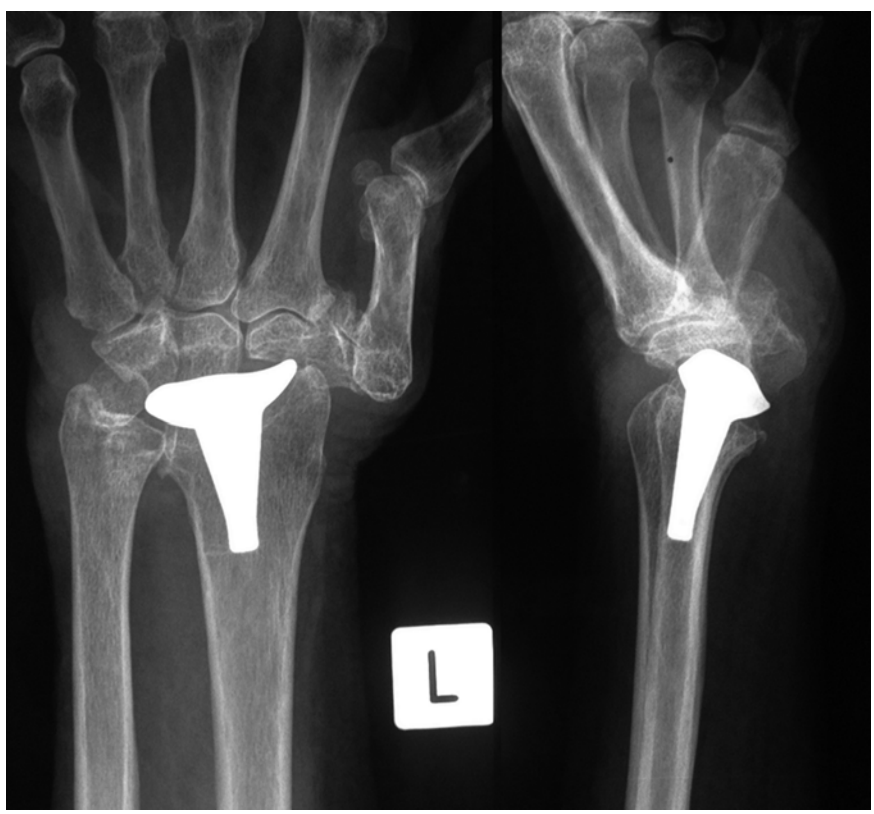


Fig. 20.7 Anteroposterior and lateral radiographs showing a hemiarthroplasty of the distal radius performed for a patient with grade 3 Kienböck's disease

Grade 4

All four articular surfaces are nonfunctional. A total wrist fusion or arthroplasty is indicated.

PRC and RSL fusions are the preferred motion preserving, reconstructive procedures because they maintain the stability of the wrist, and allow a functional range of motion to be maintained [17]. If the head of the capitate is pointed then a PRC may not be a good option, as the articulation with the lunate fossa of the distal radius may then not be congruent, and result in loading over a smaller area. This may occur in patients with a type 2 lunate, which has two distal facets, one for the capitate and the other for the hamate [18]. In this case a RSL fusion may be preferred.

A RSL fusion provides a congruent articulation, but requires arthrodesis of the distal radius to the necrotic proximal lunate, which may result in a non-union. For this reason, the authors excise the proximal half of the lunate so that the fusion is from the radius to the viable distal half of the lunate [19]. This is more challenging than a conventional RSL fusion. The surgery is performed using two 1.1 mm Kirschner wires to stabilize the lunate to the scaphoid. The scapholunate unit is then fixed to the radius using Kirschner wires, small inter-fragmentary screws or staples. The triquetrum and the distal half of the scaphoid are excised to increase the ROM, which has been confirmed by cadaver studies [19].

Scapho-trapezoid-trapezium and scaphocapitate fusions have not been included in the treatment options because these fusions compromise the loading and kinematics of the radioscaphoid facet and have a high complication rate [20].

The approach that is presented in this paper respects the articular cartilage in patients with Kienböck's disease. It places at the front of the decision making process the pathoanatomical aspects of the articular cartilage. Regardless of the method of assessment of the articular cartilage, what is important is to assess the articular surfaces involved, and to design the most appropriate procedure, taking into account the individual's pathoanatomical findings.

Although this approach was developed for vascular necrosis of the lunate, it does in principle apply to other joints in which avascular necrosis occurs.

References

1. Irisarri C. Aetiology of Kienböck's disease. J Hand Surg Br. 2004;29(3):281–7.
2. Lutsky K, Beredjiklian PK. Kienböck disease. J Hand Surg Am. 2012;37(9):1942–52.
3. Beredjiklian PK. Kienbock's disease. J Hand Surg Am. 2009;34(1):167–75.
4. Lichtman DM, Mack GR, MacDonald RI, Gunther SF, Wilson JN. Kienbock's disease: the role of silicone replacement arthroplasty. J Bone Joint Surg Am. 1977;59(7):899–908.
5. Goldfarb CA, Hsu J, Gelberman RH, Boyer MI. The Lichtman classification for Kienbock's disease: an assessment of reliability. J Hand Surg Am. 2003;28(1):74–80.
6. Ribak S. The importance of wrist arthroscopy for staging and treatment of Kienbock's disease. Presented at the 10th Triennial Congress of the International Federation of Societies for Surgery of the Hand, Sydney, March 2007.
7. Bain GI, Begg M. Arthroscopic assessment and classification of Kienbock's disease. Tech Hand Up Extrem Surg. 2006;10:8–13.
8. Menth-Chiari WA, Poehling GG, Wiesler ER, Ruch DS. Arthroscopic debridement for the treatment of Kienbock's disease. Arthroscopy. 1999;15:12–9.
9. Bain GI, Durrant A. An articular-based approach to Kienböck avascular necrosis of the lunate. Tech Hand Up Extrem Surg. 2011;15(1):41–7.
10. Quenzer DE, Linscheid RL, Vidal MA, Dobyns JH, Beckenbaugh RD, Cooney WP. Trispiral tomographic staging of Kienbock's disease. J Hand Surg Am. 1997;22(3):396–403.
11. Watson HK, Guidera PM. Aetiology of Kienbock's disease. J Hand Surg Br. 1997;22:5–7.
12. Han KJ, Kim YJ, Chung NS, Lee HR, Lee YS. Trabecular microstructure of the human lunate in Kienböck's disease. J Hand Surg Eur. 2012;37:336–41.
13. Tatebe M, Hirata H, Shinohara T, Yamamoto M, Okui N, Kurimoto S, Imaeda T. Arthroscopic findings of Kienböck's disease. J Orthop Sci. 2011;16(6):745–8.
14. Bain GI, Smith ML, Watts AC. Arthroscopic core decompression of the lunate in early stage Kienböck disease of the lunate. Tech Hand Up Extrem Surg. 2011;15:66–9.
15. Pegoli L, Ghezzi A, Cavalli E, Luchetti R, Pajardi G. Arthroscopic assisted bone grafting for early stages of Kienböck's disease. Hand Surg. 2011;16(2):127–31.
16. Lichtman DM. A classification-based treatment algorithm for Kienböck's disease - current and future considerations. Tech Hand Up Extrem Surg. 2011;15:41–7.
17. Palmer AK, Werner FW, Murphy D, Glisson R. Functional wrist motion: a biomechanical study. J Hand Surg Am. 1985;10(1):39–46.
18. Viegas SF. The lunatohamate articulation of the midcarpal joint. Arthroscopy. 1990;6(1):5–10.
19. Bain GI, Ondimu P, Hallam P, Ashwood N. Radioscapholunate arthrodesis – a prospective study. Hand Surg. 2009;14:73–82.
20. McAuliffe JA, Dell PC, Jaffe R. Complications of intercarpal arthrodesis. J Hand Surg Am. 1993;18(6):1121–8.

21 Arthroscopic Excision of Dorsal Ganglions

Meredith N. Osterman, Joshua M. Abzug, and A. Lee Osterman

Ganglion cysts about the wrist are a common pathology that present to hand surgeons and are more common in females [1]. Treatment options for these masses include observation, aspiration, or surgical excision. Historically, open surgical excision has been the gold standard of treatment. The initial description of arthroscopic ganglion excision in 1995, by Osterman and Raphael [2], has lead to an increased interest in this treatment technique, given its minimally invasive nature. However, no clear distinction exists regarding the indications for performing open versus arthroscopic excision. Proposed advantages for arthroscopic excision include improved recovery with earlier return to work, better joint visualization, the ability to identify and treat other intra-articular pathology, and more satisfying cosmetic results [2–6]. However, concerns exist regarding limited visualization, specifically of the ganglion stalk. Additional concerns include the applicability of arthroscopic excision for volar and recurrent ganglions.

Anatomy

A vast majority of wrist ganglion cysts, 60–70 %, occur on the dorsal aspect of the wrist [7]. Often these ganglions communicate directly with the wrist joint via a pedicle or stalk, which most commonly originates from the membranous portion of the scapholunate ligament [7]. The importance of removing this pedicle during surgical excision is debated in the literature. Angelides attributes his 1 % recurrence rate after open surgical excision to excising the stalk [8]. His dissection of the stalk under magnification showed a one-way valvelike system between the scapholunate joint and the ganglion [8]. This implies that without removal of the stalk the ganglion cyst would reoccur. However, other studies have shown similar recurrence rates without completely visualizing, and thus clearly excising, the stalk during ganglion removal. Osterman reported no recurrence after arthroscopic excision yet only visualized and excised 61 % of ganglion stalks [2]. Luchetti reported a recurrence of only 2 of 34 ganglions after arthroscopic surgical excision and only visualized and excised 27 stalks [3]. If the stalk is not clearly visualized, the area of capsular attachment to the scapholunate ligament is excised empirically during ganglion resection and thought to be equivalent to excising the stalk itself.

Volar ganglions represent 20 % of all wrist ganglia and frequently present in the proximal wrist crease between the flexor carpi radialis tendon and the radial artery [9]. The mass is often fixed and painful, with symptoms directly related to wrist motion [10]. The anatomic origin is commonly from the radioscaphoid or scaphotrapezial joint [10]. Occult ganglia, volar or dorsal, present without visible or palpable deformity but may contribute to wrist pain (Figs. 21.1 and 21.2).

Patient Evaluation

History and Physical Examination

The majority of patients that present for evaluation of a dorsal wrist ganglion do so secondary to cocerns regarding cosmesis. Ganglions are also associated with pain particularly on wrist extension activities and forceful grip. The volar ganglion may irritate the radial artery and the median nerve along with its palmar cutaneous branch. Occult ganglions are those that present without a palpable mass yet patients

Electronic supplementary material: Supplementary material is available in the online version of this chapter at 10.1007/978-1-4614-1596-1_21. Videos can also be accessed at http://www.springerimages.com/videos/978-1-4614-1595-4.

M.N. Osterman, M.D.
Department of Orthopedic Surgery, Thomas Jefferson University Hospital, Philadelphia, PA, USA

J.M. Abzug, M.D.
Department of Orthopaedics, University of Maryland School of Medicine, Timonium, MD, USA

A.L. Osterman, M.D. (✉)
The Philadelphia Hand Center, P.C., The Merion Building, Suite 200, 700S. Henderson Road, King of Prussia, PA 19406, USA
e-mail: loster51@verizon.net

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*, DOI 10.1007/978-1-4614-1596-1_21, © Springer Science+Business Media New York 2015

Fig. 21.1 Volar wrist gangli on cyst

Fig. 21.2 Dorsal wrist gangli on cyst

report symptoms of wrist pain. These patients present with non-traumatic, nonsystemic inflammatory wrist pain. Often these patients go undiagnosed for a period of time because clinically and radiographically there is no evidence of pathology. Ultrasound or magnetic resonance imaging can aid in the diagnosis. A study that evaluated patients with chronic wrist pain (at least 3 months) using ultrasonographic examination found 58 % of patients had an occult ganglion as the source of their pain [11]. Westbrook looked at the reason patients present to hand clinics with dorsal wrist ganglions and found that 38 % are concerned with the cosmetic appearance, 28 % are concerned that the cyst is cancerous, and 26 % present with pain [12]. A discussion of the etiology, natural history and benign nature of the mass is often enough to alleviate patient fears and the desire for surgical intervention.

When diagnosing a dorsal ganglion cyst, it is imperative to ensure that the mass is truly a ganglion cyst. Many elements of the history and physical examination are not conclusive. Occurrence, progression, size, shape, texture, presence or absence of pain, and association with traumatic or repetitive activities provide little information regarding the true diagnosis. One element of history, however, can be quite helpful in determining whether the lesion is cystic. While ganglion cysts and other tumors get larger, only ganglion cysts decrease in size as well. Exceptions to this include some vascular tumors than involute over a period of months to years; however, ganglion cysts can decrease in size as quickly as overnight. On physical examination, transillumination can be helpful to differentiate a ganglion cyst from an alternative tumor. This is performed by holding a penlight to the lesion and observing the light transmit through its fluid medium, whereas a solid tissue tumor will prevent any propagation of the light.

Occasionally, ganglion cysts may herald underlying pathology, such as a scapholunate ligament injury. The history and physical examination should focus on any recent or remote trauma. Often, patients have incompetent scapholunate ligaments that remain clinically unapparent until the manifestation of an associated dorsal ganglion cyst. One study reported on 19 wrists with painful dorsal ganglia, a positive Watson scaphoid shift test and negative radiographs that underwent ganglion excision. Postoperatively, all patients had decreased pain and 17 of the wrists had a postoperative negative Watson shift test [13]. Tenderness during palpation of the dorsal portion of the scapholunate ligament, a positive radial scaphoid shift test, or a positive straight finger resistance test may suggest scapholunate ligament pathology. Furthermore, ganglion cysts may resemble other pathologies, such as a gouty tophus, tenosynovitis, or rheumatoid pannus. A careful history and physical examination should suffice to differentiate these conditions.

Diagnostic Imaging

Magnetic resonance imaging (MRI) and ultrasonography remain the imaging modalities most commonly utilized to differentiate fluid-filled cysts from solid tumors. A study comparing the diagnostic abilities of ultrasound versus magnetic resonance imaging to detect occult wrist ganglions showed they are equally effective [14]. Nevertheless, there has been a shift toward ultrasonography as the preferred technique, given its readible availability, quickness, and lower cost. Very small ganglion cysts, known as occult ganglion cysts, although clinically significant, can be easily missed by either imaging modality. Surgeons should keep a high index of suspicion for occult ganglion cysts, even in the face of a negative reading by the radiologist. With intraoperative arthroscopic diagnosis of occult ganglia as the standard, the sensitivity of MRI scanning was found to be only 83 % and the specificity only 50 % [15].

Treatment

Nonoperative Management

The initial treatment of choice is a trial of nonoperative management, including splinting for comfort, prior to proceeding to operative intervention. However, the results of conservative treatment are unpredictable with success rates ranging from 30 % to 85 % [7]. Attempted aspiration can safely be performed on the dorsum of the wrist but attempts to aspirate volar ganglion cysts may cause injury to neurovascular structures, such as the radial artery and palmar cutaneous nerve. Adjunctive measures, such as steroid injections, sclerosing injections, and multiple cyst punctures, have been reported but show results no better than expectant management and, furthermore, carry up to a 5 % complication rate [7].

Operative Management

Surgical excision remains the treatment of choice for carpal ganglion cysts refractive to conservative measures. Prior to the recognition of the ganglion stalk, recurrence rates rivaled those of expectant management but now are reported to be as low as 1 % [8]. However, surgical intervention is not without risk and complications, which although rare, include recurrence, infection, neuroma, keloid, scar hypersensitivity, postoperative stiffness, grip weakness, and scapholunate instability.

Indications for surgical intervention include symptomatic ganglia that produce pain, weakness or limitations in wrist function/range of motion. Unacceptable cosmesis is also an indication, but typically additional symptoms are necessary for us to recommend proceeding to operative intervention.

Many patients seek excision of their ganglion for cosmetic reasons or concern that the mass is malignant. Although an open incision across the dorsum of the wrist may not seem excessive to a surgeon, the patient may have another perspective. One study reported a very high postoperative satisfaction rate after arthroscopic excision, despite the fact that 17 % of the patients were asymptomatic preoperatively and opted for surgery for cosmetic reasons [6]. The implication is that offering arthroscopic ganglion resections for patients primarily interested in the cosmetic appearance of their hands is reasonable. However, while surgical excision of the cyst will remove the "bump," a scar will replace the "bump." Arthroscopic excision of the cyst has the potential to remove the "bump" with minimal scarring.

Arthroscopic Technique

The patient is placed supine on the operating room table and a non-sterile pneumatic tourniquet is applied to the upper arm (Fig. 21.3) (Video 21.1). Subsequently, the remainder of the upper extremity is prepped and draped in the usual sterile fashion and the patient is placed in the standard wrist arthroscopy tower. Prior to suspension in the traction tower, it is useful to do a wrist exam under anesthesia. While the patient's arm is suspended in a traction tower, a 6-R portal is created as a visualization portal, by first placing an 18G needle to ensure appropriate placement of the portal. Once the needle confirmed the correct location, a stab incision is made through the skin only. Blunt dissection is carried out with a hemostat and a capsulotomy is made with the blunt trocar. The arthroscope is now inserted into the joint and directed radially to visualize the stalk of the ganglion at the junction of the fibrous and membranous portion of the scapholunate ligament. The typical initial visualization portal, the 3–4 portal, is avoided as the primary portal to prevent inadvertent decompression of the cyst.

In contrast, with volar ganglion excision the 3–4 portal is established first, as this provides good visualization of the radial wrist ligaments, the common origin of the volar ganglion. The scope is then introduced through the 4–5 or 1–2 portal for visualization during resection of the ganglion through the 3–4 portal. The radial artery and sensory branch of the radial nerve need to be protecting with use of the 1–2 portal [16].

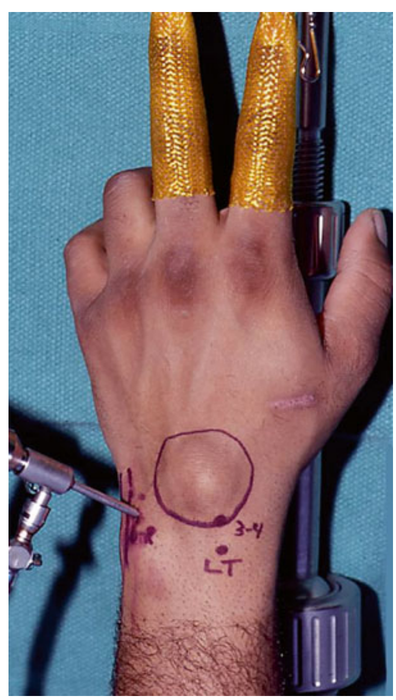


Fig. 21.3 Arthroscopic set up for dorsal ganglion cyst excision

After the 2.7-mm arthroscopic camera is directed toward the dorsal compartment of the wrist, the capsule adjacent to the scapholunate ligament can be visualized. Occasionally, a sessile or pedunculated protrusion into the joint can be seen in the area where the extrinsic capsule joins the distal portion of the dorsal scapholunate ligament. This capsular reflection serves as part of the barrier between the radiocarpal and midcarpal joints, and the protrusion located here has been termed the cystic stalk. More often, the surgeon may be impressed with the amount of synovitis and redundant capsule in this area instead of an actual stalk.

Once the stalk and cyst are visualized, a full radius shaver is placed through the cystic sac using the 3–4 portal. This action decompresses the cyst and may obscure any presence of an intra-articular stalk. If visualization is difficult to establish the 3–4 portal, we recommend finding Lister's tubercle and moving approximately 1 cm distal to locate the radiocarpal joint. The aforementioned technique of ensuring accurate placement is followed by utilization of an 18G needle followed by making the stab incision, utilization of a hemostat for blunt dissection, and finally inserting the trocar to perform the capsulotomy. A 2.9-mm, full-radius shaver is introduced through this portal, and every effort is made to avoid decompressing the cyst with simple introduction of the shaver.

Although the procedure implies that the cyst is removed by the arthroscope, this is often not the case. The arthroscopy procedure disrupts the communication between the cyst and the joint by excising the stalk of the cyst, while leaving behind a deflated sac that cannot re-inflate. Eventually, the empty sac is reabsorbed. Recurrences can happen only if another cyst is generated (Fig. 21.4).

The focus of the resection begins at the site of the ganglion stalk or redundant capsular material, if identified. This billowing, redundant material appears different from typical reactive synovitis. Although its exact significance is unclear, it seems to be continuous with the capsule that lies adjacent to the cyst. With this landmark, surgeons may confidently begin the capsulotomy. If neither structure is identified, the debridement begins adjacent to the dorsal scapholunate ligament and distal capsular reflection. Commonly, the cyst travels within the capsular reflection as it communicates with the scapholunate joint. Care should be taken to keep the blade of the shaver away from the scapholunate ligament at all times. On initial debridement of the capsular reflection, occasionally a flash of viscous cystic fluid may be visualized escaping into the joint. Debridement continues until approximately 1–1.5 cm of capsule has been removed.

A common mistake is to make the capsulotomy too small. The 2.9-mm shaver is helpful as a reference in gauging the size of the capsulotomy. Another common mistake is to create an incomplete capsulotomy that fails to communicate with the extra-articular space. We used to advise direct visualization of the extensor tendons to verify that a complete capsulotomy has been performed, but no longer feel this is necessary as long as the stalk and/or redundant capsule is resected. Removal of the cystic sac is not necessary, because it often resorbs over time after it is detached from its origin at the joint. If the cyst is particularly large, resorption may take some time, and patients may complain about residual prominence on the dorsum of the hand/wrist. Removal of the truncated sac may be performed by pulling it out of the 3–4 portal with a hemostat. Some dorsal ganglions may have a dual origin, from both radiocarpal and midcarpal joints (Fig. 21.5). One study showed that 74 % of cysts communicated with the midcarpal joint, thus we always recommend that midcarpal arthroscopy, through standard portals, be performed [6].

Some surgeons close each arthroscopic portal with one simple nonabsorbable suture, but others leave them open or place Steri-Strip with no cosmetic detriment. Open arthroscopic wounds can rarely form sinus tracts, as reported in other joint arthroscopy. Therefore, we prefer to close these wounds with one stitch. A sterile wrist dressing comprised of 4×4 s and

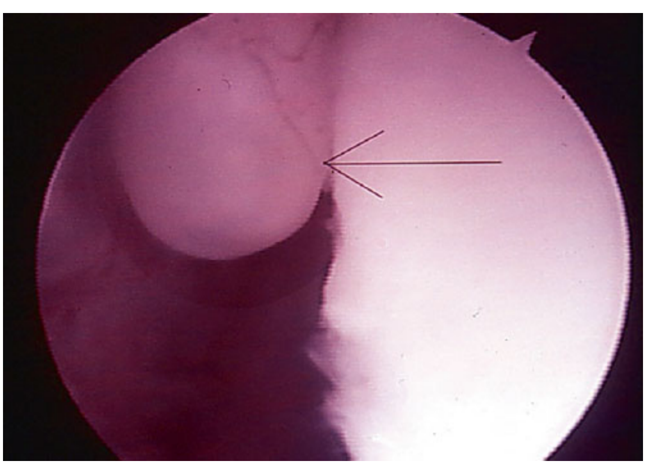


Fig. 21.4 Intraoperative arthroscopic view of ganglion stalk (*arrow*). Note the scapholunate ligament on the *right side* of the picture

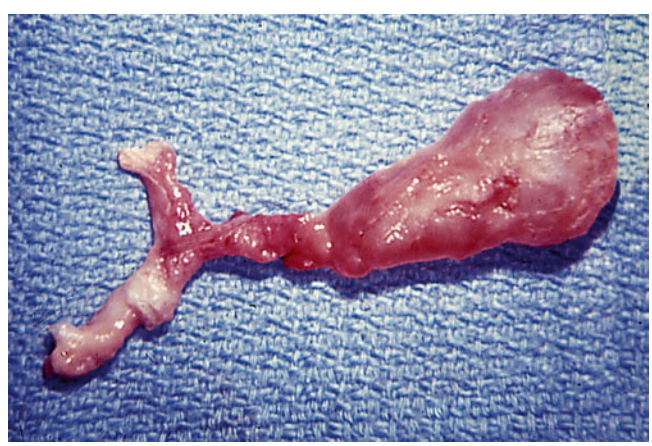


Fig. 21.5 Excised ganglion cyst with stalk

sterile webril is used in all cases and patients are placed in a volar splint for 1 week. Then a neoprene or soft support is used for comfort and as a reminder not to do forceful grip and wrist extension, such as pushups, for 6 weeks.

Adjuvant Options to the Arthroscopic Technique

A proposed disadvantage of arthroscopic ganglion excision is the inability to fully visualize, and thus excise, the ganglion stalk. Recent reports have proposed methods to help visualize the stalk.

A technique of injecting methylene blue into the ganglion prior to arthroscopic excision has been reported to aid in stalk visualization [17]. The dye is injected into the ganglion and the surgeon can track the methylene blue into the ganglion stalk, either in the radiocarpal or midcarpal joint. This aids in the debridement of pathologic tissue and prevents unnecessary removal of uninvolved tissues. With better visualization of the stalk, less capsular tissue is debrided and the incidence of iatrogenic scapholunate instability is theoretically decreased. This method is contraindicated in patients with methylene blue allergy or G6PD deficiency. In these instances, alternative contrast agents, such as indigo carmine, can be used instead. Yao and Trindade report no ganglion recurrences using the technique of injecting indigo carmine into all ganglions undergoing arthroscopic excision. They attribute the success to improved stalk visualization and complete excision [18].

Sonography-guided arthroscopy for ganglion excision has also been reported. Yamamoto et al. used sonography to aid in the assessment of ganglion size, relationship to adjacent structures and arthroscopic excision [19]. Twenty-two patients with symptomatic dorsal ganglions underwent arthroscopic excision with color Doppler sonography. Only four stalks were completely visualized with arthroscopy alone. All 22 ganglion stalks were visualized with the aid of sonography [19].

Results/Recurrence

Recurrence of the ganglion cyst is the ultimate outcome measure for a successful surgical excision. Rates following arthroscopic excision of dorsal ganglions have been low (0–10 %) in virtually every report, which is markedly lower than the recurrence rates for open excision [2, 5, 20, 21]. Recurrence rates for open excision have been reported as high as 8–40 % [4, 22, 23]. However, one prospective series comparing arthroscopic and open resection found no statistical difference in recurrence rates (10.7 % vs. 8.7 %, respectively) [4]. Open volar ganglionectomy has similar recurrence rates of 28 %, with additional complications of palmar cutaneous nerve injury and unsatisfactory scar formation [24]. In contrast, reported recurrence with arthroscopic excision is 0 % [17].

Complications

Despite arthroscopy being a minimally invasive operative intervention, it still poses risks to the patient. Potential complications inherent to the surgery include infection, damage to articular cartilage or neurovascular structures, hypertrophic scar formation, and postoperative wrist stiffness or chronic regional pain syndrome. Proper establishment of portals and thorough understanding of the anatomy is imperative to help minimize these risks, particularly in recurrent ganglion excision where the scar may have abnormally displaced the extensor tendons. A systematic review performed in 2012 looked at the incidence of complications after wrist arthroscopy and found huge variations in the literature, ranging from 1 % to 20 % [25]. Most of the complications related to the use of concomitant pin fixation for fracture treatment and very few related to diagnostic arthroscopy or ganglionectomy. Compiling the results of all the studies yielded an overall complication rate of 4.8 % [25].

Conclusion

Arthroscopic resection of dorsal, volar, or occult ganglions is a safe and effective alternative to open gangliectomy. Studies have shown that the recurrence rate is markedly lower and without increased risks of surgical complications. Concerns regarding appropriate visualization of the ganglia and/or stalk during arthroscopic excision are being addressed with newer techniques. In addition, arthroscopic excision allows for the surgeon to evaluate and/or treat coexisting intrarticular pathology, such as scapholunate or TFCC tears.

References

1. Janzon L, Niechajev IA. Wrist ganglia. Incidence and recurrence rate after operation. Scand J Plast Reconstr Surg. 1981;15:53–6.
2. Osterman AL, Raphael J. Arthroscopic resection of dorsal ganglion of the wrist. Hand Clin. 1995;11:7–12.
3. Luchetti R, Badia A, Alfarano M, Orbay J, Indriago I, Mustapha B. Arthroscopic resection of dorsal wrist ganglia and treatment of recurrences. J Hand Surg Br. 2000;25:38–40.
4. Kang L, Akelman E, Weiss A. Arthroscopic versus open dorsal ganglion excision: a prospective, randomized comparison of rates of recurrence and of residual pain. J Hand Surg Am. 2008;33(4):471–5.
5. Rizzo M, Berger R, Steinmann S, Bishop A. Arthroscopic resection in the management of dorsal wrist ganlgions: results with a minimum 2-year follow-up period. J Hand Surg Am. 2004;29:59–62.

6. Edwards SG, Johansen JA. Prospective outcomes and associations of wrist ganglion cysts resected arthroscopically. J Hand Surg Am. 2009;34:395–400.
7. Gude W, Morelli V. Ganglion cysts of the wrist: pathophysiology, clinical picture, and management. Curr Rev Musculoskelet Med. 2008;1:205–11.
8. Angelides AC, Wallace PF. The dorsal ganglion of the wrist: its pathogenesis, gross and microscopic anatomy, and surgical treatment. J Hand Surg Am. 1976;1:228–35.
9. Greenberg JA. Arthroscopic treatment of volar carpal ganglion cysts. In: Slutsky DJ, Nagle DJ, editors. Techniques in wrist and hand arthroscopy. Philadelphia, PA: Churchill Livingstone, Inc. (Elsevier); 2007. p. 188–90.
10. Greendyke SD, Wilson M, Shepler TR. Anterior wrist ganglia from the scaphotrapezial joint. J Hand Surg Am. 1992;17:487–90.
11. Chen HS, Chen MY, Lee CY, et al. Ultrasonographic examination on patients with chronic wrist pain: a retrospective study. Am J Phys Med Rehabil. 2007;89(11):907–11.
12. Westbrook A, Stephen A, Oni J, Davis T. Ganglia: the patient's perception. J Hand Surg Br. 2000;25(6):566–7.
13. Hwangg JJ, Goldfarb CA, Gelberman RH, Boyer MI. The effect of dorsal carpal ganglion excision on the scaphoid shift test. J Hand Surg Br. 1999;24(1):106–8.
14. Cardinal E, Buckwalter KA, Braunstein EM, et al. Occult dorsal carpal ganglion: comparison of US and MR imaging. Radiology. 1994;193(1):259–62.
15. Goldsmith S, Yang SS. Magnetic resonance imaging in the diagnosis of occult dorsal wrist ganglions. J Hand Surg Eur. 2008; 33(5):595–9.
16. Ho PC, Lo WN, Hung LK. Resection of volar ganglion of the wrist: a new technique. J Arthroscop Relat Surg. 2003; 19(2):218–21.
17. Lee B, Sawyer G, DaSilva M. Methylene blue-enhanced arthroscopic resection of dorsal wrist ganglions. Tech Hand Up Extrem Surg. 2011;15(4):243–6.
18. Yao J, Trindade M. Color-aided visualization of dorsal wrist ganglion stalks aids in complete arthroscopic excision. Arthroscopy. 2011;27(3):425–9.
19. Yamamoto M, Kurimoto S, Okui N, et al. Sonography-guided arthroscopy for wrist ganglion. J Hand Surg Am. 2012; 37:1411–5.
20. Ho PC, Griffiths J, Lo WN, Yen CH, Hung LK. Current treatment of ganglion at the wrist. Hand Surg. 2001;6:49–58.
21. Mathoulin C, Hoyos A, Pelaez J. Arthroscopic resection of wrist ganglia. Hand Surg. 2004;9:159–64.
22. Thronburg LE. Ganglions of the hand and wrist. J Am Acad Orthop Surg. 1999;7:231–8.
23. Clay NR, Clement DA. The treatment of dorsal wrist ganglia by radical excision. J Hand Surg Br. 1998;13:187–91.
24. Jacobs LG, Govaers KJ. The volar wrist ganglion: just a simple cyst? J Hand Surg Br. 1990;15:342–6.
25. Ahsan ZS, Yao J. Complications of wrist arthroscopy. Arthroscopy. 2012;28(6):855–9.

Arthroscopic Management Volar Ganglions

22

Carlos Henrique Fernandes
and Cesar Dario Oliveira Miranda

Introduction

Ganglia are the most common soft tissue tumors of the hand [1]. They are mucin filled cysts which may be uni- or multi-lobulated and are closely associated with either the wrist joint or tendon sheath. It is now widely accepted that dorsal and volar wrist ganglions have similar path mechanisms and arise from mucinous degeneration of the capsular and ligament structures around the joint [2, 3]. Volar wrist ganglion is the second most common mass in the wrist, arising via a pedicle from the radio scaphoid/scapholunate interval, scaphotrapezial joint, or the metacarpotrapezial joint, in that order of frequency [4]. They usually appear between the flexor Carpi Radialis tendon and the flexor pollicis longus tendon. Microscopically, the pedicle contains a tortuous lumen, connecting the cyst to the underlying joint [5]. The presence of this connection is supported by the intraoperative and arthrographic findings that demonstrated movement of intra-articular contrast from the radiocarpal joint into the ganglia in 85 % of patients with a volar wrist ganglion. As contrast does not appear to travel from the cyst into the joint, a one-way valve mechanism has been postulated [6].

Frequently they are benign, well characterized, and easily diagnosed.

In the last 20 years, the wrist arthroscopy has advanced, since diagnosing the therapeutic procedures in the treatment of disease in the joint. The arthroscopic makes it easy to visualize the small structures and allows evaluating the locals wherethrough open technique would be more difficult and would cause more lesion. However, it is a less invasive with less morbidity. The video surgery started to be a gold tool to diagnose and treat intra-articular pathologies.

About two decades ago, Osterman and Raphael [7] described the technique for the treatment of the dorsal carpal ganglion. In the beginning there was a lot of skepticism with this technique; therefore it has become a routine procedure. Throughout the last few years the arthroscopic treatment of volar carpal ganglion cyst has become more popular.

Clinical Picture

The most common reason for referral is a lump that appears on the palm side of the wrist in the wrist crease just below the thumb. Some patients may be concerned about potential malignancy. Usually the symptoms include pain in the wrist, poor activity or palpation of the mass, decreased range of motion, and decrease grip strength.

Sometimes may change in size over time but usually 1–2 cm. The skin above the cyst is unchanged and there is no associated warmth or erythema (Fig. 22.1). Sometimes occur paresthesias from compression of the ulnar or median nerves or their branches [8]. The mass itself is compressible. It will be "rubbery" in consistency, and generally movable. Transillumination of a lump in the usual anatomical location will confirm a fluid filled cyst.

Routinely a wrist X-ray evaluation is indicated to rule out preexisting osseous lesions. An Ultrasound imaging study of the wrist is also examined to confirm the diagnosis, as well as to localize the ganglion (Fig. 22.2).

Electronic supplementary material: Supplementary material is available in the online version of this chapter at 10.1007/978-1-4614-1596-1_22. Videos can also be accessed at http://www.springerimages.com/videos/978-1-4614-1595-4.

C.H. Fernandes, M.D.
Department of Orthopedic Surgery, Universidade Federal de São Paulo, São Paulo, São Paulo, Brazil

C.D.O. Miranda, M.D. (✉)
Department of Hand Surgery, Hand Surgery Institute Salvador, Av Juracy Magalhaes Jr 2096, Centro Medico Alianca Sala 402, Salvador, Bahia 41940060, Brazil
e-mail: cesarortopedia@gmail.com

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*, DOI 10.1007/978-1-4614-1596-1_22, © Springer Science+Business Media New York 2015

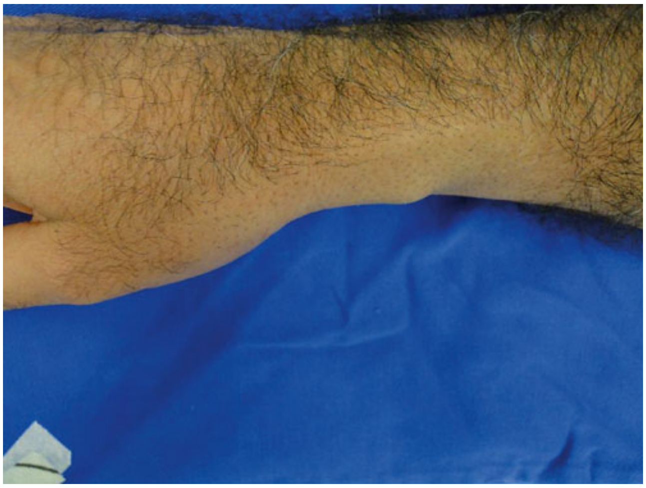


Fig. 22.1 Clinical photo of volar ganglion

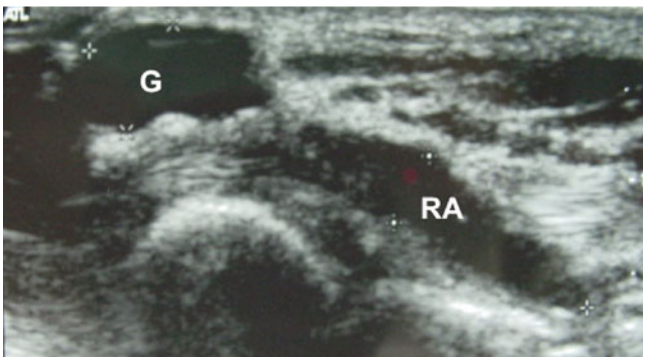


Fig. 22.2 Ultrasound appearance of volar cyst

The MRI of soft tissue masses of the wrist is useful to differentiate them. Ulnar volar ganglions are associated with tears of triangular fibro cartilage complex. An MRI in some circumstance helps to locate the stalk, other lesions, and in the diagnosis of occult ganglia.

Revision of Literature

There is a real deficit of studies of higher methodological quality, and the necessity of more studies to ensure the best prediction of outcomes in wrist arthroscopy [9].

We reviewed the literature on arthroscopic resection of volar wrist ganglion. The publication dates ranged from 2001 to 2012 (Table 22.1). Only one was a prospective randomized study; the authors compared the open resection and arthroscopic resection. All of the other studies were level IV of evidence [10–17].

A total of 232 wrists were submitted to an arthroscopic resection. The same operative technique described by Ho et al. [18, 19] was used by all authors. One author included an intrafocal cystic portal [13].

The mean age of patients described in eight articles was 40.45 years. All reported a major incidence in women with a female:male ratio of 3:1. Of nine articles, the follow-up ranged from 12 months to 56 months with a mean of 23.82 months.

There were 14 recurrences. The recurrence rate ranged from 0 % to 20 % with mean of 6.03 %.

There were 16 (6.89 %) related complications. No connection of the complication with the ganglion was described in six wrists [18, 19]. Volar hematoma was described in three patients [20, 21]. Partial lesions of the median nerve were reported in two articles [12, 21], two lesions of a branch of the radial artery [10, 11], and neuropraxis of the superficial radial nerve [10, 13, 19]. Osterman (in the 65th Annual Meeting of the American Society for Surgery of the Hand 2010) and Langner et al. [14] did not report any complications. No patient had loss of arc range of motion.

In a study of five patients of Rocchi et al. [10] the recurrence and complications were higher for midcarpal ganglions.

Recently, Langner et al. reported that patients with volar painful ganglions of the wrist and a positive ulnocarpal stress test are highly associated with TFCC abnormalities [14].

Treatment

Indications and Contraindications

Despite a natural history of spontaneous regression [15], volar ganglion cyst of the wrist can, some time, require a surgical excision. Both surgical and nonsurgical treatments are available. Recent series have documented enhanced treatment success using various aspiration techniques after three separate treatments. However, recurrence rates exceeding 40 % can still be expected. The most definitive management remains excision [22].

The literature with regard to recurrence rates demonstrates that open volar ganglion surgery is challenging. In principal complete removal of the ganglion base is required to avoid recurrence. The cases of recurrence are often due to incomplete ganglion stalk resection, which is greater on the volar aspect due to the more complex volar anatomy. The risks of complication are also common, reaching rates >20 % in some studies [16, 17]. The causes are proximity of the superficial palmar branch of the radial artery, the terminal branches of the superficial radial nerve, and the palmar cutaneous branch of the median nerve [10, 11]. Contraindications for arthroscopic management of volar ganglions are a history of wrist trauma with deformity, stiff joint, atypical volar ganglion localization like STT joint or the FCR sheath, and advanced instability degenerative disease of the wrist.

Table 22.1 Studies reporting recurrence rates and complications of arthroscopic resection of a volar wrist ganglion

	Authors	Title	Year	Study design	Evidence	Wrist operated	Average age	Gender	Follow up (months)	Recurrence	Complications
1	Ho et al.	Current treatment of ganglion of the wrist	2001	Case series	IV	6	38		16.4	0 (0 %)	01 no connection with the ganglion was found (16.66 %)
2	Mathoulin et al.	Arthroscopic resection of wrist ganglia	2004	Case series	IV	32	46	27W 05M	26	0 (0 %)	01 volar hematoma (3.12 %)
3	Rocchi et al.	Resezione artroscopica delle cisti artrogene dorsali e volari del polso. Nostra esperienza e evalutazioni cliniche	2005	Case series	IV	7	–	–	18	0 (0 %)	01 neuropraxia dorsal radial nerve (14.28 %)
4	Ho et al.	Arthroscopic volar wrist ganglionectomy	2006	Case series	IV	21	48.6	11W 10M	56	2 (9.52 %)	05 no connection with the ganglion was found (23.80 %)
5	Mathoulin and Massarella	Therapeutic interest of wrist arthroscopy about 1,000 cases	2006	Case series	IV	66	42	53W 13M	32	0 (0 %)	02 volar hematoma and 01 partial lesion of median nerve (4.54 %)
6	Rocchi et al.	Results and complications in dorsal and volar wrist ganglia arthroscopic resection	2006	Case series	IV	17	–	–	15	1 (5.88 %)	01 lesion radial artery (5.88 %)
7	Rocchi et al.	Articular ganglia of the volar aspect of the wrist: Arthroscopic resection compared with open excision. A prospective randomized study	2008	Prospective randomized study	I	25	37	18W 07M	24	3 (12 %)	01 neuropraxia dorsal radial nerve and 01 lesion radial artery (8.00 %)
8	Rhyou et al.	Arthroscopic resection of volar ganglion of the wrist joint	2010	Case series	IV	9	43	07W 2M	15	0 (0 %)	01 partial lesion of median nerve (11.11 %)
9	Chen et al.	Arthroscopic ganglionectomy through an intrafocal cystic portal for wrist ganglia	2010	Case series	IV	3	30	03W 00M	–	0 (0 %)	01 transient paresthesia radial nerve, resolution 1 month (33.33 %)
10	Ostermann	Symposium 4–Excellence in wrist arthroscopy: extending our horizons. Arthroscopic volar ganglionectomy	2010	Case series	IV	26	37	–	–	4 (15.38)	No
11	Langner et al.	Ganglions of the wrist and associated triangular fibrocartilage lesions: A prospective study in arthroscopically treated patients	2012	Case series	IV	20	40	–	12	4 (20 %)	No

Arthroscopic Technique

Because of the volar tilt of the distal radius, the volar capsule and ligaments of the radiocarpal joint are more accessible to arthroscopic instrumentation than the dorsal structures. Arthroscopic gangliectomy have the advantage of avoiding extensive dissection, scarring, and potential damage to structures. Other advantages are reduced postoperative pain and the time of return of function compared with open resection [11].

The results of the arthroscopic management of volar ganglions were originally presented in 2001 [23] by Ho et al. [9]. However, Ho et al. only described the detailed technique in 2003 [18].

Some surgeons perform the procedure by block anesthesia, but in general, we use sedation, or local anesthesia in the portal and joint. The patient lies supine.

A tourniquet is applied to the arm and inflated after exsanguinations with an esmarch rubber.

The arm is fixed to an arm table and the elbow flexed to 90° with the wrist in vertical traction using double disposable plastic finger traps placed in the second and fourth or second and third fingers.

Portal sites are palpated and marked. The portal sites used for the radiocarpal joint are routinely 3–4, 4–5, and 1–2 (Fig. 22.3).

Using a syringe with a 25×7 mm needle, the radiocarpal joint is initially distended. Approximately 5 ml of Bupivacaine is injected through the skin and subcutaneous tissues into the joint through 3–4 portals. We use a 40×8 mm needle with an outflow in portal 6U, in all cases.

Over the portals, a short skin is made, and the spreading of soft tissue with a hemostat exposes the joint capsule. This maneuver provokes extraversion of anesthetic from outside of joint. This maneuver is particularly important when the 1–2 portal is being created, to avoid injury to the radial artery and the radial nerve (Fig. 22.4).

We use a 2.4 mm arthroscope with a 30° visual angle, with irrigation fluid instilled by pump infusion.

The 3–4 portals give a better view. Through the 3–4 portals, the scope allows inspection of the volar radial side wrist ligaments, where the volar ganglion usually has its stalk. Frequently, synovial and capsular abnormalities were seen at the interval between the radioscaphocapitate (RSC) and long radiolunate (LRL) ligaments or between LRL and short radiolunate (SRL) ligaments [24] (Fig. 22.5).

The 1–2 portal is also the best for instrumentation, although it has been associated with a higher risk of damaging the radial artery and sensory branch of the radial nerve [12, 21].

Fig. 22.3 The portal used 3–4, 4–5 and the arthroscope is placed in the 1–2 portal

Fig. 22.4 The 2.7 mm arthroscope is introduced into the 3–4 portals. Blunt dissection is performed with a hemostat in the 1–2 portal

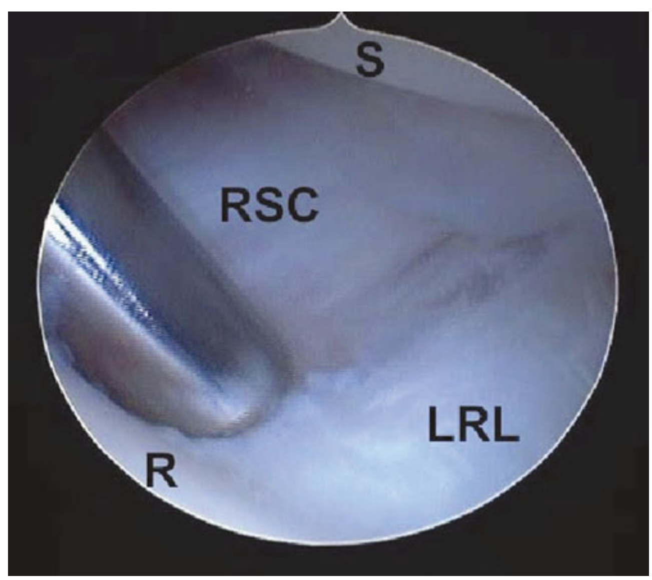


Fig. 22.5 Arthroscopic image showing the volar extrinsic wrist ligaments and the interval between the radioscaphocapitate (RSC) and long radiolunate ligament (LRL). Through this interval the cyst is resected

Fig. 22.6 Palpation of the volar cyst during the surgery. This maneuver helps to locate the interligamental interval where the shaver will debride

A 2.0- to 2.9-mm arthroscopic shaver is then introduced through 1–2 portal to deride the region. However, ganglia or their stalks cannot be observed arthroscopically in most cases. When this situation occurs, a fingertip gentle external pressure is maintained over the ganglion (Fig. 22.6). This maneuver will result in synovial and capsular bulging at the site. The shaving is performed until a hole of about 1 cm is observed in the interligamental interval. Do not use too much suction to prevent blistering and to be able to observe the mucinous liquid outlet into the radiocarpal joint (Fig. 22.7, Videos 22.1 and 22.2). Be careful that the shaver must not be advanced too anteriorly into the volar aspect of the wrist joint. A maneuver untimely could damage the important structures volar to the joint. We did not attempt to remove the ganglion wall or more of the joint capsule than was necessary to induce the gush of mucinous content. A small palmar capsulectomy defect resulted at the RSC-LRL or LRL-SRL interligamental interval after the operation, enable the flexor pollicis longus tendon can be seen, and care must be taken not to damage it with the shaver (Fig. 22.8, Videos 22.3 and 22.4).

Sometimes, we can see the mucinous liquid leakage through the portal and running down in the skin (Fig. 22.9).

The shaver was also used for trimming capsular lesion, partial tear of the scapholunate ligament, lunotriquetral ligament, volar radioscaphocapitate ligament, and triangular fibrocartilage complex (TFCC).

The ganglions that arise from the distal wrist crease are likely to originate in the scaphotrapezium-trapezoid (STT) joint or other component of the midcarpal joint (Fig. 22.10). In these situations, a finger trap applied an extra-distraction on thumb. Two extra portals are performed. The first, the radial midcarpal portal (RMC), which is located 1 cm distal to the 3–4 portals and in line with the radial margin of the third metacarpal, is performed. The second, the STT portal, is located just to the ulnar side of the extensor pollicis longus tendon, at the level of the articular surface on the distal pole

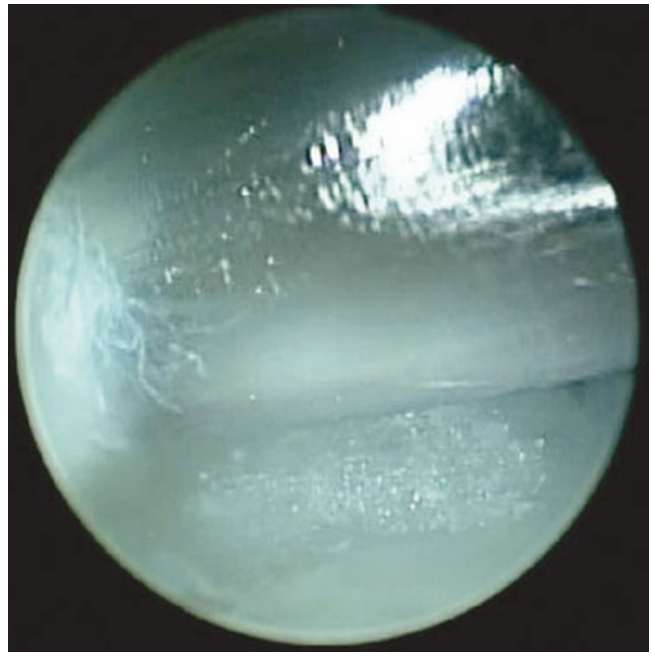


Fig. 22.7 Arthroscopic image showing mucinous liquid outlet into the radiocarpal joint

of the scaphoid (Fig. 22.11). The ganglia resection is difficult because of the narrow space. The majority of authors stated that ganglia of the STT joint are not amenable to arthroscopic decompression [10, 21].

In 2012, Yamamoto et al. reported sonography-assisted arthroscopy. With this technique, they can identify ganglia; vessels, nerves, tendons, and the blade shavers can be identified and guided to the lesion. The advantage is to avoid vascular, nerve, and tendon injuries. Unfortunately, they didn't report number of patients and if they have less complications [25].

Chen et al. [13] described a volar ganglia resection through an intrafocal cystic portal. They performed an additional puncture wound with guidance from the light source of the arthroscopy, which was introduced through the 3–4 portals, over the ganglion cyst, followed by a gentle introduction of the oscillating shaver. The objective is to remove all the residual ganglionic tissue, as well as the connecting stalk. In our opinion, because of the proximity of median nerve and radial artery, this is a very dangerous procedure.

In all cases the tourniquet is deflated before ending the intervention to check for any potential vascular injury.

During the procedure, if a TFCC lesion is identified, this will be graded according to the Palmer classification [26] and the treatment will be made according to what can be found in another specific chapter in this book.

At completion of the procedure, single stitches are made to close the portal sites, and the wrist is protected with a bandaging. Patients are advised to move their wrists when the pain permits. The stitches are removed within 1 week. Sports and heavy manual activity should be avoided for 3 month.

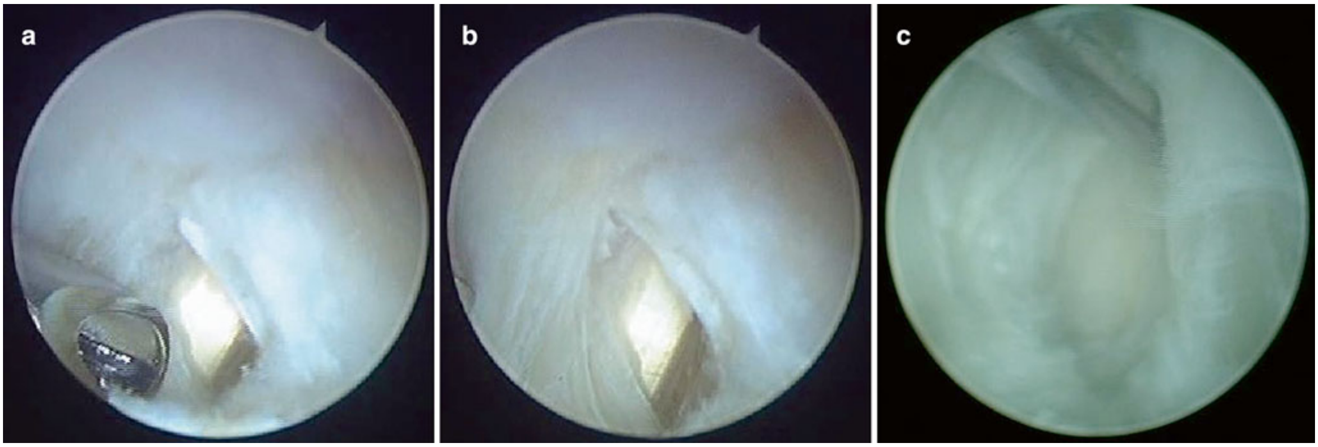


Fig. 22.8 (**a**) Arthroscopic image showing interligamental interval after the operation permit the flexor pollicis longus tendon can be seen. (**b**) Arthroscopic image showing interligamental interval after the operation permit the flexor pollicis longus tendon can be seen. (**c**) Arthroscopic image showing interligamental interval after the operation permit the flexor pollicis longus tendon can be seen

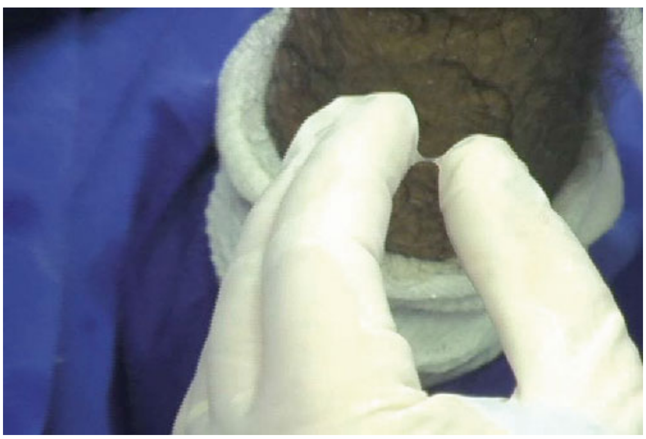


Fig. 22.9 Mucinous liquid leakage through the portal and running down in the skin

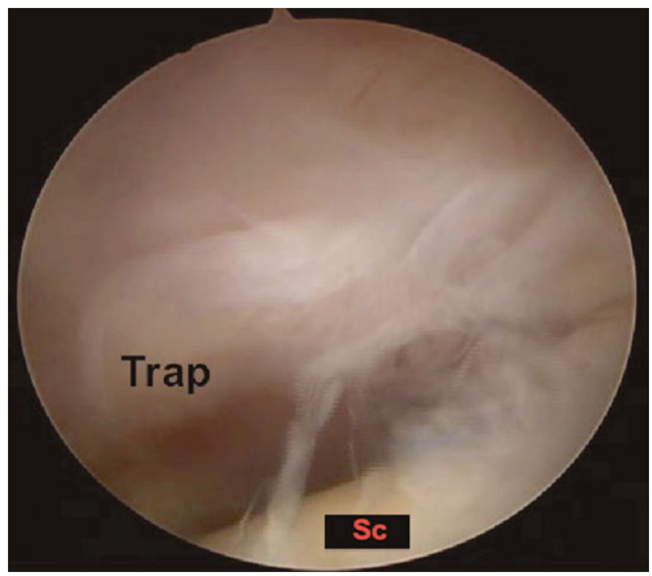


Fig. 22.11 Arthroscopic image showing the scaphotrapezium-trapezoid (STT) joint

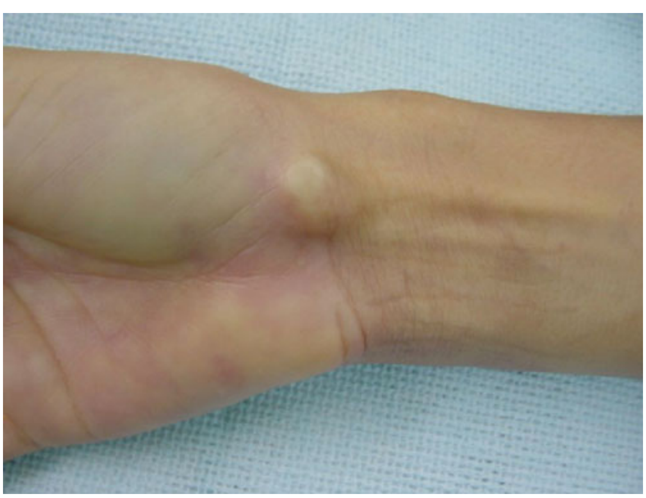


Fig. 22.10 Clinical photo of volar cyst that arise from the distal wrist crease is likely to originate in the scaphotrapezium-trapezoid (STT) joint or other component of the midcarpal joint

Our Experience

Between 2007 and 2012, we performed 31 surgeries of arthroscopic resection of volar wrist ganglion. There were 23 female and 8 male patients. The average age was 38 years. Two patients have a volar intra-osseous ganglion of lunate bone. In these cases, we also used a volar radial portal.

As complications, we observed transient paresthesia of superficial radial nerve with spontaneous regression in one patient, two volar hematomas, and one recurrence. We used the Allen test in postoperative period and we didn't observe failure of blood to diffuse into the hand.

One patient had a volar radiocarpal ganglion confirmed by ultrasound testing, but the procedure was converted to open surgery because the mass was a lipoma.

We never use a needle passing through the ganglion into the joint to identify the interval between the ligaments because the proximity of the radial artery.

We insert the scope through the 3–4 portals for inspection of the stalk. Therefore, the scope is changed to be introduced through an additional 4–5 portals and volar ganglion was debrided through the radioscaphocapitate (RSC) ligament and long radiolunate (LRL) ligament using a resector inserted from the 3–4 portals. The 1–2 portal is created only when we cannot remove the ganglion through 3–4 and 4–5 portals.

Because of the proximity of the gates 3–4 and 1–2 can have difficulties performing the triangulation technique with optical and blade shaver in the first procedures.

Sometimes we introduce a Kelly clamp inside the wrist through the 3–4 portals until the palmar capsular defects. The clamp is open and we can observe the mucinous fluid entering inside of the radiocarpal joint.

After the end of procedure, fragments of synovial tissues were collected on the occasion of an endoscopic procedure and were sent to histologic study with the purpose of proving the resection of the ganglion.

Postoperative Rehabilitation

At completion of the procedure, single stitches are made to close the portal sites, and the wrist was protected with a bandaging.

Patients are advised to move their wrists when the pain permits. The stitches are removed within 1–2 week. If the patient shows stiffness or swelling during this time a therapy program should be started. Heavy manual activity should be avoided for 2 months.

Complications

Wrist arthroscopy is a fairly safe procedure with a low rate of complications. The main complication would be recurrence. Other complications described in the literature [27] include wrist stiffness, cartilage injury; thermal burn; reflex sympathetic dystrophy; infection; tendon, nerve, and vessel injury.

References

1. Nelson CL, Sawmiller S, Phalen GS. Ganglions of the wrist and hand. J Bone Joint Surg. 1972;54(7):1459–64.
2. Angelides AC. Ganglions of the hand and wrist. In: Green DP, Hotchkiss RN, Pederson WC, editors. Green's operative hand surgery. 4th ed. New York: Churchill Livingstone; 1999. p. 2171–83.
3. Watson HK, Rogers WD, Ashmead IV D. Reevaluation of the cause of the wrist ganglion. J Hand Surg Am. 1989;14:812–7.
4. Greendyke SD, Wilson M, Shepler TR. Anterior wrist ganglia from the scaphotrapezial joint. J Hand Surg Am. 1992;17(3):487–90.
5. Tophoj K, Henriques U. Ganglion of the wrist—a structure developed from the joint. Acta Orthop Scand. 1971;42(3):244–50.
6. Andren L, Eiken O. Arthrographic studies of wrist ganglions. J Bone Joint Surg Am. 1971;53(2):299–302.
7. Osterman AL, Raphael J. Arthroscopic resection of dorsal ganglion of the wrist. Hand Clin. 1995;11:7–12.
8. Thornburg LE. Ganglions of the hand and wrist. J Am Acad Orthop Surg. 1999;7(4):231–8.
9. Fernandes CH, Meirelles LM, Raduan Neto J, Santos JBG, Faloppa F, Albertoni WM. Characteristics of global publications about wrist arthroscopy: a bibliometric analysis. Hand Surg. 2012;17(3):311–5.
10. Rocchi L, Canal R, Pelaez J, et al. Results and complications in dorsal and volar wrist ganglia arthroscopic resection. Hand Surg. 2006;11:21–61.
11. Rocchi L, Canal A, Fanfani F, Catalano F. Articular ganglia of the volar aspect of the wrist: arthroscopic resection compared with open excision. A prospective randomised study. Scand J Plast Reconstr Surg Hand Surg. 2008;42:253–9.
12. Rhyou I, Kim HJ, Suh BG, Chung C, Kim KC. Arthroscopic resection of volar ganglion of the wrist joint. J Korean Soc Surg Hand. 2010;15(3):136–42.
13. Chen ACY, Lee WC, Hsu KY, Chan YS, Yuan LJ, Chang CH. Arthroscopic ganglionectomy through an intrafocal cystic portal for wrist ganglia. Arthroscopy. 2010;26(5):617–22.
14. Langner I, Krueger PC, Merk HR, Ekkernkamp A, Zach A. Ganglions of the wrist and associated triangular fibrocartilage lesions: a prospective study in arthroscopically-treated patients. J Hand Surg Am. 2012;37:1561–7.
15. Rosson JW, Walker G. The natural history of ganglia in children. J Bone Joint Surg. 1989;71(4):707–8.
16. Jacobs LGH, Govaers KHM. The volar wrist ganglion: just a simple cyst? J Hand Surg Br. 1990;15(3):342–6.
17. Dias J, Buch K. Palmar wrist ganglion: does intervention improve outcome? A prospective study of natural history and patient reported treatment outcomes. J Hand Surg Br. 2003;28:172–6.
18. Ho PC, Lo WN, Hung LK. Arthroscopic resection of volar ganglion of the wrist: a new technique. Arthroscopy. 2003;19(2):218–22.
19. Ho PC, Law BKY, Hung LK. Arthroscopic volar wrist ganglionectomy. Chir Main. 2006;25:221–30.
20. Mathoulin C, Hoyos A, Pelaez J. Arthroscopic resection of wrist ganglia. Hand Surg. 2004;9(2):159–64.
21. Mathoulin C, Massarella M. Therapeutic interest of wrist arthroscopy about 1000 cases. Chir Main. 2006;25:145–60.
22. Chung KC, Peter M. Murray. Hand surgery update V. American Society for Surgery of the Hand; 2011. p. 791.
23. Ho PC, Griffiths J, Lo WN, Yen CH, Hung LK. Current treatment of ganglion of the wrist. Hand Surg. 2001;6(1):49–58.
24. Mathoulin C. Resection of volar ganglia. In: Geissler WB, editor. Wrist arthroscopy. New York: Springer. 2005;215:182–84.
25. Yamamoto M, Kurimoto S, Okui N, Tatebe M, Shinohara T, Hirata H. Sonography-assisted arthroscopic resection of volar wrist ganglia: a new technique. Arthrosc Tech. 2012;1(1):31–5.
26. Palmer AK. Triangular fibrocartilage complex lesions: a classification. J Hand Surg Am. 1989;14:594–606.
27. Scott W. Wolfe, William C. Pederson, Robert N. Hotchkiss, Scott H. Kozin. Wrist arthroscopy. Green's operative hand surgery. Churchill Livingstone; 6th edn. (October 11, 2010) p. 738–39.

Dry Arthroscopy and Its Applications

23

Francisco del Piñal

Introduction

Traditionally, arthroscopy has been carried out using water to create a working cavity ("wet" arthroscopy). Distending the joint with fluid, however, is not nuisance free. Water infiltrates tissues, escapes through the portals, and might cause serious problems, such as compartment syndrome. Water enormously hampers any concomitant surgery after the arthroscopic exploration due to loss of definition of anatomic planes. Finally, the use of water makes it impossible to combine arthroscopy with semi-open procedures—such as intra-articular osteotomies, TFC reinsertions, and so on—as massive seepage of water will cause constant loss of vision.

Extrapolating that in other "scopies" in the human body, such as laparoscopy or thoracoscopy, water was not used to maintain the optic cavity, we realized that traction through the fingers was sufficient to keep the wrist cavity open, making the use of fluid unnecessary. As a matter of fact, all the inconveniencies referred to above could be circumvented, without modifying the visual properties, if water were not infused inside the joint ("dry" arthroscopy) [1]. Large portals/mini incisions can be created for the passage of large instruments or the extraction of large bony fragments, without fear of losing watertightness. Open and semi-open arthroscopic assisted procedures can hence be easily combined. Finally, traditional open surgery can be carried out immediately after the arthroscopy exploration leaving tissue in pristine conditions, as there has been no extravasation of fluid outside the capsule (Fig. 23.1).

Not using fluid, on the other hand, engenders a new set of problems secondary to loss of vision caused by splashes on the tip of the scope or blood and debris in the joint. This may induce the novice to give up at the first difficulty met, but the advantages of the dry technique far outweigh the difficulties encountered on the learning curve. In this work the technical tips to carry out an uneventful operation are presented in detail.

Surgical Technique

The "dry" arthroscopy technique is similar to a standard wrist arthroscopy ("wet"), except for the fact that water is not used to maintain the optic cavity. As stated, the main shortcoming comes from the fact that if one is not able to get rid of the blood and splashes that obscure vision in an expeditious manner, surgery will become a nightmare and one will give up the dry technique.

Intuitively, one would think that removing the scope and wiping off the lens with a wet sponge is a good way of having clear vision. Although effective, this maneuver is time consuming and, in a fracture or other complex procedures described in this chapter, there may be so much blood or debris that the maneuver may need to be repeated an exasperating number of times. Based on our experience with more than 1,000 dry wrist arthroscopies, but more important seeing how others in the laboratory and surgery struggle with the same difficulties over and over again, I can recommend the following tips that are critical for a smooth procedure, some of which are improvements on our previous publications [1, 2]:

- The valve of the sheath of the scope should be kept open at all times to allow the air to circulate freely inside the joint. Otherwise, either the suction of the shaver will not function properly or the capsule will collapse inwards due to the power of the suction, resulting in blocked vision. This is critical and cannot be overemphasized (Fig. 23.2).
- Suction is necessary to clear the field but, paradoxically, suction might also blur the vision by stirring up the contents of the joint (debris, blood, or remaining saline) that may stick to the tip of the scope. It is critical, therefore, to open the suction of the shaver or burr only when there is

F. del Piñal, M.D. (✉)
Unit of Hand-Wrist and Plastic Surgery, Private Practice and Hospital Mutua Montañesa, Paseo de Pereda 20-1, 39004 Santander, Spain
e-mail: drpinal@drpinal.com; pacopinal@gmail.com

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*, DOI 10.1007/978-1-4614-1596-1_23, © Springer Science+Business Media New York 2015

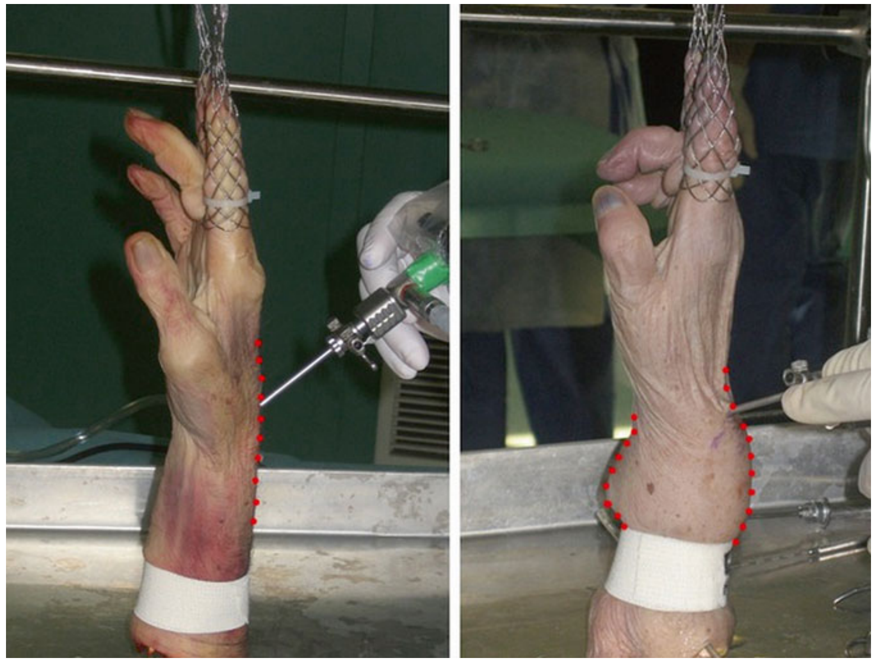


Fig. 23.1 The deformity of the wrist due to fluid extravasation after 1 h of wet arthroscopy (*right*) as compared to the *left* which was operated for the same amount of time but under the dry technique (Pictures taken during a teaching course with cadavers in Strasbourg. Both were operated by students simultaneously in different working posts) [Copyright Dr. Francisco del Piñal, 2010]

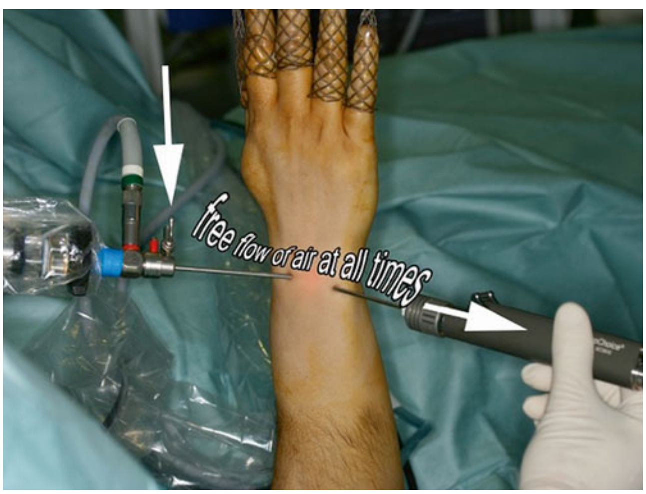


Fig. 23.2 The valve of the scope should be open at all times so as to allow air to circulate freely [Reprinted from del Piñal F. Dry arthroscopy of the wrist: its role in the management of articular distal radius fractures. Scand J Surg 2008;97:298–304. With permission from Sage Publications]

the need to aspirate something. Suction power should be locked when not needed. *To sum up, the valve of the sheath of the scope should be open at all times, but suction power should only be working when needed*.

- Avoid getting too close with the tip of the scope when working with burrs or osteotomes in order to avert splashes that might block your vision. Minor splashes can be removed by gently rubbing the tip of scope on the local soft tissue (capsule, fat, etc.).
- When a clear field is needed, so as to see a gap or a step-off, we *used to* recommend drying out the joint with neurosurgical patties [1]. However, we rarely resort to this technique now, and prefer to connect a syringe with 5–10 cc of saline to the side valve of the scope and then aspirate it with the synoviotome, in order to get rid of blood and debris. Pressure on the plunger of the syringe is unnecessary, as the negative pressure exerted by the shaver will suck the saline into the joint, thus preventing any extravasation (Fig. 23.3). Once all the water has been aspirated, the syringe is removed, and again the suction power of the shaver is enough to dry out the joint sufficiently, thus allowing the surgeon to work. *This maneuver should be repeated as necessary throughout the procedure*, as it is much quicker than struggling with blood in the joint, or trying to dry it out with the patties.
- An important waste of time occurs when the synoviotome, burr, or any other instruments connected to a suction machine clog because the aspirated debris dries out. When this happens the operation has to be stopped in order to dismount and irrigate the synoviotome for dislodging the debris. This is to be avoided at all costs by clearing the tubing with periodic saline aspiration from an external basin by the OR nurse, or by the surgeon through joint irrigation. Joint flushing should also be done in a systematic fashion in some procedures, such as intercarpal arthrodesis or arthroscopic proximal carpectomy, in which prolonged use of the synoviotomes and burrs may cause heating of the instrument itself causing local burns (see below).

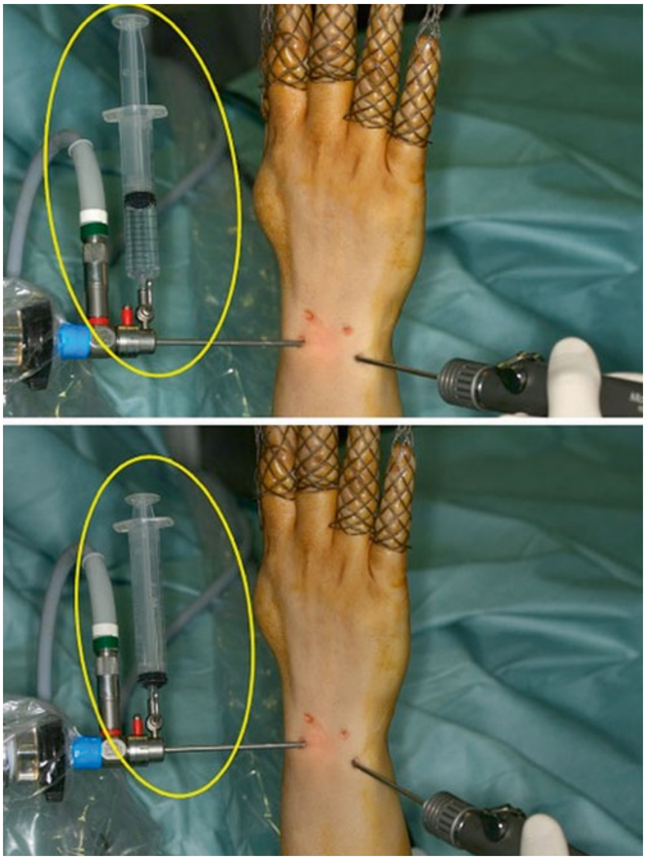


Fig. 23.3 Method used to wash out the joint and clear it of blood. Notice that the negative pressure exerted by the shaver is sufficient to aspirate the saline without extravasation of water [Reprinted from del Piñal F. Dry arthroscopy of the wrist: its role in the management of articular distal radius fractures. Scand J Surg 2008;97:298–304. With permission from Sage Publications]

- Finally, one must understand that at most times vision will never be completely clear but still sufficient to safely accomplish the goals of the procedure. Having a completely dried field except for specific times during the procedure is unnecessary and wastes valuable time, and we rely more on the irrigation-suction just explained above.

The technique can be summarized in these three fundamental tips:

- The valve of the scope should be open at all times.
- The suction should be closed except when needed.
- The joint should be irrigated as needed in order to remove debris and blood.

Contraindications

The dry technique is contraindicated when using vaporizers, lasers, etc., as the heat generated will not dissipate, risking widespread cartilage damage. The problem is solved easily, however, by swapping to the "wet" technique during the specific moment that kind of instruments are being used. Once the "vaporizer step" is terminated, the saline is disconnected and air allowed to flow in the joint. The remaining water is sucked out with the synoviotome and the procedure continues "dry." In very special scenarios where running water is paramount, such as in septic arthritis, the use of the dry technique will offer no advantage and is not advised.

Risk of compartment syndrome has been considered a contraindication for arthroscopy, particularly after severe fractures, but this is not a problem when using the dry technique. Furthermore, I cannot see open wounds as a contraindication of the dry arthroscopy either, provided debridement of the portal is carried out and thorough irrigation of the joint is performed at the end of the procedure.

One concern many surgeons have about the dry arthroscopy is the possibility of burning inside the joint by the tip of the scope. This has never occurred in our experience, as the tip of the scope never warms up to that point. I should warn the reader, however, that we have experienced minor contact burns at the portals and the dorsal skin, by the synoviotome and burr. The rotating mechanism of these instruments heats up, as a result of friction, when used for very long periods of time. This is easily overcome by flushing the joint with saline that will cool down the synoviotome, and also will improve vision.

Clinical Applications

I use the dry technique in all my arthroscopic explorations, as I personally have not found it necessary to use vaporizers. There are, however, four common pathologies where not using water makes an enormous difference, namely distal radius fractures and (distal radius) malunions, arthroscopic arthrodeses and perilunate fractures and dislocations.

Distal Radius Fractures

Despite the existence in the literature of well-performed Level 1 studies [3–5] supporting the use of the arthroscope when dealing with articular distal radius fractures, there is general resistance in the Hand Surgery community to admit so. This is sometimes justified as being due to a(-n infinitesimal) risk of compartment syndrome, and more so to the massive swelling that accompanies the wet arthroscopy which makes the open part of the procedure more awkward. Although the latter reason is true, the unvoiced reason lies in the technical difficulties of the arthroscopic part itself. This is more so the more comminuted the fracture is, which, paradoxically, is the one that benefits most from having an arthroscopic assisted reduction [6]. Yet, there is no other single field in wrist arthroscopy where the dry technique can make such a huge difference and ease the procedure, as when dealing with articular fractures of the wrist. The dry arthroscopy allows an unimpeded

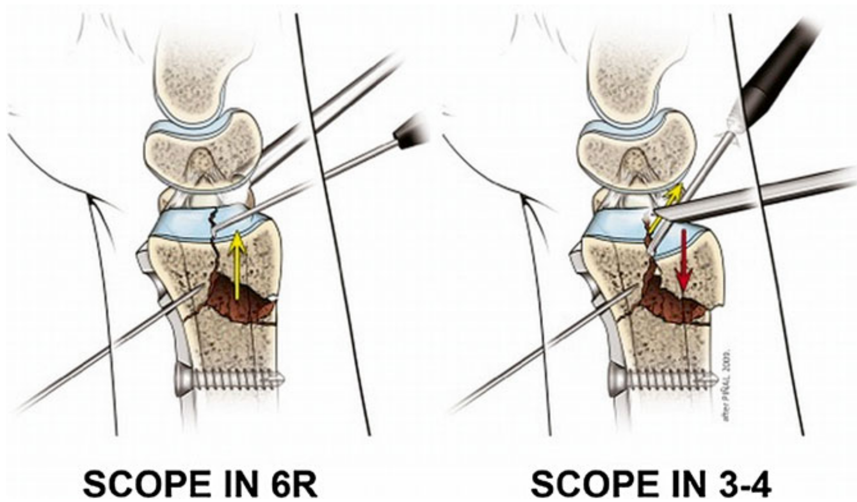


Fig. 23.4 If the scope is placed in 6R it will rest on top of the ulnar head providing a stable platform from which to work, thus avoiding conflict with the reduction (*left*). Instability of the scope and conflict of space during the reduction (*yellow and red arrows*) are inevitable when the scope is placed in any other portal (*right*) [Copyright Dr. Piñal, 2009]

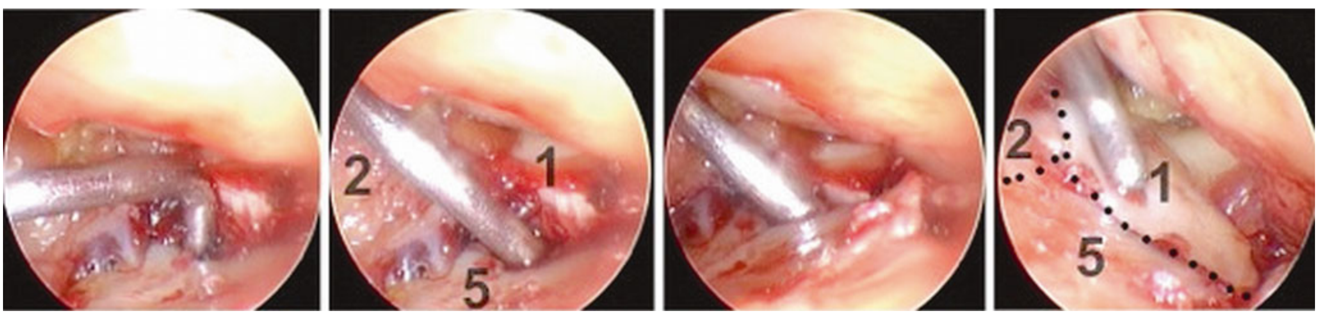


Fig. 23.5 Reduction of a depressed fragment in the scaphoid fossa. From *left* to *right*: The shoulder probe is gauging the step-off (3 mm), hooking the depressed fragment, elevating it, and leveling it to the rest of the joint (Scope in 6R, viewing radially in a right wrist. 1: volar rim of the scaphoid fossa, 2: dorsal rim; 5: scaphoid fossa) [Copyright Dr. Piñal, 2009]

combination between the open fixation part and the ability to watch the cartilaginous reduction and assess ligamentous and TFC injuries.

Our current technique [7–9] includes the use of volar locking plates in combination with arthroscopy, except in some specific fractures, such as radial styloid, where cannulated screws through a transverse incision in the styloid is the preferred fixation method. For the typical three- or four-part fracture, the radius is approached between the FCR and the radial artery. After a preliminary reduction by ordinary maneuvers, a volar locking plate is applied and stabilized by inserting only the screw into the elliptical hole on the stem of the plate. The articular fragments are reduced to the plate that act as a mold, and once the "best" reduction is obtained as judged by fluoroscopic views, the articular fragments are secured to the plate by inserting Kirschner wires (K-wire) through the auxiliary holes of the transverse component of the plate. It should be underscored that definitive fixation (screws or pegs) should not yet be used, as any change will not be possible later.

The hand is suspended from a bow, the fingers pointing to the ceiling, with a customized system that allows easy connection and disconnection from the bow without losing sterility, as fluoroscopic checkups are needed [10]. Traction is carried out on all fingers with counter-traction of 7–10 kg. A small transverse incision is made just distal to Lister's tubercle and, after dilating the portal with a straight mosquito, the scope (2.7 mm; 30° angle) is introduced and directed ulnarly. In the swollen wrist, it may be very difficult to establish 6-R portal, more so because the TFC may be detached from the fovea acting as a lid blocking the entrance into the radiocarpal joint. I overcome this eventuality by establishing this portal by going blindly with a hemostat in a radial direction immediately radial to the ECU just brushing past the proximal triquetrum.

The blood and debris are aspirated by a 2.9 mm shaver inserted in 6R. Flushing and debridement is carried out until the joint is completely clean. Once the elements that need to be mobilized are identified, the scope is swapped to 6R, where it will stay until the entire fixation is done. In this position, on top of the ulnar head, the scope will have a steady point to rest upon, and will not impede reduction or displace reduced fragments (Fig. 23.4).

In simpler cases where only a single fragment remains unreduced, the fragment is freed by backing out the specific K-wire that kept it secured to the plate. Depressed fragments are lifted by hooking them with the tip of a shoulder or knee arthroscopy probe introduced from 3-4 (Fig. 23.5).

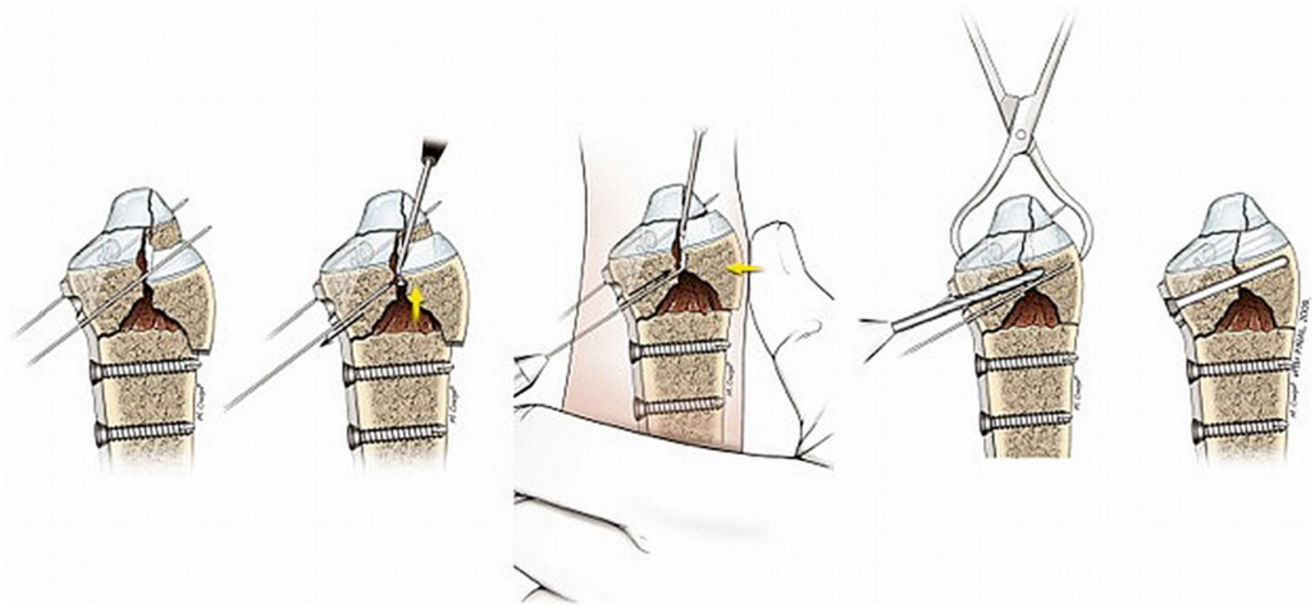


Fig. 23.6 Summary of the author's technique to reduce and stabilize the common scenario of a posterior depressed fragment that remains unreduced. Notice that the K-wire is backed out sufficiently enough to release this malpositioned fragment, whilst the rest of the reduction remains unaffected during the whole maneuver [Copyright Dr. Piñal, 2009]

Elevated fragments nearly always correspond to rim fragments that due to the effect of traction are overdistracted. They are easily repositioned by the assistant decreasing traction while the surgeon levels them with the probe or a Freer elevator. Once the fragment is reduced, it is held in position with a bone tenaculum, and stabilized by pushing the corresponding K-wire in the plate again. Free osteochondral fragments are extremely unstable, and when repositioned sink into the metaphyseal void. To avoid this we create a supporting hammock where they can lie. This is done by inserting the distal layer of pegs in the plate, while keeping these fragments slightly overreduced. Then, they are impacted by using a Freer elevator or by releasing the traction and using the corresponding carpal bone as a mold. A grasper can be useful to grab and twist a severely displaced fragment [7].

Still under arthroscopic control, locking pegs are inserted in the plate by the other surgeon in critical spots, so as to make the articular surface stable to probe palpation. This part of the operation is quite awkward as the flexor tendons are in tension blocking the vision of the plate. Retracting ulnarly the tendons with a Farabeuf, and reducing the traction to release the flexor tendons may ease the task. As soon as the major articular fragments are stabilized, the hand is put flat on the operating table, as in this position the remaining pegs and screws can be inserted expeditiously (Fig. 23.6).

Only in the most comminuted cases will several fragments continue to be displaced after the fluoroscopic part of the operation. Backing out all the K-wires, and attempting to reduce and fix all fragments at the same time, is an impossible endeavor in our hands. We recommend a step-by-step procedure beginning preferably from the ulnar part of the radius, advancing in a radial direction. The mechanics of the procedure is similar as for a single fragment: the corresponding K-wire is backed out, the fragment reduced, and the K-wire pushed in, building up the rest of the articular surface to this foundation.

Once the radius fixation is over, the hand is again placed on traction and distal radio-ulnar joint and the midcarpal joints are assessed for instability or ligament damage.

Arthroscopic Guided Osteotomy for Distal Radius Malunion

Arthroscopy can be invaluable to locate step-offs and see the personality of the malunited fragment, to cut the bone exactly at the cartilage fracture line, and to assess the reduction (Fig. 23.7). This is more so as fluoroscopy has not proved very reliable even in the setting of acute fractures [11, 12], and because a blind osteotomy can cut in an undesired spot [13].

The technique of osteotomy has been described previously [10, 13], and the early results reported [14]. Briefly, the procedure is started by preparing the proposed site of plate fixation with the arm lying on the hand table. In order to facilitate the separation of the fragments, when later doing the intra-articular osteotomy, the external callus is removed

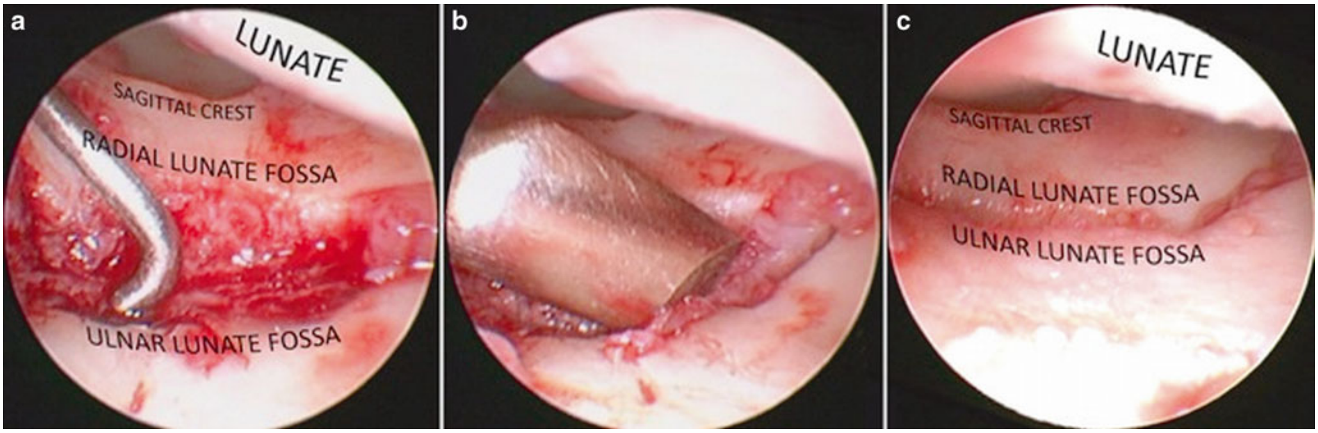


Fig. 23.7 (**a**) Correction of a 4 mm step-off on the lunate fossa (right wrist scope in 6R). (**b**) The osteotome (entering the joint through a dorsal portal) is separating the malunited fragments. (**c**) Corresponding view after reduction [Copyright Dr. Piñal, 2010]

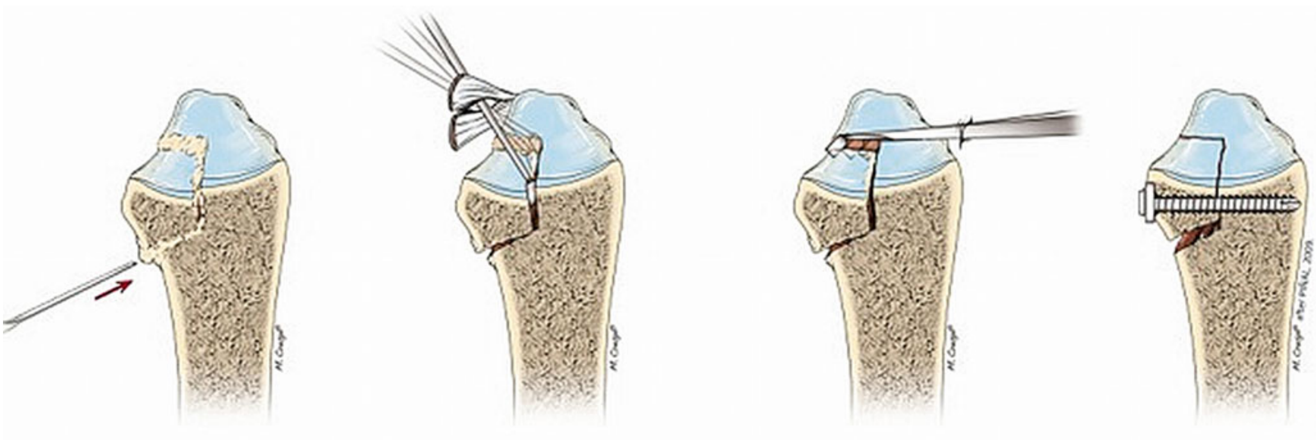


Fig. 23.8 Most malunions require multiple accesses and combinations of osteotomy types. Notice that the osteotome is introduced into the cleft between the radioscaphocapitate and long radiolunate ligaments when using the volar-radial portal [Copyright Dr. Piñal, 2009]

with a rongeur and the outer callus is weakened with an osteotome. No attempt is made to go all the way to the joint or to do any rough bending or prying open of the fragment with the osteotome, as this may break the cartilage at the incorrect place. A plate, when needed, is preplaced at this stage, and held in position with a single screw through its stem as explained for acute fractures. The hand is then placed on traction. An arthroscopic arthrolysis is first carried out to create working space, as the joint is scarred and unyielding. For cutting the bone we used a shoulder periosteal elevator (of 15 and 30° angle) (Arthrex® AR-1342-30° and AR-1342-15°, Arthrex, Naples, FL, USA), and also straight and curved osteotomes (Arthrex® AR-1770 and AR-1771). Instruments with different angles are required in order to avoid damaging the cartilage, and laceration of the extensor tendons is to be avoided by the appropriate technique [13]. The osteotomes also have to be inserted through different portals in order to adapt to the different configurations of the fracture (Fig. 23.8). Stabilization of the fragments is carried out with volar locking plates when several fragments are mobilized; screws or buttressing plates are used when only one fragment needs to be addressed.

Arthroscopic Arthrodesis

The feasibility of performing intercarpal or radiocarpal arthrodesis arthroscopically was presented by Ho in a pioneering work [15]. It may be considered by the skeptical as *just another* arthroscopic filigree. However, the procedure is sound, not only because there will be a cosmetic benefit, but above all, in my view, because the degree of insult to the ligaments will be minimized. Ligament preservation will keep the blood supply to the bones intact and with less scarring to the capsule. This, in turn, promotes bone healing and less stiffness respectively. Furthermore, the proprioception of the wrist will be undisturbed providing (in theory) some extra protection to the joint.

Although the idea of minimizing surgical insult to the wrist is appealing, the technical difficulties of the operation as presented by Ho—including more than 3 h operative time—make implementation of the technique challenging. Some of the procedural struggles come from the infusion of saline. As a matter of fact most of the difficulties mentioned for the wet A-4CA (Arthroscopic Four Corner Arthrodesis) as described by Ho [15] are circumvented when using the dry technique. Specifically, bone graft can be accurately placed, and the swelling does not mask the bony landmarks. Furthermore, we have been increasingly employing rongeurs to remove the carpals and minimizing the use of burrs, speeding up the procedure enormously.

The dry A-4CA [16] can be completed in less than 2 h (i.e., in less than 1 tourniquet time). It can be summarized in the following crucial steps:

1. Creation of a (large) Scapholunate (S-L) portal: The procedure commences by creating the portals, which are easily made ulnarly (6R and UMC), but in advanced SLAC or SNAC, are not so easily made radially. This is due to architectural derangement of the carpus and often scarring from previous surgery. My preference is to create a large (1.5 cm) transverse "scapholunate portal" (midway between 3-4 and RMC) corresponding to the location of the scapho-lunate gap or the scaphoid nonunion (Fig. 23.9). From there, work can be performed in both radiocarpal and midcarpal directions.
2. Scaphoid excision with rongeurs: The previous description of A-4CA and A-PRC [15, 17] resected the bone with a burr, but as stated, it is time consuming and the scaphoid cannot be reused as bone graft. Conversely, using pituitary rongeurs the scaphoid can be excised expeditiously and the cancellous bone graft reused later (Fig. 23.10).
3. Midcarpal joint preparation: The cartilage and subchondral bone at the site of the 4CA are removed with a burr. A 3.0-mm pineapple burr is preferred because it tends not to get caught on bone and produces a more even surface of bone as opposed to pits created by the round burr. During burring, the suction of the instrument is maintained in the off position. Otherwise, the suction stirs up the contents of the joint and obscures the visual field. To remove debris and prevent the burr from clogging, aliquots of 5–10 mL saline are flushed through the scope's side valve with a syringe. The suction is turned on at that specific time, and once the debris is removed the suction is again turned off.
4. Lunate reduction: After the joint surfaces are appropriately prepared, the hand is removed from the traction device to reduce the lunate. To correct the extended and ulnar translated lunate, the wrist is maximally flexed and radially translated. The lunate reduction is maintained with a K-wire (1.25 mm), which is inserted about 2 cm proximal to the 4–5 portal and directed slightly radially.

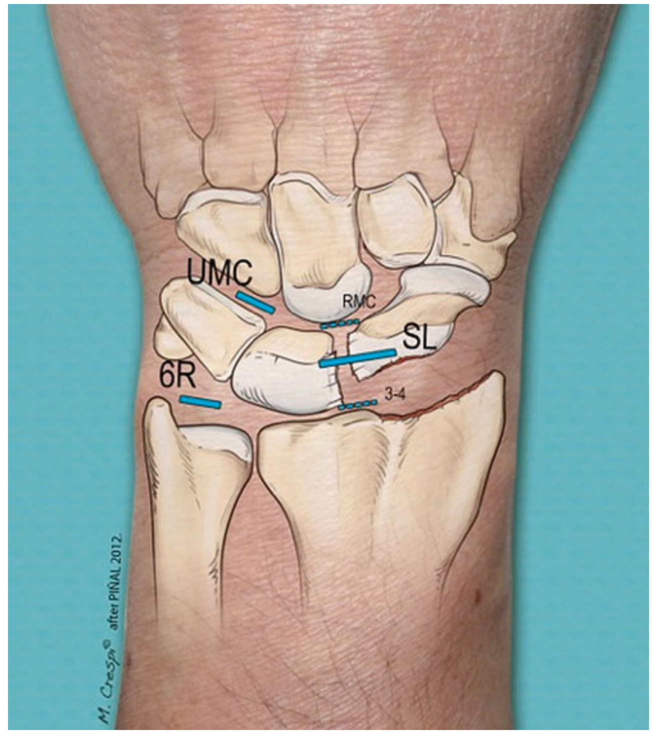


Fig. 23.9 The SL portal is located midway between the 3-4 and radial midcarpal portals (Key: *SL* scapholunate portal, *RMC* radial midcarpal, *UMC* ulnar midcarpal) [Reprinted from del Piñal F, Klausmeyer M, Thams C, Moraleda E, Galindo C. Early experience with (dry) arthroscopic 4-corner arthrodesis: from a 4-hour operation to a tourniquet time. J Hand Surg Am. 2012;37:2389–2399. With permission from Elsevier]

5. Bone grafting: With the lunate reduced, the hand is again placed on traction to allow for the placement of bone graft under arthroscopic guidance. The cavity during traction is large, but we focus on filling the anterior aspects of the lunocapitate and triquetrohamate joints as well as the most distal aspect of the lunotriquetral joint only. For the other surfaces, bone graft is not needed because cancellous bone will contact cancellous bone once the joint is reduced. After trying several devices and methods, the technique we now employ to deliver the bone graft inside the joint is a 3.5-mm (or even 4.5 mm) drill guide. The cancellous bone is loaded into the guide outside the wrist, and the guide is then placed into the joint through the SL portal. A shoulder probe, acting as a plunger, then delivers the bone into the joint, and the bone graft is manipulated into the appropriate position with a small Freer elevator or the probe itself (Fig. 23.11).
6. Midcarpal reduction and fixation: After the bone graft is placed, the hand is taken off traction, the midcarpal joint is reduced (translocating the capitate ulnarly), and the

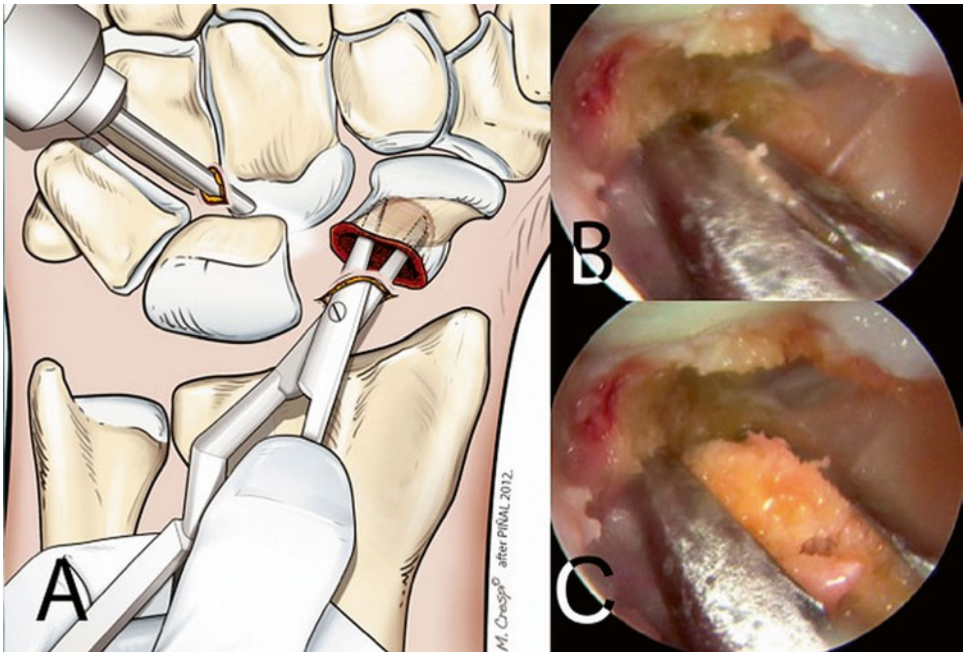


Fig. 23.10 The process of scaphoid resection with a rongeur. (**a**) With the scope in UMC the surgeon scoops out the middle third of the scaphoid with the rongeur. (**b** and **c**) Corresponding arthroscopic view [Reprinted from del Piñal F, Klausmeyer M, Thams C, Moraleda E, Galindo C. Early experience with (dry) arthroscopic 4-corner arthrodesis: from a 4-hour operation to a tourniquet time. J Hand Surg Am. 2012;37:2389–2399. With permission from Elsevier]

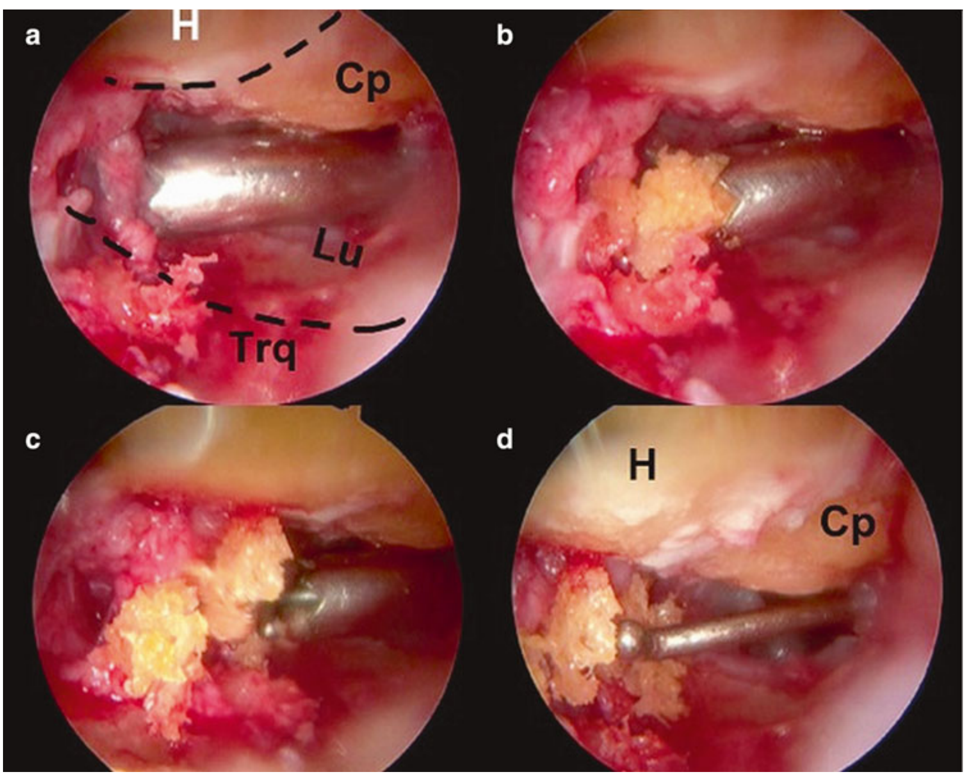


Fig. 23.11 The process of introducing the bone graft into the midcarpal space is shown. (**a**) A 3.5-mm drill guide, fully loaded of cancellous bone graft introduced from SL portal is facing the volar aspect of the lunate and triquetrum (*Lu*: lunate, *Trq* triquetrum). (**b**) The plunger (the shoulder hook in this case) is starting to push the bone graft into the joint space. (**c**) All the bone graft has been delivered in the joint. (**d**) The shoulder probe or a small Freer elevator is used to compress the bone against the palmar ligaments (*H* hamate, *Cp* capitate) [Reprinted from del Piñal F, Klausmeyer M, Thams C, Moraleda E, Galindo C. Early experience with (dry) arthroscopic 4-corner arthrodesis: from a 4-hour operation to a tourniquet time. J Hand Surg Am. 2012;37:2389–2399. With permission from Elsevier]

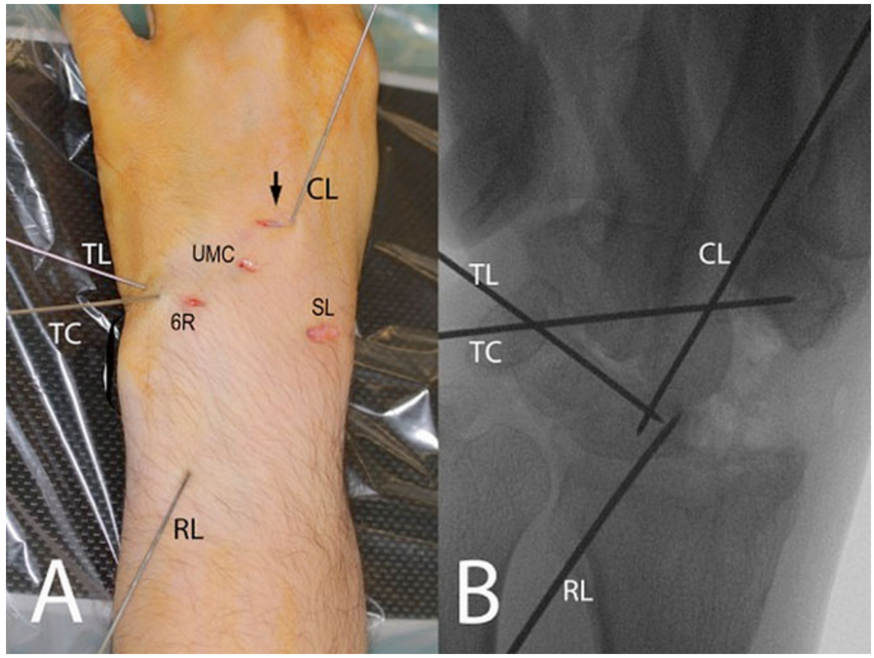


Fig. 23.12 View of the hand (**a**) and corresponding fluoroscopic view (**b**) at the end of the insertion of the guidewires. Notice that the hand is not swollen even at this late stage of the operation. (Key: *TC* triquetro-capitate, *TL* triquetro-lunate, *RL* radio-lunate, *CL* capito-lunate, *SL* scapholunate portal, *UMC* ulnar midcarpal portal. *Arrow* points to the incision needed for the insertion of the capito-lunate screw) [Reprinted from del Piñal F, Klausmeyer M, Thams C, Moraleda E, Galindo C. Early experience with (dry) arthroscopic 4-corner arthrodesis: from a 4-hour operation to a tourniquet time. J Hand Surg Am. 2012;37: 2389–2399. With permission from Elsevier]

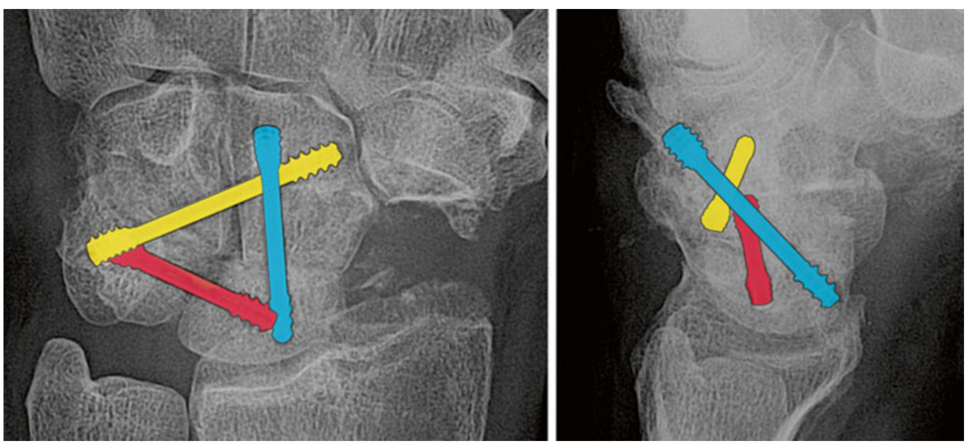


Fig. 23.13 Ideally the screws should be placed to avoid collision and provide maximal purchase as explained in the text [Reprinted from del Piñal F, Klausmeyer M, Thams C, Moraleda E, Galindo C. Early experience with (dry) arthroscopic 4-corner arthrodesis: from a 4-hour operation to a tourniquet time. J Hand Surg Am. 2012;37:2389–2399. With permission from Elsevier]

guidewires for the cannulated screws are inserted. This critical step, one of the trickiest part of the operation, is greatly facilitated by the dry arthroscopic technique; the bony anatomy is easily palpated because the swelling that results from the classic wet technique is avoided (Fig. 23.12).

The guidewires are placed in such a fashion as to maximize purchase and avoid screw collision: The capitolunate screw is directed from the dorsal distal aspect of the capitate to the volar proximal aspect of the lunate, the triquetrolunate screw is directed from the volar triquetrum to the dorsal lunate, and the triquetrocapitate screw is directed from the dorsal distal triquetrum to the volar distal capitate. This technique avoids the problem of one screw interfering with placement of the next (Fig. 23.13).

A small transverse incision is made at the base of the long finger metacarpal for guidewire insertion and later drilling of the capitate. This allows for protection of the extensor tendon of the third finger. The surgeon's hand must be oriented nearly parallel to the patient's wrist during insertion of this guidewire; otherwise, the lunate is missed. Presently, I favor another small transverse incision over the triquetrum to insert the ulnar screws, as I fear that the dorsal branch of the ulnar nerve, the ECU, and the

Fig. 23.14 SNAC III. (**a**, **b**) Preoperative plain X-rays. (**c**, **d**) X-rays at 15 months [Reprinted from del Piñal F, Klausmeyer M, Thams C, Moraleda E, Galindo C. Early experience with (dry) arthroscopic 4-corner arthrodesis: from a 4-hour operation to a tourniquet time. J Hand Surg Am. 2012;37:2389–2399. With permission from Elsevier]

EDM may be at risk if done percutaneously as I used to recommend previously [16].

Correct placement of the guidewires is confirmed on fluoroscopy. Screws of appropriate length and size (presently I use 3-mm titanium AutoFIX™ [Small Bone Innovations, New York, NY]) are inserted after predrilling the port of entrance only. The radiolunate Kirschner wire is removed and a final fluoroscopic check is performed. Although the carpal height is restored by repositioning the capitate on the lunate, the radial styloid may continue to abut the carpus. In this case, the styloid should be resected. This actually takes little time to complete with the rongeur. Care should be taken to preserve intact the RSC ligament origins on the radius. Finally, the SL portal incision is closed with intradermal sutures and the other portals are dressed with nonadherent gauze. Protected range of motion is commenced at about 2–3 weeks.

To date (February 2013), I have done nine cases of dry A-4CA without complications and with fusion in all cases (Fig. 23.14). I have experience in several types of arthrodeses under the dry technique, including the most useful radioscapho-lunate (Fig. 23.15). It is too early to prove that the results are any better than open, however. Nevertheless, the possibility of achieving complex fixations through minimally

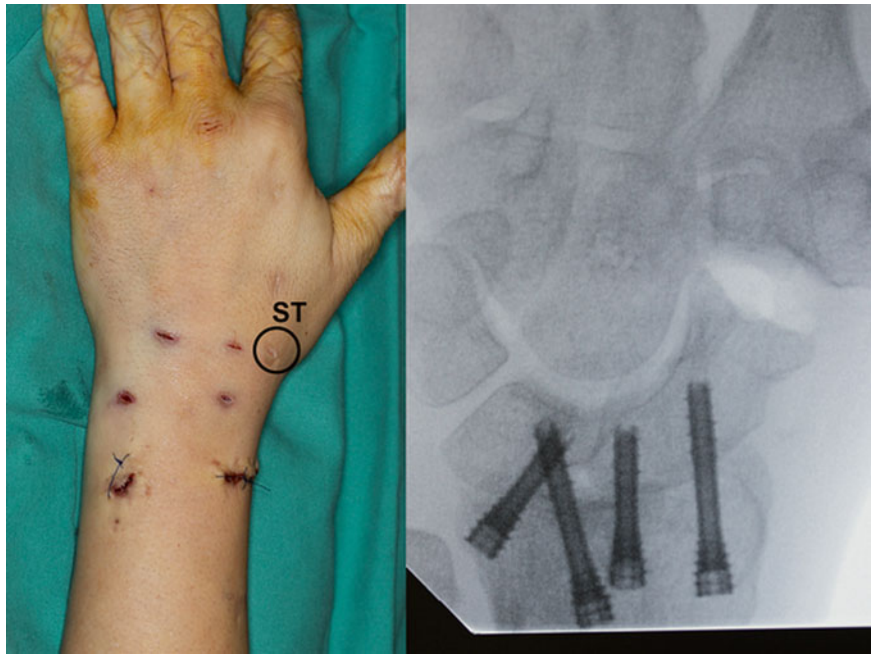


Fig. 23.15 (**a**) Notice minimal swelling at the end of the operation in a case of an R-S-L arthrodesis, resection of the distal pole of the scaphoid was also carried out through the ST portal. Cannulated screws were inserted through the proximal incisions (*arrows*). (**b**) Radiographic healing [Copyright Dr. Piñal, 2013]

invasive surgery represents the future of wrist surgery and the direction in which we should head.

Perilunate Fractures and Fracture-Dislocations

Although the benefit of treating major carpal injuries without adding further damage is self-evident, very few surgeons have experience in the technique [18–20]. Many of the difficulties of the operation come again from the need to infuse saline, as the capsular rents are massive and the fluid extravasates immediately out of the joint. Apart from a theoretical risk of compartment syndrome, the insertion of K-wires and guidewires needed to achieve carpal fixation is complicated enormously by the lack of palpable bony landmarks. Doing the arthroscopy dry reduces the difficulties.

In our practice we schedule the surgery as soon as feasible. Usually traction will reduce spontaneously the lunate but if not, after establishing RMC and UMC portals, the lunate is pulled and reduced with the shoulder probe with minimal difficulties. After assessment of the injured structures the hand is taken off traction and placed on the hand table. Two K-wires in the scaphoid and 1 (or 2) in the triquetrum are pre-set under fluoroscopic control. An additional 1.5 mm K-wire is inserted into the lunate to be used as a joystick, as this bone is uncontrollable by external maneuvers. The importance of the advantageous lack of swelling at the time of inserting these K-wires cannot be overemphasized (Fig. 23.16).

The hand is placed on traction again to reduce and stabilize the proximal carpal row under arthroscopic control. This maneuver is extremely complicated and is facilitated if the surgeon can "feel" the bony architecture. The surgeon needs to push the proximal pole of the scaphoid down with a shoulder probe (or a Freer elevator) while the lunate is kept aligned to the scaphoid (using the 1.5 mm K-wire to do so). At the same time the S-L space is closed by compressing the scaphoid and the triquetrum (Fig. 23.17). The K-wires are driven into the lunate. An optional distal scaphoid-distal capitate can be inserted to block the midcarpal joint.

When the scaphoid is fractured, the technique is slightly modified. After prereducing the wrist, under fluoroscopic control, 2 K-wires (of 1 mm diameter to serve as guidewire) are driven in through the distal pole of the scaphoid only; another K-wire is driven into the triquetrum (directed to the lunate). Reduction of the scaphoid under arthroscopic guidance is then carried out and both K-wires inserted into the proximal pole. In general, a distal to proximal screw is inserted using the best-placed K-wire of the 2, as the guidewire. If the fracture involves the proximal pole of the scaphoid, the wrist is slightly flexed and Slade's technique is followed to insert a proximal to distal screw.

The aftercare is similar to an open procedure (6–8 weeks of immobilization or as needed for the scaphoid to heal).

Kim et al. [19] in the largest case series published to date presented slightly better results as compared to open techniques, with maintenance of the carpal angles despite the fact that no ligament was sutured. Most importantly, they showed

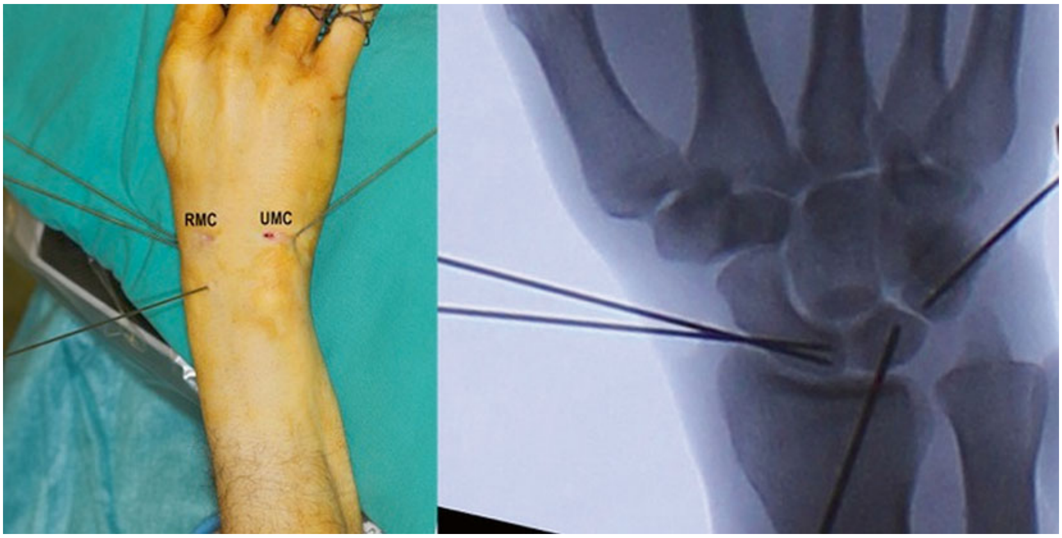


Fig. 23.16 Pre-setting of K-wires is done with the hand on the surgical table and under fluoroscopic guidance. Notice absence of swelling at the wrist, despite the fact that the joint has already been cleared of debris and the lunate reduced arthroscopically. Corresponding fluoroscopic view (*right*) [Copyright Dr. Piñal, 2013]

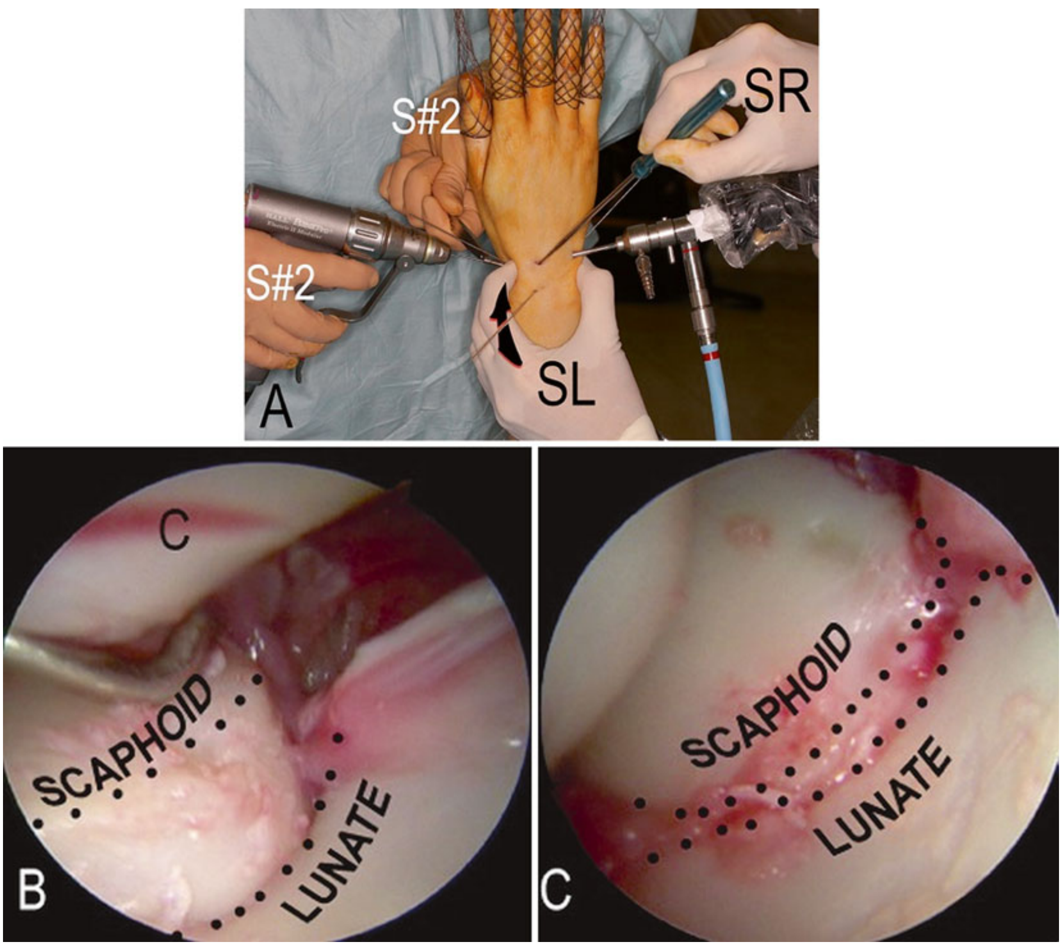


Fig. 23.17 Reduction of a perilunate dislocation. (**a**) As a one-man band, the surgeon reduces the scaphoid with the probe (Surgeon's Right hand) while with the other hand the carpals are compressed (SLeft) and with the dorsum of the index the lunate's K-wire is flipped volarly (*arrow*). The Assistant (S#2) then drives the K-wires in. (**b**) Corresponding arthroscopic view to (**a**), and after the K-wires have been driven in reducing the S-L space (**c**) [Copyright Dr. Piñal, 2013]

no case of midterm joint degeneration, inferring that arthroscopy allowed a better reduction and less blood supply disturbance on the carpals. My experience is limited to seven cases and my results endorse Park's experience [18, 19].

Summary

Wrist arthroscopy can be carried out without infusing water to maintain the optical cavity, as simple traction suffices. The lack of tissue infiltration by fluid keeps soft tissues in pristine condition in the event that open surgery is needed after the arthroscopic exploration. The fact that the dry technique makes watertightness irrelevant opens a new set of possibilities by combining arthroscopy with moderate-sized incisions. Despite the fact that any modification of a technique with which one is familiar can be regarded with major reticence, the advantages of the dry technique well merit giving it a try. As a matter of fact, although in simpler arthroscopic procedures there are probably no differences, the complex ones are much simplified by doing them dry. Sooner or later, even the most reluctant wet arthroscopists will have to swap to the dry technique to get the most out of what arthroscopy might offer. On the other hand, any accomplished wrist arthroscopist will have minimal problems to swap from wet to dry and vice versa.

I should underscore that the procedures described in this chapter have a steep learning curve even for skilled arthroscopists and require the surgeon to have precise spatial orientation at the time of guidewire or osteotome placement.

References

1. del Piñal F, García-Bernal FJ, Pisani D, Regalado J, Ayala H, Studer A. Dry arthroscopy of the wrist: surgical technique. J Hand Surg Am. 2007;32:119–23.
2. Piñal D. Dry arthroscopy and its applications. Hand Clin. 2011; 27:335–45.
3. Doi K, Hattori Y, Otsuka K, Abe Y, Yamamoto H. Intra-articular fractures of the distal aspect of the radius: arthroscopically assisted reduction compared with open reduction and internal fixation. J Bone Joint Surg. 1999;81:1093–110.
4. Ruch DS, Vallee J, Poehling GG, Smith BP, Kuzma GR. Arthroscopic reduction versus fluoroscopic reduction in the management of intra-articular distal radius fractures. Arthroscopy. 2004;20: 225–30.
5. Varitimidis SE, Basdekis GK, Dailiana ZH, Hantes ME, Bargiotas K, Malizos K. Treatment of intra-articular fractures of the distal radius: fluoroscopic or arthroscopic reduction? J Bone Joint Surg Br. 2008;90:778–85.
6. del Pinal F, Garcia-Bernal FG, Studer A, et al. Explosion type articular distal radius fractures: technique and results of volar locking plate under dry arthroscopy guidance. Presented at the FESSH Meeting in Poznan (Poland) 2009. Book of Abstracts A0180.
7. del Piñal F. Dry arthroscopy of the wrist: its role in the management of articular distal radius fractures. Scand J Surg. 2008;97:298–304.
8. del Piñal F. Treatment of explosion-type distal radius fractures. In: del Piñal F, Mathoulin C, Luchetti C, editors. Arthroscopic management of distal radius fractures. Berlin: Springer Verlag; 2010. p. 41–65.
9. del Piñal F. Technical tips for (dry) arthroscopic reduction and internal fixation of distal radius fractures. J Hand Surg Am. 2011;36:1694–705.
10. del Piñal F, García-Bernal FJ, Delgado J, Sanmartín M, Regalado J, Cerezal L. Correction of malunited intra-articular distal radius fractures with an inside-out osteotomy technique. J Hand Surg Am. 2006;31:1029–34.
11. Edwards III CC, Harasztic J, McGillivary GR, Gutow AP. Intra-articular distal radius fractures: arthroscopic assessment of radiographically assisted reduction. J Hand Surg Am. 2001;26: 1036–41.
12. Lutsky K, Boyer MI, Steffen JA, Goldfarb CA. Arthroscopic assessment of intra-articular distal radius fractures after open reduction and internal fixation from a volar approach. J Hand Surg Am. 2008;33:476–84.
13. del Piñal F. Arthroscopic-assisted osteotomy for intraarticular malunion of the distal radius. In: del Piñal F, Mathoulin C, Luchetti C, editors. Arthroscopic management of distal radius fractures. Berlin: Springer Verlag; 2010. p. 191–209.
14. del Piñal F, Cagigal L, García-Bernal FJ, Studer A, Regalado J, Thams C. Arthroscopically guided osteotomy for management of intra-articular distal radius malunions. J Hand Surg Am. 2010;35: 392–7.
15. Ho PC. Arthroscopic partial wrist fusion. Tech Hand Up Extrem Surg. 2008;12:242–65.
16. del Piñal F, Klausmeyer M, Thams C, Moraleda E, Galindo C. Early experience with (dry) arthroscopic 4-corner arthrodesis: from a 4-hour operation to a tourniquet time. J Hand Surg Am. 2012;37:2389–99.
17. Weiss ND, Molina RA, Gwin S. Arthroscopic proximal row carpectomy. J Hand Surg Am. 2011;36:577–82.
18. Park MJ, Ahn JH. Arthroscopically assisted reduction and percutaneous fixation of dorsal perilunate dislocations and fracture-dislocations. Arthroscopy. 2005;21:1153e1–8.
19. Kim JP, Lee JS, Park MJ. Arthroscopic reduction and percutaneous fixation of perilunate dislocations and fracture-dislocations. Arthroscopy. 2012;28:196–203.
20. Weil WM, Slade 3rd JF, Trumble TE. Open and arthroscopic treatment of perilunate injuries. Clin Orthop Relat Res. 2006;445:120–32.

Thumb CMC Arthroscopic Electrothermal Stabilization (Without Trapeziectomy)

24

John M. Stephenson and Randall W. Culp

Introduction

Factors leading to degeneration of the CMC joint of the thumb have been a major focus in the hand surgery literature. Strong association between laxity of the ligamentous and capsular structures and degenerative basal joint changes has been described [1]. A considerable amount of attention has been paid to the salvage of the already degenerated basal thumb joint, but much less focus has been paid to early intervention to prevent or delay the need for a salvage procedure. Historically, treatment of a lax basal thumb joint without degenerative changes has required a large arthrotomy which further destabilized the joint and was uncommonly performed. With recent advances in small joint arthroscopy, specifically arthroscopic evaluation and intervention of the thumb CMC joint, it is possible to treat early basal joint laxity in a minimally invasive fashion without further joint destabilization [2].

Thermal stabilization of capsular and ligamentous structures has been used with success in other areas of hand and wrist arthroscopy. Much of our understanding of this process has come from research into its application in larger joints such as the knee and shoulder [3–6]. At the time of surgery, the capsular tissue undergoes shrinkage which may persist for months after surgery as the tissue undergoes a thickening process. Histologic and ultrastructural alterations of the treated tissues have been noted. It has also been postulated that afferent sensory fibers in the capsular tissue are also interrupted through this process, which may result in a decrease in pain.

Most frequently a radiofrequency probe (available through several manufacturers) is used. This type of technology uses electromagnetic energy to cause rapid movement of charged particles within the tissues to generate heat. Two types of radiofrequency probes are available, monopolar and bipolar. A monopolar probe generates energy that flows from the tip to a grounding pad on the body of the patient. Questions about the depth of heat penetration have been raised regarding monopolar probes, and care must be taken due to the proximity of neurovascular structures. Bipolar probes will take a path of least resistance through a conducting irrigating solution. There is greater control of depth of heating, but more potential concerns with the amount of heat generated within the joint through indirectly heating the irrigation fluid.

Thermal stabilization exploits the heat labile intramolecular bonds that hold the triple helical structure in type I collage. Heat stable intermolecular bonds between chains are unaffected. Optimal temperatures for thermal stabilization have been described between 60 and 67 °C. Higher temperatures have been associated with thermal damage and necrosis of tissues. Thermal shrinkage occurs until a plateau is reached, beyond which further shrinkage cannot occur. As the tissue cools, up to 10 % of initial shrinkage may be lost as some of the bonds renature. Repair through fibroblast migration begins within 1 week after injury and continues for 3 months.

Clinical Presentation

Patients with laxity of the thumb CMC joint will initially present with pain especially with pinching or grasping type activities. There may be a history of associated trauma which brought this pain to the patient's attention. Tenderness may be elicited by palpation of the CMC joint especially on the volar aspect of the joint. An effusion may be noticeable around the joint when compared to the contralateral side. The so-called "CMC grind test" may be positive with pain

J.M. Stephenson, M.D.
Department of Orthopaedic Surgery, University of Arkansas for Medical Sciences, Little Rock, AR, USA

R.W. Culp, M.D., F.A.C.S. (✉)
Department of Orthopaedics, Thomas Jefferson University Hospital, The Philadelphia Hand Center, 700 S. Henderson Road, Suite 200, King of Prussia, PA 19406, USA
e-mail: rwculp@handcenters.com

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*, DOI 10.1007/978-1-4614-1596-1_24, © Springer Science+Business Media New York 2015

and/or crepitus when loading and translating the metacarpal on the trapezium. Laxity may be noted with subluxation of the joint, and dynamic fluoroscopic examination may aid in this determination. Differential diagnoses to consider include De Quervain's tenosynovitis, neuropathy of the superficial radial nerve, occult scaphoid fracture, isolated STT, or radiocarpal arthritis. Patient will often demonstrate pain and reduced key pinch strength testing. Radiographs should be obtained to rule out other significant degenerative changes of the CMC joint and other surrounding bony pathology.

A useful radiographic technique is a stress radiograph, which is a PA view of both thumbs positioned parallel to the X-ray plate with the distal phalanges pressed firmly together along their radial border. This position forces the metacarpal base laterally, and in the presence of a CMC ligament tear or laxity, radial shift of the metacarpal on the trapezium occurs.

Nonsurgical Management

Options for conservative management for the patient with a painful basal thumb joint are limited. Activity modifications specifically avoidance of grasping and key pinch may provide some temporary relief. There is a role for a trial of splinting of the joint with a hand-based thumb spica splint to see if immobilization will help with an acute pain flare. Both hard and soft thumb spica splints may be utilized by the patient in an alternating fashion depending upon their preference. An intra-articular injection of a corticosteroid can be useful in a diagnostic and therapeutic manner. Oral NSAIDs and topical anti-inflammatory gel can help with any of the above nonsurgical modalities.

Surgical Management

Diagnostic arthroscopy is a tool that can be used when there is a question of the clinical and radiographic findings, or when conservative management has failed. The degree of laxity of the CMC joint can be better quantified and arthritic changes can be documented. Findings of synovitis, loose bodies, and chondromalacia can be noted even in the presence of normal radiographs. Contraindications include generalized connective tissue disorders or excessive thumb MP hyperextension. This technique can also be utilized with joint debridement to help with painful subluxation in stage I or II CMC arthritis [7].

Preparation

General or regional anesthesia may be used for this procedure. The patient is positioned supine on an operating table with an arm table on the operative side. A tourniquet may be used if desired on the upper arm. The arm should be positioned so that it is in the center of the table to facilitate the use of a traction apparatus. Once the extremity has undergone sterile prep and drape, the traction tower is assembled. A sterile finger trap is placed on the thumb past the IP joint. It is often helpful to wrap a small coban tape around the thumb to the level of the MP joint to further secure the thumb in the finger trap (Figs. 24.1 and 24.2). The elbow is bent 90° so that the ulna is parallel to the long axis of the traction tower. A couple of folded towels should be placed below the elbow and between the ulnar border of the forearm and the traction tower. The wrist should be in slight ulnar deviation at this point. A larger coban wrap may then be used in a circular fashion to wrap the fingers together first, then to the upper traction tower and then running down from the wrist to the lower forearm. This helps to hold the arm in the most desirable position for arthroscopy of the thumb CMC joint and prevents unwanted movement of the arm during surgery. Once satisfied with the position and stability of the setup, traction of 5–10 lb is applied to the joint. The tourniquet may be inflated to 200–250 mmHg if desired.

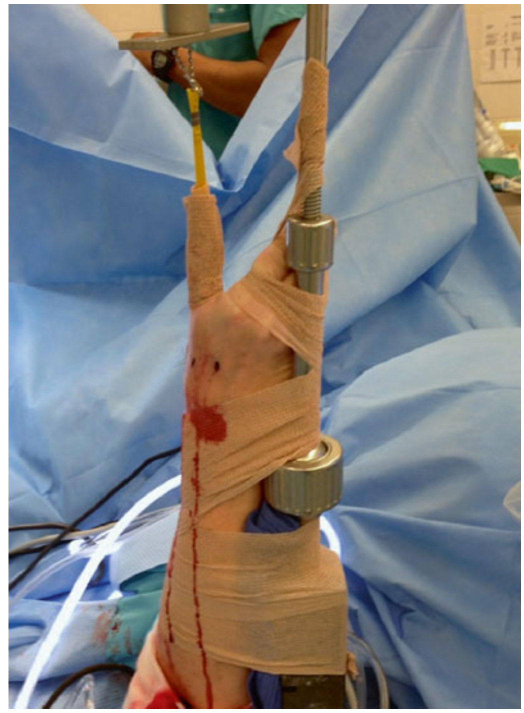


Fig. 24.1 Traction tower setup

Often it is helpful to have a mini C-arm fluoroscope available during these procedures. This should be draped and brought into the surgical field at a 90° angle so that the "C" is oriented in a dorsal to volar direction with the image intensifier at the dorsum of the wrist.

Fig. 24.2 Traction tower setup

Landmarks and Portals

Standard 1R and 1U portals have been described for CMC joint arthroscopy; however it is necessary to be familiar with the surrounding anatomy. The thumb metacarpal should be palpated and marked along with the joint line. The abductor pollicis longus (APL), extensor pollicis brevis (EPB), and extensor pollicis longus (EPL) tendons should be marked. The radial artery has been described as lying ulnar to the EPB at an average distance of 11 mm (range 4–17 mm) in a cadaveric study. However, the average distance from the EPL is within 1 mm in greater than 70 % of specimens studied [8].

The 1R portal is located at the joint line directly radial to the APL (volar), and the 1U portal is located directly ulnar to the EPB (dorsal). Approximately 1 cm will separate the two portals from one another.

An 18 gauge needle should be used to confirm the location and determine the appropriate entry angle to the joint. The needle should be directed into the joint slightly proximal to the mark for the portal. The joint should be insufflated with 1–2 mL of normal saline and the distension of the capsule should be visible. A number 11 blade should be used to cut skin only. A small mosquito type hemostat should be used to bluntly dissect the soft tissues until the capsule can be palpated with the tip of the instrument. The surgeon should be mindful of the branches of the superficial radial nerve; thus careful blunt dissection is necessary to avoid injury. Cadaveric studies have shown that of 11 specimens at least one branch of the superficial radial nerve was lying over the EPB tendon in 7 specimens, the APL tendon in 6 specimens, and over the EPL in all 11 specimens.

After careful dissection, a blunt trocar with its surrounding sheath is then gently introduced into the joint. The inclination is slightly distal at a 10–20° angle. The 1U portal is typically the first portal established. The 1U portal is in the area of the DRL (volar) and the POL (dorsal). Sweeping the trocar to find the natural division between these two ligaments can help to preserve their integrity and make entry into the joint less traumatic. Trocar placement can be confirmed with fluoroscopy, since it is easy to fall erroneously into the STT joint. For the 1R portal, the capsule is immediately deep to the APL tendon since there is no ligamentous reinforcement in this area. This portal is usually made under direct visualization and will serve as the primary working portal. Switching portals is commonly done and should be used to obtain complete visualization of the entire joint.

Diagnostic Arthroscopy Technique

Often the initial view of the joint is obscured with hypertrophic synovium. This may be resected under visualization using a small joint arthroscopic shaver or thermal device according to the surgeon's preference. It is quite common with these small shavers to have to clear debris from them several times during the case. Continuous inflow is encouraged to clear as much debris as possible to maximize visualization and inspection of the surrounding ligaments. Irrigation fluid will also help to dissipate the heat generated by these devices.

General inspection of the joint should be done systematically, looking for osteophytes, loose bodies, and damage to the articular surface. With the camera in the 1U portal, the superficial and deep portions of the anterior oblique ligament can be identified and inspected (Fig. 24.3). Moving the camera in a more dorsal direction, the ulnar collateral ligament can be visualized (Fig. 24.4).

At this point, the camera should be switched so that it is in the 1R portal. Again, the ulnar collateral ligament can be identified, and continuing to sweep dorsal, the posterior oblique ligament will come into view, followed by the dorsoradial ligament. After careful identification and examination of the ligaments, arthroscopic intervention may commence.

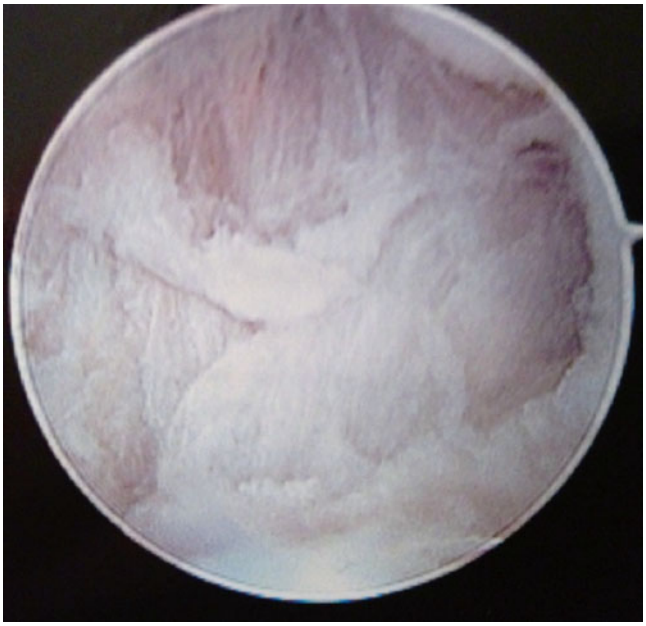


Fig. 24.3 Anterior oblique ligament

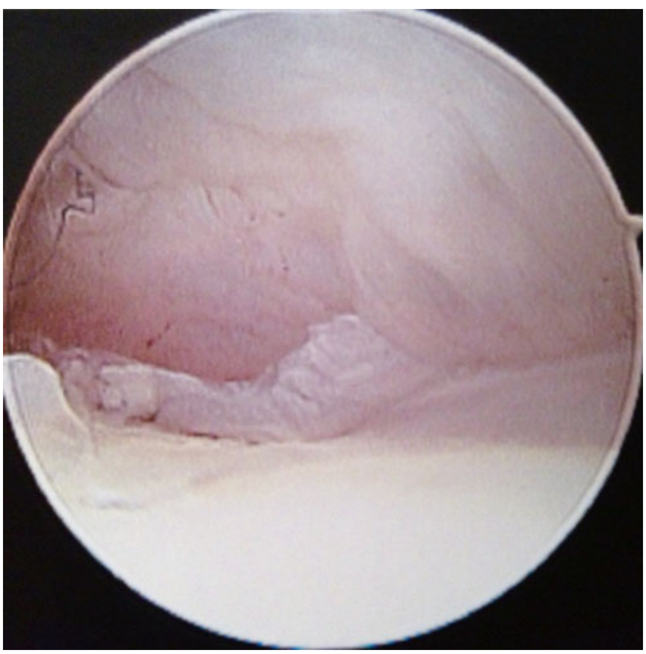


Fig. 24.4 Ulnar collateral ligament

Thermal Capsular Shrinkage Technique

With the camera in the 1U portal, the thermal probe is introduced into the 1R portal. The probe should be passed over the capsular and ligamentous structures in a controlled, systematic manner. Passing the probe too rapidly will result in inefficient shrinkage; conversely, passing too slowly may

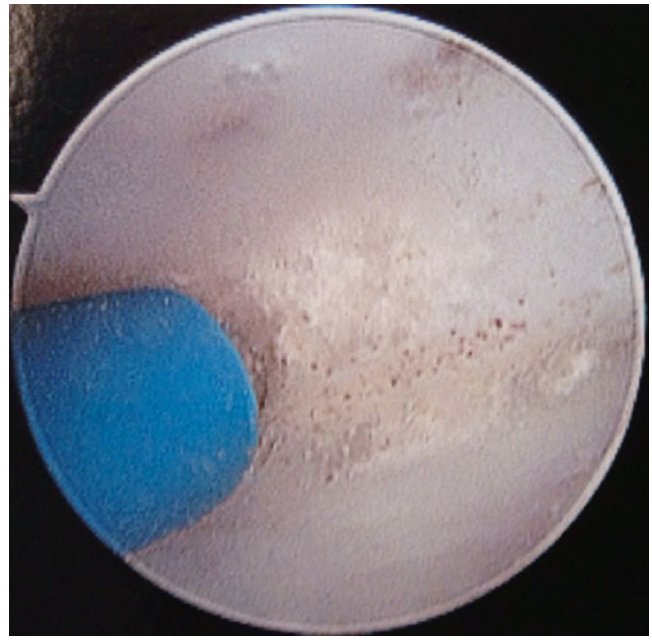


Fig. 24.5 Posterior oblique ligament after electrothermal treatment

result in extensive thermal damage. To proceed in a systematic manner, stabilization should start with the anterior oblique ligament and progress towards the ulnar collateral ligament. At this point, the portals should be switched. The remaining UCL and posterior oblique ligament, as well as the dorsoradial ligament, may be stabilized (Fig. 24.5). As the tissue is heated, a color change or "caramelization" of the tissue will occur along with visible shrinkage. If further shrinkage is deemed to be necessary a "stripe" method should be used leaving a band of healthy tissue between treated tissues to allow for the reparative process rather than heating the entire capsule-ligamentous surface (Fig. 24.6). For proper tensioning, it should be anticipated that up to 10 % of the initial shrinkage will be lost upon cooling.

If desired, a pin may be used to stabilize the joint. Under C-arm visualization the joint should be reduced and a 0.045-in. Kirschner wire should be inserted from the thumb metacarpal into the trapezium on the radial side. The joint can also be stabilized with a newer technique called a "tight-rope." This is a suture-button complex running from the base of the thumb to the base of the index metacarpal (Figs. 24.7, 24.8, and 24.9).

Postoperative Care

The wounds are closed according to the surgeon's preference and a well-padded thumb spica splint is then placed. Elevation is encouraged as well as early active range of motion of the remaining digits to decrease swelling. At 7–10 days postoperatively, the sutures may be removed and

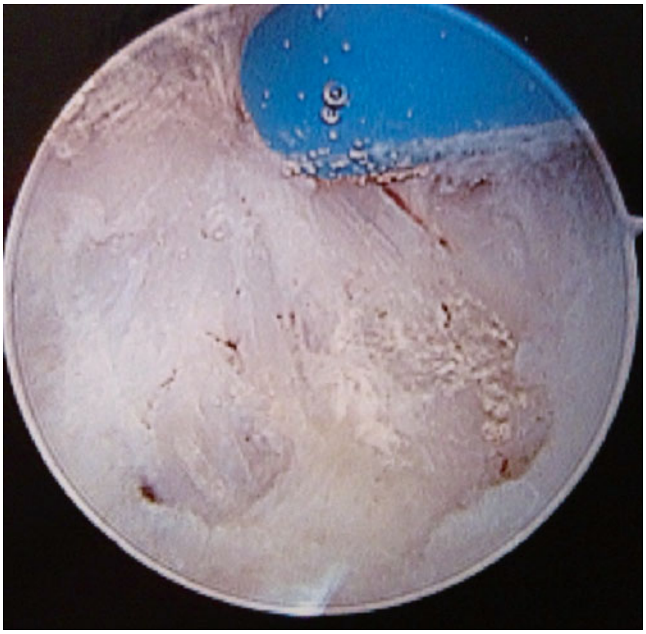


Fig. 24.6 Anterior oblique ligament-stripe technique. Notice the "caramelization" of the tissue on the inferior stripe separated from the second stripe by an untreated area of tissue

Fig. 24.7 Starting point for tightrope placement

the patient may be placed into a thumb spica cast or custom molded removable splint according to the surgeon's preference. The splint should be worn at all times. The pin, if placed, may be removed at 3–4 weeks and early motion started. Strengthening exercises may begin at 6 weeks postoperatively. The splint may be weaned starting in week 10 and after 3 months, the patient may return to previous activities with minimal restrictions.

Fig. 24.8 Tightrope trajectory

Fig. 24.9 Final placement of tightrope for stabilization

References

1. Eaton RG, Lane LB, Littler JW, et al. Ligament reconstruction for the painful thumb carpometacarpal joint: a long-term assessment. J Hand Surg Am. 1984;9:692–9.
2. Berger RA. A technique for arthroscopic evaluation of the first carpometacarpal joint. J Hand Surg Am. 1997;22:1077–80.
3. Arnoczky SP, Aksan A. Thermal modification of connective tissues: basic science consideration and clinical implications. J Am Acad Orthop Surg. 2000;8:305–13.
4. Hayashi K, Markel M. Thermal modification of joint capsule and ligamentous tissues. Tech Sports Med. 1998;6:120–5.
5. Hayashi K, Peters D, Thabit G, et al. The mechanism of joint capsule thermal modification in an invitro sheep model. Clin Orthop Relat Res. 2000;370:236–49.
6. Osmond C, Hecht P, Hayashi K, et al. Comparative effects of laser and radiofrequency on joint capsule. Clin Ortho Relat Res. 2000; 375:286–94.
7. Culp RW, Rekant MS. The role of arthroscopy in evaluating and treating trapeziometacarpal disease. Hand Clin. 2001;17(2):315–9.
8. Gonzalez MH, Kemmler J, Weinzweig N, et al. Portals for arthroscopy of the trapeziometacarpal joint. J Hand Surg Br. 1997;22(5): 574–5.

Partial Trapeziectomy and Soft Tissue Interposition

25

Tyson K. Cobb

Introduction

Almost 20 years have passed since the early description of carpometacarpal arthroscopy [1–3]. Since this time, improvement in equipment and surgical technique has allowed advancement of therapeutic options to allow the entire spectrum of CMC degenerative joint disease to be addressed arthroscopically. The most recent change in the treatment algorithm [4, 5] of CMC degenerative joint disease is the treatment of pantrapezial arthrosis by arthroscopic means [6]. As a result of the positive outcomes and ability to perform hemitrapeziectomy surgery through a minimally invasive arthroscopic technique, open trapeziectomy is no longer mandated for patients with degenerative arthritis of the scaphotrapeziotrapezoid (STT) joint.

Indications and Patient Selection

Patients presenting with pain or dysfunction in the area of the CMC joint are evaluated to rule out other potential causes of pain such as de Quervain's radial-sided wrist pain associated with scaphoid nonunion advanced collapse (SNAC) or scapholunate advanced collapse (SLAC), isolated STT arthritis, ganglion cyst, other painful masses, and neurogenic pain. Following appropriate diagnosis of basal joint arthrosis, patients undergo a period of conservative treatment including nonsteroidal anti-inflammatory drugs, splints, and hyaluronate sodium (Hyalgan®, Sanofi Aventis) or cortisone injections. Cortisone injections are being used less frequently in the author's practice due to potential side effects, including accelerated cartilage loss and capsular attenuation, and an increasing frequency of patients declining cortisone injections. While the frequency of multiple cortisone injections has drastically diminished over time, one-time injections of cortisone for CMC and/or STT arthrosis continue to be utilized for many patients.

Patients who do not respond to conservative treatment and demonstrate significant disabilities on subjective and objective assessment are offered surgical intervention. Patients are counseled with respect to minimally invasive arthroscopic resection arthroplasty versus open techniques and risks and benefits of each. They are told that the minimally invasive procedure may not provide sufficient relief and that they may require a revision open surgery at a later date.

Surgical decision-making is directed by specific patient variables. While there are numerous patient-related variables that impact decision-making for the surgical treatment of basal joint arthritis, four are critical to the success and patient satisfaction following the procedure (Fig. 25.1): (1) CMC cartilage status, (2) CMC stability, (3) STT cartilage status, and (4) metacarpophalangeal (MP) pathology.

CMC Cartilage Evaluation

Patients with minimal radiographic findings who remain persistently symptomatic despite conservative treatment are candidates for diagnostic arthroscopy [7]. The extent of the cartilage loss is usually worse than the radiograph suggests. Accurate arthritis staging requires arthroscopy [4, 5]. If the cartilage is intact (Badia Stage 1), synovectomy and capsular shrinkage may provide satisfactory results. If the cartilage loss is focal (Badia Stage 2), synovectomy and first metacarpal osteotomy is an option [8, 9]. In the author's practice, it is uncommon to see patients or operate at Stage 1 or 2 because patients have been treated conservatively elsewhere prior to referral. Patients considering the less invasive procedures described above should be well aware of the potential for progression of the pathology and potential need for arthroplasty in the future. Patients who prefer to minimize

T.K. Cobb, M.D. (✉)
Orthopaedic Specialists, 4096 Treeline Drive, Bettendorf, IA 52722, USA
e-mail: tysoncobbmd@gmail.com

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*,
DOI 10.1007/978-1-4614-1596-1_25, © Springer Science+Business Media New York 2015

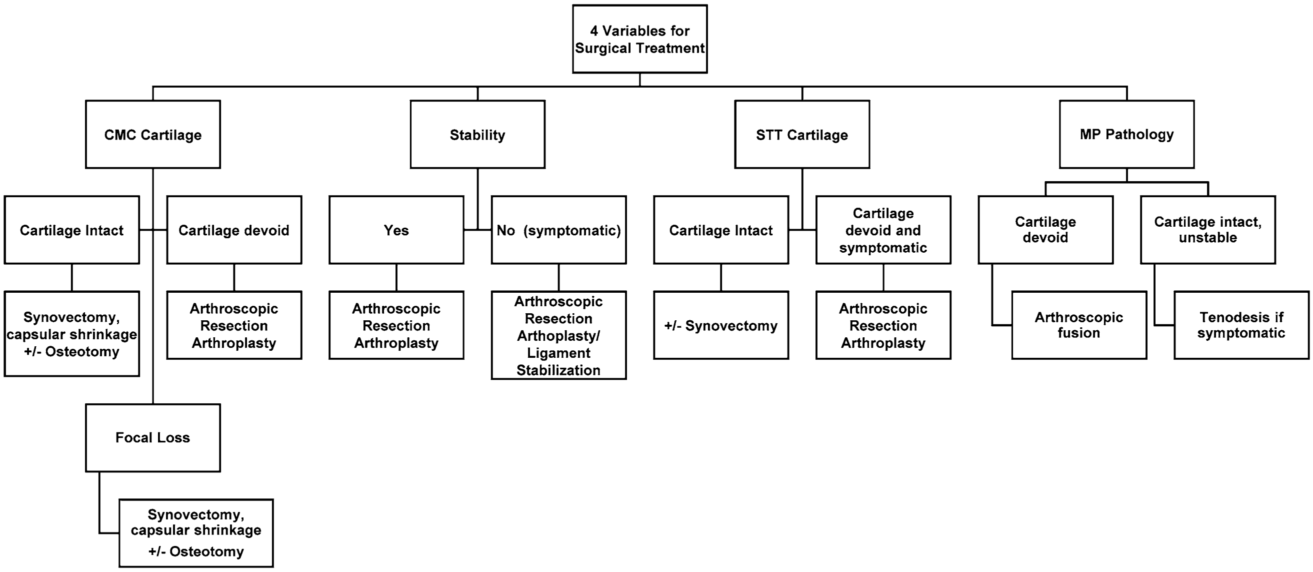


Fig. 25.1 Algorithm for surgical treatment of thumb basal joint arthritis

the likelihood of additional procedures in the future can be effectively treated with sequential cortisone injections until the arthrosis progresses sufficiently to warrant arthroplasty. While it may be true that intervening at an earlier stage with less aggressive surgical options may provide better ultimate outcome and function, evidence is lacking in the literature.

Many radiographic Eaton Stage 2 [10] cases will be found to have widespread cartilage loss (Badia Stage 3) at the time of arthroscopy. Badia Stage 3 cases are treated with arthroscopic resection arthroplasty as outlined below.

Carpometacarpal Stability

Patients with symptomatic CMC instability are counseled with respect to open and arthroscopic stabilization procedures. Many patients, especially older patients, are primarily concerned with pain relief and are less interested in stabilizing procedures. Clear benefits for this have not been demonstrated in the literature. Patients with CMC instability who desire stabilization are offered arthroscopic ligament stabilization at the time of arthroscopic resection arthroplasty. The procedure is outlined below in section "Surgical Technique CMC Stabilization."

Scaphotrapeziotrapezoid Cartilage Evaluation

Just as the CMC cartilage loss observed at the time of arthroscopy is usually worse than radiographs suggest, the same is true for cartilage loss involving the STT joint. Diagnostic arthroscopy of the STT joint can be helpful in establishing which radiographic Stage 3 cases are actually arthroscopic Stage 4. (Note: Badia's classification did not include Stage 4, but it seems a logical addition.) At times it may be difficult to determine the significance of the STT arthrosis. Diagnostic injections are occasionally used to help identify the pain contributions of CMC versus STT when the significance of STT arthrosis is in question. Diagnostic injections are performed by first injecting the CMC with 1 ml of 1 % lidocaine under fluoroscopic control to determine the amount of pain relief and improvement in pinch strength. Ten to 15 min after the CMC injection and after assessment of the amount of pain relief and strength improvement, the STT is then injected under fluoroscopic control. Ten to 15 min later, the amount of pain relief and improvement in pinch and grip strength is again evaluated. Patients who demonstrate substantial benefit from both injections are considered candidates for pantrapezial arthroscopic resection arthroplasty.

Metacarpophalangeal Joint Pathology

Metacarpophalangeal (MP) hyperextension and arthrosis should be addressed prior to surgical treatment of the CMC. Symptomatic, unstable MP joints can be stabilized with MP tenodesis. Fusion should be considered if the MP joint is symptomatic and arthritic. The author has performed many MP tenodesis for MP hyperextension (>30°) over the years. Long-term follow-up has revealed gradual return of the MP hyperextension in a number of cases. Even with return of the hyperextension, however, patients tend to remain very happy with the results provided pain relief is good. It is important to discuss the options concerning the MP joint with the patient. If the MP is unstable but asymptomatic, counsel the patient concerning the possible need for future procedures for the MP joint (if MP pathology is not addressed at the time of the index procedure). If simultaneous MP tenodesis is performed, the disadvantage discussed with the patient includes the risk of loss of correction over time, risk of converting an asymptomatic unstable joint to a symptomatic joint, and increasing the postoperative recovery time.

Surgical Technique: Arthroscopic Resection Arthroplasty of CMC and STT Joint

The procedure can be performed with general or regional anesthesia with or without a tourniquet. When a tourniquet is not used, an anesthetic with epinephrine is infiltrated preoperatively allowing sufficient time for vasoconstriction [11, 12]. The patient is placed on an operating room table with the shoulder abducted and externally rotated. The arm is placed on an arm table with a well-padded nonsterile tourniquet placed on the brachium (if used). The brachium is taped to the arm table. The arm is suspended using 5–10 pounds of finger-trap traction through the thumb (Fig. 25.2). Routine arthroscopy is performed using a 1.9 mm, a 2.3 mm, or a 2.7 mm 30° arthroscope. The smaller scopes are used on the smaller joints and in joints considered potential candidates for joint-sparing procedures such as synovectomy and metacarpal osteotomy. Most resection arthroplasties are performed with a 2.7 mm arthroscope for better field of view.

Skin incisions are made with a #15 scalpel just through the skin. A blunt hemostat is used to gently dissect through the soft tissue and through the capsule. The radial artery, superficial branches of the radial nerve, and extensor tendons are all at potential risk. These structures are protected through proper technique of blunt dissection. However, even with appropriate technique, they may be injured. These risks should be discussed with the patients preoperatively.

The 1R (volar) and 1U (dorsal) portals are used for CMC arthroscopy. STT arthroscopy is performed using 1R (volar) and 1U (dorsal) portals placed approximately 1 cm proximal to the 1R (volar) and 1U (dorsal) portals as described for CMC arthroplasty. The portals are localized with hypodermic needles with the aid of fluoroscopy (Fig. 25.3). Needles are placed into the joints and confirmed to be parallel on fluoroscopy. These portals lay on either side of the first dorsal compartment. A second dorsal portal is utilized as necessary. The second dorsal portal (dorsal ulnar portal) is placed using inside-out technique by placing a blunt probe through the 1R portal across the CMC or the STT joint and exiting the dorsum of the hand (Fig. 25.4). A cannula is placed retrograde over the probe and inserted into the joint.

A full-radius mechanical shaver (typically a 3.5 mm) with suction is used to perform synovectomy and clean the joint of debris for better visualization. Radiofrequency ablation (Serfas 3.5 mm, Stryker, Santa Clara, CA) is used to perform thermal capsulorrhaphy and to perform intra-articular joint denervation. High outflow is utilized to prevent overheating during the use of radiofrequency ablation. A 3.0 or a 4.0 mm barrel bur is used to resect 2–3 mm of bone from the distal aspect of the trapezium and proximal aspect of the first metacarpal. The STT resection arthroplasty is performed by removing 2–3 mm of bone from the distal aspect of the scaphoid and from the proximal aspect of the trapezium and trapezoid (Fig. 25.5). A 4.0 mm barrel bur (Stryker, Santa Clara, CA) is used preferentially in joints large enough to accept the larger size bur.

The author's preferred interposition material (when interposition material is used) is the Graftjacket (Wright Medical Technology, Inc., Arlington, TN). This interposition material

Fig. 25.2 Operating room setup

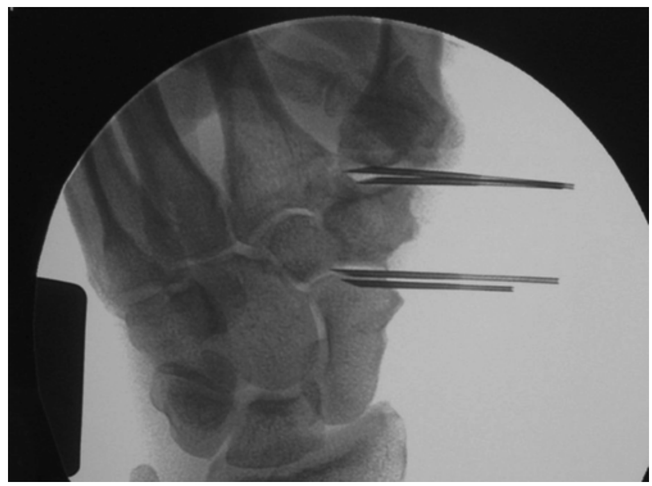


Fig. 25.3 Fluoroscopic view of portal placement. Note needles are placed parallel to the CMC and STT joints [Reprinted with permission from Cobb, T, Sterbank, P, Lemke, J. Arthroscopic resection arthroplasty for treatment of combined carpometacarpal and scaphotrapeziotrapezoid (pantrapezial) arthritis. J Hand Surg Am 2011; 36:413-414. With permission from Elsevier]

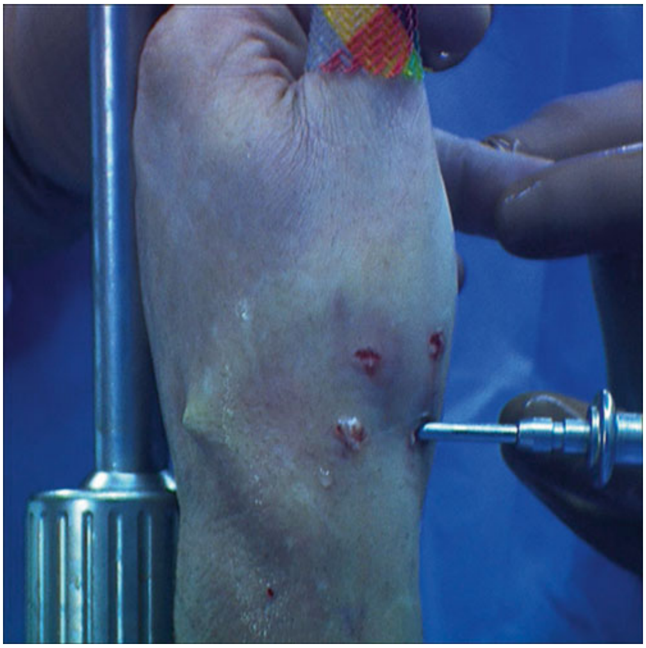


Fig. 25.4 Inside-out technique for establishing the ulnar dorsal portal for CMC or STT

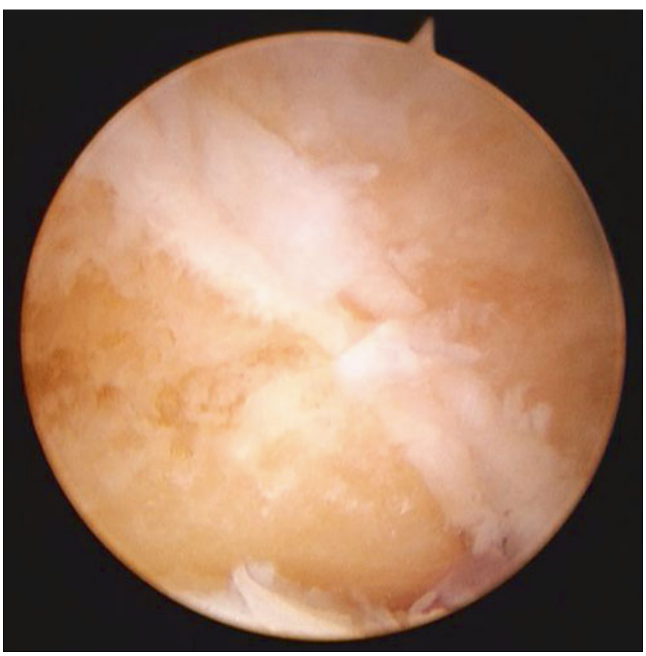


Fig. 25.5 Arthroscopic view of resected STT joint showing resection of proximal surface of the trapezium and trapezoid. The cartilage of the trapezio-trapezoid joint is shown separating the trapezium (*left*) and the trapezoid (*right*) [Reprinted with permission from Cobb, T, Sterbank, P, Lemke, J. Arthroscopic resection arthroplasty for treatment of combined carpometacarpal and scaphotrapeziotrapezoid (pantrapezial) arthritis. J Hand Surg Am 2011; 36:413-414. With permission from Elsevier]

tends to adhere effectively to the joint and seems to create less inflammatory response than other commercially available products. Early in the author's series, no graft fixation

Fig. 25.6 Keith needles are shown passing through cannula in volar portal

Fig. 25.7 Keith needles exiting dorsal surface of the hand

was utilized. However, a number of grafts were extruded from the joint, requiring removal at a later date. Because of these experiences, the author devised two methods of fixation. The most commonly used fixation involves tying sutures over buttons external to the skin on the volar and dorsal aspects of the joint thereby securing the interposition material within the joint. This is performed by passing absorbable sutures on Keith needles through the volar portal, across the resected joint, and out the dorsum of the hand (Figs. 25.6 and 25.7). The suture is used to pull the interposition material into the resected joint (Fig. 25.8). A second suture is placed on the opposite side of the interposition material before pulling the interposition material through the joint. The interposition material is centered in the joint under arthroscopic visualization. The sutures are then tied over felt and buttons on the volar and dorsal sides of the joint. Since the volar sutures are exiting through the portal, they are passed through the skin adjacent to the portal. This minimizes any potential portal healing issues. The same method of fixation can be utilized for both CMC and STT joints. Alternatively, the interposition material can be secured in the joint using standard arthroscopic knot-tying techniques (Fig. 25.9). This is performed by passing a suture through any stable soft tissue attachment including the capsule or ligament. The interposition material is then pushed into the joint on the suture with a standard knot pusher which is then utilized to tie the sutures arthroscopically. Arthroscopic suture cutters are used to remove the excess suture.

The resected joint is infiltrated with approximately 30 cc of 0.25 % Marcaine with epinephrine (if not contraindicated) to provide hemostasis and postoperative pain control. Hemostasis is best obtained if a portion of the Marcaine with epinephrine is placed preoperatively. This is performed by placing some of the Marcaine within the joint but more importantly infiltrating just external to the capsule volarly, dorsally, and medially. Following the resection arthroplasty, the assistant simply holds their fingertips over the portals to prevent the Marcaine from leaking while the surgeon infiltrates the resected joint with the remaining portion of the Marcaine. The total amount should be calculated based on patient's weight and coordinated with the anesthesia provider. There have been a few cases where we needed additional epinephrine for hemostasis purposes after we had maxed out the total amount of anesthetic which could be given. In these cases, we simply mix some epinephrine with saline to infiltrate the region, thereby providing hemostasis. On one occasion, the portal had to be extended sufficiently to allow visualization and cauterization of a bleeding branch of the radial artery.

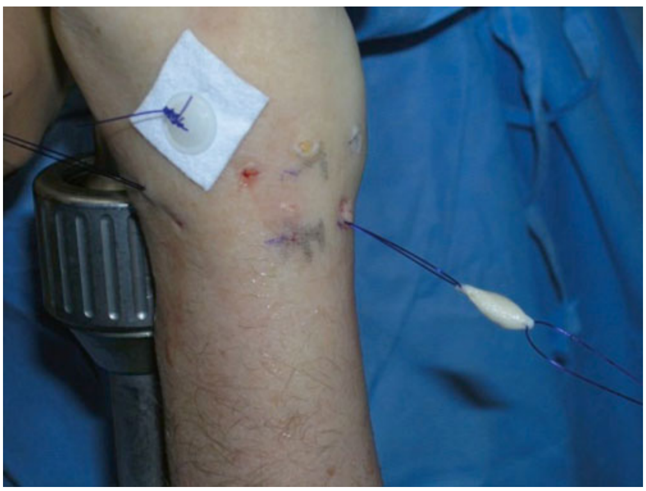


Fig. 25.8 Interposition material is pulled into the joint with sutures previously passed with Keith needles

Postoperative Care

The portals are closed with Steri-Strips. A well-padded thumb spica splint is applied with a compressive Ace. Patients are instructed to keep their extremities elevated, apply ice, and begin gentle range of motion of the digits as soon as possible. Patients are instructed to come to the clinic for a postoperative pain block the first postoperative day if they are uncomfortable. Patients very infrequently utilize a second block. Patients are scheduled to see a hand therapist on postoperative day 5–7 for application of a hand-based arthroplast splint. They are instructed for a home program of gentle range of motion of the CMC joint in all planes. This allows the surgeon to see the patient after the patient has initiated range of motion and allows for more complete assessment without the anxiety often associated with removal of the postoperative dressing. If interposition has been fixed with felt and buttons, the pullout sutures are removed at 2 weeks (Fig. 25.10). It's

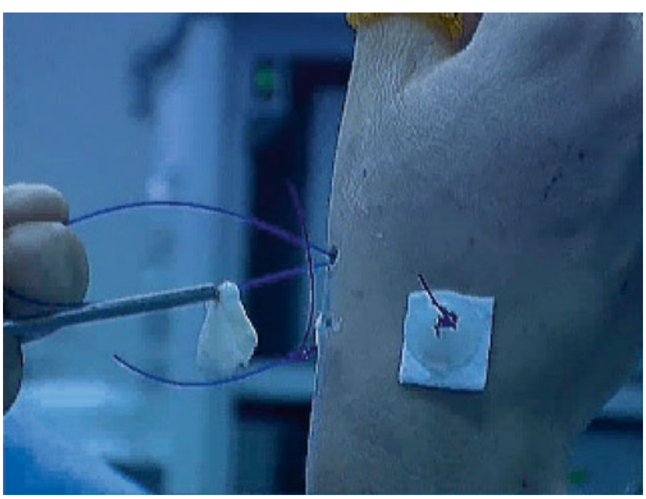


Fig. 25.9 Interposition of CMC has been tied over buttons. The STT interposition graft is being pulled into the resected STT space on PDS sutures

Fig. 25.10 Thumb motion at the time of button removal (2 weeks)

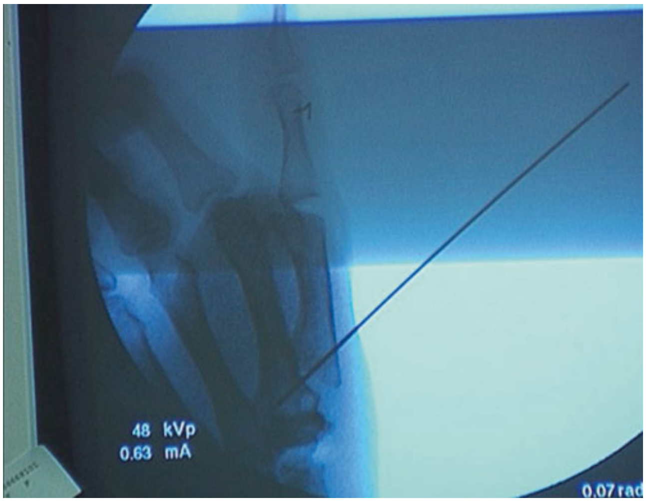


Fig. 25.11 Fluoroscopic view of guide wire placed through first metacarpal

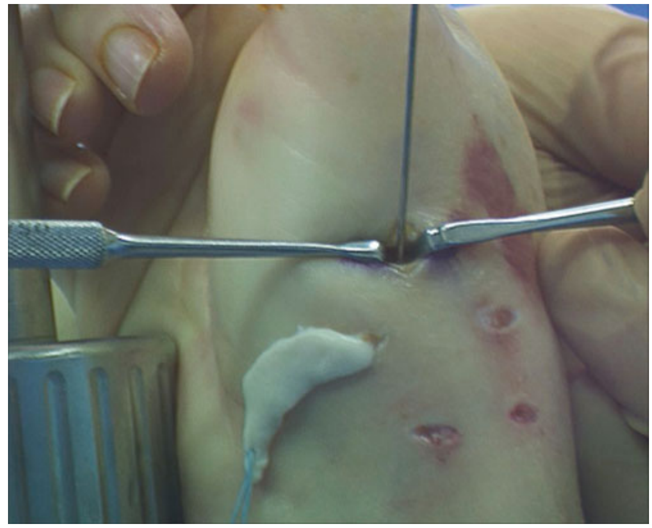


Fig. 25.12 Graph has been arthroscopically secured in the base of the second metacarpal with tenodesis screw. The graft exits the CMC volar portal. Guide wire is shown placed in the first metacarpal. Graft will be retrieved through the resected CMC space and pulled through the first metacarpal tunnel

the author's belief that early range of motion provides for better overall outcome. Postoperative blocks and continued therapy visits can be helpful to facilitate early range of motion in patients who are having difficulty.

Surgical Technique CMC Stabilization

Arthroscopic stabilization procedures may be performed with commercially available devices (Mini TightRope™, Arthrex or CMC CableFix™, Instratek) or with a tendon graft fixed with tenodesis screws in the first and second metacarpals. The stabilization procedures are performed after arthroscopic resection arthroplasty of the CMC joint. The technique of tendon graft fixation involves placement of a guide wire through the CMC volar portal across the resected CMC space and into the base of the second metacarpal. A tunnel is drilled into the second metacarpal with a 4 mm cannulated drill. A tendon graft (usually palmaris longus) is fixed in the base of the second metacarpal with a tenodesis screw (Arthrex, Naples, FL). A guide wire is then placed through the dorsal radial border of the first metacarpal approximately 1 cm distal to the proximal end (Fig. 25.11). It is driven obliquely into the resected CMC space. A 4 mm tunnel is drilled with the cannulated drill over the guide wire (Fig. 25.12). The graft is retrieved from the CMC-resected space through the first metacarpal tunnel with a suture passer. The first metacarpal is reduced, and the tendon graft is tensioned. Care must be taken not to overtighten the fixation which can lead to painful impingement between the first and second metacarpals. A tenodesis screw is then placed into the first metacarpal tunnel securing the palmaris longus tendon (Figs. 25.13 and 25.14). The 1–2 metacarpal space is pinned with a .062 k-wire for 4–6 weeks.

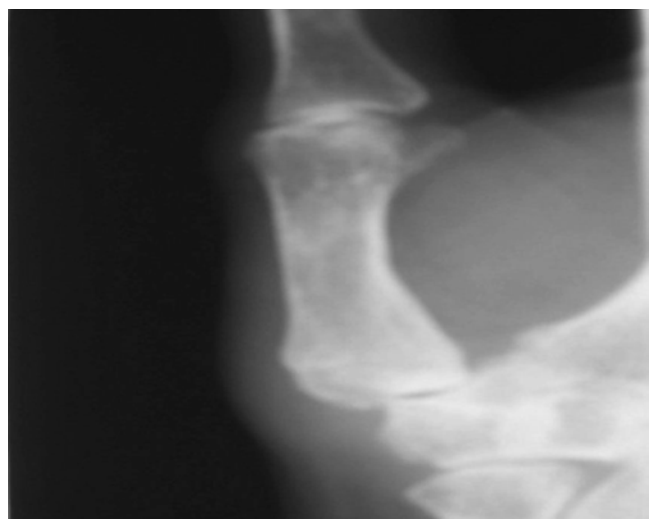


Fig. 25.13 Preoperative film showing subluxation of CMC joint

Results of Arthroscopic Resection Arthroplasty for Pantrapezial Arthritis (Stage 4)

We recently reviewed 35 cases of arthroscopic resection arthroplasty of the CMC and STT joints performed in 34 patients for pantrapezial arthrosis with minimum 1-year follow-up [6]. The average pain score improved from 7 preoperatively to 1 postoperatively ($p < 0.001$) at 1 year (Fig. 25.15). DASH scores improved from 46 preoperatively to 19 at 1 year ($p < 0.001$) (Fig. 25.16). Grip strength improved 4.3 kg ($p = 0.02$) (Fig. 25.17), and key pinch improved 1.3 kg ($p < 0.001$) (Fig. 25.18). All but one patient could reach the proximal digital crease of the small finger by 1 year postoperatively. Early studies comparing open ligament reconstruction tendon interposition arthroplasty to arthroscopic resection arthroplasty of the CMC demonstrated a reduction in return-to-work time of more than 50 % (Fig. 25.19). Thirty-two of the 34 patients stated that they would have the surgery again. Satisfaction was rated at the highest level of 5 for 25 patients. The average satisfaction at follow-up was 4 (range, 2–5).

Fig. 25.14 Post-op film showing reduction after arthroscopic ligament stabilization

Failures and Complications

Carpal tunnel syndrome frequently coexists with CMC degenerative joint disease. Swelling associated with arthroscopic resection arthroplasty of the CMC can exacerbate a subclinical carpal tunnel syndrome necessitating urgent return to the operating room for acute carpal tunnel release. Concurrent carpal tunnel release should be discussed with patients who have a positive Tinel's over the median nerve at the wrist even if classic symptoms are absent.

Four patients in our series required additional surgery. Reasons for reoperation included deep infection in one, flexor carpi radialis tendinitis in one, and persistent pain in two. Five patients reported paresthesias in the distribution of the superficial branch of the radial nerve, all of which resolved by 3 months following surgery. (The author has had patients with sustained and presumably permanent superficial branch paresthesias in cases which were not part of the published series.) Three patients developed flexor carpi radialis tendinitis, two of which responded to cortisone injection and one required surgical release.

When the author started performing arthroscopic resection arthroplasty of the CMC joint for degenerative joint disease in 2004, the longevity of this procedure was in question. However, the long-term follow-up has shown durable lasting results. The author has performed over 200 cases of arthroscopic resection arthroplasty of CMC joint. The author currently has an ongoing prospective study and joint registry with follow-up in excess of 10 years. Neither the need for revision nor the outcome appears to change with time.

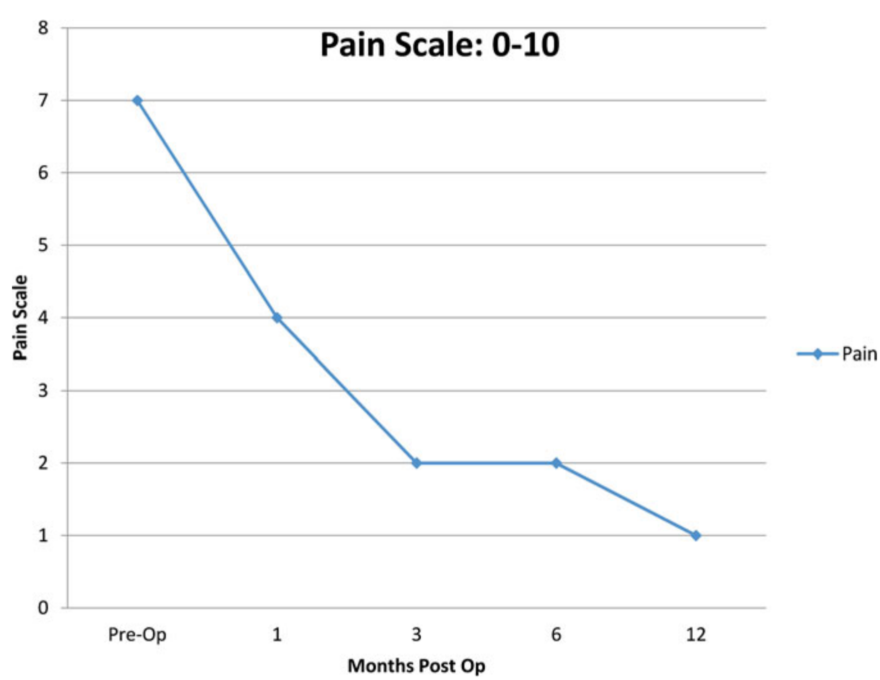


Fig. 25.15 Graph of pain scale (0–10) for preoperative and each postoperative time interval

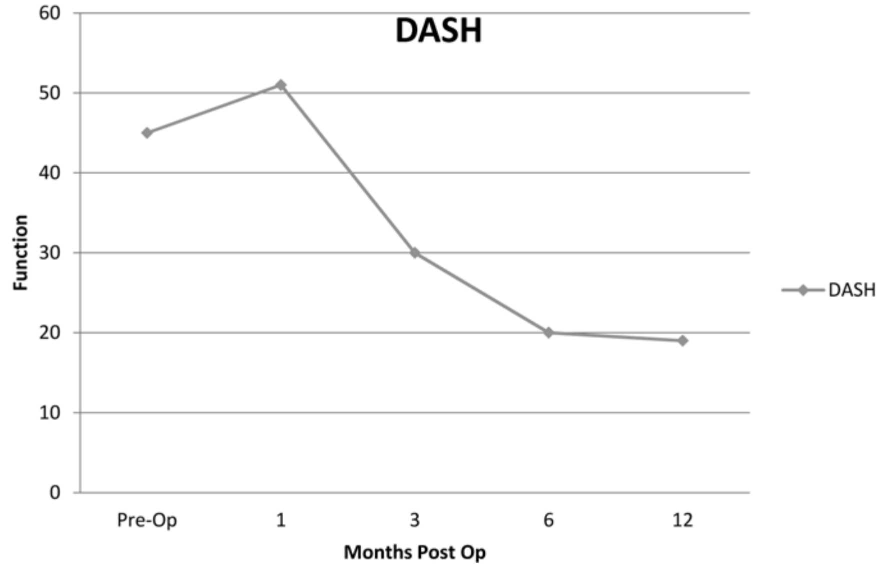


Fig. 25.16 Graph of DASH scores for preoperative and each postoperative time interval

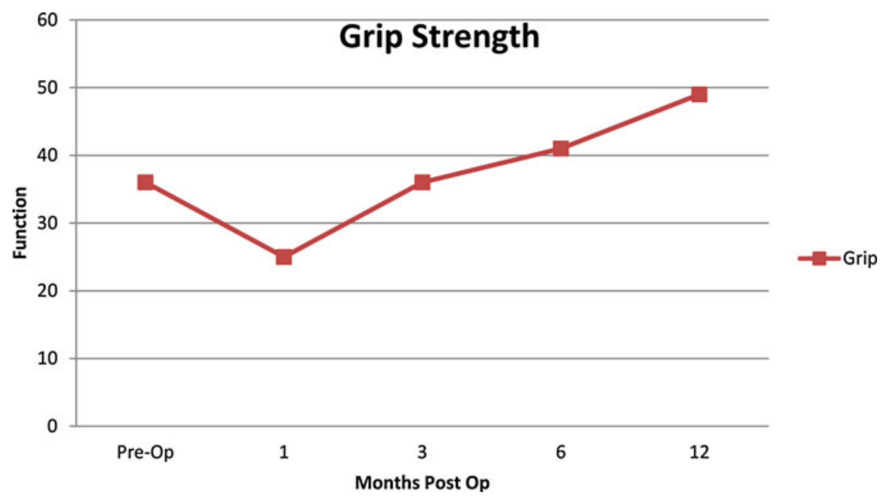


Fig. 25.17 Graph of grip strength for preoperative and each postoperative time interval

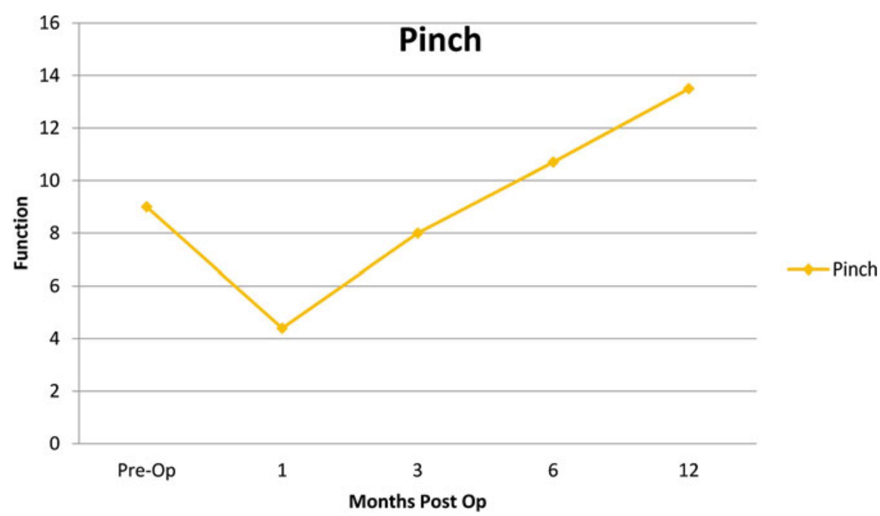


Fig. 25.18 Graph of key pinch for preoperative and each postoperative time interval

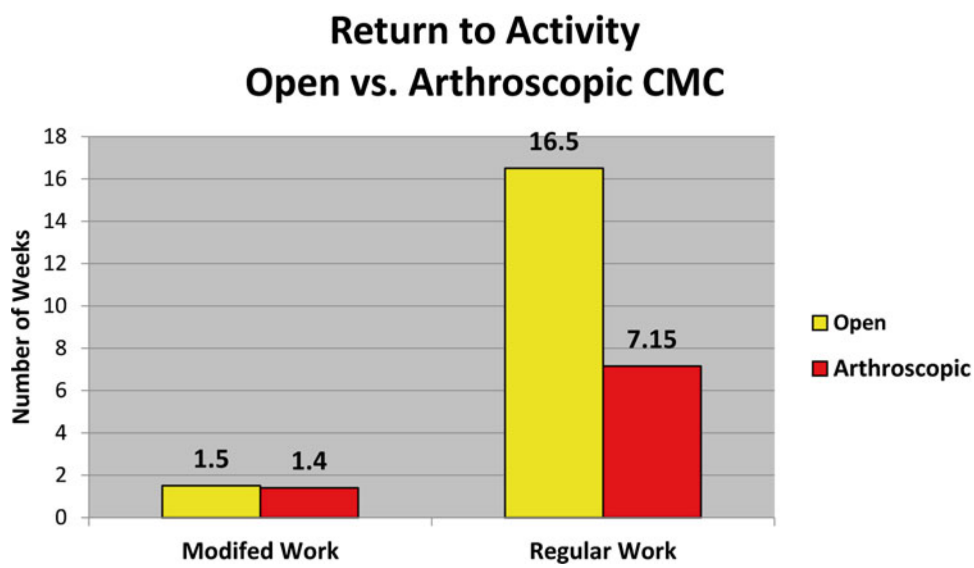


Fig. 25.19 Comparison of return to work for open ligament reconstruction tendon interposition arthroplasty versus arthroscopic resection arthroplasty of CMC

The chance of revision surgery may always be slightly higher in minimally invasive procedures because those patients who do not do well have a good option; i.e., open revision surgery. However, once open surgery such as ligament reconstruction tendon interposition arthroplasty has been performed, surgeons are much less likely to offer revision surgery because the options are few. Therefore, in high-risk patients (such as patients with secondary gain), it may be wise to do the last procedure first.

Need for Interposition

The indication for interposition is not well established. The author has had very good results with use of Graftjacket. However, very good results with resection arthroplasty without interposition [13, 14] have also been observed. There have been two cases of spontaneous arthrodesis (not part of the above published study) in patients that underwent resection arthroplasty without interposition. While arthrodesis is an accepted treatment for CMC degenerative joint disease, neither of these two patients was happy with their results. This complication has not occurred to my knowledge in patients receiving interposition. Placing interposition does increase surgical time and expense for the procedure. Furthermore, there is a potential higher risk of infection, disease transmission, and inflammation. Data are currently being collected to determine if there are any true differences in outcome between arthroscopic resection arthroplasty with and without interposition.

Comparison to the Literature

Cobb et al. [6] results seem to be similar to those reported by Ashwood et al. [15], who reported good to excellent results in nine of ten patients following arthroscopic debridement (without resection arthroplasty) of the STT joint. Rin and Mathoulin [16] reported good results in 13 cases of arthroscopic resection arthroplasty of the distal polar scaphoid for STT arthritis. Twenty-six percent improvement in grip strength and 40 % improvement in pinch were reported for Garcia-Elias et al. [17], following the open resection of the distal polar scaphoid in 21 patients. Improvement in Cobb et al.'s [6] grip and pinch was 31 % and 44 %, respectively.

Comparing the author's results to ligament reconstruction interposition arthroplasty and open hematoma distraction arthroplasty (HDA), the increased grip strength in the present study (31 %) was better than that reported by Tomaino et al. [18], (21 %) and Yang and Weiland [19] (9 %) for ligament reconstruction and interposition arthroplasty but less than that reported for HDA (47 %) by Kuhns et al. [20]. Improvement in key pinch for the present study (44 %) was better than that reported by all three studies, 8 %, 17 %, and 33 %, respectively.

References

1. Menon J. Arthroscopic management of trapeziometacarpal joint arthritis of the thumb. Arthroscopy. 1996;12(5):581–7.
2. Berger RA. A technique for arthroscopic evaluation of the first carpometacarpal joint. J Hand Surg Am. 1997;22(6):1077–80.
3. Osterman AL, Culp R, Bednar J. Arthroscopy of the thumb carpometacarpal joint. Arthroscopy. 1997;13:3.
4. Badia A. Trapeziometacarpal arthroscopy: a classification and treatment algorithm. Hand Clin. 2006;22(2):153–63.
5. Badia A. Arthroscopy of the trapeziometacarpal and metacarpophalangeal joints. J Hand Surg Am. 2006;32(5):707–24.
6. Cobb T, Sterbank P, Lemke J. Arthroscopic resection arthroplasty for the treatment of combined carpometacarpal and scaphotrapeziotrapezoid (pantrapezial) arthritis. J Hand Surg Am. 2011;36: 413–9.
7. Culp RW, Rekant MS. The role of arthroscopy in evaluating and treating trapeziometacarpal disease. Hand Clin. 2001;17(2):315–9.
8. Tomaino MM. Treatment of stage 1 trapeziometacarpal disease. Hand Clin. 2001;17:197–205.

9. Wilson J. Basal osteotomy of the first metacarpal in the treatment of arthritis of the carpometacarpal joint of the thumb. Br J Surg. 1973; 60:854–8.
10. Eaton RG, Glickel SZ. Trapeziometacarpal osteoarthritis staging as a rationale for treatment. Hand Clin. 1987;3:455–71.
11. Farhangkhoee H, Lalonde J, Lalonde DH. Wide-awake trapeziectomy: video detailing local anesthetic injection and surgery. Hand. 2011;6(4):466–7.
12. Davidson PG, Cobb T, Lalonde DH. Patient perspective on carpal tunnel surgery related to the type of anesthesia: a prospective cohort study. Hand. 2013;8(1):47–53.
13. Edwards SG, Ramsey PN. Prospective outcomes of stage 3 thumb CMC arthritis. J Hand Surg 2010.
14. Hofmeister EP, Leak RS, Culp RW, Osterman AL. Arthroscopic hemitrapeziectomy for the first metacarpal arthritis: results at seven-year follow-up. Hand. 2009;4(1):24–8.
15. Ashwood N, Bain G, Fogg Q. Results of arthroscopic debridement for isolated scaphotrapeziotrapezoid arthritis. J Hand Surg Am. 2003;28:729–32.
16. Da Rin F, Mathoulin C. Arthroscopic treatment of osteoarthritis of scaphotrapeziotrapezoid joint. Chir Main. 2006;25:S254–8.
17. Garcia-Elias M, Lluch A, Farreres A, Castillo F, Saffar P. Resection of the distal scaphoid for scaphotrapeziotrapezoid osteoarthritis. J Hand Surg Br. 1999;24:448–52.
18. Tomaino MM, Pellegrini Jr VD, Burton RI. Arthroplasty of the basal joint of the thumb. Long-term follow-up after ligament reconstruction with tendon interposition. J Bone Joint Surg Am. 1995;77:346–55.
19. Yang SS, Weiland AJ. First metacarpal subsidence during pinch after ligament reconstruction and tendon interposition basal joint arthroplasty of the thumb. J Hand Surg Am. 1998;23: 879–83.
20. Kuhns C, Emerson E, Meals R. Hematoma and distraction arthroplasty for thumb basal joint osteoarthritis: a prospective, single-surgeon study including outcomes measures. J Hand Surg Am. 2003;28:381–9.

26 Suture-Button Suspensionplasty for the Treatment of Thumb Carpometacarpal Joint Arthritis

John R. Talley and Jeffrey Yao

Introduction

Osteoarthritis causes significant disability wherever it occurs in the body. However, when it occurs in the thumb it may quickly become a career and lifestyle-altering problem. The thumb carpometacarpal (CMC) joint is a uniquely shaped biconcave joint containing two saddle shaped bones that articulate perpendicularly to each other. This allows the thumb to move into a number of different positions, which provides the thumb significant range of motion and function. However, with this considerable utility the thumb is susceptible to overuse. For reasons that are not entirely clear at this time, but thought to be due to a joint that is inherently lacking in stability, the thumb CMC joint is prone to osteoarthritis [1, 2]. A combination of overuse and a large amount of force distributed over this joint is currently the proposed etiology. As Chou et al. has shown us, 1 kg pinch at the thumb tip causes a 13 kg load at the base of the thumb [3]. It is the second most common site of osteoarthritis of upper extremity with the finger DIP joint being the most common [4].

Thumb CMC osteoarthritis is treated initially with nonsurgical measures such as splinting, medications, activity modifications, hand therapy, and intra-articular injections. However, when conservative methods are exhausted, surgical options are proposed to the patient. The surgical options are extensive and the one selected by the surgeon is often based upon preference, comfort level, and previous training. These methods include volar ligament reconstruction [5], first metacarpal osteotomy [6–9], CMC joint arthrodesis [10, 11], total joint arthroplasty [12], and trapeziectomy [13]. Partial or complete trapeziectomy is performed with or without ligament reconstruction, tendon interposition alone, or ligament reconstruction in addition to tendon interposition [14–19]. In general, an open technique is used but some of these techniques employ arthroscopy [20–22]. Studies comparing these different techniques have not demonstrated any significant long-term differences in outcomes [1, 14, 15, 23–25]. However, trapeziectomy alone does appear to have the shortest intraoperative time and the lowest rate of complications [1, 15, 23].

Consequently, given the lack of difference in long-term outcomes, there has been a focus on improving short-term outcomes and facilitating shorter postoperative recovery times.

In general, at the time of the trapeziectomy, either partial or complete, the first metacarpal is stabilized in order to maintain the space that was previously occupied by the trapezium. This is done in order to prevent collapse of the metacarpal into that space during the time of hematoma and subsequent scar formation. The method usually consists of placing a Kirschner wire from the first metacarpal into the second metacarpal for 4 weeks postoperatively [13, 26, 27]. During this period of time, the thumb is completely immobilized.

Given this considerable period of immobility, a new technique has been devised to decrease the amount of postoperative immobilization while still maintaining support. This technique involves suspending the thumb metacarpal from the second metacarpal to prevent subsidence into the newly created trapeziectomy space by utilizing a suture button (SB) [28]. This utilizes a device called the Mini Tightrope (Arthrex, Naples, FL). This device has been used in a number of other applications in the field of orthopedic surgery including treatment of hallux varus deformity, acromioclavicular joint dislocations, transtibial amputations, and ankle syndesmosis stabilization [29–32]. The device consists of braided polyester sutures looped between two steel buttons with one button affixed to the first metacarpal and the other

J.R. Talley, M.D.
Division of Plastic Surgery, Department of Surgery, Stanford University Medical Center, Palo Alto, CA, USA

J. Yao, M.D. (✉)
Department of Orthopaedic Surgery, Stanford University Medical Center, 450 Broadway Street, Suite C-442, Redwood City, CA 94063, USA
e-mail: jyao@stanford.edu

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*, DOI 10.1007/978-1-4614-1596-1_26, © Springer Science+Business Media New York 2015

to the second metacarpal. This suspends the thumb from the second metacarpal eliminating the need for a K-wire to prevent subsidence. This new technique has been compared to K-wire fixation and has been shown to create similar stability [33]. The key outcome difference in this technique is the ability to begin early mobilization at 5–10 days postoperatively instead of the standard 4 weeks.

This early return of thumb movement will potentially lead to improved rates of recovery and function. The ultimate goal is to return patients back to their jobs and daily functions as quickly as possible.

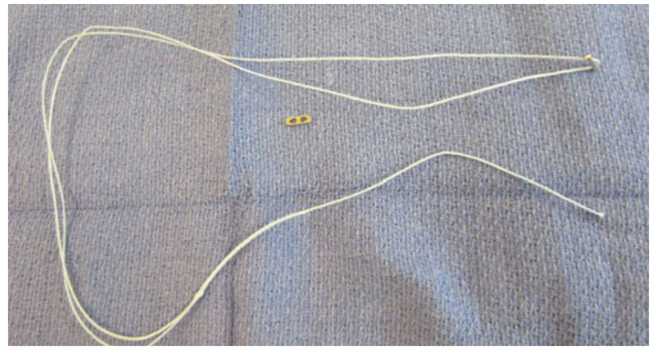


Fig. 26.1 Photo demonstrating the second generation SB device used for thumb CMC suspensionplasty

Indications for Surgery

When operative management is indicated for the management of CMC arthritis, surgeons generally make these decisions based on the radiographic classifications described by Eaton and Glickel [34]. The suture-button suspensionplasty technique in conjunction with arthroscopically assisted hemitrapeziectomy is indicated for patients with Eaton stage II or III (Fig. 26.1). Stage IV requires open complete trapeziectomy. Our operative preferences and surgical approach based on Eaton stage are delineated below.

Eaton Stage I

This stage is characterized by mild widening of the trapeziometacarpal (TM) joint. Some patients are symptomatic at stage I and don't respond to nonoperative management. They are possibly indicated for arthroscopic debridement, synovectomy, and/or electrothermal capsulorrhaphy [35, 36].

Eaton Stage II and III

These stages are characterized by loss of joint space, osteophytes, and bony sclerosis. Many surgical techniques are used to treat these stages. Our previous preference was arthroscopic hemitrapeziectomy followed by K-wire pinning across the CMC joint. However, as discussed previously, the immobilization that this causes may lead to patient dissatisfaction in the early postoperative period. The technique described in this chapter is designed to allow earlier range of motion while still preventing subsidence of the first metacarpal into the CMC space.

Eaton Stage IV

This stage is defined by pantrapezial osteoarthritic changes including the scaphotrapeziotrapezoid joint. When these findings are present, complete trapeziectomy is required through a standard open technique. Although the CMC space may be maintained with various techniques our preferred technique has been to utilize suture-button suspensionplasty after open full trapeziectomy for stage IV disease.

Surgical Technique

Arthroscopic Setup and Establishment of Portals

Thumb arthroscopy is performed under either regional or general anesthesia. Regional anesthesia has the added benefit of providing postoperative analgesia. A standard wrist arthroscopy tower and 2.3 mm arthroscope are used. The operative field is set up by first placing the thumb in the finger trap, which is suspended from the arthroscopy tower (Linvatec, Largo, FL) at 12–15 lbs of traction. The finger trap and hand are then wrapped with sterile Coban (3M, St. Paul, MN) to stabilize it in the operative field (Fig. 26.2). A tourniquet is placed proximally near the axilla and inflated to 250 mmHg.

Next, the thumb CMC joint is located by palpating at the proximal end of the thumb metacarpal and feeling for the soft spot proximal to the base of the metacarpal. The 1U portal is located directly ulnar to extensor pollicis brevis tendon. Normal saline is injected into the thumb CMC space and the visualized expansion of the joint space confirms the correct location and angle of entry. A #11 blade scalpel is used to incise the skin over the 1U portal. Using a mosquito clamp, the soft tissue is bluntly dissected to avoid injury to the abductor pollicis longus, extensor pollicis brevis, extensor pollicis longus, the dorsal radial sensory nerve, and the radial artery, which are all in the vicinity. Dissection is continued down to the CMC joint capsule. The capsule is entered and the previously injected fluid elutes from the portal, again confirming successful placement. The 2.3 mm arthroscope is then inserted into the joint space and position confirmed on

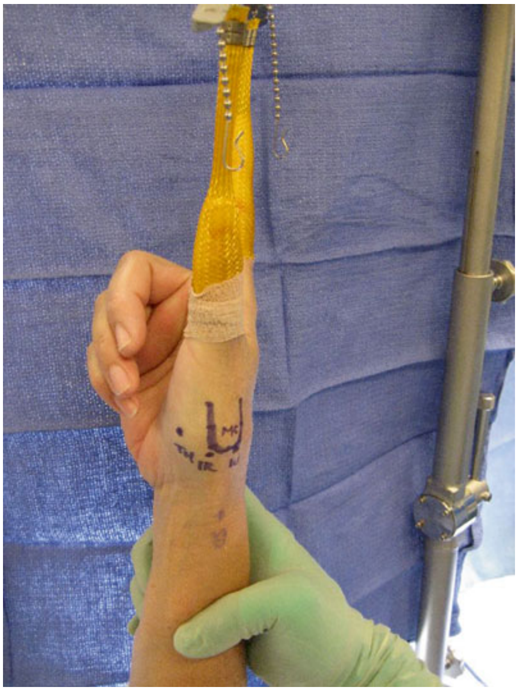


Fig. 26.2 Setup for arthroscopic hemitrapeziectomy

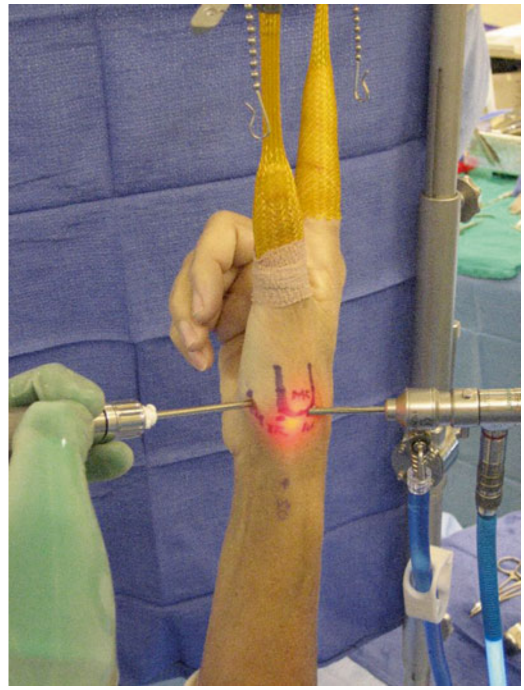


Fig. 26.3 The arthroscope is in the 1-U portal. The shaver is in the thenar portal

fluoroscopy. Saline is constantly infused through the arthroscopy pump, which is set to 30 mmHg to create proper joint distention, good visualization, and an adequate working space.

The next portal created is considered the "working portal." This may be placed into one of two locations: the 1R or thenar portals. The 1R portal is found radial to the APL at the same level as the 1U portal. The thenar portal is approximately 90° and 1 cm volar to the 1R portal. We prefer the thenar portal as it located further from structures such as branches of the dorsal radial sensory nerve. Also, the thenar and 1U portals are perpendicular to each other, which allows the instruments to approach at angles that are favorable for visualization during arthroscopy and partial trapeziectomy (Fig. 26.3).

The thenar portal is created by placing an 18 gauge needle through the thenar musculature into the CMC joint under direct arthroscopic visualization. Once the correct position is established, the portal is finalized in the same manner as the 1U portal.

Arthroscopic Hemitrapeziectomy

The working portal is used to pass a full-radius 3.5 mm shaver into the joint. This is used to debride the joint space of degenerative articular cartilage, synovitis, articular debris, and loose bodies. After completion of debridement, the shaver is retracted and a 2.9-mm burr (Linvatec, Largo, FL) with a 3.5-mm sheath is positioned to perform the hemitrapeziectomy. Placing a smaller burr within a larger sheath decreases the incidence of clogging by creating more space around the burr. Approximately 3–5 mm of the distal aspect of the trapezium should be removed in order to treat Eaton stage II or III. In order to improve visualization and excision, the shaver and the arthroscope should be alternated between the two portals. Fluoroscopy can also be used to confirm that the hemi-trapezium has been resected appropriately.

At this stage of the procedure the baseline subsidence of the thumb metacarpal is determined using a ballottement test. This is done under spot or live fluoroscopy and the thumb is alternatively pulled and compressed to visualize the amount of subsidence present. This subsidence is noted and later compared to the level of subsidence found following suture-button suspensionplasty (Fig. 26.4).

Open Trapeziectomy

There are two approaches to an open trapeziectomy: dorsoradial or volar (Wagner). We prefer the dorsoradial approach. This is done via a 2.5 cm incision made longitudinally over the tendons of the first dorsal extensor compartment. APL and EPB tendons are retracted and a longitudinal capsulotomy is made over the CMC joint. The capsule is then elevated off the joint as full thickness flaps both radially

Fig. 26.4 Ballottement test shows complete subsidence of the thumb metacarpal with an axial load following hemitrapeziectomy

and ulnarly. The trapezium is then dissected free from its attachments. It is removed with the help of osteotomes and rongeurs in a piecemeal fashion. The flexor carpi radialis tendon is preserved. Once the trapezium is removed the space may be palpated for any additional osteophytes, which are also removed. A ballottement test, as conducted in the arthroscopic technique, to establish a baseline level of subsidence is performed prior to suture-button suspensionplasty.

Suture-Button Technique of Suspensionplasty

An incision is made at the 1R portal site, which is volar to the APL tendon. The tissues are bluntly dissected down to the dorsal radial base of the first metacarpal. The positioning of the suture button in this location accomplishes two functions: it minimizes the chance of hardware prominence as the SB may be placed under a part of the abductor pollicis longus tendon and it promotes pronation of the thumb. If this stage of the technique is done via an open approach, the suture-button device is placed on the dorsoradial aspect of the first metacarpal. At this point, the next step is to drill a guidewire from the first metacarpal base obliquely to the proximal diaphysis of the second metacarpal. Originally, this was done with a 1.1 mm suture-lasso guidewire (Arthrex, Naples, FL) and then a 2.7 mm drill was placed over the guidewire to make a path for the suture button.

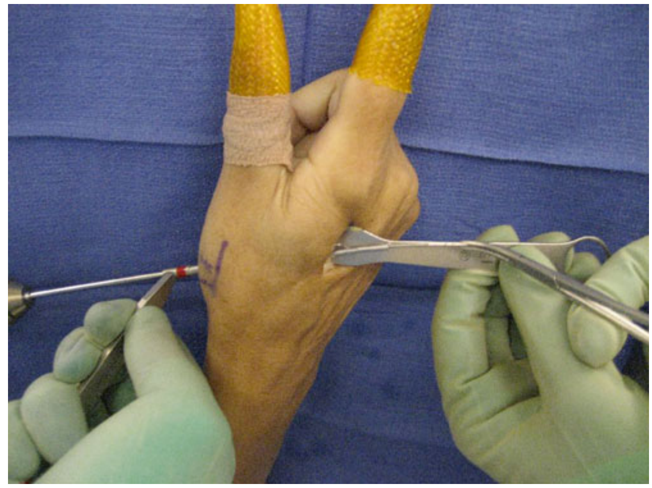


Fig. 26.5 Placement of the 1.1 mm guidewire from the thumb metacarpal to the diaphysis of the second metacarpal

There was concern for fracture of the second metacarpal with this large drill and therefore a new guidewire was engineered. The newer guidewire has a Nitinol lasso at the proximal tip so it acts as the suture passer. A second incision is made ulnar to the metacarpal and the tissues are bluntly dissected down to the bone. There is always a branch of the dorsal radial sensory nerve in this wound and it should be identified and protected. The second dorsal interosseous muscle is dissected from the dorsal ulnar side of the second metacarpal to allow exposure of the ulnar aspect of the bone. In general the guidewire is directed to the metadiaphyseal junction; however, precise orientation of the guidewire has been determined to be less important [37]. The proximal and distal trajectories have been studied and a similar thumb range of motion was found. The main difference is that the suture-button device with a proximal trajectory is located further away from the nerve to the first dorsal interosseous muscle. It is clear there is not an ideal trajectory. This cadaveric study found an equivalent and full range of motion regardless of a distal trajectory through the diaphysis or a proximal trajectory through the metaphyseal region of the second metacarpal. Based on these findings, it appears that the trajectory and placement of the suture button can be variable and does not negatively impact the joint range of motion.

The guidewire is placed bi-cortically through the first metacarpal into the second metacarpal. It may be helpful to place a C-clamp targeting guide at the entry and exit sites to help direct the angle of the guidewire. The guidewire is then pulled through the bones out of the exit site (Figs. 26.5 and 26.6). The suture-button device is consequently pulled through the drilled holes as it follows the guidewire. It is then pulled flush against the thumb metacarpal where it is anchored. The second button is fitted over the sutures

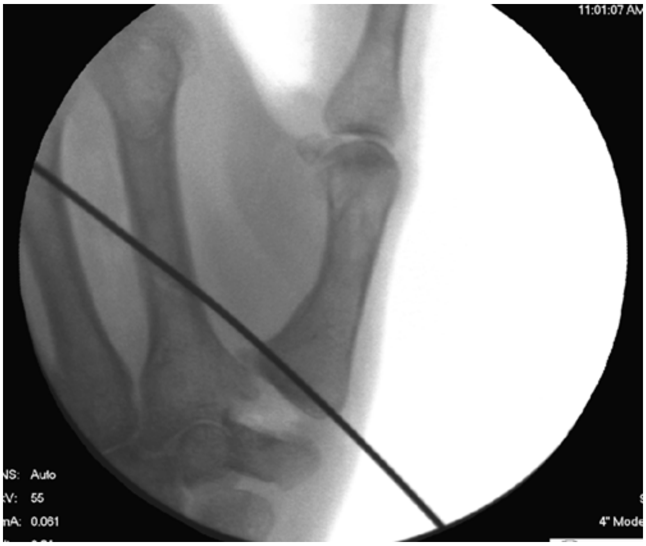


Fig. 26.6 Fluoroscopic view of the appropriate position of the guidewire

Fig. 26.7 Ballottement test shows subsidence resistance of the thumb metacarpal with an axial load following SB suspensionplasty

and placed against the dorso-ulnar cortex of the second metacarpal.

The next step in the procedure is to set the tension correctly. The suture-button device should be neither too tight such that the first metacarpal impinges on the base of the second metacarpal, nor too loose that subsidence occurs. Once a provisional knot is placed temporarily, a ballottement test is conducted under fluoroscopy to confirm proper positioning (Fig. 26.7). The thumb is then taken through the full range of motion to confirm adequate motion. Adjustments are made to the suture knot as needed and once the surgeon is satisfied with the tension based on radiographic and tactile evidence the suture is tied down. Suture ends are cut and the incisions are closed. A short-arm thumb spica splint is applied.

Postoperative Care

Surgery is performed in the outpatient setting and patient returns to clinic in 1–2 weeks for suture removal and radiographs. The films are examined for evidence of a preserved CMC joint space and then the patient is immediately enrolled in hand therapy for range of motion exercises. The patient is given a removable thermoplastic short-arm thumb spica splint to be used for comfort only.

Discussion

The above-described technique demonstrates an arthroscopic technique combined with suture-button suspensionplasty, which is minimally invasive, provides effective stabilization, and allows for early range of motion. It avoids the need for K-wire stabilization of the first metacarpal for the standard 4–5 weeks. The arthroscopic hemitrapeziectomy with suture-button placement is indicated for Eaton stage II and III whereas open trapeziectomy and suture-button suspensionplasty are our preferred techniques for Eaton stage IV. Preliminary results have been excellent.

We have performed the suture-button suspensionplasty procedure on more than 40 patients. Several of these patients have a greater than 3-year follow-up, (Fig. 26.8) and the results of which are being prepared for publication. We have had two complications occur after this procedure and both were in the same patient. The first complication was the development of chronic regional pain syndrome 6 weeks postoperatively with related disuse osteopenia. The second complication was a fracture of the second metacarpal in that same patient. Another second metacarpal fracture complication has also been reported in the literature [38]. In addition, there have been complications noted in other areas of orthopedic surgery with the suture-button device [39–42]. The complications that occurred after trapeziectomy and suture-button suspensionplasty all happened with the first generation device, and there have been no reports of complications in the second generation SB device.

CMC arthritis is treated operatively with a number of different techniques and based on the current literature the long-term results are equivalent. The possible advantage of suture-button suspensionplasty following hemi- or complete trapeziectomy would be found in the short term postoperatively. We feel that the use of the SB suspensionplasty

Fig. 26.8 Radiograph of a thumb 2 years following SB suspensionplasty. Note some subsidence has occurred, but the hemitrapeziectomy space is maintained

technique permits the patient to start thumb range of motion exercises earlier than with K-wire fixation and prevents the complications that can occur with K-wires such as pin site infections, pin migration, and skin irritation. If patients undergoing this procedure ultimately have a decreased recovery time, we expect these patients to have improved satisfaction and quality of life in the short term. Long-term studies will need to be conducted to evaluate outcomes such as strength and range of motion but current results are very promising.

References

1. Wajon A, Carr E, Edmunds I, Ada L. Surgery for thumb (trapeziometacarpal joint) osteoarthritis. Cochrane Database Syst Rev. 2009;(4):CD004631.
2. Yao J, Park MJ. Early treatment of degenerative arthritis of the thumb carpometacarpal joint. Hand Clin. 2008;24(3):251–61. v–vi.
3. Cooney 3rd WP, Chao EY. Biomechanical analysis of static forces in the thumb during hand function. J Bone Joint Surg Am. 1977;59(1):27–36.
4. Kaufmann RA, Logters TT, Verbruggen G, Windolf J, Goitz RJ. Osteoarthritis of the distal interphalangeal joint. J Hand Surg Am. 2010;35(12):2117–25.
5. Glickel SZ, Gupta S. Ligament reconstruction. Hand Clinics. 2006;22(2):143–51.
6. Hobby JL, Lyall HA, Meggitt BF. First metacarpal osteotomy for trapeziometacarpal osteoarthritis. J Bone Joint Surg Br. 1998;80(3):508–12.
7. Wilson JN. Basal osteotomy of the first metacarpal in the treatment of arthritis of the carpometacarpal joint of the thumb. Br J Surg. 1973;60(11):854–8.
8. Parker WL, Linscheid RL, Amadio PC. Long-term outcomes of first metacarpal extension osteotomy in the treatment of carpal-metacarpal osteoarthritis. J Hand Surg Am. 2008;33(10):1737–43.
9. Tomaino MM. Basal metacarpal osteotomy for osteoarthritis of the thumb. J Hand Surg Am. 2011;36(6):1076–9.
10. Hartigan BJ, Stern PJ, Kiefhaber TR. Thumb carpometacarpal osteoarthritis: arthrodesis compared with ligament reconstruction and tendon interposition. J Bone Joint Surg Am. 2001;83-A(10):1470–8.
11. Schroder J, Kerkhoffs GM, Voerman HJ, Marti RK. Surgical treatment of basal joint disease of the thumb: comparison between resection-interposition arthroplasty and trapezio-metacarpal arthrodesis. Arch Orthop Trauma Surg. 2002;122(1):35–8.
12. Badia A. Total joint arthroplasty for the arthritic thumb carpometacarpal joint. Am J Orthop. 2008;37(8 Suppl 1):4–7.
13. Gervis WH. Excision of the trapezium for osteoarthritis of the trapezio-metacarpal joint. J Bone Joint Surg Br. 1949;31B(4):537–9. illust.
14. Davis TR, Brady O, Barton NJ, Lunn PG, Burke FD. Trapeziectomy alone, with tendon interposition or with ligament reconstruction? J Hand Surg Br. 1997;22(6):689–94.
15. Park MJ, Lichtman G, Christian JB, Weintraub J, Chang J, Hentz VR, et al. Surgical treatment of thumb carpometacarpal joint arthritis: a single institution experience from 1995-2005. Hand. 2008;3(4):304–10.
16. Burton RI, Pellegrini Jr VD. Surgical management of basal joint arthritis of the thumb. Part II. Ligament reconstruction with tendon interposition arthroplasty. J Hand Surg Am. 1986;11(3):324–32.
17. Gerwin M, Griffith A, Weiland AJ, Hotchkiss RN, McCormack RR. Ligament reconstruction basal joint arthroplasty without tendon interposition. Clin Orthop Relat Res. 1997;(342):42–5.
18. Muermans S, Coenen L. Interpositional arthroplasty with Gore-Tex, Marlex or tendon for osteoarthritis of the trapeziometacarpal joint. A retrospective comparative study. J Hand Surg Br. 1998;23(1):64–8.
19. Davis TR, Brady O, Dias JJ. Excision of the trapezium for osteoarthritis of the trapeziometacarpal joint: a study of the benefit of ligament reconstruction or tendon interposition. J Hand Surg Am. 2004;29(6):1069–77.
20. Adams JE, Merten SM, Steinmann SP. Arthroscopic interposition arthroplasty of the first carpometacarpal joint. J Hand Surg Eur Vol. 2007;32(3):268–74.
21. Earp BE, Leung AC, Blazar PE, Simmons BP. Arthroscopic hemitrapeziectomy with tendon interposition for arthritis at the first carpometacarpal joint. Tech Hand Up Extrem Surg. 2008;12(1):38–42.
22. Sammer DM, Amadio PC. Description and outcomes of a new technique for thumb Basal joint arthroplasty. J Hand Surg Am. 2010;35(7):1198–205.
23. Wajon A, Ada L, Edmunds I. Surgery for thumb (trapeziometacarpal joint) osteoarthritis. Cochrane Database Syst Rev. 2005;(4):CD004631.
24. Martou G, Veltri K, Thoma A. Surgical treatment of osteoarthritis of the carpometacarpal joint of the thumb: a systematic review. Plast Reconstr Surg. 2004;114(2):421–32.
25. Vermeulen GM, Slijper H, Feitz R, Hovius SE, Moojen TM, Selles RW. Surgical management of primary thumb carpometacarpal osteoarthritis: a systematic review. J Hand Surg Am. 2011;36(1):157–69.
26. Kuhns CA, Emerson ET, Meals RA. Hematoma and distraction arthroplasty for thumb basal joint osteoarthritis: a prospective, single-surgeon study including outcomes measures. J Hand Surg Am. 2003;28(3):381–9.

27. Kuhns CA, Meals RA. Hematoma and distraction arthroplasty for basal thumb osteoarthritis. Tech Hand Up Extrem Surg. 2004; 8(1):2–6.
28. Cox CA, Zlotolow DA, Yao J. Suture button suspensionplasty after arthroscopic hemitrapeziectomy for treatment of thumb carpometacarpal arthritis. Arthroscopy. 2010;26(10):1395–403.
29. Gerbert J, Traynor C, Blue K, Kim K. Use of the Mini TightRope(R) for correction of hallux varus deformity. J Foot Ankle Surg. 2011;50(2):245–51.
30. Motta P, Maderni A, Bruno L, Mariotti U. Suture rupture in acromioclavicular joint dislocations treated with flip buttons. Arthroscopy. 2011;27(2):294–8.
31. Ng VY, Berlet GC. Improving function in transtibial amputation: the distal tibiofibular bone-bridge with Arthrex Tightrope fixation. Am J Orthop (Belle Mead NJ). 2011;40(4):E57–60.
32. Storey P, Gadd RJ, Blundell C. Complications of suture button ankle syndesmosis stabilization with modifications of surgical technique. Foot Ankle Int. 2012;33(9):717–21.
33. Yao J, Zlotolow DA, Murdock R, Christian M. Suture button compared with K-wire fixation for maintenance of posttrapeziectomy space height in a cadaver model of lateral pinch. J Hand Surg Am. 2010;35(12):2061–5.
34. Eaton RG, Glickel SZ. Trapeziometacarpal osteoarthritis. Staging as a rationale for treatment. Hand Clin. 1987;3(4):455–71.
35. Culp RW, Rekant MS. The role of arthroscopy in evaluating and treating trapeziometacarpal disease. Hand Clin. 2001;17(2):315–9. x–xi.
36. Furia JP. Arthroscopic debridement and synovectomy for treating basal joint arthritis. Arthroscopy. 2010;26(1):34–40.
37. Song Y, Cox CA, Yao J. Suture button suspension following trapeziectomy in a cadaver model. Hand. 2013;8(2):195–200.
38. Khalid M, Jones ML. Index metacarpal fracture after tightrope suspension following trapeziectomy: case report. J Hand Surg Am. 2012;37(3):418–22.
39. Willmott HJ, Singh B, David LA. Outcome and complications of treatment of ankle diastasis with tightrope fixation. Injury. 2009; 40(11):1204–6.
40. Kim ES, Lee KT, Park JS, Lee YK. Arthroscopic anterior talofibular ligament repair for chronic ankle instability with a suture anchor technique. Orthopedics. 2011;34(4).
41. Forsythe K, Freedman KB, Stover MD, Patwardhan AG. Comparison of a novel FiberWire-button construct versus metallic screw fixation in a syndesmotic injury model. Foot Ankle Int. 2008;29(1): 49–54.
42. Teramoto A, Suzuki D, Kamiya T, Chikenji T, Watanabe K, Yamashita T. Comparison of different fixation methods of the suture-button implant for tibiofibular syndesmosis injuries. Am J Sports Med. 2011;39(10):2226–32.

27 Small Joint Arthroscopy

Alejandro Badia

Introduction

Advances in fiberoptic technology and small joint instrumentation have opened up a new world in the area of arthroscopy. However, indications for small joint arthroscopy in the hand remain poorly understood and underutilized. This is mainly due to a scarcity of papers utilizing this technique in the literature, as well as scarce hands on training in the technical aspects of small joint arthroscopy. Despite the fact that these small joint arthroscopes have been readily available for decades, hand surgeons have been slow to adopt this to include this methodology within their treatment protocols of both traumatic and degenerative conditions involving small joints.

Small joints to be discussed include the trapeziometacarpal, scaphotrapezial-trapezoidal, metacarpophalangeal, fifth carpometacarpal (CMC), proximal (PIP), and even distal (DIP) interphalangeal joints. Similar instrumentation is used in the temporomandibular joints and small foot articulations but is beyond the "scope" of this chapter.

Perhaps the most common indication for small joint arthroscopy is its use in the thumb trapeziometacarpal or first CMC joint and is simply due to the ubiquitous nature of thumb basal joint arthritis and the myriad of treatment options that continue to be offered. Small joint arthroscopy offers a minimally invasive manner to achieve similar treatment goals and a previously described arthroscopic classification for basal joint osteoarthritis helps direct specific treatment depending on the stage of disease. This chapter will also review the brief history of trapeziometacarpal arthroscopy and provide insight as to how this technique can be incorporated into a treatment algorithm in managing this extremely common condition.

A. Badia, M.D. (✉)
Badia Hand to Shoulder Center,
OrthoNOW Orthopedic Urgent Care Centers,
3650 NW 82nd Avenue, Suite 103, Doral, FL 33166, USA
e-mail: Alejandro@drbadia.com

Metacarpophalangeal joint arthroscopy is even less commonly used, while traumatic and overuse injuries are frequently seen in the thumb, and present an ideal indication in certain scenarios. Painful conditions affecting the metacarpophalangeal joints of the fingers are less commonly seen, yet the small joint arthroscope presents a much clearer picture of the present pathology compared to other imaging techniques or even open, and potentially harmful, surgery due to excess capsular scarring.

Proximal interphalangeal arthroscopy remains a novel technique and few papers have outlined the indications or utilization of this in PIP pathology. Rheumatoid arthritis may be the best indication as the soft tissue pathology itself permits introduction of the scope into a small space due to capsular laxity. Treatment is best suited for earlier stages.

Distal interphalangeal arthroscopy remains anecdotal as does that of the fifth carpometacarpal joint, only possible since it is quite mobile.

The application of this technology to the smaller joints will soon make the treating surgeon realize that a myriad of pathologies are readily visible and can augment treatment as well as diagnosis. Similar to the wrist, small joint arthroscopy may one day supplant imaging techniques such as MRI or CT in establishing an accurate diagnosis.

Thumb First Carpometacarpal (CMC) Arthroscopy

Osteoarthritis of the thumb trapeziometacarpal (TM) joint remains the most common indication for small joint arthroscopy and perhaps the only small joint technique that is now consistently mentioned in academic symposia and scientific articles. There is a plethora of different surgical options for the basal joint suggesting that none of them has an optimal success rate, or conversely, it may be that many treatment options lead to satisfactory results; therefore, the clinician continues to use his favorite technique. However, this "one operation fits all" approach may not be optimal since different

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*,
DOI 10.1007/978-1-4614-1596-1_27, © Springer Science+Business Media New York 2015

stages of basal joint arthritis are clearly recognized. Furthermore, first CMC osteoarthritis of the thumb has many different clinical presentations and one technique cannot be used for all of the different stages and a patient's individual needs. When conservative treatment has failed, there are many surgical options, and should be individualized to the particular patient.

The early stages of basal joint osteoarthritis are frequently seen in middle-aged women and can be frustrating since current open surgical options may be deemed too aggressive for this patient population. These patients often fail conservative treatment and are searching for a solution to provide definitive pain relief while allowing them to be active. The use of anti-inflammatories, splinting, corticosteroids, and even hyaluronic injections serves only as palliative measures with none of these affecting a permanent change in the joint pathophysiology or mechanics. Furthermore, the use of injectable corticosteroids can hasten cartilage degradation and lead to further capsular attenuation/instability. The rare cases of transient synovitis may experience some relief, but the inevitable progressive loss of cartilage demands a more aggressive intervention. Second to the DIP joint, the thumb basal joint remains the most common, but most symptomatic location for osteoarthritis in the hand. Ironically, it is also the most critical for hand function and perhaps the increased motion and demands this joint experiences lead to the condition itself. The ascent of mankind has been largely attributed to the unique function of the human thumb basal joint and likely led to the progression of tool use in hominid evolution. Treatment of this functionally important joint remains a priority for the hand surgeon, and it is important to utilize the wide variety of surgical technique to optimally manage this condition.

Traditionally, the basal joint has been treated by surgical means only when conservative options have been exhausted and patient demands more aggressive treatment. The primary option has been, and still remains, some type of open trapezial resection arthroplasty. This explains why the procedure is not often offered to younger patients, and why high demand patients will forego operative treatment, even when symptoms are quite severe. While the literature demonstrates good results in a multitude of studies and using a variety of techniques, it nevertheless is a surgically aggressive procedure since removal of a complete carpal bone is required in order to achieve pain relief. This is understandable in the most advanced cases where the trapezium is typically flattened, has pan-trapezial disease, or has severe deformity including marginal osteophytes. However, earlier stages warrant a more conservative option that allows for future interventions if the primary treatment is not successful. Other options, perhaps less aggressive, include arthrodesis, which can provide excellent pain relief but has the obvious limitation of loss of motion, or joint replacement. Joint arthroplasty, like in any other joint in the body, has the added risk of failure of the implant, whether this be silicone or of metallic and plastic components and is still not accepted by many clinicians. This is also not a good alternative for the younger, high-demand patients.

Evolution of Basal Joint Arthroscopy

The refinement of fiberoptic technology has allowed us to apply the ideals of minimally invasive surgery to small joints including the wrist, foot, temporomandibular, and now the small joints of the foot and hand. Yung-Cheng Chen's classic treatise on arthroscopy of the wrist and finger joints in 1979 reviewed the technique and indication of performing small joint arthroscopic procedures using the Watanabe No. 24 arthroscope as early as 1970 [1]. Surprisingly, within that paper there was no mention of arthroscopy of the thumb trapeziometacarpal joint, perhaps the small joint arthroscope's broadest clinical indication. In his review, there was a detailed description of arthroscopy of the wrist, metacarpophalangeal joints, and the proximal interphalangeal joints. While wrist arthroscopy has been universally accepted [2] as a critical tool for management of pathology in this small joint, the smaller joints remain underutilized regarding this methodology. This author reviewed the extensive clinical applications of both MCP and first CMC joint arthroscopy 7 years ago [3] but only recently has the latter gained acceptance and even been discussed in academic presentations as yet another option for treatment of thumb arthritis.

Jay Menon published the first important clinical paper on basal joint arthroscopy in the *Journal of Arthroscopic and Related Surgery* in 1996 [4]. This clinical series, "Arthroscopic Management of Trapeziometacarpal Joint Arthritis of the Thumb" reviewed patients undergoing arthroscopic hemitrapeziectomy and interpositional arthroplasty using either autogenous tendon graft, Gore-Tex, or fascia lata allograft. It was not clear what extent of arthritis was involved in the series, but it appeared the technique was reserved for more advanced stages. This early paper did not present the possibility of performing arthroscopy on less advanced stages but rather avoid destabilizing the basal joint by not performing an open arthrotomy on advanced cases which otherwise would have had an open complete trapeziectomy. More than 80 % of the patients had complete pain relief in his series of 25 patients, perhaps akin to results utilizing the open technique. However, he clearly outlined the advantages of doing this arthroscopically including the minimally invasive nature with less risk of injuring the radial sensory nerve coupled with less post-op pain. He did not comment on one obvious advantage, namely that arthroscopy of the trapeziometacarpal joint can assess the true articular changes providing more accurate joint assessment than routine radiographs.

This encourages us to treat basal joint osteoarthritis in much earlier stages and the clinical indication for surgery could be failure of conservative treatment, not simply patients with advanced X-ray changes. Herein lies the major advantage of small joint arthroscopy as it provides a new option for treating patients with the earliest stages of basal joint arthritis.

One year after Menon's clinical study paper, Berger from the Mayo Clinic presented a technical discussion of first carpometacarpal joint arthroscopy as a technique paper in the *Journal of Hand Surgery* (JHS American) in 1997 [5]. The clear advantages of arthroscopy in assessing the anatomy, as opposed to a standard open arthrotomy, were presented. He reasoned that open joint visualization would be difficult due to the depth and constraint of the joint, while the arthroscope could avoid disruption of the multiple ligaments that he described with Bettinger in a separate anatomic review [6]. Berger's paper also reviewed 12 cases that he had performed from 1994 in diverse clinical indications including several Bennett fractures of the metacarpal base. He further commented that there was excellent visualization and no complication with this procedure, yet clear indications for first CMC joint arthroscopy were not outlined, but this did present a viable alternative to the more invasive open surgery. This paper was followed by an interesting barrage of letters to the editor arguing over whether Berger or Menon had presented the index article on this new technique for the thumb. The next clinical paper on thumb arthroscopy was not until 1997, by Osterman and Culp in the journal *Arthroscopy*, wherein two groups of patients were described: traumatic and degenerative [7]. Their paper validated the use of arthroscopy for the thumb carpometacarpal joint also suggesting that arthroscopy may determine the degree of trapezial surface involvement and even promoted its usage in younger patients. This led this author to use arthroscopy of the thumb carpometacarpal joint to accurately stage the degree of cartilage wear and determine specific treatment based upon this information [8]. While Jay Menon and others may have introduced the use of arthroscopy to limit the invasive nature of partial trapezial excision, I believe the technique may be uniquely suited to manage those patients who, until now, were not candidates for any surgical option.

Like any other joint, arthroscopy of the thumb carpometacarpal joint is only helpful if the operating surgeon clearly understands the anatomy, particularly the functional ligaments so critical to function and perhaps implicated in development of arthrosis. The first description of the trapeziometacarpal ligaments occurred in 1742 in a treatise by Weitbrecht, entitled Syndesmology, where these ligaments were mentioned in a cursory manner [9]. A variety of authors have since further described the details of this anatomy with the pinnacle, as mentioned, coming from Bettinger, Berger, and others from the Mayo Clinic 1999 [6]. They described a total of 16 ligaments including ligaments between the metacarpal and trapezium and two ligaments attaching the trapezium to the second metacarpal apart from separate stabilizers for the scaphotrapezial and trapezoidal joints. They determined that this complex of ligaments act as tension bands to prevent instability from cantilever bending forces exerted on the trapezium by the mechanics of pinch. This was a very important concept since large loads are transferred to the trapezium, and there is no fixed base of support since the underlying scaphoid is a mobile carpal bone. Therefore, it is the dysfunction and weakening of these key ligaments that may lead to the condition of basal joint arthritis. It was later surmised by Van Brenk that the dorsoradial collateral ligament was the critical ligament preventing trapeziometacarpal subluxation [10]. He calculated this based upon a cadaveric study where serial sectioning of four key ligaments ultimately determined that the RCL was the key structure in preventing dorsoradial subluxation. Furthermore, Zancolli, known for his thorough knowledge of functional hand anatomy, also supported this concept, although he added a controversial theory that aberrant, redundant slips of the abductor pollicis longus may cause a compressive force of the dorsoradial aspect of trapeziometacarpal joint possibly leading to arthrosis [11]. He surmised that the underlying ligamentous laxity is due to underlying variations in an individual person's ligamentous laxity or a hormonal predilection that could perhaps explain the increased prevalence amongst women. My personal discussions with him ultimately led to my developing an arthroscopic classification since the articular findings may help determine which ligaments are most commonly afflicted in the arthritic process. An intrinsic cause for basal joint arthritis was suggested by Xu and Strauch, who indicated that the trapeziometacarpal joint is smaller and less congruous in women and might also have a thinner layer of hyaline cartilage, adding an additional etiology explain the increased incidence of basal joint osteoarthritis in women [12]. This, too, is my experience and suggests that the greatest applicability of arthroscopy may be in younger women who present with this disease at a much earlier age and have, implicitly, less surgical treatment options.

In 1979, Pellegrini in Hand Clinics, reaffirmed the functional role that the volar beak ligament plays in limiting dorsal translation of the metacarpal during pinch function [13]. The volar oblique ligament and the dorsoradial ligament are well visualized during arthroscopy and can allow for therapeutic intervention as well. Pellegrini proposed that the attritional changes in the volar oblique ligament seen at its metacarpal insertion site may be related to increased estrogen receptors at this site. This is consistent with a gender predilection for this affliction. I have indeed noted consistent full thickness cartilage loss at the insertion of the volar beak ligament on the deep metacarpal base while the rest of the metacarpal appears normal via arthroscopic evaluation.

More detailed anatomic, clinical, and even biomechanical concepts have been described by Bettinger and Berger in their study emphasizing the functional ligamentous anatomy of this joint [14]. It was noted that the arthroscopic anatomy is less complicated due to limited number of structures seen from intra-articular vantage point. It was a pioneering technique article as well, outlining which of the two main portals provides visualization of which corresponding ligaments. Further portals were later described to further define the surface anatomy of this joint but predominantly to assist in performing triangulation during arthroscopic interventions. For example, Orellana and Chow described a radial portal which they suggested was safer due to its position relative to the radial artery and branches of the superficial radial nerve [15]. Later, Walsh and Akelman described the thenar portal, which was much more palmar, passing through the thenar musculature, allowing for improved triangulation and more "birds eye" visualization of the joint [16]. Slutsky later described a more distal portal, at the first webspace, allowing better exam of the dorsal structures and better access to the deep trapezial osteophyte typically seen [17]. These newer portals confirm that thumb CMC arthroscopic surgery is now in a state of evolution and hopefully will allow us to better understand arthritis at this level. Arthroscopic assessment of these structures over time may allow us to elucidate the cause of dorsal subluxation as a factor in basal joint arthritis.

An early clinical series by Culp and Rekant first suggested that arthroscopic evaluation, debridement, and synovectomy "offer an exciting alternative for patients with Eaton and Littler stages I and II arthritis" [18]. They were the first to discuss radiofrequency (RF) at the basal joint, describing radiofrequency "painting" of the volar capsule of the trapeziometacarpal joint, in order to stabilize the critical palmar ligaments that may cause dorsal subluxation and subsequent basal joint arthrosis. They recommended that if the majority of the trapezial surface is arthritic, then at least one-half of the distal trapezium should be resected via arthroscopic burr. The short-term results described in this paper followed arthroscopic hemi- or complete trapeziectomy in conjunction with electrothermal shrinkage reporting nearly 90 % excellent or good results in 22 patients with a relatively short follow-up. They were the first to indicate that no "bridges had been burned" since patients who have the arthroscopic procedure can always undergo a more aggressive open and complete excisional trapezial arthroplasty. They conclude that debridement and thermal capsular shrinkage is a good treatment option for early arthritis of the basal joint although the paper does seem to focus on a more advanced stage.

It is important to understand the role of RF in this new indication since orthopedic surgeons have benefited from the use of radiofrequency in multiple joints during the past two decades. In recent years, we are realizing that it may have some detrimental effects, and it is important to look at this technology more critically. As with any new technique, selective use of this technology and careful adherence to certain principles may allow for safe use of RF in a variety of clinical scenarios. Shoulder instability had been commonly treated using radiofrequency to stabilize the joint, particularly in those patients with global instability who traditionally had not been considered good operative candidates [19]. More recently, this technique has been largely abandoned in shoulder capsulorrhaphy due to poor results and even potential complications [20]. One must scrutinize the literature as perhaps the technology was applied in an overaggressive manner or even poor patient selection. While it has also been used in the knee and some other joints, there has been minimal mention in the literature of its application to the wrist, let alone small joints of the hand. This is largely due to the fact that arthroscopy of the small joints has had only cursory discussion in the literature.

Radiofrequency has had many medical applications since the late nineteenth century including creating lesions in brain tissue and has been used in cardiology, oncology, and colorectal surgery. Markel and colleagues first demonstrated the effect of radiofrequency energy on the ultrastructure histology of the joint capsular collagen in a basic science study [21]. They noted that similar clinical applications had been performed with a non-ablative laser in orthopedics but offered alternative that radiofrequency provided several advantages over the use of a laser. RF is less expensive and safer than laser technology, while the devices are much smaller and easily maneuverable in its application to arthroscopic techniques. Early basic science studies on a sheep joint first demonstrated that the thermal effect was characterized by the fusion of collagen fibers without tissue ablation, charring, or even crater formation. They described a linear relationship between the degree of collagen fiber fusion and increasing treatment temperature. This indicates that the technology must be judiciously utilized with avoidance of aggressive use. It was determined that the coagulated tissue mediates a mild inflammatory reaction leading to the degradation and replacement of the affected capsule with stronger, fibrous tissue. This could potentially help to stabilize a joint and might have specific application in the trapeziometacarpal joint since instability is part of the clinical spectrum in many cases. Later, Markel and Hecht looked specifically at monopolar radiofrequency energy on the joint capsular properties and determined that monopolar radiofrequency caused increased capsular damage in the immediate area and depth correlating with the wattage used [22]. Of note was that heat production increased linearly with the duration of application. Arthroscopic lavage could protect the synovial layer from permanent damage as demonstrated in sheep. These findings all indicate that radiofrequency probes must be used with adequate fluid lavage as well as for short durations and with the minimal wattage necessary to

Table 27.1 Badia arthroscopic classification for thumb CMC arthritis

Stage I	Diffuse synovitis, intact articular cartilage, volar capsular laxity
Stage II	Central focal articular cartilage loss of trapezium, deep metacarpal base loss, and synovitis
Stage III	Widespread articular cartilage loss, deep osteophyte on trapezium

achieve the desired effect. We are referring here to monopolar radiofrequency since it is commonly accepted amongst orthopedic surgeons that monopolar radiofrequency causes less heat production than bipolar modalities. This is critical to the hand surgeon since small joints have correspondingly thinner capsules and are in close continuity to neurovascular structures. This is a completely different scenario as compared to the knee or shoulder. Future studies might specifically compare monopolar versus bipolar radiofrequency treatments in these small joints.

Based upon the early clinical papers, while taking full advantage of the technologies available, it soon became clear that a thorough staging system would be beneficial, utilizing these arthroscopic findings to actually dictate treatment. First, the clinical studies discussed have primarily focused upon more advanced osteoarthritis, discussing results after some manner of arthroscopic-assisted hemitrapeziectomy. Second, there was little mention of the degrees of arthritis noted during arthroscopy and how that might influence treatment. Furthermore, it is likely that the patient whose joint is less affected might benefit most from an arthroscopic treatment method. This author therefore developed an arthroscopic classification which could dictate treatment for the respective stages herein delineated (Table 27.1).

The arthroscopic staging was gradually developed as a result of nearly 20 years of performing an arthroscopic assessment for recalcitrant basal joint arthritis which did not improve after often extensive conservative treatment. The condition is, of course, staged radiographically as per Eaton's criteria [23]. Obvious exceptions were in patients with advanced (Eaton stage IV) arthritis with significant scaphotrapezial-trapezoidal (STT) arthrosis or trapezial collapse who then underwent a trapezial excisional suspensionplasty using a slip of abductor pollicis longus similar to Thompson's description [24]. The advanced stage of disease really required excision of the entire trapezium, while stage IV patients with mild STT changes were still often treated via arthroscopy. Cobb describes a technique where both trapeziometacarpal and STT joints can simultaneously undergo arthroscopic treatment although I did not consider that in my treatment algorithm here described [25]. An additional exception was for older, low demand patients who did well using a cemented total joint arthroplasty as this required almost no immobilization and minimal therapy [26, 27]. This open surgery also allowed me to correct z-deformities by performing intrinsic releases of the adduction contracture coupled with an MCP volar capsulodesis. The last exception to arthroscopic management was the occasional young, usually male laborer who underwent a trapeziometacarpal joint fusion in good position of function for heavy pinch and grip. This indication for arthrodesis has been amply described in the literature and remains a good option, although arthroscopic hemitrapeziectomies may soon obviate even that procedure in some cases [28].

Except in clear-cut radiographic stages, where one can predict the arthroscopic stage, one performs the procedure with understanding that several therapeutic options are available once the arthroscopic stage is defined. These stages will later be delineated. The arthroscopic surgery is performed under wrist block regional anesthesia, usually only requiring several cc's of lidocaine at median and radial sensory nerves of the wrist, 2–3 cm proximal to volar wrist crease. It is performed with tourniquet control and the upper arm is secured to arm board over this tourniquet via either wide tape or a Velcro strap. A single large Chinese finger trap is used on the thumb with 5–8 lbs. of longitudinal traction using a shoulder holder directly in line with the elbow flexed at 90° so that the thumb tip points to the ceiling. One can utilize the specialized wrist arthroscopy traction tower but is superfluous and more costly, since easy unencumbered access to the thumb is later necessary to drive a K-wire and fluoroscopy can be more easily introduced into the field. The trapeziometacarpal (TM) joint is then identified by palpating the more prominent metacarpal base. The joint is best localized by using an 18 gauge needle on a small syringe containing either lidocaine or lactated ringer's solution so that the joint can be insufflated and distended. The needle needs to be introduced a bit more distal than expected and aimed cephalad since the metacarpal dorsal flare/lip needs to be cleared (Fig. 27.1). One can usually only introduce 1–2 cc due to small nature of the joint and the degree of laxity and joint swelling will influence this. Caution must be used to ensure the STT joint is not actually distended and less experienced surgeons should use fluoroscopy when the needle is in the joint to both confirm precise location and help determine trajectory of the soon to be placed trochar/sheath assembly. The location for this initial distention will often vary based upon which hand (left or right), and location of occasional large, interfering prominent osteophytes. The longitudinal portal stab wound incision is then made in line with the needle penetration and will likely be at either the 1-R or 1-U portal as described by Berger [5]. The incision for the 1-R (radial) portal is placed just volar to the abductor pollicis longus (APL) tendon and is typically used for clear assessment of the dorsoradial ligament (DRL), posterior oblique ligament (POL), and ulnar collateral ligament (UCL). The incision for the 1-U (ulnar) portal, which allows better evaluation of the anterior oblique ligament (AOL-volar/oblique) and UCL, is made just ulnar

Fig. 27.1 Joint insufflation of the thumb basal joint in preparation for arthroscopic exploration. Note the needle trajectory which follows course of thumb metacarpal base flare and helps orient for correct arthroscope insertion angle

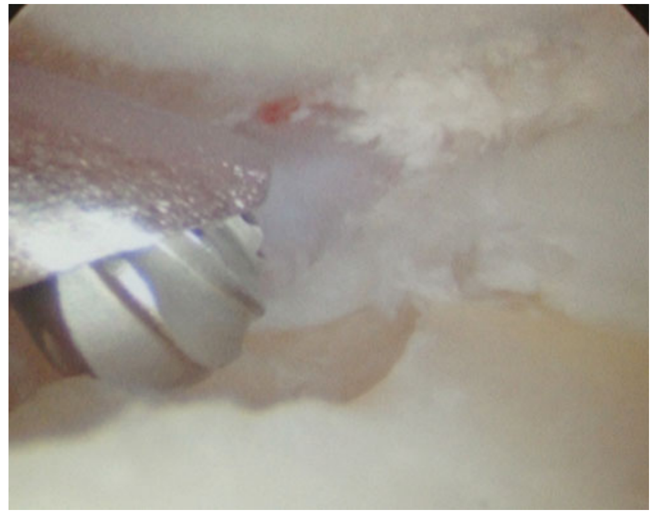


Fig. 27.2 Arthroscopic view of thumb trapeziometacarpal joint demonstrating dorsoradial resection of trapezial surface using a 2.9 mm burr in a Badia stage III arthritic joint

to the extensor pollicis brevis (EPB) tendon but palmar to the extensor pollicis brevis (EPL). The portals should be just distal to the dorsal branch of radial artery which lies across the ST joint, and should avoid any sensory radial nerve branches since the portals are, again, longitudinal, but one should always enter the capsule and spread with a straight small mosquito clamp. This will push the sensory nerves away from the portal sites. A short-barrel 1.9 mm 30° inclination arthroscope is usually used for complete visualization of the TM joint articular surfaces, capsule, and intrinsic ligaments. A 2.7 mm scope may be preferred when a more advanced Eaton stage is indicated since the larger scope may scuff the articular cartilage but is irrelevant in that scenario. The larger scope will actually assist in distracting the joint and provide a better field of view, while not risking the more delicate, and costly, 1.9 scope. A 2.0 mm full radius mechanical shaver with suction is used in most cases, particularly for initial debridement and visualization. Again, the larger 2.9 mm more aggressive shaver or cutter may be used in advanced cases where a hemitrapeziectomy is fully expected to be undertaken. The larger shavers allow for much better suction and evacuation of debrided joint material. Many cases utilize radiofrequency, for either ablation or thermal shrinkage as discussed, so need to be available per surgeon's choice. Radiofrequency can also be used to perform chondroplasty in less advanced cases demonstrating focal articular cartilage wear or fibrillation. Ligamentous laxity and capsular attenuation are treated with thermal capsulorrhaphy also using the same RF shrinkage probe. One must be careful to avoid thermal necrosis and consequently, a striping technique is used to tighten the capsule of redundant or lax joints. Ample joint irrigation fluid is necessary during this treatment in order to minimize any thermal injury. In lesser stages of arthrosis, the arthroscopic treatment is completed once the joint synovectomy is performed, arthroscopic stage has been assigned, and the joint adequately debrided. Decision to use RF is made at this point but no further arthroscopic procedure is done in the early stages. Decision will have been made if adjunctive corrective metacarpal osteotomy is to be performed. In advanced cases, the shaver is now substituted for a mechanical shaver in order to proceed with partial trapeziectomy. A 2.9 mm long barrel type burr is then used to remove the distal 3–5 mm of remaining articular cartilage and subchondral bone. This is preferable to the round burrs due to speed and ease of use while some surgeons (Berner, Cobb etc.) try to utilize a larger, 3.5 mm burr since this will quickly remove the necessary trapezial surface. A strategic plan of joint resection is needed in order to avoid leaving significant prominent ridges or sections of the trapezium that may cause later impingement and persistence of pain. My strategy has usually been to divide the trapezial surface into four quadrants, two dorsal and two volar, or radial and ulnar. One begins at the area of shaver entry since the bone to resection is directly afoot, and this will create space to easier approach the other quadrants (Fig. 27.2). If the scope is in 1-R portal of a right thumb, then the burr would be in the 1-U portal facilitating subchondral resection of the dorsoulnar quadrant first. Once that side of the joint is cleared, the arthroscope can be changed to the opposite portal allowing the resecting burr to now enter the opposite portal, namely the 1-R portal in the previous example delineated. The radial palmar/dorsal quadrants can now be better approached for resection. At this point, several options are possible in order to encourage fibrous tissue ingrowth to create a new pseudo-joint. Menon described a variety of materials including gore-tex, graft jacket, or tendon to interpose [4]. In my early experience, spanning nearly 10 years, I used a tendon graft which would serve as an "arthroscopic anchovy" and function as a biologic, albeit now inert, material to encourage fibrous ingrowth. This was quite successful and was even utilized in Ehlers-Danlos patients, notoriously known for poor results in basal joint reconstruction due to their extreme underlying joint laxity, the proposed cause for the current arthritic process. Several patients did well enough to request the opposite thumb be similarly addressed, and my first experience in handling this challenging clinical scenario was published as a case report [29]. However, the dead tissue being pushed into the joint was not easily controllable via portals and I did not feel the complete joint surface was well lined by this flimsy material, despite being autogenous. Around 2004, a synthetic but biologically compatible material known as artelon began to be used for open thumb CMC joint stabilization. This material degraded into lactic acid chains and CO_2 over time, and there were basic science studies suggesting the neoformation of fibrocartilage in animals [30]. This material demonstrated good clinical results in several early studies, particularly showing improved pinch strength recovery as opposed to classic complete trapezial resection procedures [31]. While I too utilized it in a number of open cases, it soon became apparent that the material could naturally be used for an arthroscopic interposition (Fig. 27.3). The material "wings" did not need to be secured as the joint capsule itself would keep the material in place and it would serve as a scaffold for fibrous tissue ingrowth.

Fig. 27.3 Arthroscopic view of artelon polyurethane urea sheet lining the trapezium after arthroscopic limited hemiresection

This was described in a technique journal article but after many years, was largely abandoned by this author due to cost issues and other unrelated matters [32]. It should be noted that in my experience, and that of many others, there was never an adverse reaction clinically seen. However, a recent trend to simplifying the trapezial resection procedures led me to consider not interposing any material at all. Meals gave rebirth to the simple concept that resection of the trapezium alone would suffice and he added simple k-wire pinning of the joint in a distracted position soon termed "hematoma distraction arthroplasty" or HDA. He demonstrated very comparable results to much more complex procedures traditionally utilized [33]. This was simply a fancier delineation of complete trapeziectomy published by Gervin a half century ago [34]. However, it appears that the pinning provides several beneficial effects, including keeping the joint distracted so ample fibrous tissue can form within a maintained biologic cavity. The other advantage for the arthroscopic technique is that little joint stabilization is provided in this minimally invasive surgery; therefore, pinning of the metacarpal base over the trapezium keeps the joint well reduced and the metacarpal "centralized" over the functional center of the trapezium (Fig. 27.4). A thumb spica cast is typically worn for 5–6 weeks to allow for hematoma maturation and fibrous tissue ingrowth; hence any decrease in swelling, or unopposed pull of the APL tendon, might allow for dorsal re-subluxation of the metacarpal base, possibly hindering the formation of this stabilizing tissue. New techniques, including suture/bone button stabilization devices, allow for "suspension" of the metacarpal base without the

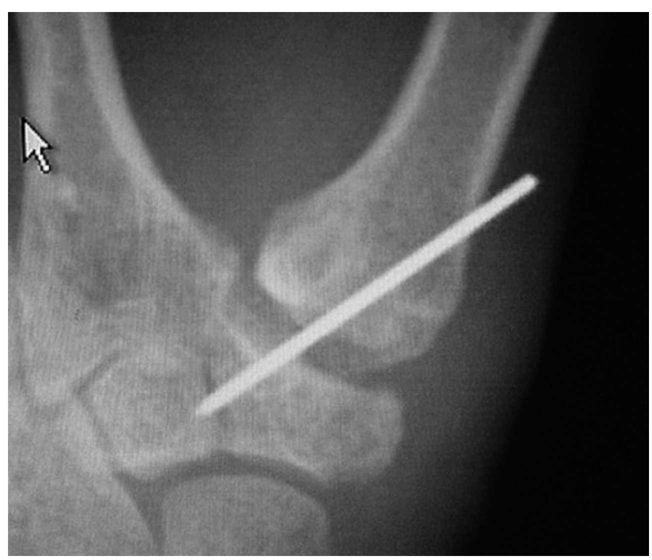


Fig. 27.4 X-ray demonstrating transfixing pin of the thumb trapezio-metacarpal joint in palmar abduction after arthroscopic hemiresection of the trapezium in a Badia stage III joint. The immobilization allows for fibrous tissue ingrowth in the new space created and now maintained by the temporary pin fixation

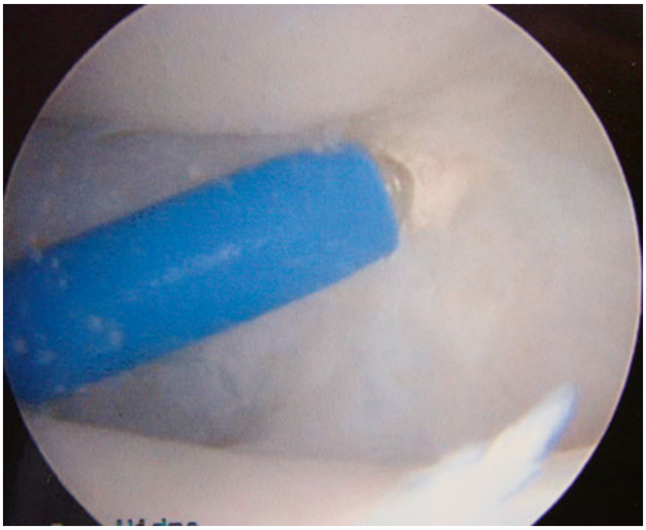


Fig. 27.5 Arthroscopic view of Badia stage I basal joint arthritis illustrating the synovitis but intact articular cartilage surface on both trapezium and metacarpal base

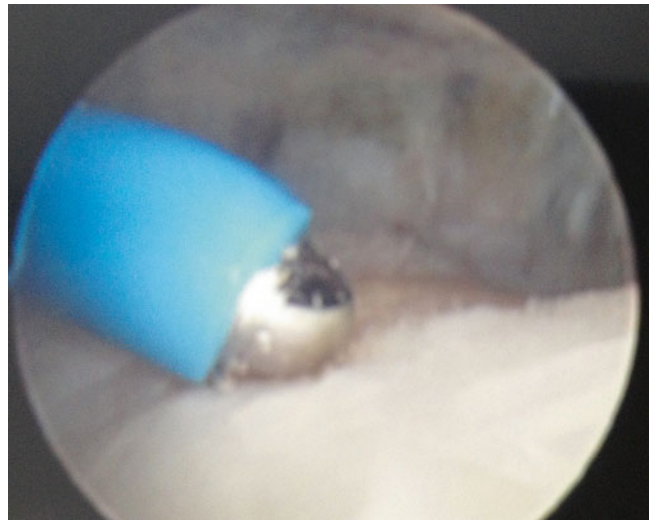


Fig. 27.6 Radiofrequency stabilization of the edge of a focal cartilage defect in a thumb Badia arthroscopic stage II. The joint contact points will subsequently be altered by a dorsoradial closing wedge osteotomy during same procedure

need for pinning. However, complications such as impingement against the second metacarpal base, or bone fracture at the tunnel location, must be taken into account [35].

These arthroscopic interposition arthroplasties are obviously indicated for more advanced arthritis, but a joint modification might only be needed if the joint can be debrided and stabilized; hence a discussion on arthroscopic staging [8] is necessary to delineate when and how metacarpal base osteotomy is performed.

Staging by arthroscopy (Badia) is critical in order to indicate what further joint procedure, articular or extra-articular, is performed once the assessment has been made after synovectomy and appropriate debridement. Arthroscopic stage I patients are characterized by diffuse synovitis but with minimal, or no, articular cartilage loss (Fig. 27.5). Capsular or specific ligamentous laxity is a typical finding at this stage. This arthroscopic appearance is not commonly seen, since most patients present late, having dealt with symptoms for a prolonged period, or referred at a delayed time, once conservative means have been exhausted. Primary care physicians, orthopedic surgeons, and even hand specialists typically feel there are few options available to these patients failing traditional nonoperative treatment. These patients will undergo synovectomy, by both mechanical shaving and radiofrequency, with frequent shrinkage capsulorrhaphy performed depending on findings. The joint is then stabilized in a thumb spica cast from 1 to 4 weeks depending on the extent of capsular laxity. More unstable joints required longer immobilization in order to achieve joint stability and might also be pinned in a reduced position with thumb in palmar abduction. Stabilization of the capsule and aggressive synovectomy is hoped to slow the progression of articular cartilage degeneration.

Arthroscopic stage II patients are typified by focal articular wear on the central to dorsal aspect of the trapezium. It can be argued that this likely represents an irreversible degenerative process and demands a joint modifying procedure in order to alter joint deforming forces and progression of subluxation. Once synovectomy, debridement, and any loose bodies are removed, the joint is evaluated to determine the degree of instability and extent of capsular incompetence. A thermal shrinkage capsulorrhaphy is then often performed, with thermal chondroplasty occasionally done to anneal the cartilage borders (Fig. 27.6). The scope is then removed and an open incision usually extended from the ulnar portal is performed in order to identify the metacarpal base and metaphyseal-diaphyseal junction. A dorsoradial closing wedge osteotomy, according to Wilson's original technique [36], is then performed in order to place the thumb in a more extended and abducted position altering the joint force vector (Fig. 27.7). Usually, only a 2–3 mm wide dorsoradially based wedge of bone is excised by combination of oscillating saw/osteotome. The idea is to minimize the tendency for metacarpal subluxation as well as change the contact points of degenerative articular cartilage. The osteotomy is stabilized usually by a single oblique Kirschner wire, also placed across the TM joint in a reduced position so that the metacarpal base sits squarely over the trapezium. This fixation allows for healing of the osteotomy in the reduced position and hopefully leads to a correction of the metacarpal subluxation, typically seen in this stage. A thumb spica short arm cast is worn during osteotomy bone healing and the wire is removed at 5–6 weeks post-op. While the osteotomy has been published as solely an open surgery by multiple authors, only arthroscopy can truly determine which patients should

Fig. 27.7 X-ray showing centralized metacarpal base and pin fixation after dorsoradial closing wedge osteotomy in order to alter joint force vector and minimize further cartilage wear

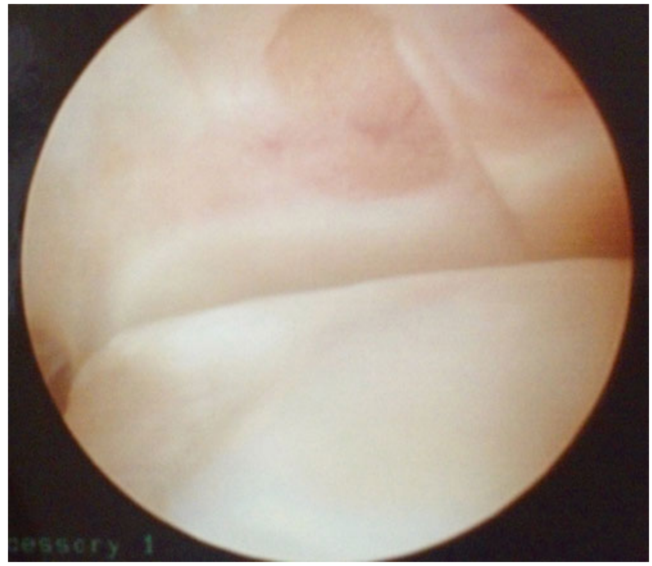


Fig. 27.8 Arthroscopic view of the scaphotrapezial-trapezoidal (STT) joint showing scaphoid distal pole to be burred down limiting painful impingement from overlying trapezium and trapezoid

undergo this osteotomy. This has demonstrated good results in the past, including a more recent paper by Tomaino [37], but we can surmise that perhaps any poor results achieved were due to a poor indication; namely that only patients with a moderate stage of arthritis should undergo osteotomy, and this can now be determined arthroscopically. I published a modest series of patients having undergone this technique of combined arthroscopic debridement with metacarpal osteotomy while further outlining specifics of the technique [38]. This represented only a fraction of the potential patient series that underwent this surgery and, interestingly, even late follow-up on my patients has demonstrated that the metacarpal remains "centralized." It is frankly unclear if the capsular shrinkage played a major role versus the alteration of joint mechanics by the osteotomy but suffice it to say that I have yet to convert any of these arthroscopic-assisted joint modifying procedures into any type of trapeziectomy or salvage procedure.

Arthroscopic stage III is characterized by nearly complete trapezial articular cartilage loss (Fig. 27.8). The metacarpal base can also demonstrate loss of cartilage to varying degrees. Arthroscopic findings indicate that this is not an articulation that can be salvaged and a simple debridement or even joint modifying osteotomy would not provide a good result in this scenario. At this point, an arthroscopic hemitrapeziectomy, as earlier described, is performed by burring away the remaining articular cartilage and subchondral bone to achieve a bleeding surface. This acts to not only increase the joint space, but provides the key bleeding which creates the so-called hematomaplasty. Whether interposition material is placed or not, an oblique transfixing K-wire is used, coupled with a thumb spica cast in an abducted position, and maintained for about 6 weeks in order to encourage fibrous tissue ingrowth within the interposition space. This is followed by generally a minimal period of hand therapy to focus on pinch strengthening as joint motion is rapidly restored no matter what therapy is done. While Artelon material for interposition represents a good option obviating tendon procurement, it has become increasingly apparent that generous resection of the trapezial surface without specific interposition material should suffice.

It should always be noted that arthroscopic stage III can also be treated by any traditional open technique such as excisional arthroplasty, arthrodesis, or even total joint replacement. This will largely depend on surgeon preference as well as patient needs and wishes.

Since arthroscopy remains underutilized and joint images are not readily available to study, we must take note of the correlations between arthroscopic and radiographic staging in order to better understand the role of arthroscopy and the typical findings at each stage. The most consistent arthroscopic findings in the group of patients who displayed radiographic changes compatible with stage I of the disease included fibrillation of the articular cartilage on the ulnar third of the base of the first metacarpal, disruption of the dorsoradial ligament, and diffuse synovial hypertrophy. We also noted attenuation of the anterior oblique or beak ligament (AOL) often being able to visualize the thenar muscles below the capsule, almost as a veil. The frequent injection of steroids likely influences this factor and a future study correlating frequency/amount of corticosteroids with joint findings would be quite valuable.

Typical arthroscopic findings seen in patients determined to be stage II arthritis were significant but focal wear of the distal surface of the trapezium, loss of metacarpal base cartilage near insertion of the AOL ligament, disruption of the dorsoradial ligament, and more significant attenuation of the AOL. We typically would also see more intense synovial hypertrophy. Most of the patients with this arthroscopic stage also presented as stage II radiographically, but it is not uncommon to discover patients deemed stage I may actually have more advanced findings once the joint is accurately assessed. This represents the great advantage of this technology since there is little other way to see what the true joint status is. Only rarely did we find less cartilage wear than was supposed or predicted on the plain X-rays. Therefore, radiographic stage III is only rarely considered stage II arthroscopically, but that finding would greatly influence and expand the treatment options. Since arthroscopic findings in early disease may have the most clinical impact on our decision making for definitive treatment, due to lack of good options for conservative treatment, it is important to review the patient outcomes for arthroscopic stage II disease.

In 2003, a retrospective assessment evaluated arthroscopic stage II patients with adequate follow-up in the prior 3-year period [38]. Forty-three patients (38 female and 5 male) had been arthroscopically diagnosed as having stage II basal joint osteoarthritis of the thumb between 1998 and 2001. All the procedures were performed by me with follow-up data generated by visiting fellows for objectivity. The average age was 51 with range of 31–69 years of age. The right thumb was involved in 23 patients and the left in 20. There was no improvement after a minimum 6 weeks of conservative treatment under my direction although most patients had been failing conservative measures by referring doctors for over a year. The surgical procedure consisted of arthroscopic synovectomy, debridement, frequent thermal capsulorrhaphy followed by an extension-abduction closing wedge osteotomy in all cases. A .045-in. Kirschner wire provided stability to the osteotomy site while a short arm thumb spica cast was maintained for 4–6 weeks until pin removal. The average follow-up was 43 months (range: 24–64 months).

Consistent arthroscopic findings in the selected group were frank eburnation of the articular cartilage of the ulnar third of the base of the first metacarpal and central third of the distal surface of the trapezium, disruption of the dorsoradial ligament, attenuation of the anterior oblique ligament, and synovial hypertrophy. The osteotomy healed within 4–6 weeks in all the cases. Radiographic studies at final follow-up depicted maintenance of centralization of the metacarpal base over the trapezium and no appreciable progression of arthritic changes in almost all 42 patients. Average range of thumb metacarpophalangeal (MP) joint motion was 5–50° and thumb opposition reached the base of the small finger in all cases. The average pinch strength was 9.5 lbs (73 % from non-affected side). At final follow-up patients were evaluated by Buck-Gramcko score, which takes into account both the subjective as well as objective outcomes [39]. The mean total Buck-Gramcko score in our series was 48.4 representing a "good outcome." The constant pain in one of the patients was due to progressive osteoarthritis after the procedure. She did not respond to steroid injections and finally had to undergo arthroscopic-assisted hemitrapeziectomy due to progressive arthritis. A long-term follow-up should be obtained in future to better assess the utility of this technique and publish these findings specifically in stage II patients after minimum 10-year follow-up.

Arthroscopy in patients who had radiographic features of stage III and IV generally displays widespread full thickness cartilage loss with or without a peripheral rim on both articular surfaces, paradoxically less severe synovitis although we do note more frayed volar ligaments and often less laxity. This clearly constitutes arthroscopic stage III and the treatment options here are quite varied. The arthroscope can be removed and the most appropriate open procedure performed. I prefer the arthroscopic interposition arthroplasty in most of the cases. Based on the above findings and clinical experience, I proposed the arthroscopic classification and treatment algorithm as outlined in Table 27.1.

Trapeziometacarpal Arthroscopy: Clinical Utility

Clinical assessment and radiographic studies used to be the only tools available for the selection of treatment modalities for thumb CMC arthritis. Eaton and Glickel proposed a staging system for this disease that has been widely applied [20]. Later, Bettinger et al. [40] described the trapezial tilt as a parameter to predict further progression of the disease. They found that in advanced stages (Eaton III and IV) the trapezial tilt was high (50° ± 4°; normal: 42° ± 4°). Barron et al. concluded that there appears to be no indication for magnetic resonance imaging (MRI), tomography, or ultrasonography in the routine evaluation of basal joint disease [41].

While I believe that a radiographic classification is important for a stepwise interpretation of the progression of this entity, my experience has demonstrated instances when it is very difficult to make an accurate diagnosis of the extent of disease based solely on radiographic studies. Recent advances in arthroscopic technology have allowed complete examination of smaller joints throughout the body with minimal morbidity [1]. Moreover, arthroscopy has already proved to be reliable for direct evaluation of the first carpometacarpal joint as previously discussed [5].

In early stages of thumb basal joint arthritis, for instance, in Eaton stage I, it is very common to find essentially normal radiographic studies despite the presence of painful limitation of the thumb. In our experience, we have found that this group of patients displays mild to moderate synovitis which could benefit from a thorough joint debridement combined with thermal shrinkage of the ligaments to enhance the stability. This, of course, after assuming they have not responded well to conservative treatment including splinting, NSAID use, and corticosteroid injection. This stage is typically seen in middle-aged women who are not suitable candidates for more aggressive procedures. Arthroscopic treatment provides a particularly good option for this ubiquitous subset of the patients.

Tomaino concluded that first metacarpal extension osteotomy is a good indication for Eaton stage I [37]. This may not be necessary in the occasional patient who undergoes arthroscopy at an early time and demonstrates no focal cartilage loss. Future studies may indicate that synovectomy, and perhaps thermal capsulorrhaphy, may avoid progression of disease and the need for a mechanical intervention. However, the arthroscopic findings that I previously described for arthroscopic stage II of the disease demand a joint modification such as osteotomy, in order to minimize the chance of further articular degeneration. My retrospective study indicates that this approach is efficacious with only one out of 43 thumbs developing progressive arthritis requiring further surgery.

There remains little doubt that if complete articular cartilage loss is the arthroscopic scenario; the logical further step is to perform some type of trapezium excision with interposition arthroplasty. Menon described a technique demonstrating arthroscopic debridement of the trapezial articular surface and interposition of autogenous tendon, fascia lata, or Gortex patch into the CMC joint in patients with stage II and III with excellent results [2]. I have demonstrated that this arthroscopic technique is even effective in patients with underlying severe ligamentous laxity, as in Ehrler-Danlos syndrome [33]. Newer techniques may allow the arthroscopic insertion of Artelon, which has proven successful with open techniques and confirmed histologically [30]. In either case, complete excision of the trapezium may not be desirable, particularly in younger patients. The stage III treatment needs to be further assessed by evaluating long-term clinical results.

According to the arthroscopic classification proposed, I recommend arthroscopic synovectomy and debridement of the basal joint in patients with stage I arthritis. In patients with stage II disease, synovectomy and debridement is combined with dorsoradial osteotomy of the first metacarpal. In both these stages, thermal shrinkage is used to manage ligamentous laxity. Finally, for stage III of the disease, arthroscopic interposition arthroplasty is my treatment of choice, although other factors must be considered in making this determination.

Arthroscopic assessment of the trapeziometacarpal joint allows direct visualization of all components of the joint including synovium, articular surfaces, ligaments, and the joint capsule. It also allows for the extent of joint pathology to be evaluated and staged with intraoperative management decisions making based on this information. I recommend this arthroscopic staging to ensure better judgment of this condition in order to provide the most adequate treatment option to patients who have this disabling condition.

Future studies assessing the clinical long-term results utilizing arthroscopy will likely ensure its place in the treatment armamentarium for trapeziometacarpal osteoarthritis.

STT Arthroscopy (Scaphotrapezial-Trapezoidal)

Arthroscopy of the STT joint was a natural offshoot to the thumb CMC joint since the former is frequently involved when advanced basal joint arthritis is present. While Cobb reported simultaneous arthroscopic management of both TM and STT joints [42], the role of arthroscopy for the STT joint is likely best suited for focal disease where a minimally invasive option is sought. Ashwood and Bain described simple arthroscopic debridement for isolated STT arthritis demonstrating 90 % good and excellent results in their small series [43]. Fontes also described simple resection of the distal pole of the scaphoid as a useful technique for painful STT arthrosis [44].

The technique is relatively simple since instability is not an issue and the goal is to increase the joint space and avoid painful impingement. The joint is localized by ascending the scaphoid from the radial midcarpal portal, followed by creating a working portal that can be volar [44] or more recently, a radial portal has been described by Carro et al. [45]. Simple debridement is done using a 2.0 mm full radius shaver and then limited resection of the distal pole of the scaphoid is performed using burr (Fig. 27.9). The joint space is markedly widened but one must be careful to not resect the critical volar ST ligaments, one advantage of this procedure as opposed to open techniques.

Minimal post-op immobilization is another surgical advantage of this methodology, and pain relief is generally excellent assuming patient selection was properly performed.

A long-term study is necessary to determine the late outcomes and secure the role of STT arthroscopy amongst the various techniques used for treatment of this common arthritic malady.

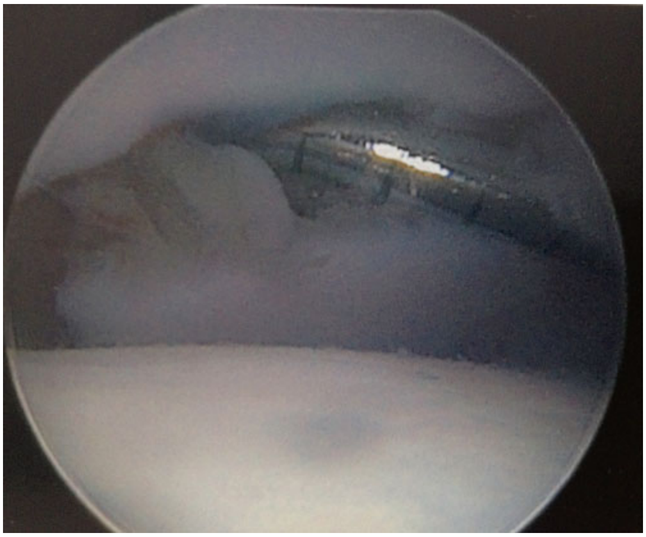


Fig. 27.9 Arthroscopic view of the thumb MCP joint illustrating how a hook probe can derotate an avulsed bony gamekeeper fragment, obviating the need for joint arthrotomy to reduce

Metacarpophalangeal Arthroscopy

While arthroscopy of the metacarpophalangeal joints of the hand was first described almost three decades ago, the clinical utility and indications remain poorly understood. Many orthopedic surgeons are unfamiliar with this possibility, hence unable to offer it to their patients as an option. Furthermore, hand surgeons rarely utilize this technology despite the fact that both acute injury and chronic pain are commonly found in the MCP joint, thumb, and digits alike. It seems that minimal exposure within the literature as well little hands on training has contributed to the underutilization of what is a very useful technique to manage certain pathology in the hand.

Dr. Chen first described arthroscopy of the metacarpophalangeal (MCP) joints, amongst other small joints of the hand as previously mentioned, in his 1979 paper in *Orthopedic Clinics of North America* representing a paradigm shift in arthroscopy indications [1]. Despite a cursory review, this paper first described the use of the Watanabe #24 arthroscope within the wrist, metacarpophalangeal joints, and even interphalangeal joints of the hand. Although he described both PIP and DIP joints being scoped, there was surprisingly no mention of the trapeziometacarpal joint. However, he did first introduce the concept of placing a small arthroscope into the metacarpophalangeal joint of several digits including the thumb. He went on to describe the anatomy followed by several clinical case reports where he described the arthroscopic findings and clinical utility. Overall, he described 90 arthroscopies performed in multiple joints encompassing 34 clinical cases as well as two cadaveric arms. Despite this broad introduction to small joint arthroscopy, the idea of MCP joint treatment was not truly developed until much later.

Ironically, it was sports medicine arthroscopists, Vaupel and Andrews, who first described a report using arthroscopic treatment of the metacarpophalangeal joint about 6 years after Chen's report [46]. They described a professional golfer who was severely limited due to a 1-year history of chronic painful synovitis within the thumb MCP joint. They performed a synovectomy and also an arthroscopic burring of a small chondral defect that had been identified at the time of procedure. The patient did so well that he was able to return to his sport within a 6-month period and was remained pain free at his 2-year follow-up. While this was a tremendous clinical advance, it was published in the *American Journal of Sports Medicine* where hand surgeons would likely not take note of this paper. Furthermore, despite an excellent outcome and a positive response to a new technique, no clinical indications were recommended for future usage and this remained an isolated case report until 2 years later when Wilkes presented the first clinical series of an MCP joint problem treated with arthroscopic means [47]. He reported on 13 cases of arthroscopic rheumatoid synovectomy in five patients suffering from advanced rheumatoid arthritis. While these patients lacked the usual joint subluxation or advanced destruction, they did have marked synovitis found in the joint space and within the recesses of the collateral ligament origins. Despite an adequate follow-up of nearly 4 years, the patients did demonstrate recurrence of pain and this treatment did not seem to alter the natural history of RA at the MCP joint. This series was also published in a low profile journal, the *Journal of the Medical Association of Georgia*, and therefore gave limited exposure to hand surgeons or even arthroscopic surgeons. A clinical paper exposed to hand surgeons was not seen until 1994 where it finally reached the *Journal of Hand Surgery—British Volume* in another case report [48]. The subject was a young male presenting with swelling and recalcitrant locking of the metacarpophalangeal joints of both index and middle fingers, bilaterally, and represents a typical presentation for hemochromatosis. Until then, the treatment of arthropathy was osteotomy and arthroplasty or even a joint arthrodesis for more advanced cases. Hemochromatosis is a rarely seen hematologic condition that is actually treated with phlebotomy and the joint manifestations are not well understood. Nevertheless, it was apparent to these surgeons that arthroscopy presented a superior alternative to open surgery with better visualization of the joint and subsequent treatment of the synovitis with faster recovery due to its minimally invasive approach. The focus, however, of the case report was on the disease itself and gave no further recommendations regarding arthroscopy besides stating that arthroscopic surgery is "of value." Since the arthroscopic treatment was downplayed by the unusual pathology being treated, the common clinical application of this technology was not clearly apparent or yet elucidated.

In 1995, Ryu and Fagan presented a small series on the treatment of the ulnar collateral ligament Stener lesion arthroscopically, which represented the first time that we could see a common clinical application for this new minimally invasive approach [49]. They described an arthroscopic reduction of a Stener lesion in eight thumbs, with average follow-up period of just over 3 years, showing how simple reduction of the Stener lesion into the joint can place the avulsed ligament alongside its insertion site on the debrided base of the proximal phalanx. Prior to reduction, the ligament had been sitting outside the adductor aponeurosis and could therefore not heal in the necessary position. Once the reduction was performed, the ligament insertion site was aggressively debrided and the joint pinned to immobilize and allow healing. Upon removing the cast, a brief course of therapy was introduced and at follow-up no patient reported any pain or functional limitation. There was an excellent range of motion with strength parameters equal to or often greater than the thumb on the unaffected side. The only reported complication was an isolated simple pin tract infection. These results demonstrated that an all arthroscopic reduction of a Stener lesion obviated the need for open repair and subsequent complications such as prolonged recovery and stiffness. This was a clear clinical advantage and represented the first common clinical application that could encourage arthroscopic treatment of MCP joint pathology. Surprisingly, there was no mention of bony gamekeeper's lesions, and there was not a comparative study with the open method. Nevertheless, the primary triumph of this paper was that it was published in a widely read journal, first exposing hand surgeons to this minimally invasive technique and opening the door to other utilizations. In reality, this paper first introduced the concept of arthroscopic surgery in small joints to the greater hand surgery community. Nevertheless, despite the fact that this paper was published nearly 20 years ago, the technique remains minimally utilized and there have been few clinical series since then.

About 5 years later, in 1999, Rozmaryn and Wei presented the first broad paper on the technical aspects of metacarpophalangeal arthroscopy with elaboration on the possible indications and advantages of this still unknown technique [50]. They commented that there may be a misconception that the MCP joint is too small to perform any arthroscopic procedures in a useful or relevant manner. Although no clinical series was presented, they discussed the wider indications that might be addressed with this procedure. They discussed joint synovectomies and biopsies as previously mentioned and reaffirmed the concept of collateral ligament debridement while mentioning the possibility of ligament repair. They also introduced removal of loose bodies, treatment of osteochondral lesions, management of juxta-articular lesions, and treatment of intra-articular fractures and other possible clinical applications. They also noted that only a few case reports were present in the literature, and they surmised why this technique perhaps was not yet expanded upon. We must be cognizant, however, that this ample review was published in the journal *Arthroscopy: The Journal of Arthroscopic-Related Surgery*, and this would have created little exposure to dedicated hand surgeons, the clinicians most apt to utilize the technique. This report discussed some technical aspects and reviewed the anatomic landmarks for the first time since Dr. Chen's simplistic description with a rudimentary arthroscope nearly 20 years before. They stated that the advantages of arthroscopic versus open techniques were similar to those enjoyed in larger joints and that over time, more indications would emerge.

During the same year of Rozmaryn and Wei's technical paper, a broad review paper was published in *Hand Clinics* and entitled, "Arthroscopy of the Metacarpophalangeal Joint," by Slade and Gutow [51]. This represented the initial thorough analysis of the technique, including detailed technical explanations followed by some representative cases, including brief mention of minor complications and how to avoid them. However, the mantra "triumph of technology over reason" was also mentioned, suggesting arthroscopy of this small joint may not have been seen as practical or even useful. They explained that small joint arthroscopy required not only specialized instrumentation but also a working understanding of the anatomy within these joints. Their broad review soon revealed that there were a wide variety of indications that could greatly benefit from this technology. Detailed treatment techniques were described illustrated by case examples, particularly in the topic of intra-articular fracture treatment. A new method was also described where arthroscopy could be combined with small bone anchor application for reattachment of collateral ligament injuries. This may represent a difficult technique, but the authors clearly outlined the relative advantages of this method. In a discussion comparing arthroscopic synovectomies in rheumatoid patients with other joints treated in the same patient with open means, both surgeons and the patients alike clearly noted the decreased post-op swelling and the expedited rehab leading to faster return to activity. This represents a clear advantage of the arthroscopic technique as opposed to open means and in that same year, there was an obscure paper in the rheumatology literature that discussed the use of "mini-arthroscopy" of metacarpophalangeal joints in staging a synovitis and using this as an effective biopsy tool. The paper was written by rheumatologists in Germany and the paper focused on the scoring system of synovitis within rheumatoid patients with minimal elaboration of the operative technique [52]. They simply used this as a tool for assessing the degree of disease involvement but again emphasized its clinical utility. The authors, nonsurgeons, noted that micro-arthroscopy provided an objective technique for joint evaluation allowing visual guided synovial biopsy with improved accuracy and diminished the risk of any sampling errors. They performed this under local anesthesia, showing that general anesthesia was not necessary and, of course, could be done as an ambulatory procedure. Therefore, if the rheumatologists could see the great benefit of this technique, hand as well as arthroscopic surgeons could further develop its clinical application. In that same year Wei, who had coauthored the first technical description of metacarpophalangeal joint arthroscopy [50], presented an ample clinical series of arthroscopic synovectomies in rheumatoid arthritis describing 21 patients treated with arthroscopic synovectomy with good short-term results [52]. Although his intent was for this to be a technique article, he noted that the early results were promising and that this procedure would be useful in other types of arthritis or orthopedic maladies. He questioned the long-term outcomes and theorized what might be the ideal timing for this surgery in arthritic patients. This remains an unanswered question although Sekiya et al. elaborated on previous surgeons' descriptions by assessing 21 patients with rheumatoid arthritis in 27 proximal interphalangeal joints and 16 metacarpophalangeal joints. This represented the first clinical use of PIP joint arthroscopy and lent further support for metacarpophalangeal joint arthroscopic synovectomy [53]. He supported the concept that arthroscopic assessment of the joint surface and synovial lining was an optimal indication for arthroscopy including diagnostic biopsies under direct visualization. He also reasoned that arthroscopy for the small joints in the hands "will become a standard procedure in the near future." Their study did not assess other pathologies. Their study, also published in an arthroscopy journal, represents the last clinical series of arthroscopic surgery within the MCP joint. It is apparent that there is a paucity of clinical papers in the literature and that further discussion regarding the indications and clinical application of this tool is necessary in order to stimulate the hand surgeon to include this option in his realm of treatment possibilities. While the arthroscopic surgeon, typically known as a "sports medicine" specialist, may consider this option, it certainly remains for the hand surgeon to develop the clinical indications since we typically assess the more complex injuries, particularly the recalcitrant few. Therefore, it is up to hand surgeons to expand the applications of this still vastly underused methodology and this might include hand specialists who commonly do not perform wrist arthroscopy since the technique is much less daunting as later to be outlined. It is important to understand the indications and what role arthroscopy has in both detecting and treating these pathologies.

MCP Arthroscopy Indications

Traumatic and degenerative problems of the metacarpophalangeal joint are commonly encountered by hand specialists. Acute injury can involve any one of these joints and the thumb is the most commonly affected due to its relatively unprotected position. The Thumb MCP ulnar collateral ligament (UCL) tear is a frequently seen injury and is often erroneously termed "gamekeeper's thumb" when this should really be coined "skier's thumb" as the former refers more to a chronic attritional lesion. Acute trauma can also affect the finger MCPs with both ligamentous injuries and articular fractures presenting as a painful, swollen joint after injury. The term "overuse syndromes" may actually represent a previously occult acute injury that was not addressed or a chronic synovitis of unknown etiology. Plain X-rays will rarely shed light on chronic pain issues unless advanced degenerative disease or arthropathy is present, and imaging studies such as MRI are notoriously nonspecific in such small joints. Ultrasound presents a newer, more cost-effective modality that can determine if effusion is present, but not allow for anatomic diagnosis. Therefore, arthroscopy of the involved MCP joint will clarify the diagnosis, and also allow for potential treatment in a wide variety of indications of both thumb and digit MCP joints (Table 27.2).

Surgical indications to perform MCP arthroscopy will usually involve chronic conditions as opposed to acute injury since the latter can often be managed conservatively with appropriate immobilization. The thumb UCL avulsion is a common exception where open repair of a stener lesion is often required and simple immobilization may not suffice. In fact, an arthroscopic repair has been described in the literature as previously outlined [31]. With increasing familiarity of small joint arthroscopy, more acute indications may develop allowing accurate assessment of the precise injury and subsequent specific treatment.

Table 27.2 Indications for MCP arthroscopy

Acute	Chronic
Recent thumb ulnar collateral stener	Persistent MCP pain after trauma
Bony displaced gamekeeper's thumb	MCP OA—early/moderate grade
Septic MCP joint	Rheumatoid arthritis w/o ulnar drift
Articular die-punch fracture phalangeal base	Chronic synovitis

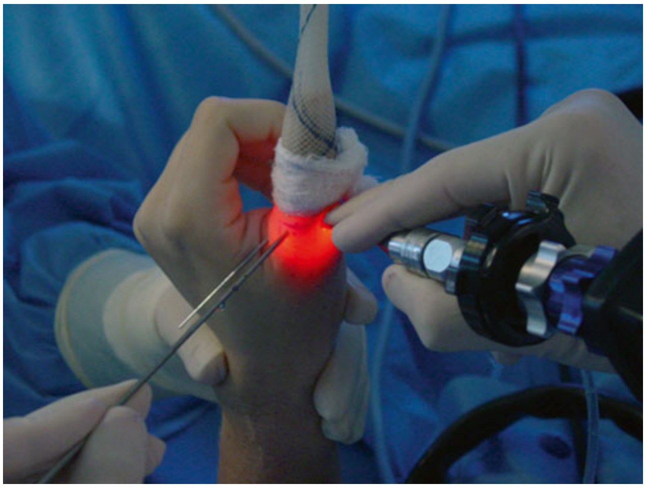


Fig. 27.10 External view of MCP arthroscopic treatment of an ulnar collateral bony avulsion where k-wire fixation will maintain reduction of the arthroscopically reduced fragment

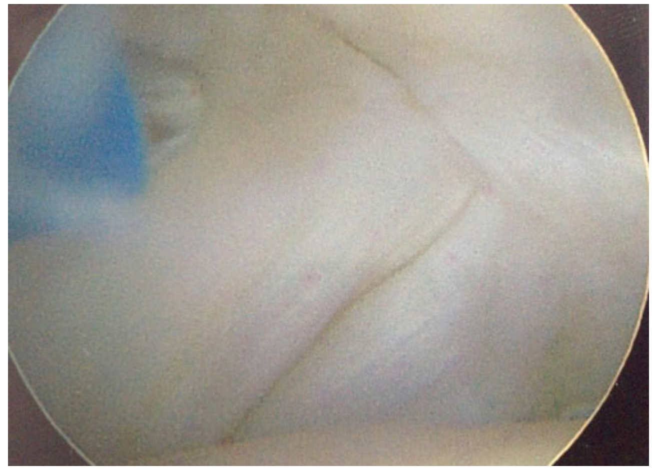


Fig. 27.11 Thermal shrinkage capsulorrhaphy in a chronically painful MCP joint stabilizes the capsule and collateral ligament minimizing the chance of recurrent painful synovitis. A period of post-op immobilization is necessary and dictated by the severity of the collateral ligament fraying

Acute indications generally involve an associated fracture that will need synovectomy, fracture debridement followed by articular reduction. This is likely true since the majority of ligamentous injuries will adequately heal with conservative immobilization, or are so severe that the resultant instability will lead to open management and repair. Perhaps the ideal acute indication for MCP arthroscopy is reduction of a collateral ligament avulsion fracture with a rotated fragment sitting within the joint. Once arthroscopic debridement at the fracture site has been performed, a small hook probe is used to simply derotate the bony fragment via arthroscopic visualization (Fig. 27.9). Kirschner wire fixation can then be performed with combination of arthroscopic control and fluoroscopic confirmation as published by this author [54] (Fig. 27.10). Additionally, another acute, albeit less common, indication would be a die-punch articular fracture, usually of the proximal phalanx base, where the scope can be used to control for the best articular reduction possible while facilitating the reduction itself. Besides a thorough synovectomy, the complete removal of any floating loose osteochondral fragments can be performed. This helps reduce the post-trauma inflammatory process in addition to reducing the fracture more anatomically. This arthroscopic method has the intrinsic advantage of a more exact articular reduction with the minimally invasive perk of limiting capsular adhesions, therefore faster recovery of an improved range of motion. Furthermore, like in any other arthroscopic acute indication, thorough assessment of associated soft tissue lesions can be performed and treated as needed. This may include MCP dislocations, where the acute capsule and ligamentous avulsions can be debrided after reduction, minimizing the scarring and expediting the healing process, even without actual soft tissue repair.

Chronic processes affecting the MCP joint, however, tend to be the most common indications for arthroscopy of these small joints. This is a welcome alternative since few options exist in a persistently painful “knuckle” joint. As discussed, most acute injuries heal with appropriate rehabilitation and/or immobilization with more severe trauma being managed by open repairs. Therefore, persistent pain and disability despite prolonged conservative treatment in both thumb and finger MCP trauma may represent the most common indication for MCP arthroscopy. It is not infrequent to encounter persistent symptoms after cast treatment for a skier’s thumb or perhaps a border digit hyperabduction injury. This is likely due to a more severe ligamentous injury than originally assessed, or perhaps a concomitant articular cartilage injury associated with persistent synovitis. Oftentimes the contralateral ligament is injured as well and was not fully addressed at time of initial treatment. An arthroscopic evaluation, whether in acute or chronic setting of injury, can accurately determine the location and extent of injury and can lead to concomitant treatment, whether by simple debridement and/or thermal radiofrequency capsulorrhaphy (Fig. 27.11). Typically, these types of ongoing complaints are managed by a prolonged course of NSAIDs, therapy, or a number of cortisone injections. In the setting of more substantial pathology, these treatments only provide temporary relief, if any, and cannot be sustained indefinitely. Herein lies the optimal value of arthroscopic treatment, since it provides a relatively simple option to both make a definitive diagnosis and provide treatment based on these findings.

Persistent, occult pain, often associated with chronic swelling and stiffness, also represents a clear indication to offer arthroscopic evaluation as well. These symptoms may stem from an unrecognized injury, initial presentation of osteoarthritis, or even an idiopathic synovitis that is occasionally seen and remains a diagnostic and even therapeutic dilemma Open synovectomy has been mostly indicated for rheumatoid indications, but until now, this has been the sole option for any patient presenting with a swollen, painful MCP joint that has failed conservative measures [55]. Steroid injections are frequently effective here, but can classically lead to acceleration of cartilage and capsular degeneration. These repeat injections to one joint must be recognized as a catabolic process and must be diminished. Arthroscopic debridement will avoid this complication and even possibly retard the degenerative and arthritic process. This benefit greatly outweighs the minimal complications that we might rarely see while the recovery is rapid.

Although not as common a location as other hand joints, degenerative arthritis of the MCP joints may represent a new frontier for arthroscopic assessment and treatment in managing this frustrating condition. The earliest stages of osteoarthritis are not clearly seen on plain radiographs and the diagnosis is often a clinical one. After adequate conservative treatment with NSAIDs and perhaps a course of therapy, the logical next step for treatment remains an intra-articular corticosteroid injection. If symptoms recur despite several injections, clinicians are often at a dead end since surgery is not usually offered to early stages of arthrosis or even younger patients. In this scenario, arthroscopic debridement becomes the best option short of joint replacement. Open arthrotomies with synovectomy are difficult due to limited visualization and poor access to certain regions of the joint. Furthermore, the approach itself can lead to marked post-op stiffness simply due to the arthrotomy itself. In rheumatoid disease, silicone arthroplasty remains the gold standard for MCP joints while post-traumatic arthrosis and osteoarthritis are not typically good indications for replacement arthroplasty [56]. Arthroscopy provides a minimally invasive alternative before offering arthroplasty, which in this indication would consist of the newer metallic or pyrocarbon non-constrained replacement options now available [57].

Inflammatory arthritides, such as rheumatoid arthritis, are typically managed with systemic pharmacotherapy, the newer disease modifying agents, and perhaps in later stages, replacement arthroplasty for MCP involvement. Rarely, a mono- or pauci-articular form is identified and a biopsy can be taken during arthroscopic rheumatoid synovectomy, confirming the diagnosis. Therefore, early stage involvement of these joints may warrant an arthroscopic synovectomy and capsular shrinkage as shown by Sekiya [53]. However, this approach is best suited when only a few joints are involved perhaps retarding the joint destruction and is impractical for severe, diffuse involvement. Furthermore, long-term results of arthroscopic rheumatoid synovectomy are necessary. Until more surgeons become adept at this technique, it will be difficult to collect sufficient data to justify its use in these advanced indications. Therefore, to break this vicious cycle, hand surgeons must learn this minimally invasive approach and begin to frequently apply it in the more ubiquitous pathologies.

MCP Arthroscopic Technique

Metacarpophalangeal arthroscopy demands use of an arthroscope 1.9 mm in diameter or less due to the narrow, relatively constrained anatomy of these small joints. A 1.9 mm 30° arthroscope as described by maxillofacial surgeons for temporomandibular (TMJ) pathology is utilized [58]. While newer arthroscopes are becoming available, even as small as 1 mm, the 1.9 scope should suffice for the described indications herein. The use of a 2.0 mm shaver is critical for synovectomy and most debridements, while small radiofrequency probes, including ablation and shrinkage applications, are often useful.

Small joint arthroscopy, including MCP joints, only requires local anesthesia and light IV sedation. The portal sites are both injected with minimal local anesthesia, followed by several cc’s of lidocaine, or similar short acting agents, introduced into the joint once the hand is vertically suspended using a single Chinese fingertrap on the involved digit. Intravenous sedation may be needed only to control tourniquet discomfort depending on the planned time of procedure or patient/anesthesiologist preference. The use of lidocaine with epinephrine may even obviate the need for a tourniquet since these are typically short lasting procedures.

Once 3–4 kg (5–8 lbs) of traction is applied, the joint-line is typically palpable and more local might be introduced into the joint, typically with the 18 gauge needle in order to determine the locations site for the portals. Longitudinal portal small incisions (stab wounds) are made with a small scalpel in the site of visible capsular bulging. This orientation is used since the patients MCP joint is typically immobilized in flexion and the incision direction is orientated parallel to the plane of motion. It is crucial to introduce the trocar into the joint in atraumatic fashion since most indications are for otherwise pristine joints and one must minimize iatrogenic injury within the narrow interval. The space between metacarpal head and proximal phalanx base is very narrow and one should find the appropriate position and insertion angle by inserting a small curved clamp once the joint is adequately distended with lidocaine or lactated ringer’s solution. The arthroscope is then inserted at this exact same angle and a thorough cursory joint examination is now performed. Portal anatomy is relatively simple as radial and ulnar portals lie on either side of the visible or palpable extensor tendon. Rarely, a third portal is for outflow, or better instrument direction, and is created by palpating the capsule, identifying area moving due to external pressure, and then inserting an 18 gauge needle to mark the area and possible portal site. A thorough synovectomy is usually performed at the outset, since this allows thorough inspection of the joint and to localize the pathology. As this is done with a small full radius shaver, the articular structures including capsule and collateral ligaments will soon be more apparent. A radiofrequency ablator probe can also make this ablation process more precise and rapid. It is important to use RF judiciously, as the joint capsule is relatively thin and subcutaneous, and thermal injury can result to either capsule or articular surface. Once synovectomy is underway, the surgeon can now begin to identify any pathology or anatomic variations and should be done in a reproducible systematic manner in order to avoid overlooking pathology. For example, one may begin on the radial collateral ligament, then assess the volar plate, look for sesamoids, then the ulnar collateral ligament and finally followed by dorsal capsule and extensor. The articular surface of both proximal phalanx and metacarpal head is then evaluated including the synovial recesses and the collateral ligament origins. Once specific pathology is identified and treated, the arthroscope is retired and portals are closed with benzoin and steri-strips only, obviating any stitches which is where dorsal hand scarring may result and can easily be avoided. Any pins utilized are cut underneath the skin and the thumb MCP is usually protected with a short arm thumb spica plaster intra-op splint in MCP extension and thumb palmar abduction/opposition. Conversely, arthroscopy of any of the digits will necessitate a dorsal metacarpophalangeal block splint, usually in full MCP flexion in order to allow the collateral ligaments to heal in their most taut position and to minimize any resultant loss in motion, usually flexion. The period of immobilization is determined by the type and extent of pathology found during the arthroscopic intervention and can be determined intraoperatively. Post-op therapy often plays a crucial role, although only after the appropriate period of immobilization.

MCP arthroscopy remains a vastly underutilized but very useful technique for both diagnosing and treating acute and chronic injuries afflicting that joint. While the indications expand amongst the few utilizers, the majority of hand surgeons would benefit from the minimal training needed to include this in their treatment armamentarium [59, 60].

Proximal Interphalangeal Arthroscopy

Arthroscopy of the Proximal interphalangeal (PIP) joints should still be viewed as an emerging procedure and very little has been written in the literature. Despite this, Chen's hallmark paper in *Orthopedic Clinics of North America* did present one clinical case and eight cadaveric studies utilizing small joint arthroscopy of the PIP joint [1]. The only clinical case was in a rheumatoid patient which foreshadowed future attempts since only RA has been studied as an indication in this rarely performed procedure.

The initial paper devoted solely to PIP joint arthroscopy was published by Thomsen et al. in a 2002 volume of the *Journal of Hand Surgery* [61]. They focused on anatomic findings, including portal anatomy, in eight cadaveric PIP joints followed by two clinical cases. The only firm conclusion was that the technique was possible, although technically demanding and limited by instrumentation, and that indications needed to be delineated while commenting that synovitis, infection, and loose body excision would be the main indications. In this early clinical description, one of the patients was rheumatoid while the other was a removal of a loose body coupled with synovectomy.

In the same year, Sekiya and his group presented a thorough analysis of both MCP and PIP arthroscopy in 21 rheumatoid patients as previously mentioned in the MCP arthroscopy discussion [53]. Twenty-seven PIP joints and 16 MCP joints underwent rheumatoid synovectomy although most reportedly had only "joint irrigation." They determined it was a promising procedure allowing biopsies and concluding that synovectomies led to early clinical improvement. There was no mention of the results longevity but it was felt that small joint arthroscopy, including PIP, could become a standard procedure in the future. They did warn that technique was very limited, both by joint configuration/morphology and largely by the equipment utilized. The rigidity and relative size of the arthroscope would not permit exploration of the volar half of the middle phalanx base and even the proximal phalangeal condyles could only be seen by significant flexion of the joint. Therefore, this is the only hand joint where vertical traction is not utilized and the finger is held horizontally while the small scope is introduced in the interval between central slip and lateral band in his modified portal from Thomsen's description. While this study focused on rheumatoid disease we must recall that the PIP joint is more commonly involved in routine osteoarthritis. No clinical study reviewing this very common pathology has been published. It should also be noted that this work was published in the journal *Arthroscopy* where, again, few hand surgeons might see a technique reviewed that likely only they would utilize. This can now be seen as a recurring theme that perhaps has slowed the advent of small joint arthroscopy of the hand.

Sekiya did publish a follow-up study, now in a hand techniques journal, where he expanded modestly upon his experience in RA PIP arthroscopy but did now conclude that the results tend to be long lasting, and that no patients had required reoperation, a notable finding [62]. His follow-up study also included one thumb interphalangeal joint, perhaps the first clinical mention of arthroscopy in a distal interphalangeal joint (DIP). Actually, the true DIP joint of a digit was first scoped in order to realize an arthroscopic-assisted arthrodesis as described by Cobb in his chapter on "Frontiers in Small Joint Arthroscopy" with coauthors, Berner, Badia, and Topper in 2011 Hand Clinics [60]. The topic of DIP arthroscopy is so novel and currently limited that it warrants no further discussion. Suffice it to say that when microarthroscopes, in range of 1–1.2 mm, become widely available in the future, we may then see indications develop for this innovative approach. Arthroscopic debridement for early OA, truncation of mucous cysts with evacuation, and synovectomy may all be routine procedures in future as the technology emerges.

Indications do remain narrow for PIP arthroscopy largely due to the relative large size and rigidity of the scope in this bicondylar joint, which is anything but a flat surface. Although similar to the knee in bony architecture, the small size of the joint does not permit the same visualization at the current time.

Therefore, the technique remains limited to dorsal compartment synovectomy, mainly in rheumatoid, and perhaps larger osteoarthritic patients. Removal of loose bodies, infection lavage, and now joint arthrodesis might be possible as well. Joint debridement and synovectomy should be performed solely with mechanical shaving since the joint is subcutaneous where application of RF (radiofrequency) could be problematic.

PIP Arthroscopic Technique

The anatomic nuances of the PIP joint necessitate that this arthroscopy be performed horizontally, allowing free motion of the digit during the scope permitting visualization of most elements of the joint, although the entire volar compartment is essentially inaccessible. Traction in a vertical position would hamper that visualization and would not permit joint flexion.

The PIP joint should be insufflated with 1–2 cc of lidocaine once adequate digital block anesthesia is achieved. This joint distention is performed dorsally allowing the dorsal recesses to become prominent and facilitate 1.9, or perhaps 1.5 mm, arthroscope insertion. The portals are simply on either side of the central slip, easily found between that key landmark and the lateral bands. In his initial paper, Sekiya described a more volar and lateral portal, essentially traversing the transverse retinacular ligament, about 1–2 mm dorsal to the mid-axial line [53]. It must again be emphasized that the palmar aspect of the joint is not visualized sufficiently which happens to be the predominant location for synovitis at the PIP joint, in addition to the dorsal recess, currently amenable to excision. This technical issue could be overcome if perhaps flexible micro-arthroscopes can pass over and around the proximal phalangeal condyles, hence providing more visualization. The procedure would also require smaller shavers that can also follow the contours of the joint. An additional problem is that inadequate suction power currently limits the efficacy of shavers this small in diameter. Even today's 2 mm suction shavers are somewhat limited when trying to aggressively debride and aspirate a dense amount of scarred capsule. Therefore, there are currently both optical and mechanical limitations in technically being able to realize an optimal PIP joint arthroscopic procedure. Once these issues are resolved, the indications should quickly expand although it may be some decades before this becomes an everyday procedure for the hand surgeon.

CMC Arthroscopy of Ulnar Digits

The fourth and fifth carpometacarpal joints are also amenable to arthroscopic intervention due the flexible nature of these joints. Pathology, however, is relatively rare here and the indication is primarily for traumatic related condition. It is relatively common to have post-traumatic issues at this joint, either arthrosis and/or synovitis, that would benefit from synovectomy and debridement [60]. Articular fractures of either the hamate or corresponding metacarpal base often lead to later degenerative changes that can cause pain. Insertion of a 1.9 mm arthroscope and concomitant debridement with a shaver and/or RF probe (Fig. 27.12) can provide good pain relief and perhaps avoid fusion of the CMC joint which is currently a necessary procedure in cases of post-traumatic arthrosis not responding to conservative treatment such as corticosteroid injection. The fusion itself might be able to be done arthroscopically as currently seen in limited carpal fusions by colleagues such as Ho [63].

Fig. 27.12 Arthroscopic debridement of the fifth CMC joint in patient with persistent pain after an articular fracture of the small finger metacarpal base

Conclusion

Small joint arthroscopy of the hand is currently limited by a combination of technical considerations that are improving continuously, and a lack of clear indications and surgeon utilization likely due to scarce arthroscopy training and scant literature on the topic. The latter reason is self-imposed, and hand surgery organizations must provide more opportunities for "hands-on" training in the usage of the small arthroscope to emerging surgeons who might not be exposed to this in their fellowship training. EWAS (European Wrist Arthroscopy Association) has made major strides in training hand surgeons to push the envelope when it comes to wrist arthroscopic procedures even publishing entire textbooks covering a single indication for its usage [64]. There have been some courses (AANA, Miami, Strasbourg) that have covered the topic to some degree, largely in the area of the thumb basal joint, enabling colleagues to now consider this as a viable alternative for treatment in their patients. Much more needs to be done to expose surgeons to all the small joint procedures possible in the hand, ultimately to benefit their patients who are increasingly looking towards minimally invasive options.

References

1. Chen YC. Arthroscopy of the wrist and finger joints. Orthop Clin North Am. 1979;10(3):723–33.
2. Gupta R, Bozentka DJ, Osterman AL. Wrist arthroscopy: principles and clinical applications. J Am Acad Orthop Surg. 2001;9(3):200–9.
3. Badia A. Arthroscopy of the trapeziometacarpal and metacarpophalangeal joints. J Hand Surg Am. 2007;32(5):707–24.
4. Menon J. Arthroscopic management of trapeziometacarpal joint arthritis of the thumb. Arthroscopy. 1996;12:581–7.
5. Berger R. Arthroscopic evaluation of the first carpometacarpal joint. J Hand Surg Am. 1998;23:757.
6. Bettinger PC, Linscheid RL, Berger RA, Cooney WP, Kai-Nan A. An anatomic study of the stabilizing ligaments of the trapezium and trapeziometacarpal joint. J Hand Surg Am. 1999;24:786–98.
7. Osterman AL, Culp R, Bednar J. Arthroscopy of the thumb carpometacarpal joint. Arthroscopy. 1997;13:3.
8. Badia A. Trapeziometacarpal arthroscopy: a classification and treatment algorithm. Hand Clin. 2006;22:153–63.
9. Weitbrecht J. Syndesmology. Philadelphia: WB Saunders; 1969. p. 1742.
10. Van Brenk B, Richards RR, Mackay MB, Boynton EL. A biomechanical assessment of ligaments preventing dorsoradial subluxation of the trapeziometacarpal joint. J Hand Surg Am. 1998;23:607–11.
11. Zancolli EA, Cozzi EP. The trapeziometacarpal joint: anatomy and mechanics. In: Zancolli E, Cozzi EP, editors. Atlas of surgical anatomy of the hand. New York: Churchill Livingstone; 1992. p. 443–4.
12. Xu L, Strauch RJ, Ateshian GA, et al. Topography of the osteoarthritic thumb carpometacarpal joint and its variation with regard to gender, age, site, and osteoarthritic stage. J Hand Surg Am. 1998;23:454.
13. Pelligrini VD. Pathomechanics of the thumb trapeziometacarpal joint. Hand Clin. 2001;17(2):175–84.
14. Bettinger PC, Berger RA. Functional ligamentous anatomy of the trapezium and trapeziometacarpal joint (gross and arthroscopic). Hand Clin. 2001;17(2):151–69.
15. Orellana MA, Chow JC. Arthroscopic visualization of the thumb carpometacarpal joint: introduction and evaluation of a new radial portal. Arthroscopy. 2003;19(6):583–91.
16. Walsh EF, Akelman E, Fleming BC, DaSilva MF. Thumb carpometacarpal arthroscopy: a topographic, anatomic study of the thenar portal. J Hand Surg Am. 2005;30:373–9.
17. Slutsky D. The use of a dorsal-distal portal in trapeziometacarpal arthroscopy. Arthroscopy. 2007;23(11):1244.e1–4.
18. Culp RW, Rekant MS. The role of arthroscopy in evaluating and treating trapeziometacarpal disease. Hand Clin. 2001;17(2):315–9.
19. Massoud SN, Levy O, Copeland SA. Radiofrequency capsular shrinkage for voluntary shoulder dislocation. J Shoulder Elbow Surg. 2007;16(1):43–8.
20. Lubowitz JH, Poehling GG. Glenohumeral thermal capsulorrhaphy is not recommended—shoulder chondrolysis requires additional research. Arthroscopy. 2007;23(7):687.
21. Lopez MJ, Hayashi K, Fanton GS, Thabit G, Markel MD. The effects of radiofrequency energy on the ultrastructure of joint capsular collagen. Arthroscopy. 1998;14(5):495–501.
22. Hecht P, Hayashi K, Cooley AJ, Lu Y, Fanton GS, Thabit G, Markel MD. The thermal effect of monopolar radiofrequency energy on the properties of joint capsule. Am J Sports Med. 1998;26(6):808–14.
23. Eaton RG, Glickel SZ. Trapeziometacarpal osteoarthritis. Staging as a rationale for treatment. Hand Clin. 1987;3:455–71.
24. Thompson JS. Suspensionplasty: trapeziometacarpal joint reconstruction using abductor pollicis longus. Operat Tech Orthop. 1996;6:98–105.
25. Cobb T, Sterbank P, Lemke J. Arthroscopic resection arthroplasty for treatment of combined carpometacarpal and scaphotrapeziotrapezoid (pantrapezial). J Hand Surg Am. 2011;36(3):413–9.
26. Braun RM. Total joint replacement at the base of the thumb—preliminary report. J Hand Surg. 1982;7:245–51.
27. Badia A, Sambandam SN. Total joint arthroplasty in the treatment of advanced stages of thumb carpometacarpal joint osteoarthritis. J Hand Surg Am. 2006;31(10):1605–14.
28. Goldfarb C, Stern P. Indications and technique for thumb carpometacarpal joint arthrodesis. Tech Hand Up Extrem Surg. 2002;6(4):178–84.
29. Badia A, Young L, Riano F. Bilateral arthroscopic tendon interposition arthroplasty of the thumb carpometacarpal joint in a patient with Ehlers-Danlos syndrome: a case report. J Hand Surg Am. 2005;30(4):673–6.
30. Gisselfält K, Edberg B, Flodin P. Synthesis and properties of degradable poly(urethane urea)s to be used for ligament reconstructions. Biomacromolecules. 2002;3:951–8.
31. Nilsson A, Liljensten E, Bergstrom C, Sollerman C. Results from a degradable TMC joint spacer (Artelon) compared with tendon arthroplasty. J Hand Surg Am. 2005;30(2):380–9.
32. Badia A. Arthroscopic indications for artelon interposition arthroplasty of the thumb trapeziometacarpal joint. Tech Hand Up Extrem Surg. 2008;12(4):1–6.
33. Kuhns CA, Meals RA. Hematoma and distraction arthroplasty for basal thumb osteoarthritis. Tech Hand Up Extrem Surg. 2004;8:2–6. Gervis simple resection.
34. Gervis HW. Excision of the trapezium for osteoarthritis of the trapeziometacarpal joint. J Bone Joint Surg Br. 1949;31:537–9.
35. Yao J. Suture-button suspensionplasty for the treatment of thumb carpometacarpal joint arthritis. Hand Clin. 2012;28(4):579–85.
36. Wilson JN. Basal osteotomy of the first metacarpal in the treatment of arthritis of the carpo-metacarpal joint of the thumb. Br J Surg. 1973;60:854–8.

37. Tomaino MM. Treatment of Eaton stage I trapeziometacarpal disease with thumb metacarpal extension osteotomy. J Hand Surg Am. 2000;25(6):1100–6.
38. Badia A, Khachandani P. Treatment of early basal joint arthritis using a combined arthroscopic debridement and metacarpal osteotomy. Techniques in Hand & Upper Extremity Surgery June. 2007;11(2):168–73.
39. Buck-Gramcko D, Dietrich FE, Gogge S. Evaluation criteria in follow-up studies of flexor tendon therapy [in German]. Handchirurgie. 1976;8:65–9.
40. Bettinger PC, Linscheid RL, Cooney 3rd WP, An KN. Trapezial tilt: a radiographic correlation with advanced trapeziometacarpal joint arthritis. J Hand Surg Am. 2001;26:692–7.
41. Barron OA, Eaton RG. Save the trapezium: double interposition arthroplasty for the treatment of stage IV disease of the basal joint. J Hand Surg Am. 1998;23:196–204.
42. Cobb T. Arthroscopic STT, arthroplasty. J Hand Surg Am. 2009;34 Suppl 1:42–3.
43. Ashwood N, Bain G, Wardle N. STT scope. Results of Arthroscopic Debridement for Isolated Scapho-trapeziotrapezoidal Arthritis. Orthopaedic proceedings of JBJS (Br) 2008; 90-B (Supp I 3-4).
44. Bare J, Graham A, Tham S. Scaphotrapezial joint arthroscopy: a palmar portal. J Hand Surg Am. 2003;28:605–9.
45. Carro L, Golano P, Farinas O, Cereza L, Hidalgo C. The radial portal for scaphotrapeziotrapezoid. Arthroscopy. 2003;19(5):547–53.
46. Vaupel GL, Andrews JR. Diagnostic and operative arthroscopy of the thumb metacarpophalangeal joint. A case report. Am J Sports Med. 1985;13(2):139–41.
47. Wilkes LL. Arthroscopic synovectomy in the rheumatoid metacarpophalangeal joint. J Med Assoc Ga. 1987;76:638–9.
48. Leclercq G, Schmitgen G, Verstreken J. Arthroscopic treatment of metacarpophalangeal arthropathy in haemochromatosis. J Hand Surg Br. 1994;19:212–4.
49. Ryu J, Fagan R. Arthroscopic treatment of acute complete thumb metacarpophalangeal ulnar collateral ligament tears. J Hand Surg Am. 1995;20:1037–42.
50. Rozmaryn LM, Wei N. Metacarpophalangeal arthroscopy. Arthroscopy. 1999;15:333–7.
51. Slade 3rd JF, Gutow AP. Arthroscopy of the metacarpophalangeal joint. Hand Clin. 1999;15:501–27.
52. Wei N, Delauter SK, Erlichman MS, Rozmaryn LM, Beard SJ, Henry DL. Arthroscopic synovectomy of the metacarpophalangeal joint in refractory rheumatoid arthritis: a technique. Arthroscopy. 1999;15:265–8.
53. Sekiya I, Kobayashi M, Taneda Y, Matsui N. Arthroscopy of the proximal interphalangeal and metacarpophalangeal joints in rheumatoid hands. Arthroscopy. 2002;18:292–7. Badia bony gamekeeper.
54. Badia A, Riano F. Arthroscopic reduction and internal fixation for bony gamekeeper's thumb. Orthopedics. 2006;29(8):675–8.
55. Thompson M, Douglas G, Davison EP. Synovectomy of the metacarpophalangeal joints in rheumatoid arthritis. Proc R Soc Med. 1973;66(2):197–9.
56. Swanson AB. Finger joint replacement by silicone rubber implants and the concept of implant fixation by encapsulation. Ann Rheum Dis. 1969;28 Suppl 5:47–55.
57. Parker WL, Rizzo M, Moran SL, Hormel KB, Beckenbaugh RD. Preliminary results of nonconstrained pyrolytic carbon arthroplasty for metacarpophalangeal joint arthritis. J Hand Surg Am. 2007;32(10):1496–505.
58. McCain JP, Sanders B, Koslin MG, Quinn JH, Peters PB, Indresano AT. Temporomandibular joint arthroscopy: a 6-year multicenter retrospective study of 4,831 joints. J Oral Maxillofac Surg. 1992; 50(9):926–30.
59. Berner S. Metacarpophalangeal arthroscopy: indications and technique. Tech Hand Up Extrem Surg. 2008;12(4):208–15.
60. Cobb T, Berner S, Badia A. New frontiers in hand arthroscopy. Hand Clin. 2011;27(3):383–94.
61. Thomsen N, Nielsen N, Jorgensen N, Bojsen-Moller F. Arthroscopy of the proximal interphalangeal joints of the finger. J Hand Surg Br. 2002;27(3):253–5.
62. Sekiya I, Kobayashi M, Okamoto H, Iguchi H, Waguri-Nagaya Y, Goto H, Nozaki M, Tsuchiya A, Otsuka T. Arthroscopic synovectomy of the metacarpophalangeal and proximal interphalangeal joints. Tech Hand Up Extrem Surg. 2008;12(4):221–5.
63. Ho P-C. Arthroscopic partial wrist fusions. Tech Hand Up Extrem Surg. 2008;12(4):242–65.
64. DelPinal F, Luchetti R, Mathoulin C, editors. Arthroscopic management of distal radius fractures. Heidelberg, Germany: Springer Verlag; 2010.

Endoscopic Carpal Tunnel Release

28

Steven M. Topper

Introduction

The debate in the literature between open and endoscopic carpal tunnel release (ECTR) through the 1990s and into the early part of the twenty-first century was voluminous. In the end we were left with no definitive scientific proof favoring one procedure over the other. Consequently both are still done today. While the controversy has died down, questions still remain. The Academy of Orthopedic Surgeons work group, which created clinical and diagnosis guidelines for carpal tunnel release, expressed in their 179 page report what is generally accepted as the conventional wisdom. They concluded that ECTR was favored for outcome measures of pain, pinch strength, and fewer wound complications at 12 weeks. Open carpal tunnel release was favored for the complication of reversible nerve issues (neuropraxia is less likely with OCTR). There were no differences for functional status and symptom severity at 1 year, including complications or infections [1]. In other words both procedures are equally safe and effective and there is a somewhat quicker recovery with the endoscopic approach in the first 3 months. Perhaps societal issues such as cost effectiveness and quality of life will drive us to seek more definitive answers such as happened with laparoscopic cholecystectomy [2]. Until that time we are left with randomized controlled trials and meta-analyses that generally have insufficient power and inconsistent outcome measures making it hard to draw conclusions [3]. Fortunately, division of the transverse carpal ligament is an effective way to treat carpal tunnel syndrome. The application of minimally invasive (endoscopic) techniques to the most commonly performed orthopedic procedure, back in the 1980s, made sense. The hope was that it would decrease the morbidity of the procedure and yield a quicker recovery. In so doing it may also create a societal cost savings, in light of the number of working young people that have carpal tunnel surgery. Though there is no definitive scientific proof that this has been accomplished there is also no proof that it hasn't. Early on there were major concerns about safety because the technical aspects of the procedure required a relatively new skill set. Triangulation used in all arthroscopic and endoscopic procedures is a universal skillset among orthopedic, plastic, and general surgeons today.

Anatomy

There are several anatomic points that are important to understand in order to perform endoscopic carpal tunnel release safely and effectively.

Transverse Carpal Ligament

Incomplete release of the transverse carpal ligament (TCL) has been touted as a cause for failure of both open and endoscopic carpal tunnel release. From the endoscopic perspective the distal aponeurotic portion of the ligament can be hidden by the fat pad. Additionally, just beyond the distal aspect of the ligament (about 4.8 mm) lies the superficial palmar arch. While striving for a complete release is important this must be done judiciously so as not to cause neurovascular injury. The goal is to maximize volume increase in the carpal canal in order to decompress the median nerve. In a cadaver study Cobb et al. [4] demonstrated that incomplete release of the distal 4 mm of the TCL allows carpal arch widening (volume increase) that is no different from that following complete division of the TCL (Fig. 28.1). So, while complete release is the goal it is not necessary to fight for every last distal fiber and increase the risk of neurovascular injury.

S.M. Topper, M.D. (✉)
Colorado Hand Center, 3470 Centennial Boulevard, Suite 200, Colorado Springs, CO 80907, USA
e-mail: stopper@coloradohandcenter.com

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*,
DOI 10.1007/978-1-4614-1596-1_28, © Springer Science+Business Media New York 2015

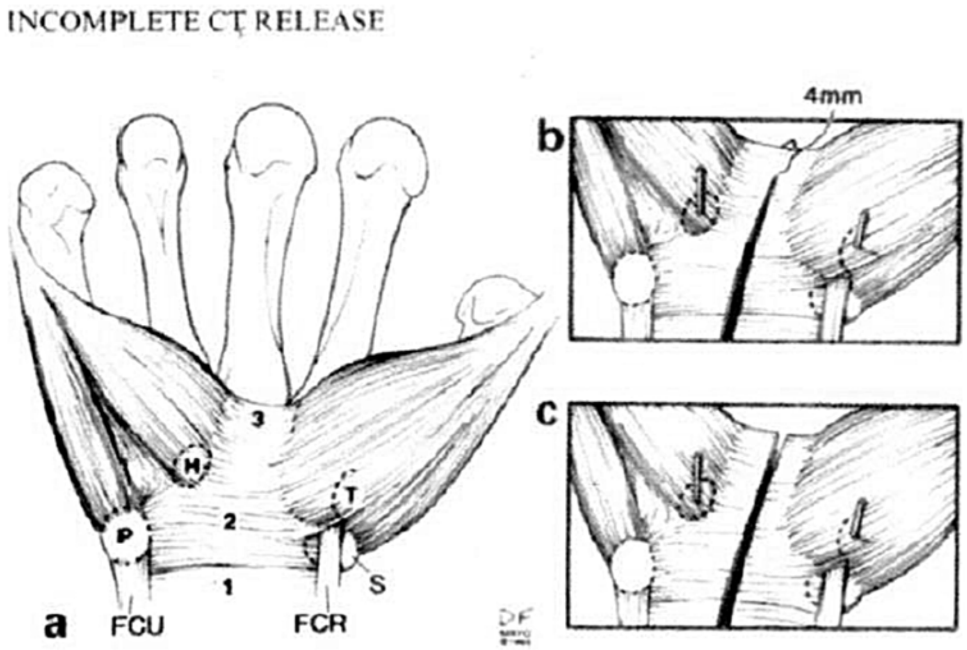


Fig. 28.1 (**a**) Three segments of flexor retinaculum. *H* hamate hook, *T* trapezium, *P* pisiform, *S* scaphoid, *FCU* flexor carpi ulnaris, *FCR* flexor carpi radialis. 1: proximal, 2: middle, true transverse carpal ligament, 3: distal aponeurotic portion of the flexor retinaculum. (**b**) partial release of the flexor retinaculum. (**c**) Complete release of the flexor retinaculum. K wires are shown in hamate hook and trapezium [Reprinted from Cobb TK, Cooney WP. Significance of Incomplete Release of the Distal Portion of the Flexor Retinaculum. J Hand Surg Br. 1994; 19: 283–285. With permission from Sage Publications]

Hook of the Hamate

There is an increased risk of neuropraxia with endoscopic carpal tunnel release. This can be minimized by hugging the ulnar aspect of the carpal canal with the endoscopic instrument. In order to do this effectively and provide for a straight line of pull it is important to place the skin incision in relation to the hook of the hamate. Unfortunately, the hook of the hamate can be difficult to palpate and the use of Kaplan's cardinal line is unreliable. Based on an anatomic study [5] the hook of the hamate can be reliably localized with the technique demonstrated in Fig. 28.2.

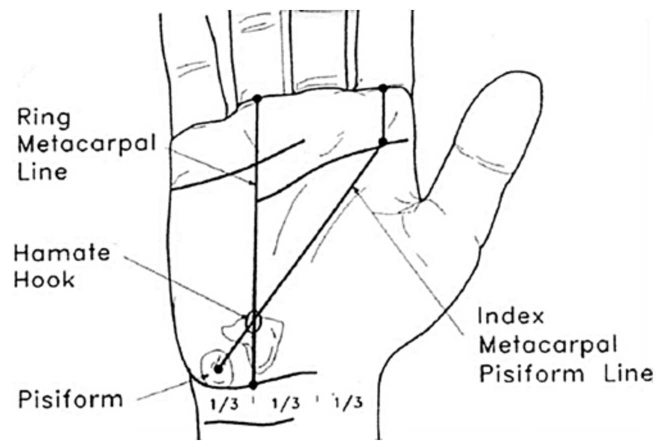


Fig. 28.2 The pisiform is palpated. A line is drawn from this point to the proximal palmar crease at the level of the central aspect of the index finger. A second line is drawn from the central portion at the base of the ring finger to the distal flexor crease of the wrist at the junction of the middle and ulnar thirds. The junction of these two lines marks the location of the hook of the hamate [Reprinted Cobb TK, Cooney WP, An K. Clinical location of Hook of Hamate: A technical Note for Endoscopic Carpal Tunnel Release. J Hand Surg Am. 1994; 19: 516-518. With permission from Elsevier]

Palmar Fascia

Palmar displacement of the flexor tendons after release of the transverse carpal ligament (Bowstringing) has been implicated as a cause for weakness after carpal tunnel surgery. In fact step cut lengthening of the transverse carpal ligament has been advocated to prevent this [6]. The majority of the palmar fascia is not divided with endoscopic carpal tunnel release which provides an uninjured natural tissue barrier to bowstringing.

Transligamentous Branch of the Median Nerve

The recurrent motor branch of the median nerve passes around the distal edge of the TCL in most cases. It also can pass through the ligament in up to 23 % of cases which causes challenges with both open and endoscopic carpal tunnel release [7]. Fortunately, the nerve rarely arises from the ulnar aspect of the median nerve and is therefore rarely encountered. This underscores another important reason to hug the ulnar aspect of the canal when performing endoscopic carpal tunnel release. Anatomic variations such as a persistent median artery or aberrant muscle tendon relationships and dimpling of the TCL should alert the surgeon to the presence of a transligamentous branch. Dealing with a transligamentous branch safely, for both open and endoscopic carpal tunnel release, is about visualization. Therefore the

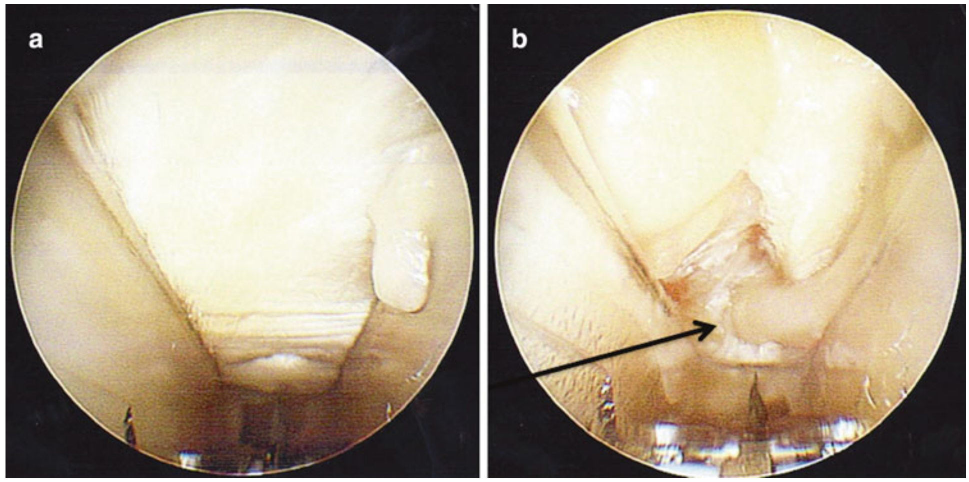


Fig. 28.3 (**a**) Endoscopic view showing a dimple in the distal 1/3 of the transverse carpal ligament. There is a small synovial frond on the *right*. (**b**) Post-division of the TCL. *Arrow* locates the transligamentous branch of the median nerve

presence of a transligamentous branch does not necessarily preclude accomplishing the procedure (Fig. 28.3).

Glabrous Skin

Glabrous skin (palm of hands and sole of feet) is unique in that it has no hair follicles and it is highly innervated. One of the distinct advantages of the single incision approach to endoscopic carpal tunnel release is the ability to place the incision outside of the glabrous skin, avoiding the associated morbidity and potential wound complications. This advantage is lost with the two incision endoscopic technique. Additionally the two incision technique is fraught with a higher complication rate [8].

Exposure

The patient is positioned supine on the operating room table with the arm abducted on a hand table. It is useful to place the hand palm up in a holder or over a surgical towel so that the wrist is extended 15–20° (Fig. 28.4). The hand, wrist, forearm, and the arm proximal to the elbow should be completely exsanguinated using an Esmark bandage. The tourniquet is then elevated to create a bloodless field. The surgeon's hand, when holding the instrument, should naturally align the blade assembly so that it points axially from the ulnar side of the carpal tunnel to the base of the ring finger. This course is anatomically optimal for avoiding injury to the median nerve. Right-handed surgeons will usually prefer a position in the axilla for a right carpal tunnel release and cephalic position for a left release. It is vice versa for left-handed surgeons. The surgeon should be able to easily view the monitor over the assistant's right or left shoulder. General or regional anesthesia is advised so that visualization is not obscured by a carpal canal full of anesthetic fluid.

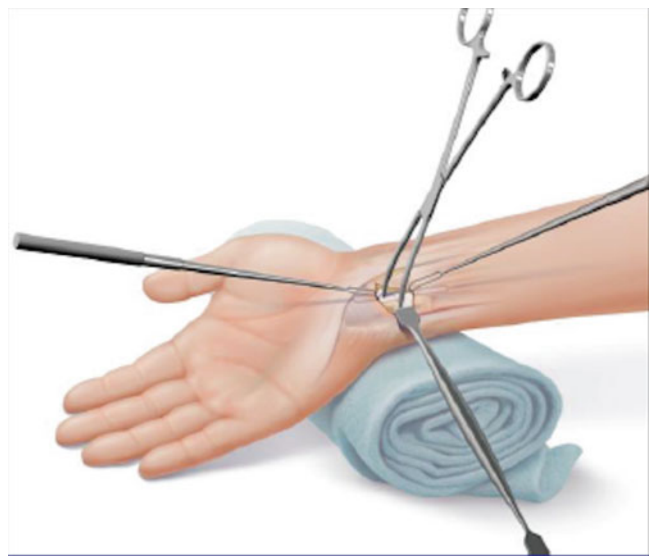


Fig. 28.4 Patient positioning [Reprinted from Centerline Endoscopic Carpal Tunnel Release: Surgical Technique. Arthrex, Inc.; 2010. With permission from Arthrex, Inc.]

The surgical incision is placed transversely in or near one of the wrist flexion creases (usually the proximal) between the flexor carpi ulnaris and the palmaris longus (PL) (Fig. 28.5). If the patient does not have a PL, the radial extent of the incision should be 2 cm ulnar to the flexor carpi ulnaris. The incision is usually 2 cm in length. Veins that cross the incision are coagulated with a bipolar and divided. Placement of the skin incision and the position of the hook of the hamate will set the trajectory of the endoscopic device. Therefore it is advisable to mark out the hook of the hamate, at least initially, as a surgeon is becoming comfortable with placement of the incision.

The soft tissue dissection is started on the radial aspect of the incision and taken directly down to the antebrachial fascia. In this location the flexor retinaculum is closely adherent to the antebrachial fascia. As you move medial and lateral

Fig. 28.5 Incision [Reprinted from Centerline Endoscopic Carpal Tunnel Release: Surgical Technique. Arthrex, Inc.; 2010. With permission from Arthrex, Inc.]

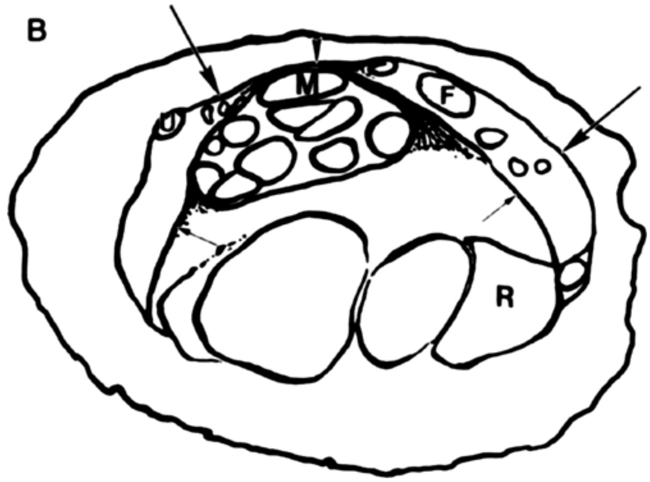


Fig. 28.6 Cross section of the wrist. The flexor retinaculum and the antebrachial fascia are closely apposed anteriorly in the middle (*arrowhead*) and split medially and laterally. *Large arrows* show antebrachial fascia. *Small arrows* show flexor retinaculum. *M* median nerve, *U* flexor carpi ulnaris, *F* flexor carpi radialis [Reprinted from Cobb TK, Dalley BK, Posteraro RH, Lewis RC. Anatomy of the Flexor Retinaculum. J Hand Surg Am. 1993; 18: 91-99. With permission from Elsevier]

from the center these tissues divide and it is much easier to get out of the proper plane of dissection [9] (Fig. 28.6). This dissection is then swept in an ulnar direction. This method reveals a consistent plane that mobilizes Guyon's canal contents, allowing for their retraction out of harm's way. During this portion of the procedure, fascial bands are often encountered that may inhibit the mobilization of these tissues.

This is overcome by simply dividing the restricting fascial bands. Once mobilized the subcutaneous fat and Guyon's canal contents are retracted in an ulnar direction with a blunt retractor. The antebrachial fascia is divided in line with the incision by simply spreading with a blunt tip scissor. It is not necessary to create a U shaped flap as has been advocated, which creates unnecessary surgical trauma. This maneuver creates access to the carpal tunnel. A small two-prong skin retractor is placed on the leading edge of the transverse carpal ligament and used to elevate this structure. This is actually the most important step of the operation. By securing the leading edge of the TCL the exposure is set and should be maintained until the operation is complete.

Preparation

A small Hagar Dilator is then used to dilate the carpal tunnel and create a track for the endoscopic device (Fig. 28.7). The dilator is aimed at the base of the ring finger while holding

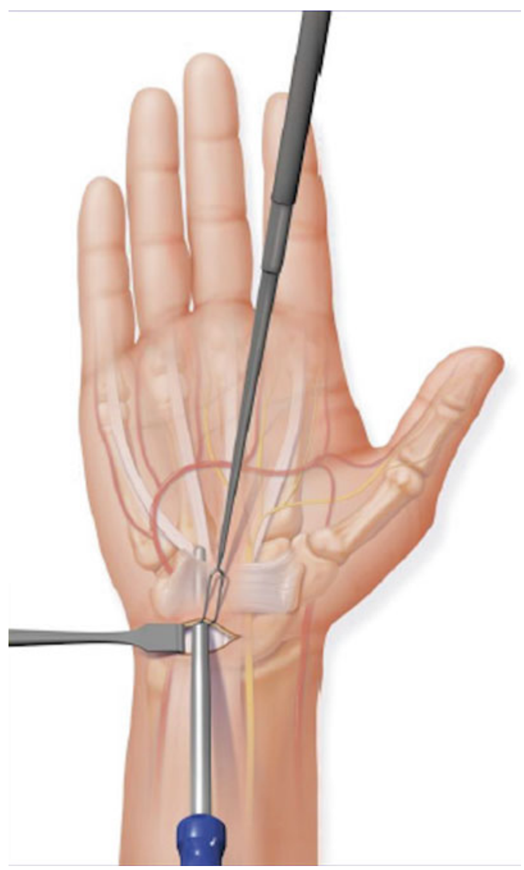


Fig. 28.7 Dilation of the carpal canal [Reprinted from Centerline Endoscopic Carpal Tunnel Release: Surgical Technique. Arthrex, Inc.; 2010. With permission from Arthrex, Inc.]

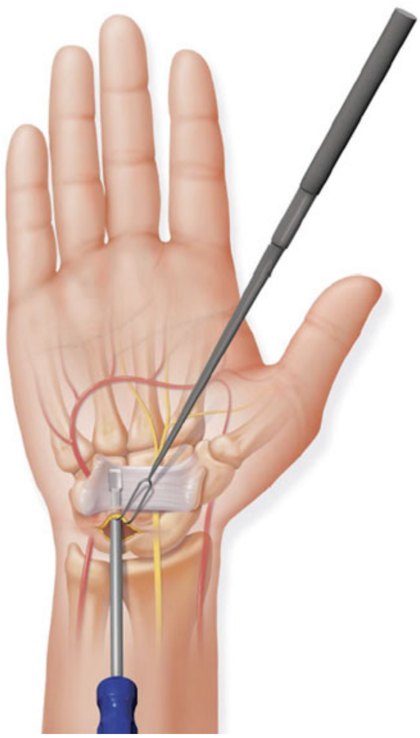


Fig. 28.8 Synovial elevator [Reprinted from Centerline Endoscopic Carpal Tunnel Release: Surgical Technique. Arthrex, Inc.; 2010. With permission from Arthrex, Inc.]

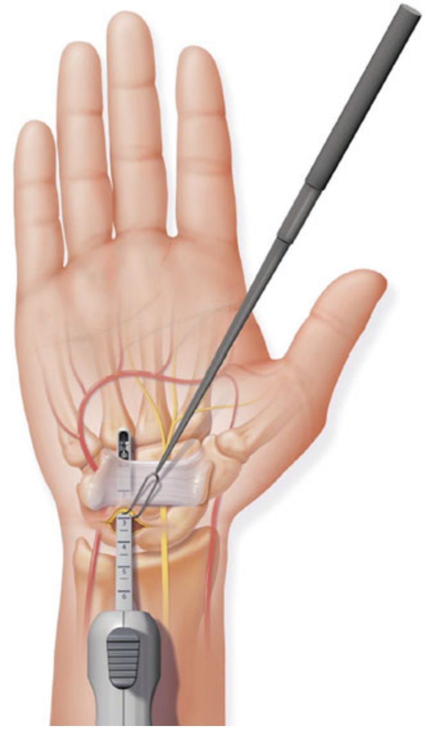


Fig. 28.9 Placement of the endoscopic device, hugging the ulnar aspect of the carpal canal and axially aligned with the ring finger [Reprinted from Centerline Endoscopic Carpal Tunnel Release: Surgical Technique. Arthrex, Inc.; 2010. With permission from Arthrex, Inc.]

the wrist in slight extension. Gently pass the dilator distally down the ulnar side of the tunnel hugging the hook of the hamate, and advancing distally until the tip is past the transverse carpal ligament. This is palpated by the index finger on the surgeon's non-instrument hand. When the dilator is in the carpal canal there is a definite sense of a substantial structure (TCL) between the dilator and the skin. When the dilator is subcutaneous or in Guyon's canal it is distinct and easily palpated. Next a small Synovial Elevator is used to dissect adherent synovium from the underside of the transverse carpal ligament (Fig. 28.8). This is a critical step because the safety of this procedure is directly related to clear visualization of the underside of the transverse carpal ligament. Follow the same path as the dilator and scrape the underside of the transverse carpal ligament from proximal to distal. A noticeable rough, washboard like effect will be felt. The carpal tunnel is now prepared for insertion of the endoscopic device; however, it is important to check for proper blade extension and retraction before insertion into the patient's hand.

Procedure

The endoscopic device is then inserted into the carpal canal (Fig. 28.9). It is important to hug the underside of the TCL and use the leading edge of the device to push synovium out of the way. This is achieved by the surgeon dropping his hand toward the patients arm as soon as the device is inserted and prior to advancing it into the carpal canal. While aiming at the base of the ring finger, advance the instrument distally, hugging the hook of the hamate to assure an ulnar course. Use a sufficient number of proximal-to-distal passes to accurately define an ulnar "strip" of the transverse carpal ligament. Transverse fibers of the ligament should be the only thing visualized in the viewing portal of the device. It is important not to deploy the blade until this level of visualization is achieved (Fig. 28.10). Defining the distal edge of the TCL is assisted by using a digit from the non-instrument hand to ballot in the area of the distal edge previously defined during the dilation of the canal. This demonstrates the transition between the terse TCL and the more pliable distal aponeurotic fibers. Sometimes this can be obscured by the distal fat pad but that doesn't matter because you never deploy the blade into the fat pad! Once a clear path from the distal end of the TCL to the proximal end is confirmed, the blade is deployed distally and the transverse carpal ligament is divided as the device is withdrawn along the previously established path. It is important to ensure that the device hugs the underside of the transverse carpal ligament during this portion of the procedure (Fig. 28.11). It is advisable not to put any downward pressure on the hand with the surgeon's non-instrument hand during this portion of the procedure.

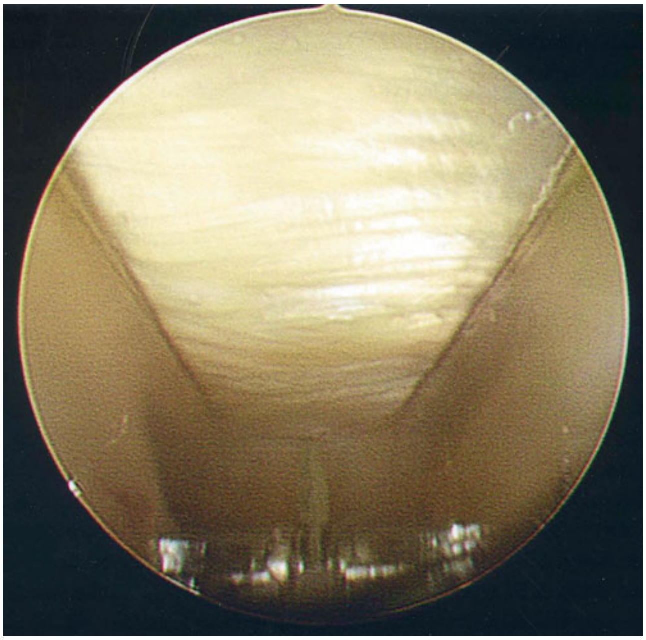


Fig. 28.10 Endoscopic view pre-cut

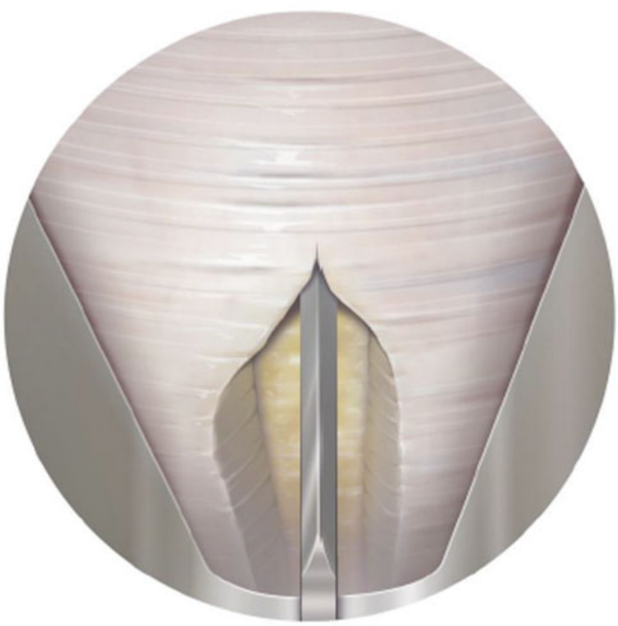


Fig. 28.11 The blade is deployed distally and withdrawn smoothly in one continuous motion dividing the TCL. It is important to hug the underside of the ligament during this motion to keep any surrounding soft tissues out of the viewing portal so that there is nothing for the blade to cut except the TCL [Reprinted from Centerline Endoscopic Carpal Tunnel Release: Surgical Technique. Arthrex, Inc.; 2010. With permission from Arthrex, Inc.]

This helps avoid injury to the ulnar artery as it often takes a more oblique course from the hook of the hamate to the superficial arch than is depicted in standard anatomic textbooks [10].

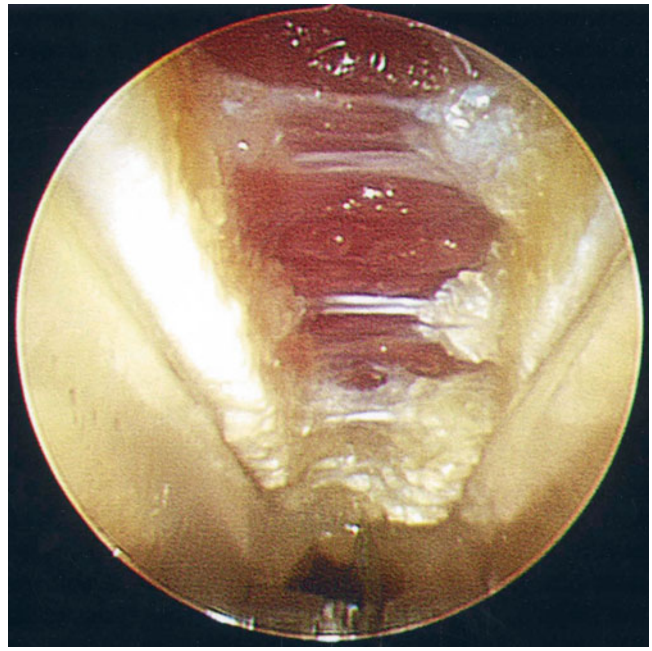


Fig. 28.12 Endoscopic view post-cut

The device is then reinserted to confirm complete division of the transverse carpal ligament (Fig. 28.12). It should be easier to insert the device after TCL division. The spread of the TCL and consequent stretching of the fat pad will often reveal a few distal fibers initially hidden by the fat pad that are divided at this time. In the past some have advocated a partial ligament resection of the distal portion of the TCL with the first pass. The proximal portion is then cut with a second pass. The completeness of TCL division is then refined and accessed with a third pass. I have found this approach to be unnecessary as minimizing passes with the instrument also minimizes neuropraxia. The procedure is complete when the device can be freely advanced to the mid-palm without obstruction. The device may also be rotated (blade retracted) after a complete release to allow the surgeon to inspect the cut edges of the ligament. In addition to the video monitor image, assess completeness of ligament division by several means; sensing the reduced "pressure" upon the instrument when it is reinserted in a decompressed carpal tunnel; noting the more subcutaneous course of the blade assembly after division; the scope light shining through the skin without obstruction; and inserting a small right-angle retractor and looking directly inside of the released carpal tunnel at the cut edges of the ligament. In some cases there will be a persistent constriction of the proximal forearm fascia on carpal tunnel contents. In these cases, it may be necessary to release the proximal forearm fascia. Using tenotomy scissors, release the forearm fascia proximal to the skin incision, taking care to protect the median nerve.

This prevents the forearm fascia from acting as a constricting band that could continue to compromise median nerve function. I find this to be necessary in about 10 % of cases. The wound is closed with a subcuticular suture or steri-strip which yields the best cosmetic results. During the initial exposure I like to preserve the subcutaneous fat as a vascularized flap if possible. This can then be placed between the antebrachial fascia and the skin to provide for vascularized interposition that minimizes adhesions. It is a good idea to inject marcaine without epinephrine into the carpal tunnel for immediate postoperative pain control. The wound is dressed with xeroform, gauze sponge, and Coban and the tourniquet is released. The Coban bandage is changed to a BAND-AID® before the patient leaves the postoperative holding area.

Aftercare

The wound is kept clean and dry for 5 days. Activity is only restricted by the patient's comfort level as there are no mandatory restrictions. The wound is checked at 2 weeks postoperatively and a final check is performed at 6 weeks postoperatively.

References

1. CTS treatment guideline (American Academy of Orthopedic Surgeons Web site). http://www.aaos.org/Research/guidelines/CTStreatmentguide.asp Link to PDF, "CTS Treatment Guideline." 2008. Accessed 23 Jan 2009.
2. Chung KC, Walters MR, Greenfield ML, Chernew ME. Endoscopic versus open carpal tunnel release: a cost-effectiveness analysis. Plast Reconstr Surg. 1998;102:1089–99.
3. Abrams RA. Endoscopic versus open carpal tunnel release. J Hand Surg Am. 2009;34:535–9.
4. Cobb TK, Cooney WP. Significance of incomplete release of the distal portion of the flexor retinaculum. J Hand Surg Br. 1994;19(3):283–5.
5. Cobb TK, Cooney WP, An K. Clinical location of hook of hamate: a technical note for endoscopic carpal tunnel release. J Hand Surg Am. 1994;19:516–8.
6. Jakab E, Ganos D, Cook FW. Transverse carpal ligament reconstruction in surgery for carpal tunnel syndrome: a new technique. J Hand Surg Am. 1991;16:202–6.
7. Tountas CP, Bihrle DM, MacDonald CJ, Bergman RA. Variations of the median nerve in the carpal canal. J Hand Surg Am. 1987;12:708–12.
8. Palmer DH, Paulson JC, Lane-Larsen CL, Peulen VK, Olson JD. Endoscopic carpal tunnel release: a comparison of two techniques with open release. Arthroscopy. 1993;9:498–508.
9. Cobb TK, Dalley BK, Posteraro RH, Lewis RC. Anatomy of the flexor retinaculum. J Hand Surg Am. 1993;18:91–9.
10. Rotman MB, Manske PR. Anatomic relationships of an endoscopic carpal tunnel device to surrounding structures. J Hand Surg Am. 1993;18(3):442–50.

Elbow Arthroscopy: Anatomy, Setup, Portals, and Positioning

29

Sonya M. Clark

Arthroscopy of the elbow is a technically challenging yet rewarding procedure. Elbow arthroscopy has greatly evolved since its introduction. Burman [1] initially described elbow arthroscopy in 1931, but it was not until more than 50 years later in 1985, when Andrews and Carson [2] described intraarticular elbow anatomy and the various portals used for elbow arthroscopy in the supine position. More recently, in 1989, the prone position for elbow arthroscopy was described by Poehling and colleagues [3].

Since its introduction, the indications and procedures performed with elbow arthroscopy has expanded. Elbow arthroscopy can be a safe and effective procedure, but it poses greater neurologic and technical challenges than arthroscopy of the shoulder and knee. There is potential for neurovascular injury because of the complex relationship of these structures to the joint (Fig. 29.1). To safely perform elbow arthroscopy, great familiarity of the normal elbow anatomy and surrounding neurovascular structures must be appreciated when making portals.

This chapter will provide a summary of the key anatomy, portal placement, and basic surgical setup and technique for elbow arthroscopy.

Anatomy

A comprehensive understanding of the anatomy of the elbow is essential before proceeding with elbow arthroscopy. Important bony anatomic landmarks include: the medial and lateral epicondyles, the olecranon process, and the radial head. Anatomic landmarks should be palpated and marked prior to portal placement.

The soft spot, also known as the anconeus triangle, is located in the center of the triangle formed from the lateral epicondyle, radial head, and olecranon process. The soft spot can be used to insufflate the joint prior to portal placements, and it can also be used as a direct lateral portal (Fig. 29.2).

Several sensory nerves surround the elbow, including: the medial antebrachial cutaneous, the medial brachial cutaneous, the lateral antebrachial cutaneous, and the posterior antebrachial cutaneous nerves [4]. The medial antebrachial cutaneous nerve provides sensation to the medial aspect of the forearm and elbow. The medial brachial cutaneous nerve supplies sensation to the posteromedial aspect of the arm, to the level of the olecranon. The lateral antebrachial cutaneous nerve, supplies sensation to the elbow and lateral aspect of the forearm. It is a branch of the musculocutaneous nerve, and exits between the brachialis muscle and the biceps. The posterior antebrachial cutaneous nerve supplies sensation to the posterolateral elbow and posterior forearm. It is a branch of the radial nerve and courses down the lateral aspect of the arm [5].

The median, radial, and ulnar nerve and brachial artery are the main neurovascular structures around the elbow [4].

Indications and Contraindications

The indications for elbow arthroscopy are numerous and include both diagnostic and therapeutic indications. Diagnostic indications include septic arthritis, traumatic and degenerative arthritis, and intra-articular fractures [6, 7]. Therapeutic indications include the removal of loose bodies, synovectomy, capsular release, plica excision, treatment of osteochondritis dessicans, and tennis elbow release. New evolving indications include olecranon bursectomy and arthroscopic assisted fracture management [8, 9].

Contraindications for elbow arthroscopy include any conditions that distort the normal soft-tissue or normal bony anatomy, which prevents making accurate portal placement [10]. In patients with prior ulnar nerve transposition, or a subluxing ulnar nerve, the nerve should be identified prior to portal placement to prevent iatrogenic injury.

S.M. Clark, D.O. (✉)
Upstate Hand Center, 1702 Skylyn Drive, Spartanburg, SC 29307, USA
e-mail: drsonya1@yahoo.com

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*, DOI 10.1007/978-1-4614-1596-1_29, © Springer Science+Business Media New York 2015

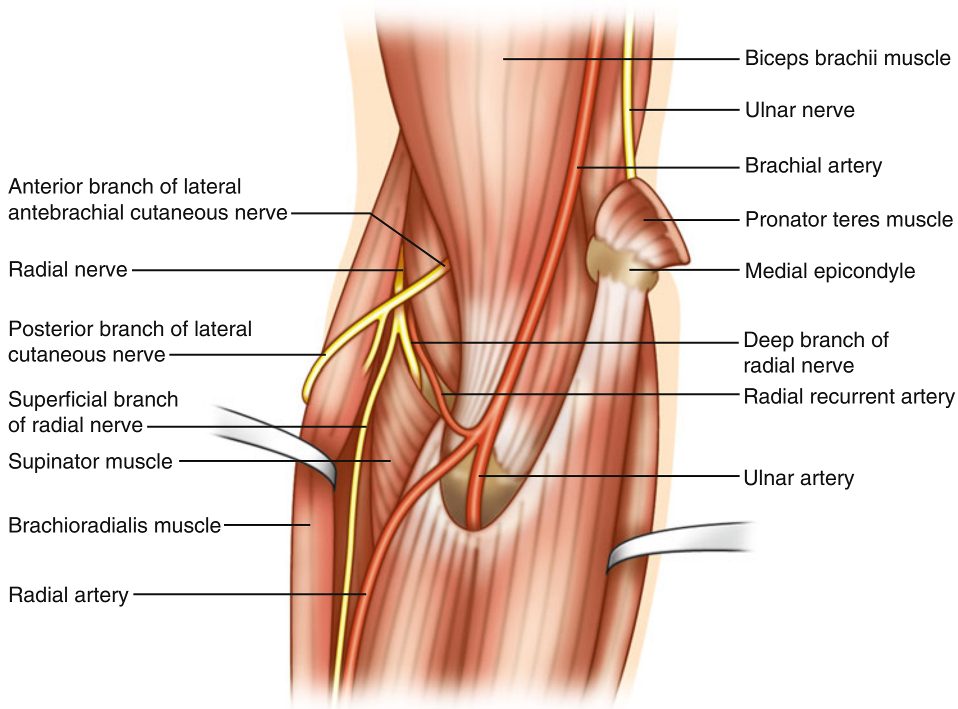


Fig. 29.1 Important neurovascular structures within the antecubital fossa

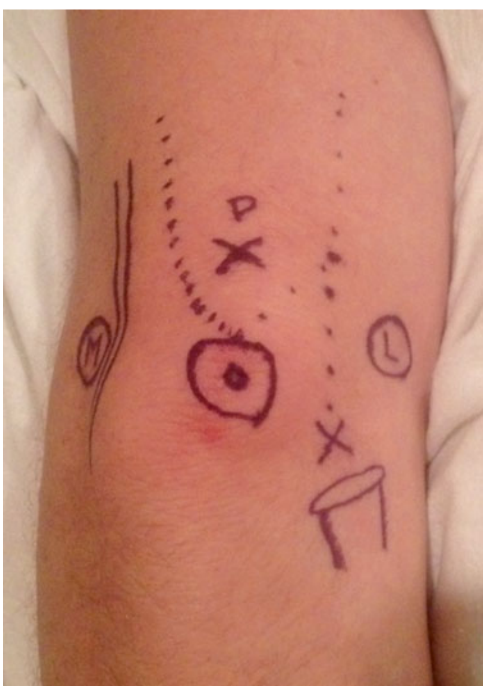


Fig. 29.2 Surface landmarks of elbow. Posterior view. Medial epicondyle, ulnar nerve, olecranon process are outlined in relation to elbow joint. *X* marks soft spot portal. *P* marks posterocentral portal

Extensive heterotrophic ossicification, prior skin grafts or flaps and burns preclude safe joint access and should be avoided [11].

Surgical Technique

Anesthesia

General or regional anesthesia may be used for elbow arthroscopy. Most surgeons prefer general anesthesia for elbow arthroscopy because of patient comfort and complete muscle relaxation. The use of regional anesthesia can complicate the postoperative neurologic assessment and can be compromised by the use of supraclavicular and extended axillary blocks [5].

Instrumentation

A standard 4.0-mm, 30° arthroscope provides exceptional visualization of the elbow joint. Sometimes a smaller 2.7 mm arthroscope may be useful for visualization in adolescent patients, and in smaller viewing spaces, such as the direct lateral portal and in the posterior compartment [5, 8]. Cannulas are utilized to allow ease in switching working and viewing portals, without repeated joint capsule trauma. In addition, the risk of neurovascular injury is minimized when fewer portals are established. It is vital to maintain the arthroscopy portals with cannulas in order to decrease fluid extravasation into the soft tissues and swelling [5]. Maintaining capsular distention is key to successful elbow arthroscopy. If there is fluid extravasation into the soft tissues, the capsule will collapse, and prevent further elbow arthroscopy.

In elbow arthroscopy, side-vented inflow cannulas should be avoided to prevent fluid extravasation into the soft tissues [12]. Only blunt-tipped and conical trocars should be used, to decrease the possibility of articular cartilage or neurovascular injury [8]. Specialized arthroscopic instruments: forceps, probes, shavers, and burrs are utilized in elbow arthroscopy [5].

Gravity inflow or a mechanical pump can be used in elbow arthroscopy. Some surgeons think gravity provides for enough joint distention while minimizing fluid extravasation. A mechanical pump can safely be used, but the inflow pressure should be minimized, no greater than 35 mmHg, in order to lessen fluid extravasation [5].

Fig. 29.3 Prone positioning with shoulder flexed and abducted 90° over a padded arm table with folded blankets

Patient Positioning

Supine Position

Andrews first described supine positioning for elbow arthroscopy in 1985 [2]. After adequate anesthesia has been obtained, care is taken to pad all bony prominences and place the shoulder at the edge of the operating table. The patient is positioned with the shoulder in 90° of abduction, and 90° of elbow flexion. The arm is then secured using an overhead traction device and a non-sterile tourniquet is applied.

Supine positioning offers numerous advantages [13]. The supine setup is simple and allows for easy airway access for anesthesia. The anatomy is clearly defined and oriented in this familiar anatomic position. Furthermore, if the procedure needs to be converted to open, it's a simple task.

The weakness of the supine position includes the difficulty working in the posterior compartment and the need for an additional traction device.

Prone Position

Poehling first described the prone position for elbow arthroscopy in 1989 [3]. After adequate anesthesia has been obtained, the patient is rolled onto chest rolls. The nonoperative extremity is placed onto a well padded arm board, with the shoulder in 90° of abduction and the elbow in 90° of flexion (Figs. 29.3 and 29.4). The operative extremity should be supported appropriately to allow the shoulder to be abducted 90° and the elbow hanging freely at 90° of flexion. This can be achieved by either a padded bolster, or several rolled towels positioned on an arm board.

There are several advantages to the prone position. The posterior compartment is easily accessed without the need for traction. In addition, the arm can be effortlessly manipulated from full extension to full flexion. "Flexion of the elbow allows the neurovascular structures to sag anteriorly, providing a greater margin of error, when establishing anterior portal sites" [14].

Fig. 29.4 Prone positioning for elbow arthroscopy

The main disadvantage of the prone position is the general anesthesia requirement and poor airway access by anesthesia. Furthermore, conversion to an open procedure is much more difficult as compared to the supine position. Therefore, if anterior open procedures are necessary, this will require repositioning to a supine procedure.

Lateral Decubitus Position

O'Driscoll and Morrey first described the lateral decubitus position in 1993 [15].

After the patients are placed under general anesthesia on a bean bag, the patient is turned and secured in a lateral decubitus position. An axillary roll and non-sterile tourniquet is applied. The shoulder is flexed and internally rotated 90°. The arm is positioned on a padded arm holder, positioning the elbow in 90° of flexion (Fig. 29.5).

The lateral decubitus position allows for the benefits of prone positioning, without the airway difficulty of the prone position. The disadvantage of the lateral decubitus position is the need for a padded arm holder and difficulty with converting to an open procedure.

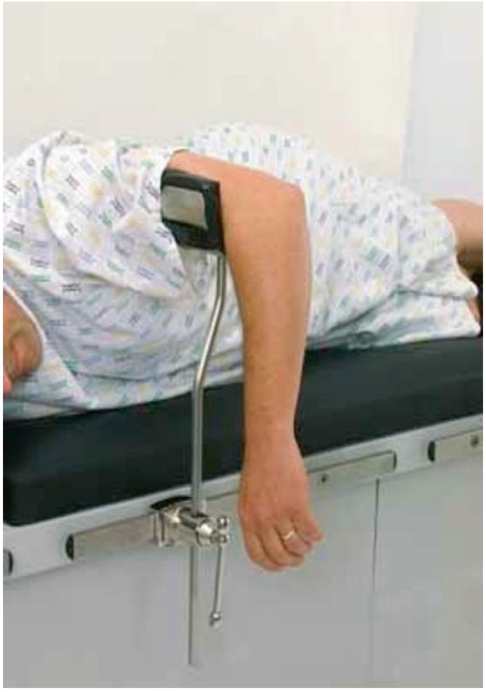


Fig. 29.5 Picture of arm holder for lateral position

Fig. 29.6 Lateral view of bony landmarks and portals. *AL*, marks proximal anterolateral portal. *X'*, marks direct lateral, or soft spot portal. *0*, olecranon process. *P*, Posterocentral portal. *L* lateral epicondyle

Portals

Numerous portals have been described for elbow arthroscopy. The most common portals utilized are the anterolateral, proximal lateral, midlateral, anteromedial, proximal medial, and straight posterior [11].

Portal placement is key to visualization and protection of the nearby neurovascular structures. The initial portal utilized can be an area of debate, but is a matter of surgeon preference. Some surgeons describe initial visualization in the posterior compartment, but most prefer to visualize the anterior compartment first [8, 16, 17]. The real debate rests in where to start anteriorly: anteromedially or anterolaterally.

Several authors have studied the distances from the portals to the various neurovascular structures. Knowledge about the distances between the portals and neurovascular structures is paramount because it helps to diminish the risk of injury. Using the anterolateral portal, Lynch et al. [18] found the average distance to the radial nerve was 4 mm (range 3–10 mm) from the sheath of the arthroscope. Andrews and Carson [2] found that the radial nerve was 7 mm. Lidenfeld in his study [17] found the average distance to the radial nerve was 3 mm (range, 2–5 mm).

The Anteromedial portal, according to Andrews and Carson [2] study showed the median nerve to be 10 mm away. Lynch et al. [18] found the median nerve to be 3–10 mm away and Lidenfeld [17] measured an average distance of 11 mm to the median nerve (range, 10–12 mm).

Numerous authors have described beginning with an anteromedial approach to decrease the risk of injuring the neurovascular structures because of the average distance between the median nerve and medial portals is greater than the distance between the lateral portals and the radial or posterior interosseous nerve [8, 16, 17, 19]. However, there are also many surgeons who initially create a lateral portal, and then establish a medial portal either under direct visualization with a spinal needle, or utilize an inside-out technique with a switching stick [16].

Anterior Portals

Proximal Anterolateral Portal

Field and several authors [4, 20, 21], have described the proximal anterolateral portal as located 2 cm proximal to the lateral epicondyle, and 2 cm anterior to the lateral epicondyle, or directly on the anterior humerus (Fig. 29.6). Visualization from this portal best illustrates the trochlea, tip of the coronoid the medial structures of the joint (Figs. 29.7 and 29.8). Investigators have illustrated that this portal is the safest anterolateral portal, as it is the furthest from the radial nerve [14].

Anterolateral Portal

In 1985, Carson and Andrews originally described the anterolateral portal as being located 3 cm distal and 2 cm anterior to the lateral epicondyle [2]. However, this portal

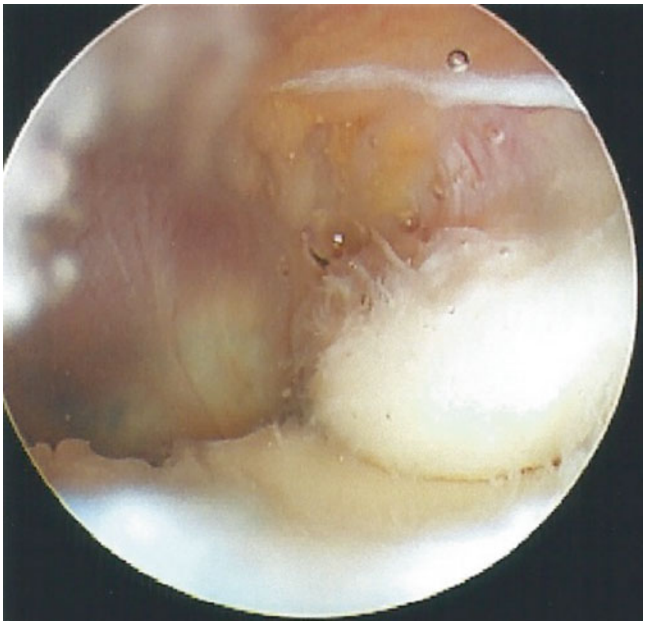


Fig. 29.7 Supine position: view from proximal anterior lateral portal

Fig. 29.9 Prone position: view from middle anterior lateral portal

Fig. 29.8 Supine Position: view from proximal anterior lateral portal, showing medial capsule

places the radial nerve at risk for injury [18]. Several authors have described the radial nerve to be located an average 3–7 mm from the anterolateral portal [2, 17, 18]. In an effort to reduce iatrogenic injury, the original distal anteolateral portal should be avoided, and a more proximal anterolateral portal should be utilized. In 1994, Field and colleges compared three lateral portals: the proximal anterolateral portal, a middle anterolateral portal, and the distal anterolateral portal. The anterolateral (distal) portal is closest to the radial nerve and should be avoided.

Middle Anterolateral Portal

Some refer to this portal as the Anterior superior lateral portal. This portal is described as 1–2 cm directly anterior to the lateral epicondyle [14] (Fig. 29.9). This portal is ideal for arthroscopic lateral epicondyle release. Use of this portal, increases the distance to the radial nerve, compared to the anterolateral portal (Fig. 29.10).

Proximal Anteromedial Portal

This portal is also known as the Superomedial portal. Popularized by Poehling, it is located 2 cm proximal to the medial epicondyle and 2 cm anterior, or just anterior to the intermuscular septum [3] (Fig. 29.11). The medial intermuscular septum should be palpated, and the portal is established anterior to the septum, this minimizes injury to the ulnar nerve. This portal provides excellent visualization of the lateral elbow and radiocapitellar joint. The more proximal location of this portal allows the arthroscope to lie almost parallel to the median nerve when inserted and is considered safer than the anteromedial portal [5, 17].

Anteromedial Portal

Located 2 cm anterior and 2 cm distal to the medial epicondyle [2]. This portal visualizes the proximal capsular insertion and lateral elbow joint. It is used primarily for instrumentation when working in the medial recess of the elbow [8]. The Medial antebrachial cutaneous nerve is at risk when this portal is created.

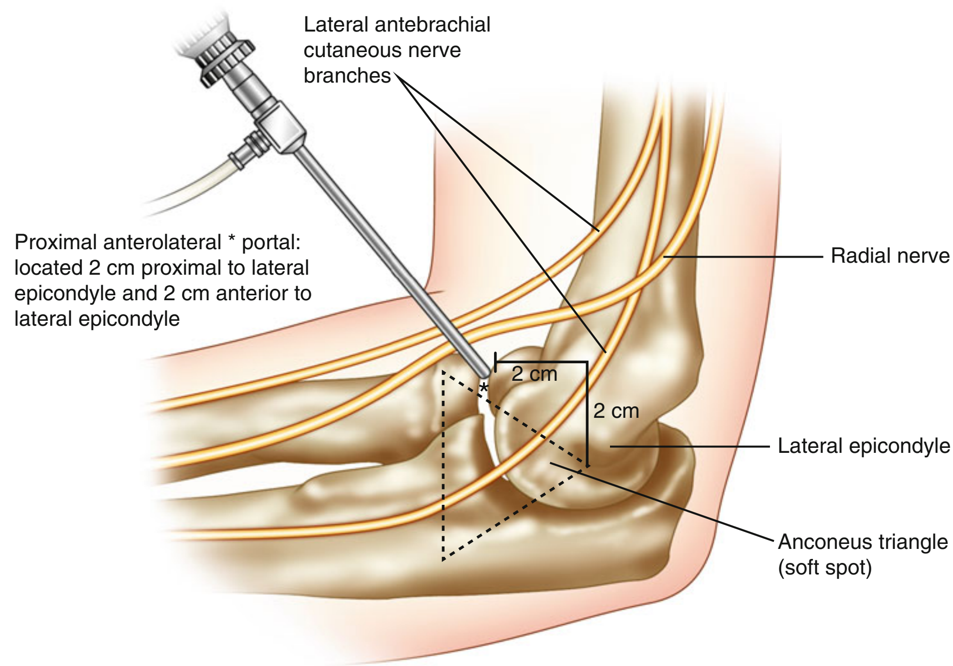


Fig. 29.10 Lateral view of elbow in prone position

Fig. 29.11 Medial view of surface landmarks and portals. *AM*, marks proximal anteromedial portal. *P*, marks posterocentral portal. *Dashed line* marks intermuscular septum

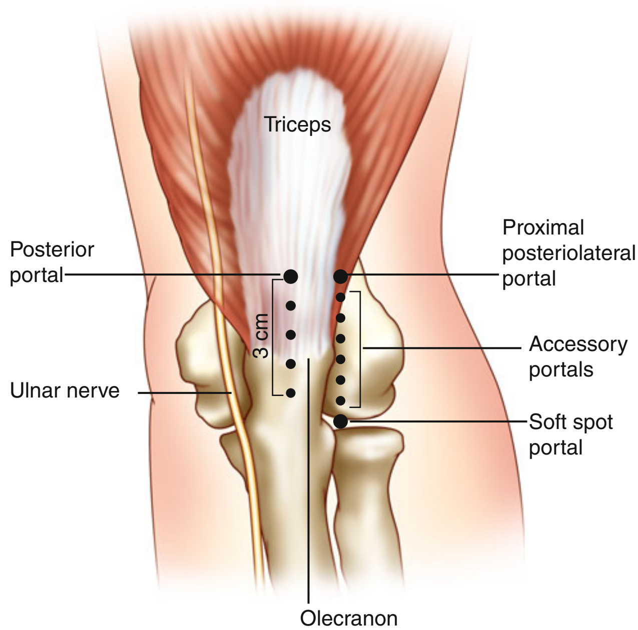


Fig. 29.12 Posterior view of elbow

Posterior Portals

Posterocentral Portal

This portal is located 3 cm proximal to the tip of the olecranon. It passes within 23 mm of the posterior antebracial cutaneous nerve and 25 mm within the ulnar nerve [4] (Fig. 29.12). It allows excellent visualization of the entire posterior compartment, and it pierces the triceps muscle just proximal to the musculotendinous junction [8]. To improve visualization when making this portal, the cannula and trocar are placed and maneuvered in a vigorous circular motion, to rid the soft tissues adherent in this area.

Proximal Posterolateral Portal

This portal, also known as the posterolateral portal, is located at the lateral border of the triceps tendon, and 2–3 cm proximal to the tip of the olecranon. Usually, it is made under direct visualization with a spinal needle, with the arthroscope in the posterocentral portal. Once localized, a blunt trocar is placed aiming towards the olecranon fossa, while passing through the triceps muscle. The olecranon tip, olecranon fossa and posterior trochlea can be well visualized; however, initial visualization may be difficult because of synovitis and fat pad hypertrophy, requiring initial debridement with a shaver. The posterior capitellum is not well visualized from this portal [4]. This portal is useful as a working portal for removal of loose bodies and osteophytes from the posterior compartment [7, 22]. The posterior and medial antebrachial cutaneous nerves average 25 mm from this portal [18]. The Ulnar nerve is not at risk for injury, as long as the cannula is kept lateral of the posterior midline, it is approximately 25 mm from this portal [4].

Accessory Posterolateral Portals

Portal placement can be anywhere along a line, extending from the posterolateral portal to the soft spot portal, because of the unique posterolateral anatomy of the elbow.

Varying the portal position is useful for gaining access to the posterolateral recess, and changing the orientation of the joint.

Direct Lateral Portal (Soft-Spot Portal)

This portal is located at the center of the triangle formed by the lateral epicondyle, olecranon process, and radial head. Initially, it is used by many to insufflate the joint. Using a spinal needle, the portal is created under direct visualization. The posterior antebrachial cutaneous nerve passes approximately 7 mm from this portal. The portal is used as a working portal in radial head resection, osteochondritis dessicans lesions, and a viewing portal for the posterior compartment [12]. Only this portal, allows access and visualization of the radioulnar joint and posterior capitellum [5].

Conclusion

Arthroscopy of the elbow is an accepted surgical procedure for numerous elbow conditions [5]. In order to be successful in elbow arthroscopy, a thorough knowledge of the anatomy and portal placement is mandatory. The complexity of elbow arthroscopy procedures attempted should be determined by the individual surgeon's experience and skill level. Future advances in elbow arthroscopy will continue to emerge as clinical experience and new techniques and surgical equipment is refined.

References

1. Burman MS. Arthroscopy or the direct visualization of the joints: an experimental cadaveric study. J Bone Joint Surg. 1931; 13:669–95.
2. Andrews JR, Carson WG. Arthroscopy of the elbow. Arthroscopy. 1985;1:97–107.
3. Poehling GG, Whipple TL, Sisco L, Goldman B. Elbow arthroscopy: a new technique. Arthroscopy. 1989;5:220–4.
4. Baker CL, Brooks AA. Arthroscopy of the elbow. Clin Sports Med. 1996;15:261–8.
5. Baker CL, Grant LJ. Arthroscopy of the elbow. Am J Sports Med. 1999;27:251–64.
6. Ramsey ML. Elbow arthroscopy: basic set up and treatment of arthritis. Instr Course Lect. 2002;51:69–72.
7. Savoie FH, Nunley PD, Field LD. Arthroscopic management of the arthritic elbow: indication, technique and results. J Shoulder Elbow Surg. 1999;8:214–9.
8. Abboud JA, Ricchetti ET, Tjoumakaris F, Ramsey ML. Elbow arthroscopy: basic setup and portal placement. J Am Acad Orthop Surg. 2006;14:312–8.
9. Dodson CC, Nho SJ, Williams RJ, Altchek DW. Elbow arthroscopy. J Am Acad Orthop Surg. 2008;16(10):574–85.
10. O'Driscoll SW, Morrey BF. Arthroscopy of the elbow: diagnostic and therapeutic benefits and hazards. J Bone Joint Surg Am. 1992;74:84–94.
11. Walcott GD, Savoie FH, Field LD. Arthroscopy of the elbow: setup,portals and diagnostic technique. In: Altchek DW, Andrews J, editors. The athletes elbow. Philadelphia, PA: Lippincott Williams and Wilkins; 2001. p. 249–73.
12. Ramsey ML, Naranja RJ. Diagnostic arthroscopy of the elbow. In: Baker Jr CL, Plancher DL, editors. Operative treatment of elbow injuries. New York, NY: Springer; 2002. p. 162–9.
13. McKenzie PJ. Supine position. In: Savoie FH, Field LD, editors. Arthroscopy of the elbow. New York NY: Churchill Livingstone; 1996. p. 35–9.
14. Field LD, Altchek DW, Warren RF, O'Brien SJ, Skyhar MJ, Wickiewicz TL. Arthroscopic anatomy of the lateral elbow: a comparison of three portals. Arthroscopy. 1994;10:602–7.
15. Rubin CJ. Prone or lateral decubitus position. In: Savoie FH, Field LD, editors. Arthroscopy of the elbow. New York, NY: Churchill Livingstone; 1996. p. 41–7.
16. Andrews JR, St. Pierre RK, Carson Jr WG. Arthroscopy of the elbow. Clin Sports Med. 1986;5:653–62.
17. Lindenfeld TN. Medial approach in elbow arthroscopy. Am J Sports Med. 1990;18:413–7.
18. Lynch GJ, Meyers JF, Whipple TL, Caspari RB. Neurovascular anatomy and elbow arthroscopy: inherent risks. Arthroscopy. 1986;2:191–7.
19. Verhaar J, Memeren HV, Brandsma A. Risks of neurovascular injury in elbow arthroscopy: starting anteromedially or anterolaterally? Arthroscopy. 1991;7:287–90.
20. Strothers D, Day B, Regan WR. Arthroscopy of the elbow: anatomy, portal sites, and description of the proximal lateral portal. Arthroscopy. 1995;11:449–57.
21. Savoie FH, Field LD. Anatomy. In: Savoie FH, Field LD, editors. Arthroscopy of the elbow. New York, NY: Churchil Livingstone; 1996. p. 3–24.
22. Drabicki RR, Field LD, Savoie FH. Diagnostic elbow arthroscopy and loose body removal. In: Savoie FH, Field LD, editors. The elbow and wrist. Philadelphia, PA: Elsevier; 2010. p. 17–24.

Arthroscopic Management of Elbow Contractures

30

Erich M. Gauger and Julie E. Adams

Introduction

The primary purpose of the elbow is to aid in the placement of the hand in space and act as a stabilizer during carrying, lifting, pushing, and pulling. The elbow must have mobility, stability, strength, and be pain-free to allow independent function [1]. The main focus of this chapter is to outline the surgical technique for arthroscopic management of elbow contracture to achieve sufficient mobility to carry out these functions.

Normal elbow range of motion in the sagittal plane (flexion–extension) is 0–145° [2]. There have been several papers addressing the functional range of motion of the elbow. Morrey et al. [3] demonstrated in 1981 that most activities of daily living can be accomplished with elbow flexion from 30° to 130° and 100° arc of pronosupination. More recent studies have utilized three-dimensional optical tracking system with results that have differed slightly [4–7]. Sardelli et al. [7] demonstrated a maximal flexion arc of 130° (23–142) for functional tasks (including cellular telephone tasks and typing on a keyboard). The definition of a stiff elbow varies by study with ranges from 30° to 40° of reduction in extension or flexion less than 105–130° [8, 9]. Davila et al. [1] point out that loss of extension can be compensated for by simply moving closer to an object while one cannot flex the wrist and neck enough to reach the face if elbow flexion is less than 105–110°.

E.M. Gauger, M.D.
Department of Orthopaedic Surgery, University of Minnesota, 2450 Riverside Ave., R 200, Minneapolis, MN 55454, USA

J.E. Adams, M.D. (✉)
Department of Orthopaedic Surgery,
University of Minnesota, 2450 Riverside Ave., R 200,
Minneapolis, MN 55454, USA
e-mail: adams.julie.e@gmail.com

Etiology and Classification

Causes of elbow contracture include posttraumatic issues, primary arthritis (rheumatoid, septic, osteoarthritis, hemophilic arthritis), congenital (arthrogryposis), burns, spasticity, head injury, stroke, and heterotopic ossification [1, 10]. It has been suggested that contracture types may be categorized into two types [11]. Intrinsic contractures are secondary to intra-articular pathology (incongruity, chondral defects, osteophytes, loose bodies, fracture malunion). Extrinsic causes related to extra-articular pathology such as contracture of the ligaments and joint capsule, muscle contracture or adherence to the capsule and heterotopic ossification. Most cases are mixed; with secondary extra-articular soft tissue contractures present in intrinsic contractures [11].

The elbow is vulnerable to stiffness for several potential reasons: (1) it possesses a highly congruent articular surfaces comprising three joints (ulnotrochlear, radiocapitellar, proximal radioulnar) within a single joint capsule, which can thicken as much as 3–4 mm after injury, (2) it is vulnerable to heterotopic ossification formation after injury, possibly due to the brachialis muscle covering the anterior capsule, (3) prolonged immobilization is sometimes prescribed for complex fractures, and (4) the position of minimal intra-articular pressure and maximum compliance of the elbow is in 70° flexion—pain generation may occur with motion outside of this pressure nadir [1, 8, 12–15].

Surgical Indications and Contraindications

The main indication for arthroscopic management of elbow contracture is the loss of a functional arc of motion that persists after a period of conservative therapy consisting of physical therapy and/or splinting. During the preoperative evaluation, passive and active arc of motion should be assessed, as well as the quality of the end range of motion. A distinct block to range of motion may be due to impinging

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*,
DOI 10.1007/978-1-4614-1596-1_30, © Springer Science+Business Media New York 2015

osteophytes or heterotopic ossification, whereas a more soft endpoint can be secondary to capsular contraction. Pain at the extremes of range of motion may indicate an osteophyte impinging in the olecranon fossa (extension) or the coronoid fossa (flexion). Although arthroscopic treatment can address intrinsic issues such as osteophytes, loose bodies, or contracture, presence of arthritic pain throughout the arc of motion is suggestive of more widespread changes in the joint that may not be adequately addressed by arthroscopy. The status of the major peripheral nerves should be documented prior to surgery; specifically, many patients with elbow contracture may have concomitant ulnar neuropathy. Some patients may not specifically note ulnar nerve symptoms until they are brought to attention by specific query, examination, and provocative maneuvers. The location of the ulnar nerve is noted and patients are examined for a subluxating ulnar nerve.

Imaging studies in general include three view plain film radiographs of the elbow, and consideration of axial imaging. CT scan particularly with three dimensional reconstructions is specifically useful to identify bony areas of impingement which limit motion. MRI may be especially useful for assessment of chondral lesions and synovitis.

Contraindications to arthroscopic contracture release include factors that cannot be addressed by arthroscopy: severe heterotopic ossification, extrinsic disease such as contracture secondary to muscle spasticity, stroke or scar tissue (burns) and extensive widespread joint changes which may respond more appropriately to a joint resurfacing type procedure. In addition, forearm pronation/supination can only be addressed in a limited fashion arthroscopically. Relative contraindications primarily relate to distorted anatomy such as prior ulnar nerve transposition—particularly submuscular, or the severely contracted elbow.

Surgical Technique

General anesthesia is preferred by most surgeons including the authors [16]. Patient positioning under regional anesthesia may be uncomfortable. Use of general anesthesia allows for immediate assessment and following of neurological function in the postoperative period.

Set Up: Elbow arthroscopy can be performed with the patient in the supine, prone, or lateral decubitus positions [17]. The supine position was the first position described by Andrews and Carson [18]. There are several benefits to this position including ease of set up, excellent exposure of the anterior joint without viewing the anatomy “upside down” and direct access to the airway for the anesthesiologist. Unfortunately, the supine position requires the use of a traction device and an assistant to stabilize the elbow during the procedure as well as limits access to the posterior aspect of the joint. The prone position allows more freedom of movement and better access to the posterior aspect of the elbow if more invasive procedures are required including open debridement of olecranon osteophytes. Disadvantages include the difficulty in the actual positioning of the patient which requires careful attention to padding of bony prominences and the challenge of airway management. The lateral decubitus position allows for many of the advantages of the prone position without the anesthetic concerns and is the authors’ preferred position. The patient can be positioned with the use of a bean bag and safety straps. After positioning, the arm in placed in an arm holder. The elbow should be slightly higher than the shoulder to prevent impingement of the arthroscopic instruments on the table [17]. The arm is inspected, insuring that there is complete access to the elbow with instruments and that it can be flexed and extended. Airplaning the bed slightly towards the surgeon allows for improved access to the elbow. A sterile or nonsterile tourniquet may be used.

Because fluid extravasation and edema can limit safety and working time, it is important to consider fluid management at the start of the procedure. Techniques to limit extravasation such as low pump pressures (25–35 mmHg) and low flow cannulas without side fenestrations as well as increased use of retractors to permit visualization instead of simply relying on joint distension may be helpful [16, 19]. In addition, early establishment of a working outflow site is critical to allow appropriate fluid control.

It is helpful to mark the anatomic landmarks on the skin before potential distortion from joint distension and edema caused by extravasation of saline [17, 20, 21]. The medial epicondyle and lateral epicondyles, radial head, olecranon medial intermuscular septum, and the path of the ulnar nerve are outlined [22]. Close attention should be paid to the location of the ulnar nerve, specifically noting if it subluxates. Intended portal sites are then marked out in relation to the anatomic landmarks.

Following inflation of the tourniquet, the elbow is insufflated with 20–30 ml of sterile saline into the joint with an 18-G needle through an intended portal or via the center of a triangle bordered by the olecranon, lateral epicondyle, and radial head known as the “soft spot.” Joint distension expands the joint to push the neurovascular structures away from the portal sites and facilitate entry into the joint [12, 17, 20, 21, 23]. Another step which has been suggested to decrease the risk of neurovascular injury is to place the portals with the elbow in flexion, which has been shown to increase the nerve to portal distance [24]. Gallay et al. [25] demonstrated that the stiff elbow has 15 % the capsular compliance of a normal elbow and less ability for capsular distension with the volume of a normal elbow averaging 14 ml compared to 6 ml for a stiff elbow. Neurovascular structures are therefore at increased risk in the arthroscopic treatment of elbow contractures.

Portal Placement: There has been no demonstration of superiority for any given starting portal but several points should be taken into consideration. Since the anterior compartment portals are in closer proximity to neurovascular structures, the argument is made that these portals should be placed first prior to excessive fluid extravasation. The choice between an anterior medial and anterior lateral portal is also based upon surgeon preference [18, 24, 26, 27]. The authors prefer starting anterolateral first. An 18G needle is placed just anterior to the radiocapitellar joint. This can be used to insuflate saline into the joint; extension of the elbow indicates intra-articular placement. The skin only is incised with a #15 blade and blunt dissection down to the capsule proceeds with a hemostat, with a sudden egress of fluid indicating penetration of the capsule. The blunt trocar and cannula for a standard 4.0 or 4.5 mm arthroscope are placed.

The anteromedial portal, which generally lies 1 cm anterior and 1 cm medial to the medial epicondyle, is made with an inside out technique. Once intra-articular placement of the trocar and cannula is confirmed either by bony feel or by visualization with the camera, the blunt trocar is replaced and driven over to the medial side to push out towards the skin. The portal site is made and a cannula placed. A switching stick can be used during the procedure to switch the viewing and working portals.

Additional portals may be used for visualization or working, or for retraction. The proximal anteromedial portal was described by Poehling et al. [26] 2 cm proximal to the prominence of the medial epicondyle and directly anterior to the medial intermuscular septum. This is the safest of all medial portals but offers the worst visualization of the radiocapitellar joint; it is very effective as a retractor portal [17].

The mid anterolateral portal is placed 1 cm anterior to the prominence of the lateral epicondyle and just proximal to the radiocapitellar joint [28]. The proximal anterolateral portal is located 1–2 cm proximal and 1 cm anterior to the lateral epicondyle and penetrates the brachioradialis, brachialis, and extensor carpi radialis muscles. The proximal anterolateral portal provides excellent visualization of the radiocapitellar joint and may also be used for instrument or retractor placement. A “soft-spot” portal can be used to visual the radial head; it is made at the center of a triangle between the radial head, lateral epicondyle, and tip of the olecranon.

Once the anterolateral and anteromedial portals are made, the arthroscope is placed in the anterolateral portal and a shaver in the anteromedial portal. In general, bony work is completed prior to capsular work to limit fluid egress [19]. An arthroscopic shaver is utilized to debride intra-articular adhesions, thickened synovium, and plicae. The shaver is usually allowed to drain to the floor without suction, which could potentially pull in capsule or other tissues unintentionally. Loose bodies are removed with the shaver or appropriately sized biter. The shaver should be aimed away from the capsule to prevent inadvertent injury to neurovascular structures. A burr can be used to remove osteophytes from the coronoid and radial head fossae. One key to visualization is the use of retractors in accessory portals. The capsule can be stripped off of the humerus with an elevator; if capsular resection is performed, it proceeds from a medial to lateral direction. Previous radial head fractures may distort local anatomy and create arthrofibrosis and adhesions between the capsule and radial nerve. Because of the close proximity of the radial nerve, resection of the anterior capsule within 2–3 cm of the radial head is avoided [19]. Unlike open procedures, in which capsulectomy is routinely performed, arthroscopic capsulectomy increases the risk of nerve injury and is not commonly performed; in the authors’ hands, capsulotomy is typically adequate.

Posterior Compartment

Following completion of work in the anterior portion of the joint, attention is turned towards the posterior compartment. The direct posterior portal is the main working portal. It is made 2–3 cm proximal to the tip of the olecranon. Because this portal is through the thick triceps muscle, an incision is made with the blade down to bone. This directly enters the posterior fossa, and is a “potential” space. This is usually filled with fat and fibrous tissue. It is useful to use the blunt trocar to sweep the fossa to clear it and provide a space for visualization; it is usually necessary to shave the synovium to gain a view. The posterolateral portal is made level with the olecranon tip at the lateral joint line. It is most commonly used for visualization [17, 19, 29]. An additional retractor portal can be placed at any site away from the ulnar nerve [17].

After obtaining adequate visualization, facilitated by aggressive debridement of excess synovium at the olecranon fossa, bony work can proceed with removal of loose bodies and burring of osteophytes, particularly within the olecranon fossa but also along the tip and sides of the olecranon. Caution should be exercised in the posteromedial aspect of the joint, as the ulnar nerve is located directly adjacent to the capsule; the shaver should be aimed away from the capsule while facing that area. The elbow is repeatedly flexed and extended while looking for impingement of the olecranon within the fossa. Keener et al. [30] demonstrated that 12–14 mm of the olecranon tip can be resected without injuring the insertion of the triceps. Capsular release can be performed with a blunt trocar to elevate the capsule off the posterior humerus, arthroscopic biter, or sharp dissection. Capsular release is completed when the triceps is visualized at which time any adhesions between the capsule and triceps can be disrupted.

Ulnar Nerve

Special consideration must be given to the ulnar nerve when surgically managing an elbow contracture. In a cadaver study, Gelberman et al. [31] demonstrated that elbow flexion led to decreased cubital tunnel volume and increased intraneural pressure. Williams et al. [32] conducted a retrospective review of 164 consecutive patients who underwent open or arthroscopic release of a contracted elbow and found that 15.2 % of patients with preoperative flexion ≤100° had new-onset post procedure ulnar nerve symptoms compared to 3.7 % patients with preoperative flexion >100°. This supports previous recommendations to decompress the ulnar nerve if there is less than 90–100° of preoperative flexion or if the patient had symptoms consistent with ulnar nerve compression at the elbow [10, 22, 33]. Typically, decompression has been accomplished through an open approach that can allow concurrent release of the posteromedial capsule [10, 33] or the posterior bundle of the medial collateral ligament [22]. Ruch et al. [34] showed that open release of the posterior and transverse bundles of the medial collateral ligament can be performed without compromise of elbow stability. Recently, there has been evidence to suggest that arthroscopic ulnar nerve decompression is possible [35]. The technique involves utilizing a posterolateral portal for viewing and a direct posterior portal for initial debridement with a shaver followed by a smooth biter to carefully resect capsule from 3 to 4 cm proximal to the medial epicondyle to the posterior edge of the medial collateral ligament [35].

Postoperative Management

At the conclusion of the procedure, the arthroscope is removed and excess fluid is "milked" out of the joint, portals are closed with nylon sutures and elbow range of motion is carefully assessed with a goniometer prior to applying a sterile compressive dressing. The goal of postoperative rehabilitation is to maintain or improve on the range of motion measured at the completion of the procedure. There is no single protocol for the contracted elbow; depending on the severity of the contracture and patient compliance, therapy programs are individualized. Typically, each elbow is placed in a posterior slab splint in full extension with the extremity elevated and judicious use of ice for edema control. The splint is removed on the first postoperative day at which time range of motion commences. For minimal contractures and a compliant patient, instruction in a home physical therapy regimen including active and passive range of motion exercises may be all that is required; most patients are referred to physiotherapy and find it useful. For more substantial contractures, a night-time static progressive splint may be beneficial. For severe contractures or noncompliant patients, one can consider continuous passive motion (CPM) machines. However, recent evidence questions the efficacy of CPM use after open elbow contracture release [36]. If CPM is utilized, it is necessary to use the full range of motion, necessitating satisfactory pain control with narcotics, continuous regional anesthetics, or local anesthetic by continuous infusion [37]. One potential issue with CPM use under regional block is the potential for ongoing nerve irritation (i.e., the ulnar nerve), which is masked by the regional anesthesia.

Outcomes and Complications

There have been no randomized control trials evaluating arthroscopic elbow contracture release but there does exist a substantial body of literature suggesting that arthroscopic release improves range of motion [38–51] (Table 30.1). Arthroscopic debridement has been shown to improve range of motion and pain in a cohort of 35 professional athletes with elbow osteoarthritis. All athletes returned to their sport and 18 continued to participate in high-level competitions with five patients winning national or international competitions [50].

Only one study directly compared open versus arthroscopic elbow contracture release in the setting of ostoarthritis; outcomes and complication rates are comparable and both procedures can yield reliable improvements in elbow range of motion [52]. Likewise, when examining the literature with respect to open and arthroscopic releases, the outcomes appear to be similar [53–58].

While elbow arthroscopy has been utilized for a variety of clinical problems, it remains a technically challenging procedure with the potential for serious complications given the proximity of important neurovascular structures. Injury to each of the susceptible peripheral nerves about the elbow has been reported following elbow arthroscopy; injury is probably underreported. In addition, certain diagnoses or conditions confer what appears to be an increased risk with this procedure. In a series from the Mayo Clinic, transient nerve palsies were noted in 12 of 473 elbow arthroscopies [16]. Statistically significant factors associated with injury included diagnosis of contracture and performing a capsular release [16]. Posttraumatic contractures are also subject to distortion of bony and or soft tissue landmarks, which may make neurovascular structures more vulnerable to injury [38]. Compartment syndrome has been shown to be an infrequent, albeit devastating complication of the procedure [59]. Kim et al. [60] studied the learning curve for arthroscopic treatment for limitation of elbow range of motion and found a statistically significant decrease in operative time after the initial 15 patients and that operative time was negatively correlated with range of motion. Interestingly, increasing surgeon experience did not correlate with postoperative motion and clinical outcomes; the authors theorize that this is related to the influence of "case mix," or the tendency for a surgeon to treat more difficult cases as they become more proficient [60].

Table 30.1 Literature regarding contracture release

Author (Year)	# pts	Surgical indication	Exclusion criteria	Mean F/U (mos)	Mean flexion (°)			Mean extension (°)			Improve arc of motion	Complications	Comments
					Pre-Op	Post-Op	Improve	Pre-Op	Post-Op	Improve			
Jones and Savoie [13]	12	Flexion contracture and failed nonoperative tx: ≥3 mos of PT and splinting		22	106	138	32	–38	–3	35	67	1 permanent PIN palsy required surgical intervention 1 MUA 3 weeks post-op	
Timmerman and Andrews [39]	19	Post traumatic pain and stiffness that failed conservative therapy, minimum 15° flexion contracture	arthroscopic finding of loose bodies or osteophytes without capsular or soft tissue scarring	2	123	134	11	–29	–11	18	29	1 repeat arthroscopic procedure for debridement. 1 open arthrotomy 5 mos after arthroscopic procedure	
Byrd [40]	5	Dysfunction due to limited ROM secondary to radial head fx. No improvement with PT		24	124	138	14	–41	–11	30	44	None	
Kim et al. [41]	25	ADL disrupted due to lack of elbow ROM with no improvement after 6 mos PT	Rheumatoid arthritis, PVNS	25	113	130	17	–21	–14	7	24	2 cases transient median nerve palsy. 1 arthroscopic burr breakage	
Phillips and Strasburger [42]	25	Arthrofibrosis		18	118	137	19	–31	–7	24	41	1 reoperation due to inadequate capsular release with continued stiffness/pain	
Savoie et al. [43]	24	Painful restricted motion due to arthritic process refractory to 3–6 mos nonop tx		32	90	139	49	–40	–8	32	81	1 portal site infection: resolved with Abx, HO in 1 patient, 2 pts with recurrent effusion with 1 requiring excision radial head	Arthroscopic modification of the open Outerbridge-Kashiwagi procedure
Kim and Shin [44]	63	ADL disrupted due to lack of elbow ROM with no improvement after 3 mos PT	Arthrofibrosis caused by inflammatory disease and tuberculous arthritis	42.5	108	131	23	–29	–9	20	43	2 cases transient median nerve palsy.	
Ball et al. [45]	14	Restricted elbow ROM interfered with ADL and did not improve with nonop tx	Sig intrinsic disease, primary degenerative or inflammatory arthritis, post traumatic HO	≥12	117.5	133	15.5	–35.4	–9.3	26.1	50	1 portal site infection: resolved with Abx and I&D	
Lapner et al. [46]	20	Undisplaced radial head fx with failure of ≥6 mos therapy and <30–130° ROM or pain		54	130	137	7	–22	–10	12	9	None	Incomplete data on 8 pts lost to follow-up

(continued)

Table 30.1 (continued)

Author (Year)	# pts	Surgical indication	Exclusion criteria	Mean F/U (mos)	Mean flexion (°)			Mean extension (°)			Improve arc of motion	Complications	Comments
					Pre-Op	Post-Op	Improve	Pre-Op	Post-Op	Improve			
Nguyen et al. [47]	22	Failure of nonsurgical tx for >6 mos and interference with ADL, avocation, sports, or hobbies	Insufficient nonsurgical tx, active infection, inadequate motion or skin coverage, post-op compliance, HO, poor articular surfaces	25	122	141	19	−38	−19	19	38	No major neurovascular complications Medial antebrachial cutaneous nerve neuroma 3 pts portal tenderness	1 patient with pre-op flexion 75° developed ulnar neuropathy, resolved by 3 year follow-up
Kelly et al. [48]	24	Degenerative arthritis with impingement with an average of 56 mos nonoperative tx		67	111	132	21	−20	−9	11	32	None	
Somanchi and Funk [49]	22	Painful or stiff elbow with or without locking episodes after a period of failed nonoperative tx		25	132	138	6	−26.6	−24	2.6	18	2 ulnar neuropathy: 1 resolved spontaneously, 1 resolved after decompression	
Yan et al. [50]	35	Pain that affected their athletic training with failed conservative therapy for >3 mos		43	125	134	9	−14	−7	7	16	2 pts with residual loose bodies with 1 pt returning to OR. 1 transient ulnar neuropathy.	All patients were professional athletes (mostly wrestling, judo, weightlifting)
Cefo and Eygendaal [51]	27	Symptomatic loss of flexion or extension >20° despite 6 mos PT	Unable to comply with post-op rehab protocol, Sig intrinsic disease, HO, primary degenerative or inflammatory arthritis, previous ulnar nerve decompression, required hardware removal	3	123	133	10	−24	−7	17	26	1 portal site infection: resolved with Abx	

tx treatment, *PT* physical therapy, *ROM* range of motion, *fx* fracture, *ADL* activities of daily living, *mos* months, *F/U* follow-up, *PVNS* pigmented villonodular synovitis, *sig* significant, *HO* heterotopic ossification, *PIN* posterior interosseous nerve, *MUA* manipulation under anesthesia, *abx* antibiotics, *pts* patients, *I&D* irrigation and debridement, *OR* operating room

References

1. Davila SA, Johnston-Jones K. Managing the stiff elbow: operative, nonoperative, and postoperative techniques. J Hand Ther. 2006; 19(2):268–81.
2. O'Driscoll S. Arthroscopic osteocapsular arthroplasty. In: Yamaguchi K, O'Driscoll S, King G, McKee M, editors. Advanced reconstruction elbow. 1st ed. Rosemont, IL: American Academy of Orthopaedic Surgeons; 2007.
3. Morrey BF, Askew LJ, Chao EY. A biomechanical study of normal functional elbow motion. J Bone Joint Surg Am. 1981;63(6):872–7.
4. Magermans DJ, Chadwick EK, Veeger HE, van der Helm FC. Requirements for upper extremity motions during activities of daily living. Clin Biomech (Bristol, Avon). 2005;20(6):591–9.
5. Henmi S, Yonenobu K, Masatomi T, Oda K. A biomechanical study of activities of daily living using neck and upper limbs with an optical three-dimensional motion analysis system. Mod Rheumatol. 2006;16(5):289–93.
6. Pieniazek M, Chwala W, Szczechowicz J, Pelczar-Pieniazek M. Upper limb joint mobility ranges during activities of daily living determined by three-dimensional motion analysis: preliminary report. Ortop Traumatol Rehabil. 2007;9(4):413–22.
7. Sardelli M, Tashjian RZ, MacWilliams BA. Functional elbow range of motion for contemporary tasks. J Bone Joint Surg Am. 2011; 93(5):471–7.
8. Hotchkiss R. Elbow contracture. In: Green D, Hotchkiss R, Pederson W, Wolfe S, editors. Green's operative hand surgery. 5th ed. New York, NY: Churchill-Livingstone; 2005. p. 667.
9. Søjbjerg JO. The stiff elbow. Acta Orthop Scand. 1996;67(6): 626–31.
10. Blonna D, Bellato E, Marini E, Scelsi M, Castoldi F. Arthroscopic treatment of stiff elbow. ISRN Surg. 2011;2011:378135.
11. Morrey BF. Post-traumatic contracture of the elbow. Operative treatment, including distraction arthroplasty. J Bone Joint Surg Am. 1990;72(4):601–18.
12. Lindenhovius AL, Linzel DS, Doornberg JN, Ring DC, Jupiter JB. Comparison of elbow contracture release in elbows with and without heterotopic ossification restricting motion. J Shoulder Elbow Surg. 2007;16(5):621–5.
13. Tucker SA, Savoie FH 3rd FH, O'Brien MJ. Arthroscopic management of the post-traumatic stiff elbow. J Shoulder Elbow Surg. 2011;20(2 Suppl):S83–9.
14. Nirschl R, Morrey B. Rehabilitation. In: Morrey B, editor. The elbow and its disorders. 3rd ed. Philadelphia, PA: Saunders; 2000. p. 141.
15. Morrey B. Splints and bracing at the elbow. In: Morrey B, editor. The elbow and its disorders. 3rd ed. Philadelphia, PA: Saunders; 2000. p. 150–4.
16. Kelly EW, Morrey BF, O'Driscoll SW. Complications of elbow arthroscopy. J Bone Joint Surg Am. 2001;83-A(1):25–34.
17. Steinmann S. Elbow arthroscopy. J Am Soc Surg Hand. 2003;3:199–207.
18. Andrews JR, Carson WG. Arthroscopy of the elbow. Arthroscopy. 1985;1(2):97–107.
19. Keener JD, Galatz LM. Arthroscopic management of the stiff elbow. J Am Acad Orthop Surg. 2011;19(5):265–74.
20. Adams JE, Steinmann SP. Nerve injuries about the elbow. J Hand Surg Am. 2006;31(2):303–13.
21. Lynch GJ, Meyers JF, Whipple TL, Caspari RB. Neurovascular anatomy and elbow arthroscopy: inherent risks. Arthroscopy. 1986;2(3):190–7.
22. Van Zeeland NL, Yamaguchi K. Arthroscopic capsular release of the elbow. J Shoulder Elbow Surg. 2010;19(2 Suppl):13–9.
23. O'Driscoll SW, Morrey BF. Arthroscopy of the elbow diagnostic and therapeutic benefits and hazards. J Bone Joint Surg Am. 1992;74(1):84–94.
24. Stothers K, Day B, Regan W. Arthroscopy of the elbow: anatomy, portal sites, and a description of the proximal lateral portal. Arthroscopy. 1995;11(4):449–57.
25. Gallay SH, Richards RR, O'Driscoll SW. Intraarticular capacity and compliance of stiff and normal elbows. Arthroscopy. 1993; 9(1):9–13.
26. Poehling GG, Whipple TL, Sisco L, Goldman B. Elbow arthroscopy: a new technique. Arthroscopy. 1989;5(3):222–4.
27. Lindenfeld TN. Medial approach in elbow arthroscopy. Am J Sports Med. 1990;18(4):413–7.
28. Field L, Altchek D, Warren R. Arthroscopic anatomy of the lateral elbow: a comparison of three portals. Arthroscopy. 1994;10(6): 602–7.
29. Yamaguchi K, Tashjian R. Setup and portals. In: Yamaguchi K, O'Driscoll S, King G, McKee M, editors. Advanced reconstruction elbow. Rosemont, IL: American Academy of Orthopaedic Surgery; 2007. p. 3–11.
30. Keener J, Chafik D, Kim H, Galatz L, Yamaguchi K. Insertional anatomy of the triceps brachii tendon. J Shoulder Elbow Surg. 2010;19(3):399–405.
31. Gelberman RH, Yamaguchi K, Hollstien SB, Winn SS, Heidenreich Jr FP, Bindra RR, et al. Changes in interstitial pressure and cross-sectional area of the cubital tunnel and of the ulnar nerve with flexion of the elbow an experimental study in human cadavera. J Bone Joint Surg Am. 1998;80(4): 492–501.
32. Williams BG, Sotereanos DG, Baratz ME, Jarrett CD, Venouziou AI, Miller MC. The contracted elbow: Is ulnar nerve release necessary? J Shoulder Elbow Surg. 2012;21(12):1632–6.
33. Sahajpal D, Choi T, Wright TW. Arthroscopic release of the stiff elbow. J Hand Surg Am. 2009;34(3):540–4.
34. Ruch DS, Shen J, Chloros GD, Krings E, Papadonikolakis A. Release of the medial collateral ligament to improve flexion in post-traumatic elbow stiffness. J Bone Joint Surg Br. 2008; 90(5):614–8.
35. Kovachevich R, Steinmann SP. Arthroscopic ulnar nerve decompression in the setting of elbow osteoarthritis. J Hand Surg Am. 2012;37(4):663–8.
36. Lindenhovius AL, van de Luijtgaarden K, Ring D, Jupiter J. Open elbow contracture release: postoperative management with and without continuous passive motion. J Hand Surg Am. 2009; 34(5):858–65.
37. O'Driscoll SW, Giori NJ. Continuous passive motion (CPM): theory and principles of clinical application. J Rehabil Res Dev. 2000;37(2):179–88.
38. Jones GS, Savoie 3rd FH. Arthroscopic capsular release of flexion contractures (arthrofibrosis) of the elbow. Arthroscopy. 1993;9(3): 277–83.
39. Timmerman LA, Andrews JR. Arthroscopic treatment of posttraumatic elbow pain and stiffness. Am J Sports Med. 1994;22(2): 230–5.
40. Byrd JW. Elbow arthroscopy for arthrofibrosis after type I radial head fractures. Arthroscopy. 1994;10(2):162–5.
41. Kim SJ, Kim HK, Lee JW. Arthroscopy for limitation of motion of the elbow. Arthroscopy. 1995;11(6):680–3.
42. Phillips BB, Strasburger S. Arthroscopic treatment of arthrofibrosis of the elbow joint. Arthroscopy. 1998;14(1):38–44.
43. Savoie 3rd FH, Nunley PD, Field LD. Arthroscopic management of the arthritic elbow: indications, technique, and results. J Shoulder Elbow Surg. 1999;8(3):214–9.
44. Kim SJ, Shin SJ. Arthroscopic treatment for limitation of motion of the elbow. Clin Orthop Relat Res. 2000;375:140–8.

45. Ball CM, Meunier M, Galatz LM, Calfee R, Yamaguchi K. Arthroscopic treatment of post-traumatic elbow contracture. J Shoulder Elbow Surg. 2002;11(6):624–9.
46. Lapner PC, Leith JM, Regan WD. Arthroscopic debridement of the elbow for arthrofibrosis resulting from nondisplaced fracture of the radial head. Arthroscopy. 2005;21(12):1492.
47. Nguyen D, Proper SI, MacDermid JC, King GJ, Faber KJ. Functional outcomes of arthroscopic capsular release of the elbow. Arthroscopy. 2006;22(8):842–9.
48. Kelly EW, Bryce R, Coghlan J, Bell S. Arthroscopic debridement without radial head excision of the osteoarthritic elbow. Arthroscopy. 2007;23(2):151–6.
49. Somanchi BV, Funk L. Evaluation of functional outcome and patient satisfaction after arthroscopic elbow arthrolysis. Acta Orthop Belg. 2008;74(1):17–23.
50. Yan H, Cui G, Wang J, Yin Y, Ao Y. Arthroscopic debridement of osteoarthritic elbow in professional athletes. Chin Med J (Engl). 2011;124(24):4223–8.
51. Cefo I, Eygendaal D. Arthroscopic arthrolysis for posttraumatic elbow stiffness. J Shoulder Elbow Surg. 2011;20(3):434–9.
52. Cohen AP, Redden JF, Stanley D. Treatment of osteoarthritis of the elbow: a comparison of open and arthroscopic debridement. Arthroscopy. 2000;16(7):701–6.
53. Charalambous CP, Morrey BF. Posttraumatic elbow stiffness. J Bone Joint Surg Am. 2012;94(15):1428–37.
54. Urbaniak JR, Hansen PE, Beissinger SF, Aitken MS. Correction of post-traumatic flexion contracture of the elbow by anterior capsulotomy. J Bone Joint Surg Am. 1985;67(8):1160–4.
55. Husband JB, Hastings 2nd H. The lateral approach for operative release of post-traumatic contracture of the elbow. J Bone Joint Surg Am. 1990;72(9):1353–8.
56. Marti RK, Kerkhoffs GM, Maas M, Blankevoort L. Progressive surgical release of a posttraumatic stiff elbow. Technique and outcome after 2–18 years in 46 patients. Acta Orthop Scand. 2002; 73(2):144–50.
57. Tan V, Daluiski A, Simic P, Hotchkiss RN. Outcome of open release for post-traumatic elbow stiffness. J Trauma. 2006;61(3): 673–8.
58. Katolik LI, Cohen MS. Anterior interosseous nerve palsy after open capsular release for elbow stiffness: report of 2 cases. J Hand Surg Am. 2009;34(2):288–91.
59. Angelo RL. Advances in elbow arthroscopy. Orthopedics. 1993; 16(9):1037–46.
60. Kim SJ, Moon HK, Chun YM, Chang JH. Arthroscopic treatment for limitation of motion of the elbow: the learning curve. Knee Surg Sports Traumatol Arthrosc. 2011;19(6):1013–8.

Arthroscopic Management of Elbow Arthritis

31

Roger P. van Riet

Introduction

Osteoarthritis (OA) of the elbow is relatively uncommon, with a prevalence of about 2 %. It is not commonly found under the age of 40 or in women [1], with a ratio of approximately 4:1 [2]. It is assumed that genetic factors, as well as manual labor or sports play a role in the etiology of elbow OA. Trauma to the elbow can lead to early posttraumatic arthritis (PTA), even in nondisplaced fractures. Unless there are specific posttrauma deformities, PTA usually presents itself in a similar fashion to OA, albeit often in younger patients. As in other joints, narrowing of the joints space, osteophyte formation, and the development of loose bodies characterize OA of the elbow. In contrast to other joints large osteophytes are more commonly found, when compared to joint space narrowing [3].

The incidence of inflammatory types of arthritis, such as rheumatoid arthritis (RA), has decreased significantly in recent years, due to the increased efficacy of new pharmacological options, that can actually change the disease process.

Clinical Presentation

OA of the elbow usually presents itself by a decreased range of motion. Locking or impingement type pain at the end of flexion and extension are also common. Pain and crepitus throughout the range of motion may be present in cases, where there is near complete loss of articular cartilage.

Locking of the elbow caused by intra-articular loose bodies can occur early in the disease process. Even relatively small loose bodies can cause severe disability when they are temporarily compressed between the articular surfaces. The patient can usually unlock Tekst the elbow by rotation of the forearm or by carefully moving the elbow. Locking is often very painful and leads to recurrent synovitis and hydrops. It can be assumed that loose bodies may increase the progression of OA, mechanically by damaging the articular surfaces and indirectly by causing recurrent inflammation of the joint.

Structural elbow stiffness is caused by osteophyte formation on the tips of the coronoid and olecranon, as well as bone formation in the fossae and corresponding thickening of the olecranon fossa membrane [4]. Capsular thickening and adhesions will further decrease the range of motion in more advanced stages of OA.

Bony deformation, inflammation, and capsular thickening can lead to ulnar nerve compression and dysfunction. Cubital tunnel syndrome is very common in patients with elbow OA and RA and is found in nearly half of patients that require surgery [5]. The ulnar nerve is somewhat protected by the loss of flexion, present in severe OA, and ulnar nerve pathology may not come to light until range of motion is improved surgically. Failure to recognize impending ulnar nerve compression may necessitate early secondary surgery to release or transpose the ulnar nerve [6].

Unlike in patients with PTA, or inflammatory disease RA, severe bone loss or ligamentous insufficiency does not usually occur in patients with primary OA. Instability is therefore not a common problem in patients with OA and physiological laxity often decreases in these patients. Instability may however be a very important finding in patients with PTA or RA and this may change the indications for arthroscopic surgery.

Technical Investigations

Plain radiographs are usually sufficient to show arthritis of the elbow. Osteophytes are readily visible, as well as some loose bodies and narrowing of the joint space (Fig. 31.1). In patients with PTA, malunion, nonunion, or articular

R.P. van Riet, M.D., Ph.D. (✉)
Department of Orthopedics and Traumatology, Monica Hospital, Erasme University Hospital, Stevenslei 20, Antwerp 2100, Belgium
e-mail: drrogervanriet@azmonica.be

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*, DOI 10.1007/978-1-4614-1596-1_31, © Springer Science+Business Media New York 2015

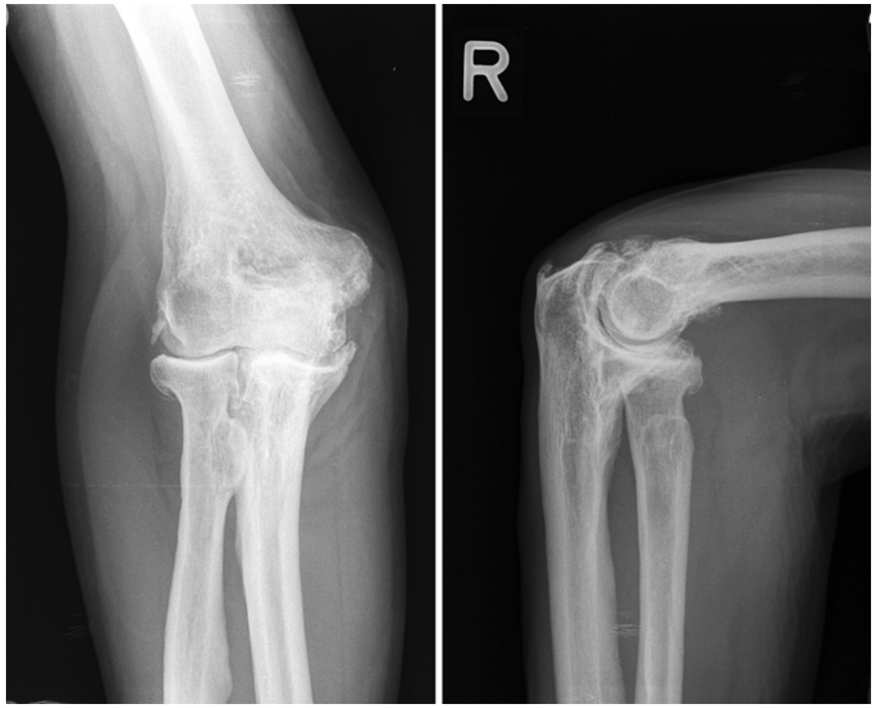


Fig. 31.1 Anteroposterior and lateral radiographs of a right elbow showing signs of advanced stage osteoarthritis. Note the joint symmetrical joint space narrowing, as well as ulnohumeral and radiohumeral osteophytes and obliteration of the anterior and posterior fossae. (Courtesy of MoRe Foundation)

Fig. 31.2 The exact location of impinging osteophytes gets clear when analyzing CT images. Large osteophytes are present on the coronoid tip and coronoid fossa. These are likely to block flexion. The olecranon fossa has been filled by another large osteophyte and a large loose body is present in the posterior compartment. There is a smaller corresponding osteophyte at the tip of the olecranon. (Courtesy of MoRe Foundation)

incongruities should specifically be noted, as well as the potential presence of heterotopic ossification (HO). When planning open or arthroscopic surgery, computed tomography (CT) scanning of the elbow is highly recommended (Fig. 31.2). In some elbows, plain radiographs may only show mild changes, whereas CT images and three-dimensional (3D) reconstructions can reveal more pronounced arthritic changes (Fig. 31.3) or articular incongruity or malunion of fractures. CT images are necessary to accurately plan surgery, to locate impinging osteophytes and loose bodies. Particularly, the number of loose bodies should be noted from the scan, as they may shift and are easily missed during surgery. Three-dimensional (3D) rendering of the images helps in preoperative planning as well, by showing the relationship of pathological changes to the articulation, but they are most helpful as a tool to inform the patient (Fig. 31.4).

Ultrasound scans, Magnetic Resonance Imaging (MRI) and Technetium bone scans are usually not indicated, unless in cases where inflammation of the joint and/or discrete cartilage disruption or ligamentous injury are suspected.

Electromyography (EMG) is indicated when ulnar nerve symptoms are present. If the EMG is positive, an ulnar nerve release should be performed at the time of the arthroscopic procedure. If the preoperative arc of motion is less than 90° an ulnar nerve release should be contemplated, even when the EMG is negative.

Indications for Arthroscopic Surgery

The most common indications for surgery are pain and elbow stiffness, locking, or recurrent synovitis. Conservative measures such as physiotherapy, nonsteroidal anti-inflammatory drugs, and intra-articular corticosteroid injections are the first line of treatment, together with the pharmacological treatment of inflammatory disease, but if these fail surgery

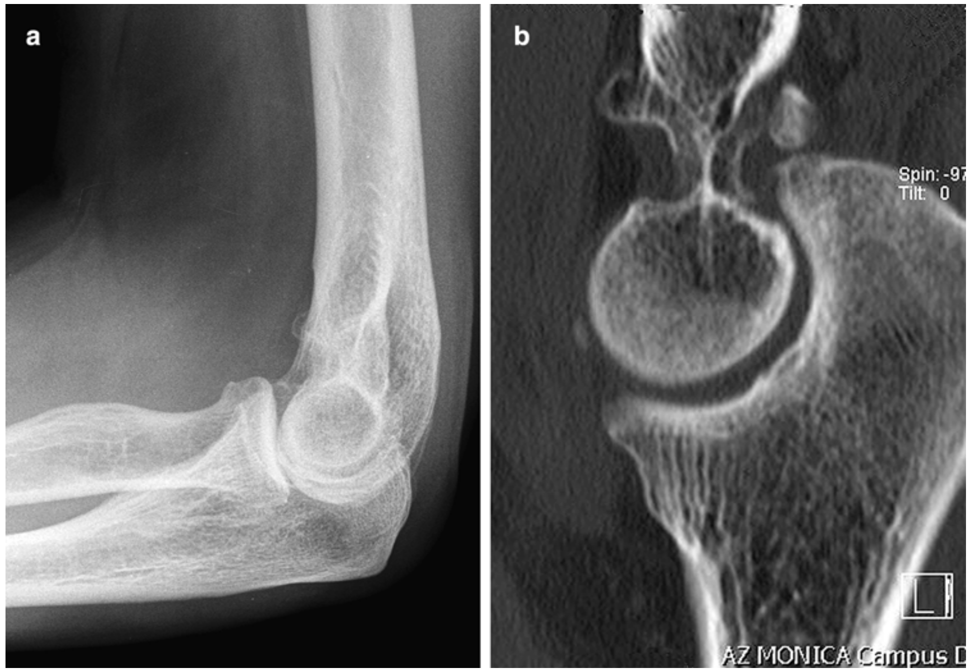


Fig. 31.3 (**a**) Lateral radiograph of a left elbow showing mild osteoarthritic changes. (**b**) CT scan of the same elbow showing signs of advanced osteoarthritic disease with loose bodies and thickening of the olecranon fossa membrane. (Courtesy of MoRe Foundation)

Fig. 31.4 Three-dimensional reconstructions of native CT images are particularly helpful in localizing loose bodies, such as here in the radio-humeral gutter. (Courtesy of MoRe Foundation)

may become an option. Pro's and cons as well as potential complications of all surgical options should be discussed with the patient. Arthroscopic and open debridement, the possibility of a total elbow arthroplasty and even arthrodesis should are discussed, depending on the severity of the symptoms and progression of the arthritis, so that the patient can make an informed decision. Arthroscopic arthroplasty is my preferred choice for the surgical management of elbow osteoarthritis.

ContraIndications for Arthroscopic Surgery

Besides general contraindications for surgery, such as poor health or significant comorbidities, there are no specific absolute contraindications to use an arthroscopic technique in the treatment of elbow arthritis. There are however several relative contraindications mostly relating to the safety of the procedure. These depend greatly on the experience of the surgeon and may include multiple prior surgeries and scars, retained hardware, previous ulnar nerve surgery, severe stiffness or instability, heterotopic ossification etc. It is important for the surgeon to know their limits as arthroscopic osteocapsular arthroplasty is technically demanding and becomes increasingly difficult if any of the previously mentioned cofactors are present.

In cases of severe bone loss or instability, arthroscopy is not likely to significantly improve the patient's symptoms and an arthroscopic technique will not be indicated [7]. If the surgeon thinks the risk of complications or the potential gain from the arthroscopic technique are unacceptable, an open procedure or an intra-operative conversion to an open procedure should be possible and this should preoperatively be discussed with the patient.

Arthroscopic Technique

The elbow is examined thoroughly, once general anesthesia has been administered. The elbow is taken through the arc of motion and range, end-feeling (hard or soft), crepitus, or mechanical blocking are tested. Varus-valgus and rotator stability are tested as well. The patient is then positioned in lateral decubitus, with the arm over an armrest. Prone and supine positions are also possible, depending on the surgeon's preference. The arm is exsanguinated and a tourniquet is used. The ulnar nerve is palpated and marked with a sterile skin marker. If a mini-open ulnar nerve release is indicated, it can be done at this moment. Other landmarks, such as the olecranon, epicondyles, and radial head can be marked as well. The elbow capsule is distended with approximately 25 ml of saline. The volume of the capsule can be significantly decreased in severe OA with capsular retraction.

It depends on the surgeon's preference whether the anterior or posterior compartment is treated first. Some prefer to start the arthroscopy at the posterior compartment because it is often difficult to get a good view of the posterior structures. A posterior synovectomie and removal of fibrosis and intra-articular adhesions can be quite laborious and becomes more difficult once the soft tissues are swollen. Others prefer to start at the anterior comportment as neurovascular structures are particularly at risk anteriorly. Swelling and edema are limited at the beginning but are often pronounced at the end of the procedure.

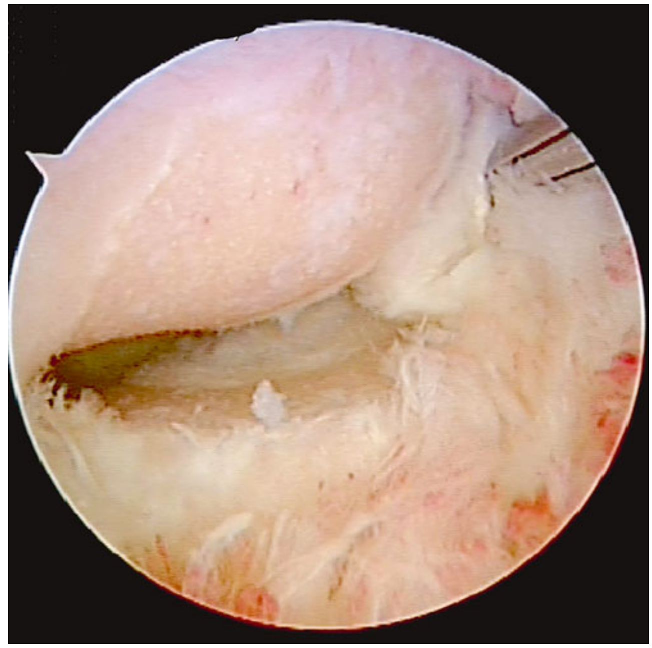


Fig. 31.5 Arthroscopic view of the anterior compartment of the elbow, showing loss of cartilage from the radial head (*bottom*) and capitellum (*top*) and accompanying synovitis. (Courtesy of MoRe Foundation)

Anterior Compartment

The anteromedial portal is made 2 cm proximal and 1 cm anterior to the medial epicondyl [8, 9]. The skin is incised only in order to protect the medial antebrachial cutaneous nerve. If a mini-open ulnar nerve release was performed, the portal can be included in this skin incision. The fascia anterior to the intermuscular septum is pierced with a blunt trocar. The humerus is posterior to the trocar at his point. In patients with OA it is very important to keep the trocar in contact with the humerus and directed at the radial head, as anterior osteophytes may deflect the trocar anteriorly in the direction of the radial nerve. The capsule is pierced and a standard 4.5 mm scope is inserted. The radial head is brought into view (Fig. 31.5). The position of the scope can be confirmed by rotating the forearm. The anterior compartment is inspected in a standard fashion, starting from the radial head and radiocapitellar joint. The scope is directed medially to visualize the coronoid process, coronoid fossa, and radial fossa on the humerus. The elbow can be flexed to improve the view.

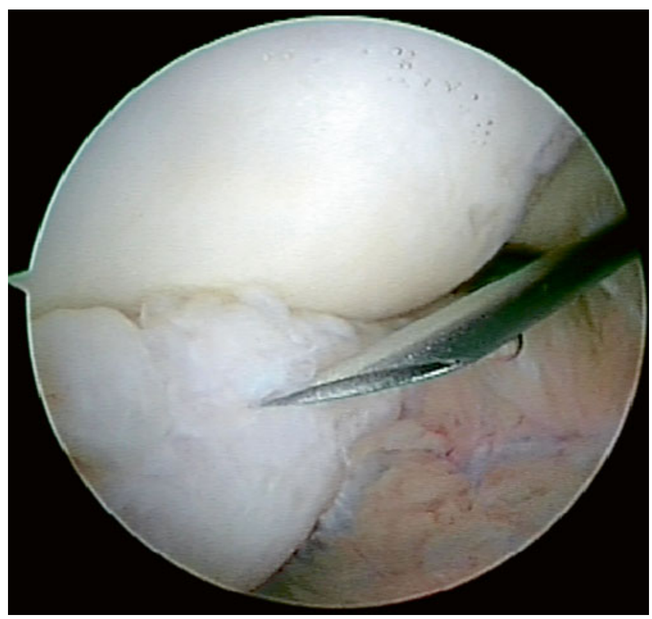


Fig. 31.6 The position of the anterolateral portal is confirmed with a needle directed at the tip of the arthritic coronoid process. (Courtesy of MoRe Foundation)

The position of the lateral portal is determined with a needle. The radial head is palpated and the needle is inserted into the joint, anterior to the radial head. The tip of the needle is directed towards the coronoid process, to make sure further instruments will be able to reach. The position of the lateral portal is crucial. If the portal is placed too posteriorly instruments it will not be possible to remove coronoid osteophytes (Fig. 31.6). The radial nerve will be at risk if the portal is placed too anteriorly [10].

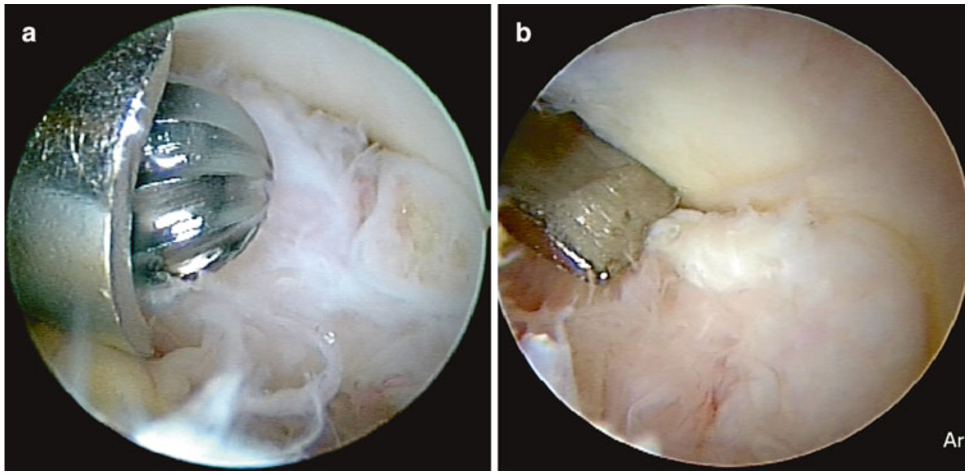


Fig. 31.7 (**a**) Osteophytes at the tip of the coronoid process can be removed with a burr or (**b**) an osteotome. (Courtesy of MoRe Foundation)

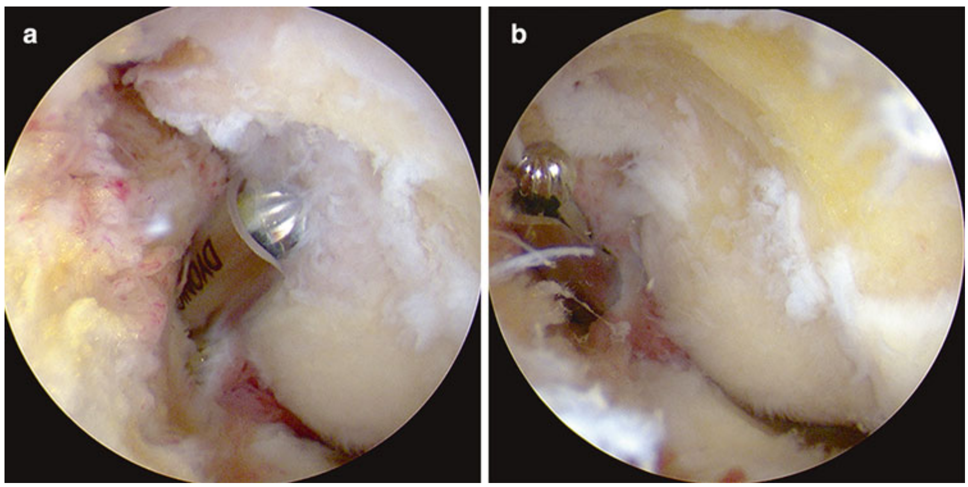


Fig. 31.8 (**a**) The burr is directed at a large osteophyte extending from the radial into the coronoid fossa. (**b**) the osteophyte is removed, so there is no longer a bony block to flexion. (Courtesy of MoRe Foundation)

A more proximal position (proximal anterolateral portal) will decrease the risk, when compared to a distal portal (anterolateral portal), but may again decrease the ability to work on the medial side of the elbow. An excellent 3D knowledge of the elbow's anatomy is necessary in order to avoid injury to the important anterior structures.

A synovectomie is performed with a shaver or radiofrequency (RF) probe and intra-articular adhesions are removed. In severe cases this step is necessary before the medial side of the elbow can be visualized. Care should be taken not to cut the capsule at this point, as this will increase swelling in the surrounding soft tissues, complicating the rest of the procedure. It should be noted that the capsule in patients with RA is often not thickened and is often relatively loose. It is imperative that the tip of the shaver is always in direct view and suction is not used when the shaver is active. The loose capsule in patients with RA can easily be sucked into the shaver and could be cut accidentally. This will of course increase the risk of neurovascular complications. Coronoid osteophytes are removed with a burr or a 5 mm osteotome (Fig. 31.7). Osteophytes blocking the coronoid and/or radial fossae are removed with a burr (Fig. 31.8). The elbow is moved to full flexion in order to check for further impingement. The radial head can be resected with a burr. Resection starts on the anterolateral quadrant of the head and further resection is done by rotating the forearm, while the burr is placed on the radial head. If it is not possible to resect the entire radial head, this can quite easily be finished from the soft spot portal with the scope in radial gutter.

A capsulectomy is performed at the end of the bony procedure. This step is not necessary if range of motion is normal was full preoperatively. Typically the scope is switched to the lateral portal and capsule is cut, from medial to lateral, with a duckbill. Alternatively the capsule can be cut from lateral to medial. The remainder of the capsule is then removed with a shaver. Particularly at this point, the radial nerve is at risk and care should be taken to protect the nerve at all times. The nerve is situated slightly medial to the anterior center of the radial head, directly against the capsule. The median nerve and brachial artery are somewhat protected

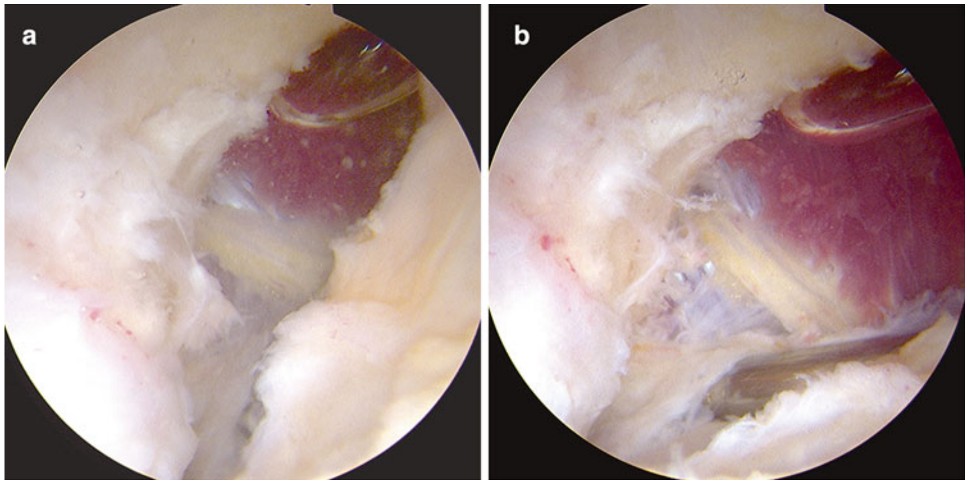


Fig. 31.9 (**a**) Humerus (*left*) and capsule (*right*) are separated with a shaver or a blunt instrument. (**b**) Once the capsulotomy is completed the remaining capsule can be removed with a shaver, but this is not always indicated and increases the risk of neurovascular complications. (Courtesy of MoRe Foundation)

by the brachialis muscle that lies between the nerve and the capsule [11].

It has not conclusively been proven that a complete capsulectomy offers a clear advantage over a simple release and some surgeons therefore prefer to perform a capsulotomy. This is technically less challenging and it may decrease the risk of neurologic injury. A capsulotomie is performed with the shaver on the humeral bone. The shaver is advanced from distal to proximal and the capsule is stripped from the bone. A blunt instrument can be used to further strip the capsule, until muscular fibers become visible and the capsule is fully detached from the bone (Fig. 31.9).

Posterior Compartment

The standard viewing portal is the posterolateral portal. It is made at the lateral border of the olecranon. Originally it was described about 3 cm proximal from the olecranon tip [10] but placing the portal just lateral to the olecranon eases entry into the radiohumeral gutter later on in the procedure. It is often difficult to immediately get a clear view of the posterior structures as osteophytes, synovitis, and fibrosis of the fat pad obscure the view in osteoarthritic elbows. The scope is moved medially to the ulnar gutter. The ulnar gutter is usually still readily visible and if loose bodies were visible on the preoperative CT scan, they can often be found there. Once the ulnar gutter is identified, the scope can be moved laterally toward the tip of the olecranon. The olecranon fossa can be completely obliterated by osteophytes in severe cases. Extension of the elbow may show impinging osteophytes blocking full extension (Fig. 31.10). The straight posterior, or central posterior portal is made in the midline, 3 cm proximal to the tip of the olecranon. It is important that this portal is made sharply all the way through to the olecranon fossa, as entering the joint forcefully multiple times will have a more damaging effect on the tendon then sharply creating a portal that is large enough for instruments to enter the joint. The scope is then directed to the ulnar gutter once again and loose bodies are removed with a grasper through the central posterior portal. It is potentially risky to enter instruments into the ulnar gutter as the tip of the instrument can often not be seen when it is placed in the gutter. It is however usually relatively easy to "milk" loose bodies out of the gutter into the olecranon fossa by applying pressure onto the gutter and pushing the loose body from distal to proximal. A loose body can then safely be removed.

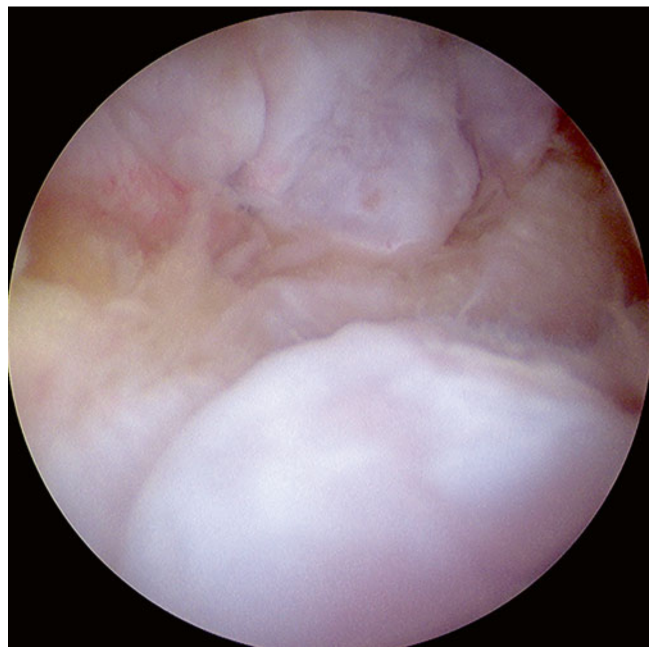


Fig. 31.10 Osteophytes on the olecranon (*bottom*) and in the olecranon fossa (*top*) often block extension in osteoarthritic elbows. (Courtesy of MoRe Foundation)

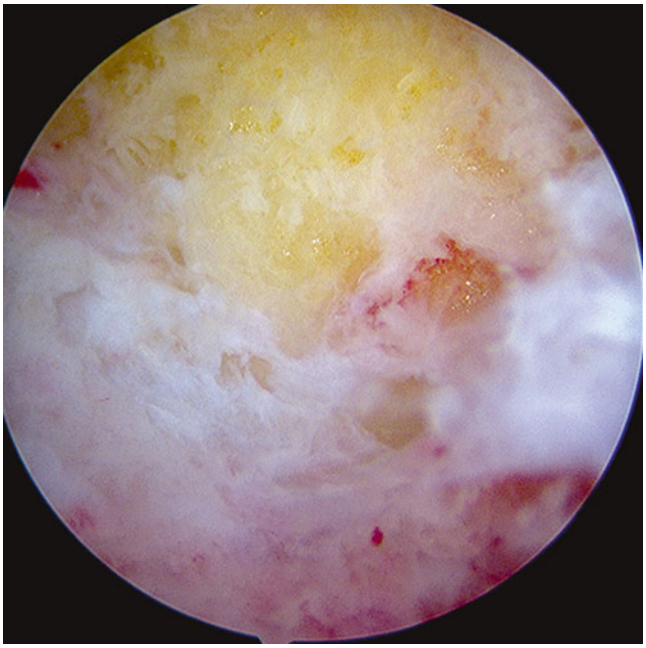


Fig. 31.11 The olecranon fossa is deepened and the anatomy is reconstituted after removal of the osteophytes. (Courtesy of MoRe Foundation)

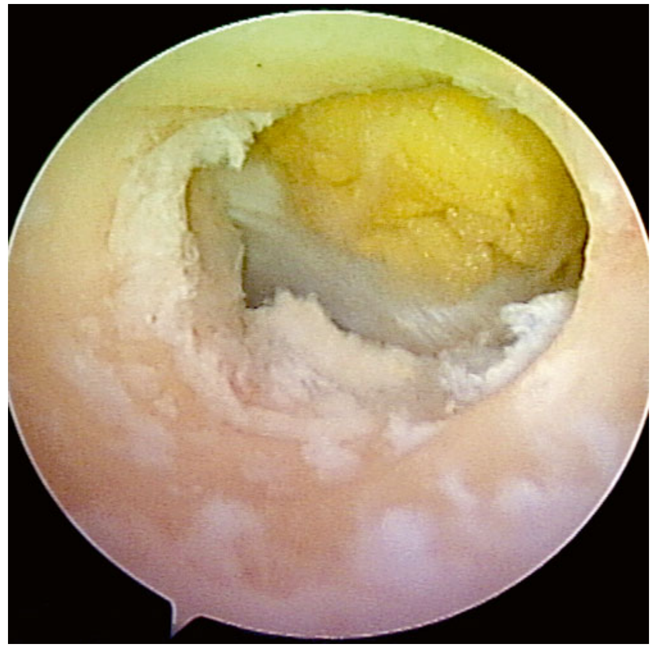


Fig. 31.12 A fenestration of the olecranon fossa can be performed but this is rarely necessary. In this particular case, a fenestration was done after removal of an osteoid osteoma in the olecranon fossa membrane. (Courtesy of MoRe Foundation)

A shaver or RF probe is used to debride soft tissue so that a clear view of the bony structures can be obtained. This step can be done first as additional loose bodies often become visible after this step. An osteotome or burr is then used to remove osteophytes from the tip of the olecranon. The use of a 5 mm osteotome will increase accuracy and safety on the medial aspect of the olecranon as soft tissue, including the ulnar nerve, may be pulled into the burr at this position. The osteotome enters the joint through the central posterior portal and is placed directly on the posterior surface of the olecranon. Especially in throwing athletes, care is taken not to remove any part of the articulating surface of the olecranon, as removal of excess bone will increase strain on the medial collateral ligament [12, 13]. Osteophytes should also be removed from the olecranon fossa. Some authors advocate fenestration of the fossa [14, 15] but if an anatomical reconstruction of the fossa is possible, fenestration is not necessary (Figs. 31.11 and 31.12). The amount of resection of the olecranon tip and contouring of the olecranon fossa are evaluated by extending the elbow with the scope in the olecranon fossa. Sufficient bone has been removed once there is no longer any bony impingement present.

Finally, the scope is directed to the radiohumeral joint. Following the tip of the olecranon laterally best does this. Once the radiohumeral gutter is visualized, the scope is advanced towards the radial head. There is often a synovial fold covering the radial head or a plica. Once the synovial fold and plica are removed, the cartilage of the radial head can be seen. Impinging osteophytes at the back of the capitellum can be removed. The scope can then carefully be brought towards and into the ulnohumeral joint space. A bare area is visible in nearly all elbows, between the coronoid process and the olecranon. This is a normal physiological finding and should not be confused with OA (Fig. 31.13). If instability is associated with OA, the scope can be brought all the way to the medial side, from the radial gutter. This "drive trough" is not possible in stable elbows.

Range of motion is noted at the end of the procedure. The elbow is often swollen and range of motion may be underestimated as swelling may prevent some motion. Portals are closed at the end of the procedure and the elbow is immobilized with a posterior splint in an extended position for 24 h.

Postoperative Rehabilitation

Most of these cases are done in day surgery. The patient removes the splint after 24 h. Portal sites are disinfected and dressed with a light bandage. The elbow should be mobilized immediately. Both active and passive motion is encouraged. A formal physiotherapy program may be indicated. Pain relief in the form of paracetamol and a NSAID is prescribed. Patients are instructed to take pain relief only if necessary. Most patients only use pain relief for 24–48 h, in the initial postoperative period.

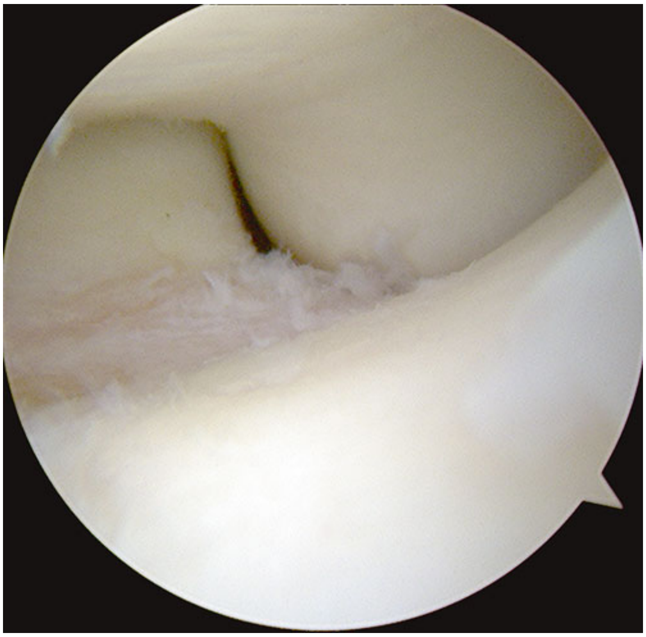


Fig. 31.13 View into the ulnohumeral joint. The scope is situated in the posterior radial gutter. A physiological bare area can be seen on the proximal ulna (*bottom*). This should not be confused with a cartilage defect. (Courtesy of MoRe Foundation)

Continuous passive motion may also be helpful in some cases, but this is not routinely used in our practice unless the patient is admitted to the hospital for the initial rehabilitation period. In these cases a prolonged brachial plexus block may be administered through an indwelling catheter and a patient controlled pump, so that the elbow can be mobilized pain free.

Results

Decreased pain and improvement in range of motion are significant in most cases. Improvement in arc of motion ranges from 8° to more than 80° [2, 14, 15]. Others have reported an increase in arc of motion at around 30° in patients with primary osteoarthritis of the elbow [16, 17]. Preoperative range of motion depends on mechanical factors as well as pain. It is therefore important to examine range of motion before and after the procedure, when the patient is under general anesthesia. Increase in motion can be dramatic, even before the arthroscopy has started, as only mechanical factors, such as osteophytes, loose bodies, and capsular retraction, will remain. Arthroscopy for OA in the elbow has been reported to have excellent results with regards to pain relief [14–18] and in a direct comparison with an open technique, arthroscopy yielded better results with regards to pain [15].

As a general rule, patients can expect approximately 30° increase of motion and a clinically significant decrease in pain levels in rest and during activities. It is important to note to patients that the progression of OA may slow down or may temporarily even be stopped but that cartilage loss cannot be replaced at this time and some symptoms may remain, even after an optimal surgical procedure.

Similar results have been reported in patients with RA, although there is some question regarding the longevity of the results in these patients [7].

Complications

Although this is a difficult procedure, reported complication rates are relatively low.

Deep infection of the elbow following elbow arthroscopy is a rare complication and occurs in less than 1 % [19].

Three cases of heterotopic ossification have been reported in the world literature as an exceedingly rare complication after elbow arthroscopy [20–22]. Prophylactic radiotherapy or NSAID are not generally recommended.

Transient or permanent nerve palsies more commonly occur from elbow arthroscopy and are a feared complication. Transient nerve palsy has been reported in approximately 2.5 %, with contracture and RA as significant risk factors [19]. Complete transection of the radial, median, and ulnar nerves has also been reported [23–26]. Fortunately, permanent damage to the neurovascular structures is a rare complication and its frequency seems to have decreased with the improvement of the technique [27]. Nonetheless, it has to be emphasized that the low frequency of permanent neural complications is due to the vigilance of the surgeon performing the procedure. Surgeons should remain aware of their limitations and have an excellent knowledge of the position of the nerves in order to avoid this disastrous complication. A late complication of arthroscopic osteocapsular release of the elbow is delayed onset ulnar nerve palsy. The incidence of postoperative onset of ulnar nerve symptoms may be decreased by a prophylactic concomitant release of the ulnar nerve. It is recommended that an ulnar nerve release is indicated if the arc of motion is less than 90° preoperatively [28]. The threshold to release or at least identify the ulnar nerve by a mini open approach should also be low in patients with previous ulnar nerve surgery, release, or transposition.

Finally, minor complications of elbow arthroscopy include persistent contracture and superficial portal drainage [19].

References

1. Stanley D. Prevalence and etiology of symptomatic elbow osteoarthritis. J Shoulder Elbow Surg. 1994;3(6):386–9. Epub 1994/11/01.
2. Krishnan SG, Harkins DC, Pennington SD, Harrison DK, Burkhead WZ. Arthroscopic ulnohumeral arthroplasty for degenerative arthritis

of the elbow in patients under fifty years of age. J Shoulder Elbow Surg. 2007;16(4):443–8. Epub 2007/01/27.

3. Lim YW, van Riet RP, Mittal R, Bain GI. Pattern of osteophyte distribution in primary osteoarthritis of the elbow. J Shoulder Elbow Surg. 2008;17(6):963–6. Epub 2008/08/05.
4. Suvarna SK, Stanley D. The histologic changes of the olecranon fossa membrane in primary osteoarthritis of the elbow. J Shoulder Elbow Surg. 2004;13(5):555–7. Epub 2004/09/24.
5. Oka Y, Ohta K, Saitoh I. Debridement arthroplasty for osteoarthritis of the elbow. Clin Orthop Relat Res. 1998;351:127–34.
6. Rettig LA, Hastings 2nd H, Feinberg JR. Primary osteoarthritis of the elbow: lack of radiographic evidence for morphologic predisposition, results of operative debridement at intermediate follow-up, and basis for a new radiographic classification system. J Shoulder Elbow Surg. 2008;17(1):97–105. Epub 2007/11/27.
7. Lee BP, Morrey BF. Arthroscopic synovectomy of the elbow for rheumatoid arthritis. A prospective study. J Bone Joint Surg Br. 1997;79(5):770–2. Epub 1997/10/23.
8. Poehling GG, Whipple TL, Sisco L, Goldman B. Elbow arthroscopy: a new technique. Arthroscopy. 1989;5(3):222–4. Epub 1989/01/01.
9. Andrews JR, Carson WG. Arthroscopy of the elbow. Arthroscopy. 1985;1(2):97–107. Epub 1985/01/01.
10. Lynch GJ, Meyers JF, Whipple TL, Caspari RB. Neurovascular anatomy and elbow arthroscopy: inherent risks. Arthroscopy. 1986;2(3):190–7. Epub 1986/01/01.
11. Stothers K, Day B, Regan WR. Arthroscopy of the elbow: anatomy, portal sites, and a description of the proximal lateral portal. Arthroscopy. 1995;11(4):449–57. Epub 1995/08/01.
12. Kamineni S, ElAttrache NS, O'Driscoll SW, Ahmad CS, Hirohara H, Neale PG, et al. Medial collateral ligament strain with partial posteromedial olecranon resection. A biomechanical study. J Bone Joint Surg Am. 2004;86-A(11):2424–30. Epub 2004/11/04.
13. Kamineni S, Hirahara H, Pomianowski S, Neale PG, O'Driscoll SW, ElAttrache N, et al. Partial posteromedial olecranon resection: a kinematic study. J Bone Joint Surg Am. 2003;85-A(6):1005–11. Epub 2003/06/05.
14. Savoie 3rd FH, Nunley PD, Field LD. Arthroscopic management of the arthritic elbow: indications, technique, and results. J Shoulder Elbow Surg. 1999;8(3):214–9.
15. Cohen AP, Redden JF, Stanley D. Treatment of osteoarthritis of the elbow: a comparison of open and arthroscopic debridement. Arthroscopy. 2000;16(7):701–6. Epub 2000/10/12.
16. Adams JE, Wolff 3rd LH, Merten SM, Steinmann SP. Osteoarthritis of the elbow: results of arthroscopic osteophyte resection and capsulectomy. J Shoulder Elbow Surg. 2008;17(1):126–31. Epub 2007/12/11.
17. DeGreef I, Samorjai N, De Smet L. The Outerbridge-Kashiwaghi procedure in elbow arthroscopy. Acta Orthop Belg. 2010;76(4): 468–71. Epub 2010/10/27.
18. Kelly EW, Bryce R, Coghlan J, Bell S. Arthroscopic debridement without radial head excision of the osteoarthritic elbow. Arthroscopy. 2007;23(2):151–6.
19. Kelly EW, Morrey BF, O'Driscoll SW. Complications of elbow arthroscopy. J Bone Joint Surg Am. 2001;83-A(1):25–34. Epub 2001/02/24.
20. Sodha S, Nagda SH, Sennett BJ. Heterotopic ossification in a throwing athlete after elbow arthroscopy. Arthroscopy. 2006; 22(7):802. e1–3. Epub 2006/07/20.
21. Hughes SC, Hildebrand KA. Heterotopic ossification: a complication of elbow arthroscopy—a case report. J Shoulder Elbow Surg. 2010;19(1):e1–5. Epub 2009/08/04.
22. Gofton WT, King GJ. Heterotopic ossification following elbow arthroscopy. Arthroscopy. 2001;17(1):E2. Epub 2001/01/12.
23. Haapaniemi T, Berggren M, Adolfsson L. Complete transection of the median and radial nerves during arthroscopic release of post-traumatic elbow contracture. Arthroscopy. 1999;15(7):784–7. Epub 1999/10/19.
24. Ruch DS, Poehling GG. Anterior interosseus nerve injury following elbow arthroscopy. Arthroscopy. 1997;13(6):756–8. Epub 1998/01/27.
25. Gay DM, Raphael BS, Weiland AJ. Revision arthroscopic contracture release in the elbow resulting in an ulnar nerve transection: a case report. J Bone Joint Surg Am. 2010;92(5):1246–9. Epub 2010/05/05.
26. Reddy AS, Kvitne RS, Yocum LA, Elattrache NS, Glousman RE, Jobe FW. Arthroscopy of the elbow: a long-term clinical review. Arthroscopy. 2000;16(6):588–94. Epub 2000/09/08.
27. Cefo I, Eygendaal D. Arthroscopic arthrolysis for posttraumatic elbow stiffness. J Shoulder Elbow Surg. 2011;20(3):434–9. Epub 2011/03/15.
28. Antuna SA, Morrey BF, Adams RA, O'Driscoll SW. Ulnohumeral arthroplasty for primary degenerative arthritis of the elbow: long-term outcome and complications. J Bone Joint Surg Am. 2002;84-A(12):2168–73. Epub 2002/12/11.

Lateral Epicondylitis

32

Mark Steven Cohen

Introduction

Lateral epicondylitis, or tennis elbow, is the most common affliction of the elbow.

The origin of the extensor carpi radialis brevis (ECRB) has been implicated as the source of pathology in this condition [1–11]. Reported histopathologic findings in the affected tendon origin include vascular proliferation and hyaline degeneration, which are consistent with a chronic, degenerative process [6, 8, 11, 12]. Most commonly, surgical treatment is directed at excision of this pathologic tissue through an open approach or more recently arthroscopic methods [2, 9, 13–20].

This chapter covers the anatomy of the extensor tendon origins at the humeral epicondyle based on anatomic dissections [21]. The location of the ECRB tendon origin is defined relative to intraarticular landmarks. Using this data, a technique for arthroscopic lateral epicondylitis surgery is presented with early clinical results.

Anatomy

The ECRL and the ECRB have a unique relationship at the level of the elbow. The ECRL overlies the proximal portion of the ECRB such that the ECRL must be elevated anteriorly in order to visualize the superficial surface of the ECRB. A thin film of areolar connective tissue separates these two structures.

The ECRL origin is entirely muscular along the lateral supracondylar ridge of the humerus (Fig. 32.1). The muscle origin has a triangular configuration with the apex pointing proximally. In contrast, the origin of the ECRB is entirely tendinous. While it blends with the origin of the EDC, when dissected from a distal to proximal direction and using the tendon undersurface, it can be separated from the EDC back to the humerus (Fig. 32.1). The anatomic origin of the ECRB is located just beneath the distal most tip of the lateral supracondylar ridge (Fig. 32.2). The footprint is diamond shaped measuring approximately 13 by 7 mm (Fig. 32.3). At the level of the radiocapitellar joint, the ECRB is intimate with the underlying anterior capsule of the elbow joint, but it is easily separable at this level [21]. Using this data, an arthroscopic technique was designed for lateral epicondylitis.

Technique

The patient is positioned in the lateral decubitus position with the arm supported. All bony prominences well padded. We favor regional anesthesia. Bony landmarks are drawn out including the path of the ulnar nerve. Once the tourniquet is inflated, the elbow is insufflated with an 18 gauge needle introduced through the soft-spot of the elbow (mid-lateral portal).

Next, a standard anteromedial portal is established (Fig. 32.4). This is started several centimeters proximal and anterior to the medial epicondyle and well anterior to the palpable intermuscular septum. Care is taken to slide along the anterior humerus and the joint is entered with a blunt introducer or a switching stick. This medial portal allows one to view the lateral joint including the radial head, capitellum, and the lateral capsule. It is often helpful at this point to open the inflow to allow distension of the capsule. If visualization is a problem, a retractor can be introduced through a proximal anterolateral portal 2–3 cm proximal and just anterior to the lateral supracondylar ridge. A simple freer elevator is useful for this purpose. By tensioning the capsule anteriorly, improved visualization of the lateral capsule and soft-tissues can be achieved.

M.S. Cohen, M.D. (✉)
Department of Orthopaedic Surgery, Rush University Medical Center, 1611 W. Harrison Street, Suite 300, Chicago, IL 60612, USA
e-mail: Mark_S_Cohen@rush.edu

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*,
DOI 10.1007/978-1-4614-1596-1_32, © Springer Science+Business Media New York 2015

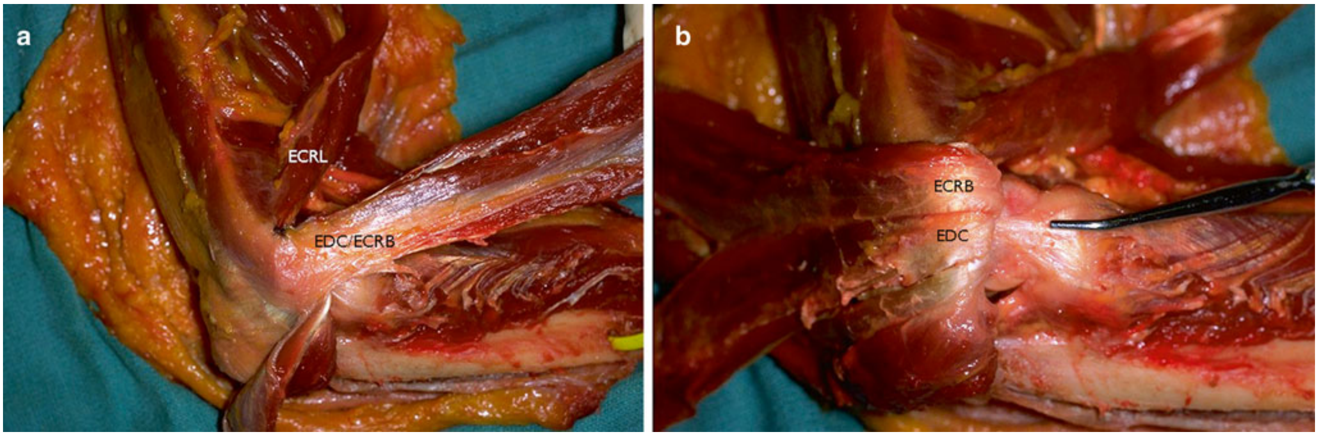


Fig. 32.1 (**a**) Lateral view of cadaveric specimen. The ECRL has been reflected anteriorly (it has a purely muscular origin) and the extensor carpi ulnaris posteriorly revealing the common extensor tendon origin of the ECRB and EDC. These are indistinguishable when viewed from the outer surface. (**b**) The muscles and tendons have been reflected proximally. The origins of the ECRB anteriorly and the EDC posteriorly are identifiable on the undersurface of the extensor origin. Note the underlying lateral collateral ligament (probe) [Courtesy of Mark S. Cohen, Chicago, IL with permission]

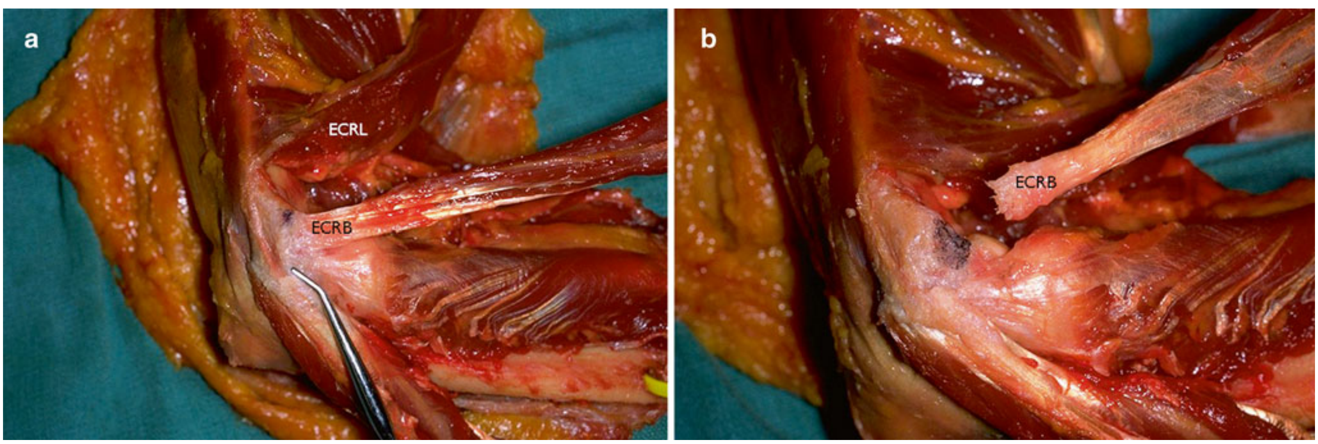


Fig. 32.2 (**a**) The EDC has been removed allowing better visualization of the bony ECRB origin on the humerus. (**b**) The ECRB footprint is identified with elevation of the tendon from the humerus [Courtesy of Mark S. Cohen, Chicago, IL with permission]

A modified anterolateral portal is established using an inside-out technique. This is started 2–3 cm above and anterior to the lateral epicondyle (Fig. 32.4). The portal is slightly more proximal than a standard anterolateral portal. This allows instrumentation down to the tendon origin rather than entering the joint through the ECRB tendon itself. If lateral synovitis is present, this can be debrided with a resector.

The capsule is next released. Occasionally in epicondylitis, one can find a disruption of the underlying capsule from the humerus (Fig. 32.5). Most commonly, the capsule is intact although small linear tears can be present (Fig. 32.6). We have found it easier to release the lateral soft-tissues in layers using a monopolar thermal device. In this way, the capsule is first incised or released from the humerus. When it retracts distally, one can appreciate the ECRB tendon posteriorly and the ECRL, which is principally muscular, more anterior. As noted above, the ECRB tendon spans from the top of the capitellum to the midline of the radiocapitellar joint.

Once the capsule is adequately resected, the ECRB origin is released from the epicondyle (Figs. 32.4 and 32.6). This is started at the top of the capitellum and carried posteriorly. The lateral collateral ligament is not at risk if the release is kept anterior to the midline of the radiocapitellar joint [18]. On average, adequate resection of the ECRB must include approximately 13 mm of tendon origin from anterior to posterior [21]. Care is taken to drive the scope in adequately to view the release down to the midline of the

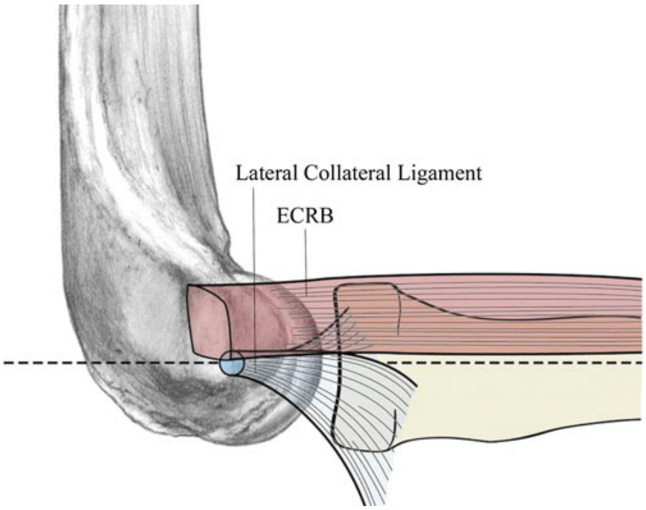


Fig. 32.3 Schematic diagram depicting the relationship between the ECRB origin at the humerus and bony landmarks. Note that the ECRB footprint origin is diamond shaped and located between the midline of the joint and the top of the humeral capitellum beneath the most distal extent of the supracondylar ridge. The tendon does not originate on the epicondyle specifically. Note the relationship between the ECRB origin and the underlying lateral collateral ligament [Courtesy of Mark S. Cohen, Chicago, IL with permission]

radiocapitellar joint. Typically, the entire ECRB retracts distally away from the humerus.

Care is taken not to release the extensor aponeurosis, which lies behind the ECRB tendon. This can be visualized as a stripped background of transversely (longitudinally) oriented tendon and muscular fibers much less distinct than the ECRB (Fig. 32.6). It is located posterior to the ECRL which again is principally muscular in origin. If the aponeurosis is violated, one will debride into the subcutaneous tissue about the lateral elbow.

Discussion

In recent years, there has been an interest in arthroscopic treatment of lateral epicondylitis [13–20]. A cadaveric study demonstrated that arthroscopic release of the extensor carpi radialis brevis was a safe, reliable, and reproducible procedure for refractory lateral epicondylitis [16]. However, the results of results of arthroscopic treatment of this condition have been variable. Tseng reported satisfactory results in 9 of 11 patients [20]. However, he also had a 33 % complication rate. Stapleton and Baker compared five patients treated arthroscopically with ten patients treated by open debridement [19]. They reported similar results and complication rates between the two groups. Later, Baker et al. reported on 39 elbows treated arthroscopically with 37 reporting being "better" or "much better" at follow-up [13]. Peart et al. reported on 33 arthroscopic procedures for lateral epicondylitis with 28 % of patients failing to achieve good or excellent outcomes [17].

The variable results reported using various arthroscopic techniques may be related to increased difficulty in identifying the ECRB origin through the arthroscope [15]. The tendon is extraarticular and capsular release is required to visualize its origin. The tendon footprint is diamond shaped and located between midline of the radiocapitellar joint and the top of the humeral capitellum averaging 13 by 7 mm (Fig. 32.3). The posterior interosseous nerve should be well medial and distal to the area of dissection. The lateral collateral ligament is not compromised as long as the release does not course posterior to the midline of the radial head [18]. The ligament is not at risk if the release is kept anterior to the midline of the radiocapitellar joint. Care is taken not to release the extensor aponeurosis, which lies superficial to the ECRB tendon.

We reviewed a consecutive series of 36 patients with recalcitrant lateral epicondylitis treated with arthroscopic release using the aforementioned technique [22]. There were 24 men and 12 women with an average age of 42 years at the time of surgery. The cohort had symptoms for an average of 19 months prior to surgical intervention. Intraoperative findings revealed significant lateral intraarticular synovitis in approximately 30 % of patients. Approximately 75 % of cases had an intact elbow capsule or a minor linear capsular tear, while 25 % had a significant proximal capsular disruption. All patients were evaluated by independent examiners for the purposes of this study at a minimum 2 year follow-up. On average, patients required 4 weeks to return to regular activities and 7 weeks to return to full work duties. No major complications were reported. One patient had a neurapraxia of the superficial radial nerve that resolved by 2 weeks postoperatively. The average functional component of the Mayo Elbow Performance Score at follow-up averaged 11.1 out of 12 (range 5–12). Grip strength averaged 91 % of the opposite, uninvolved side. Subjective pain ratings as measured on a visual analog scale improved from 8.1 to 1.5 ($p < 0.01$). However, 10 patients reported continued pain with strenuous activities and repetitive use of the affected arm. Two patients continued to have significant pain and were considered failures [22].

In summary, arthroscopic release of the ECRB appears to be an effective option for the surgical treatment of chronic lateral epicondylitis unresponsive to conservative modalities. Knowledge of the anatomy, including the extensor tendon origins as visualized from an intraarticular perspective, is essential for effective surgical release.

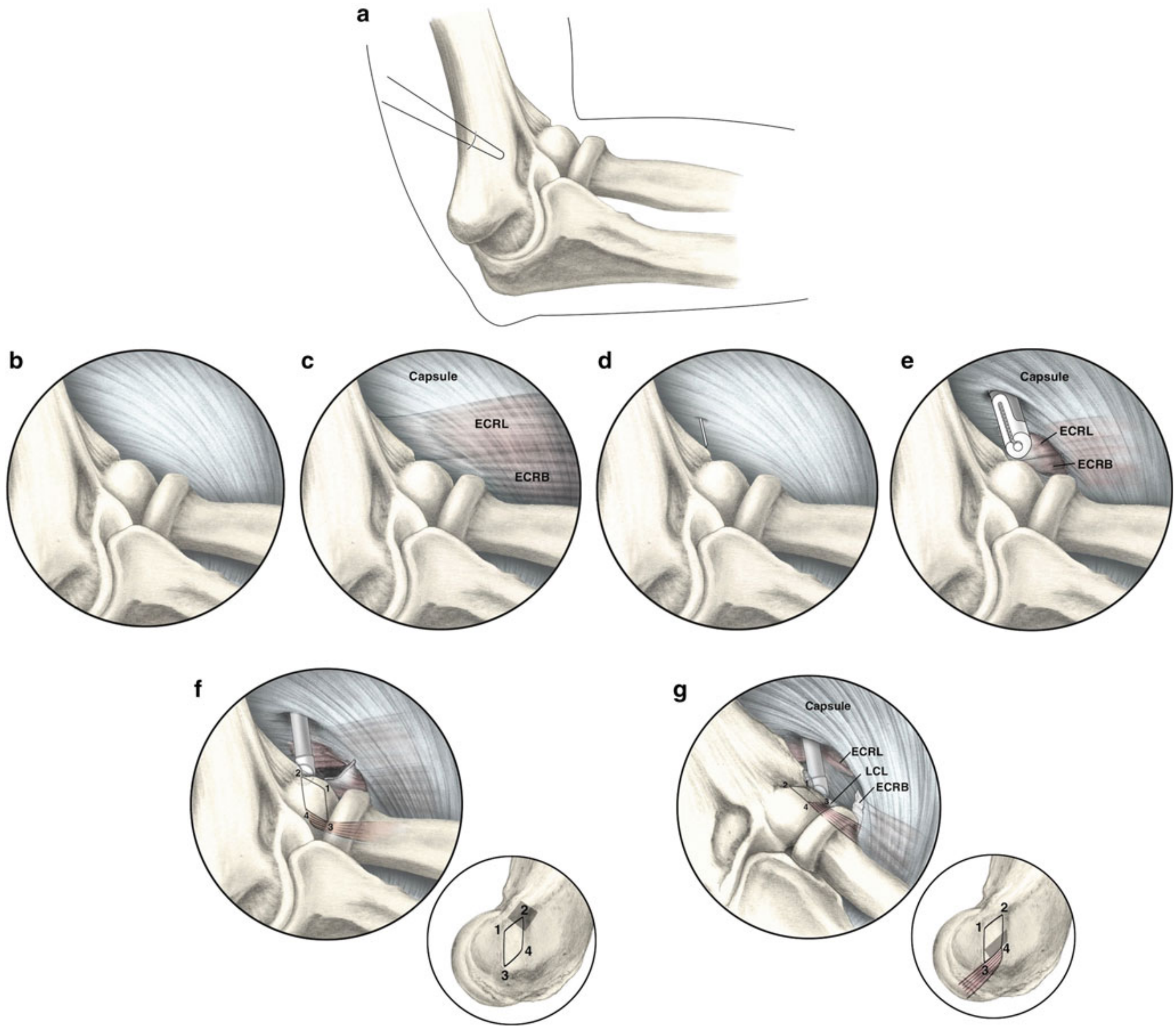


Fig. 32.4 (**a**) Diagram depicting the medial portal used in visualization for the arthroscopic lateral epicondylar release. (**b**) Field of view from the medial portal. (**c**) Diagram depicting the relationship of the extensor tendon origins when viewed intraarticularly. These are located outside (*behind*) the elbow capsule. (**d**) Needle used to help establish a modified lateral portal. Note how this is begun slightly proximal and anterior to the proximal margin of the humeral capitellum. (**e**) Release of the capsule from the lateral humeral margin allowing visualization of the tendinous origins behind. The ECRL is more anteriorly located and is muscular. The ECRB is more posterior. (**f**) The ECRB is released from the top of the capitellum to the (**g**) midline of the radiocapitellar joint [Courtesy of Mark S. Cohen, Chicago, IL with permission]

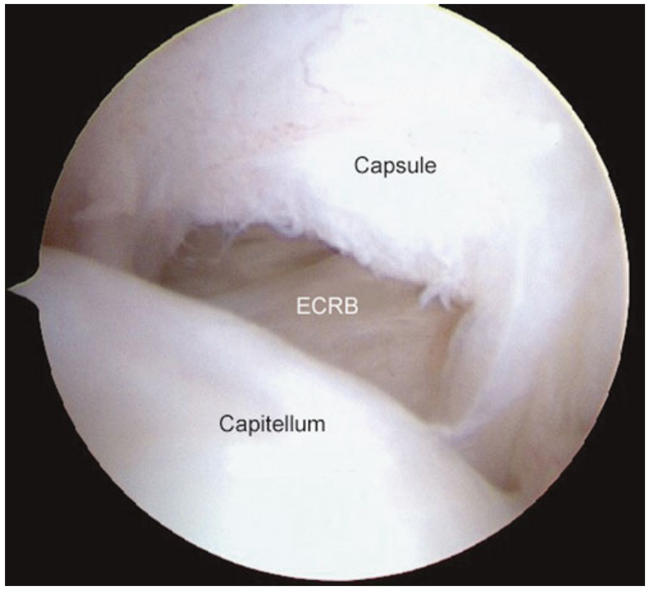


Fig. 32.5 Initial intraoperative view of a patient with recalcitrant lateral epicondylitis. Note the capsular disruption. In some cases, the capsule is noted to have torn away from its humeral origin [Courtesy of Mark S. Cohen, Chicago, IL with permission]

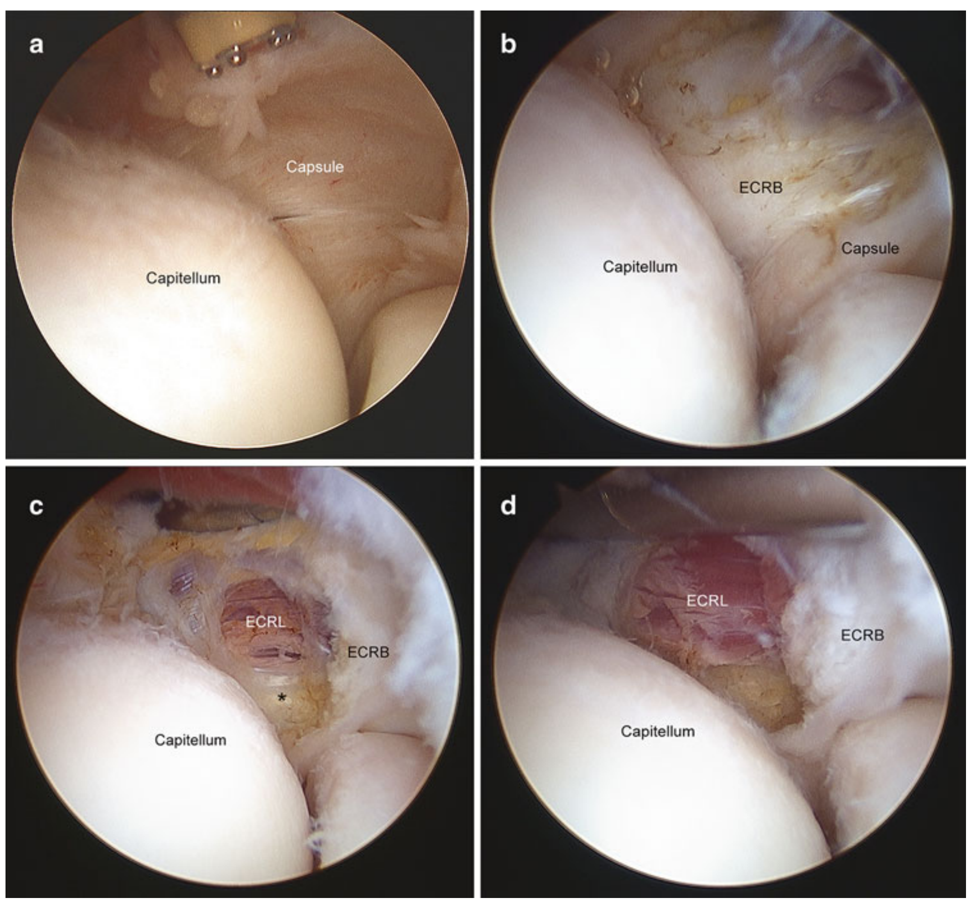


Fig. 32.6 (**a**) Initial intraoperative view of a patient treated surgically for lateral epicondylitis. The lateral capsule obstructs the view of the extensor tendon origins. Note the small longitudinal rent in the capsule. (**b**) The capsule has been released revealing the muscular ECRL anteriorly and the tendinous ECRB more posteriorly. Note the capsular layer distally which is deep to the tendon. (**c**) The ECRB has been released. Behind this, one can see the muscular ECRL anteriorly and the extensor aponeurosis which lies behind the ECRB (*asterisk*). It is characteristically composed of longitudinally stripped tendinous fibers much less distinct than the ECRB. (**d**) Final close up view following ECRB release. One can see the thick ECRB origin which has retracted distally following release [Courtesy of Mark S. Cohen, Chicago, IL with permission]

References

1. Bunata RE, Brown DS, Capelo R. Anatomic factors related to the cause of tennis elbow. J Bone Joint Surg. 2007;89A:1955–63.
2. Coonrad RW, Hooper WR. Tennis elbow: its course, natural history, conservative and surgical management. J Bone Joint Surg. 1973;55A:1177–82.
3. Cyriax JH. The pathology and treatment of tennis elbow. J Bone Joint Surg. 1936;18:921–40.
4. Garden RS. Tennis elbow. J Bone Joint Surg. 1961;43-B:100–6.
5. Gardner RC. Tennis elbow: diagnosis, pathology, and treatment. Clin Orthop. 1970;72:248–51.
6. Kraushaar BS, Nirschl RP. Tendinosis of the elbow (tennis elbow). Clinical features and findings of histological, immunohistochemical, and electron microscopy studies. J Bone Joint Surg. 1999;81A:259–78.
7. Morrey BF. Reoperation for failed surgical treatment of refractory lateral epicondylitis. J Shoulder Elbow Surg. 1992;1:47–55.
8. Nirschl RP. Elbow tendinosis/tennis elbow. Clin Sports Med. 1992;11:851–70.
9. Nirschl RP, Pettrone FA. Tennis elbow. The surgical treatment of lateral epicondylitis. J Bone Joint Surg. 1979;61A:832–9.
10. Organ SW, Nirschl RP, Kraushaar BS, Guidi EJ. Salvage surgery for lateral tennis elbow. Am J Sports Med. 1997;25:746–50.
11. Regan W, Wold LE, Coonrad R, Morrey BF. Microscopic histopathology of chronic refractory lateral epicondylitis. Am J Sports Med. 1992;20:746–9.
12. Spencer GE, Herndon CH. Surgical treatment of epicondylitis. J Bone Joint Surg. 1953;35-A:421–4.
13. Baker CL, Murphy KP, Gottlob CA, Curd DT. Arthroscopic classification and treatment of lateral epicondylitis: two-year clinical results. J Shoulder Elbow Surg. 2000;9(6):475–82.
14. Cohen MS, Romeo AA. Lateral epicondylitis: open and arthroscopic treatment. J Am Soc Surg Hand. 2001;3(1):172–6.
15. Cummins CA. Lateral epicondylitis: in vivo assessment of arthroscopic debridement and correlation with patient outcomes. Am J Sports Med. 2006;34:1486–91.
16. Kuklo TR, Taylor KF, Murphy KP, Islinger RB, Heekin RD, Baker Jr CL. Arthroscopic release for lateral epicondylitis: a cadaveric model. Arthroscopy. 1999;15:259–64.
17. Peart RE, Strickler SS, Schweitzer Jr KM. Lateral epicondylitis: a comparative study of open and arthroscopic lateral release. Am J Orthop. 2004;33:565–7.
18. Smith AM, Castle JA, Ruch DS. Arthroscopic resection of the common extensor origin: anatomic considerations. J Shoulder Elbow Surg. 2003;12(4):375–9.
19. Stapleton TR, Baker CL. Arthroscopic treatment of lateral epicondylitis. Arthroscopy. 1996;10:335–6.
20. Tseng V. Arthroscopic lateral release for treatment of tennis elbow. Arthroscopy. 1994;10:335–6.
21. Cohen MS, Romeo AA, Hennigan SP, Gordon M. Lateral epicondylitis: anatomic relationships of the extensor tendon origins and implications for arthroscopic treatment. J Shoulder Elbow Surg. 2008;17(6):954–60.
22. Lattermann C, Romeo AA, Anbari A, Meininger AK, McCarty LP, Cole BJ, Cohen MS. Arthroscopic debridement of the extensor carpi radialis brevis for recalcitrant lateral epicondylitis. J Shoulder Elbow Surg. 2010;19(5):651–6.

33 Arthroscopic and Open Radial Ulnohumeral Ligament Reconstruction for Posterolateral Rotatory Instability of the Elbow

Michael J. O'Brien, Felix H. Savoie III, and Larry D. Field

Introduction

Elbow dislocations are rare injuries that usually respond very favorably to conservative treatment in a brace. However, persistent instability that results from an elbow dislocation can be devastating. There has been a growing interest in the diagnosis and treatment of posterolateral rotatory instability (PLRI) of the elbow since the original description by O'Driscoll in 1991 [1]. PLRI has been described as an instability pattern of the elbow that results from an incompetent radial ulnohumeral ligament complex (RULC). Anatomical studies have attempted to define the involved tissue. Dunning et al. stated that both the radial ulnohumeral ligament (RUHL) and the radial collateral ligament (RCL) must be sectioned to achieve PLRI. They also stated that they could not visually differentiate the two ligaments at their humeral origin. The authors could only distinguish the RUHL from the RCL by identifying the distal extent of the RUHL at the supinator crest of the ulna [2]. Seki et al. were able to show that sectioning just the anterior band of the lateral collateral complex induced instability. This suggests that an intact RUHL alone cannot stabilize the elbow [3]. This data demonstrates that the entity of PLRI is in fact a spectrum of injury. Although originally described as sequelae of an elbow dislocation, these anatomic studies and a report by Kalainov et al. support our own experience that there is a continuum of injury between PLRI and frank elbow dislocation [1, 4, 5].

This instability is best demonstrated clinically with the pivot shift test of the elbow. This test, as first described by O'Driscoll, in the supine position may elicit gross instability or simply pain and apprehension [1]. Two other clinical tests described by Regan are also useful in the diagnosis of PLRI, (1) pain when pushing up from an arm chair with the palms facing inward, and (2) having the patient push up from a prone or wall-leaning position first with the forearms maximally pronated and then repeating the test with the forearms supinated, reproducing either pain, instability, or both [6, 7].

We prefer to examine the elbow with the patient in the prone position and use the table as a base to stabilize the humerus. The elbow in this position mimics the exam of a flexed knee and the findings are more easily reproduced between examiners. We begin by manually rotating the forearm with the elbow in 90° of flexion, palpating the radiocapitellar joint and using the wrist to supinate the forearm. This movement reproduces the radial column subluxation as the forearm rotates away from the humerus. The radial head movement on the capitellum is more easily seen and felt in this position, and the elbow can be flexed and extended while maintaining the subluxation force (Fig. 33.1a, b).

Imaging studies for PLRI can be helpful. Radiographs may reveal an avulsion fragment from the posterior aspect of the humeral lateral epicondyle in acute cases. However, radiographs are often normal. A stress radiograph or fluoroscopy while performing the pivot shift test may show the radial head and proximal ulna moving together in a subluxated and posterolaterally rotated position. Magnetic resonance imaging (MRI) of the elbow has been described to identify a lesion in the RUHL [8]. MRI arthrography is the best modality to identify lesions to the medial and lateral collateral ligaments. A formal arthrogram with injection of contrast dye into the elbow joint prior to the scan can greatly enhance the effectiveness of the test.

While much has been written about the pathoanatomy and biomechanics of the lesion, little has been reported on the surgical treatment of these patients. There are no large published series on the outcomes of the surgical treatment of PLRI. The present study reviews the outcomes of the authors' experiences with arthroscopic repair, plication, and open grafting techniques previously described by the senior authors [4].

M.J. O'Brien, M.D. • F.H. Savoie III, M.D. (✉)
Department of Orthopaedics, Tulane University School of Medicine, 1430 Tulane Avenue, SL-32, New Orleans, LA 70112, USA
e-mail: fsavoie@tulane.edu

L.D. Field, M.D.
Upper Extremity, Mississippi Sports Medicine and Orthopaedic Center, Jackson, MS, USA

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*,
DOI 10.1007/978-1-4614-1596-1_33, © Springer Science+Business Media New York 2015

Surgical Technique

Most cases of simple dislocation respond to nonoperative management. However, return to full activities may take 3–4 months. In cases in which the instability recurs, or when initial evaluation reveals a bony avulsion of the lateral collateral ligament complex proximally off of the humerus, surgical treatment may be indicated. Acute repair of the RUHL may also be indicated in high level athletes, who cannot afford to miss large portions of the athletic season. Arthroscopy of the acutely injured elbow demands speed and precision. A concrete preoperative plan must be formulated and followed, with adjustment made for arthroscopic findings. Patients with significant coronoid fracture, associated radial head fracture or distal humerus fracture are not included in this report.

Arthroscopic Repair

In the elbow with an acute or chronic avulsion of the RUHL, arthroscopic repair can very effective. The procedure begins with the establishment of a proximal anterior medial portal and a diagnostic arthroscopy of the anterior compartment. Fractures of the radial head or coronoid can be identified. In the acute setting, abundant hematoma will be encountered in the joint (Fig. 33.2), and tearing of the anterior capsule is readily apparent. One can often also see the damage to the brachialis muscle through the torn capsule (Fig. 33.3a, b). A proximal anterior lateral portal can be established to clean out the associated hematoma.

On the lateral side, laxity of the annular ligament and lateral collateral ligament (LCL) complex will be evident in every case. Occasionally, the LCL complex will be flipped into the

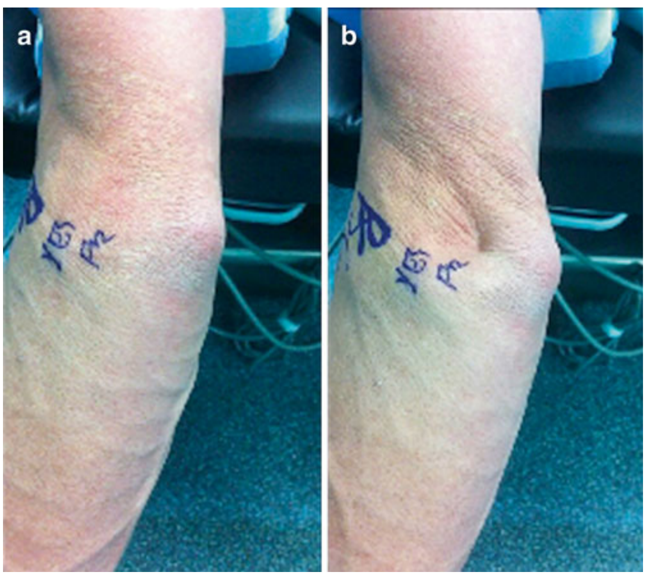


Fig. 33.1 Demonstration of the prone pivot shift exam, showing the elbow reduced (**a**), and subluxated (**b**) with a dimple over the dislocated radiocapitellar joint [Courtesy of Dr. Felix H. Savoie, III]

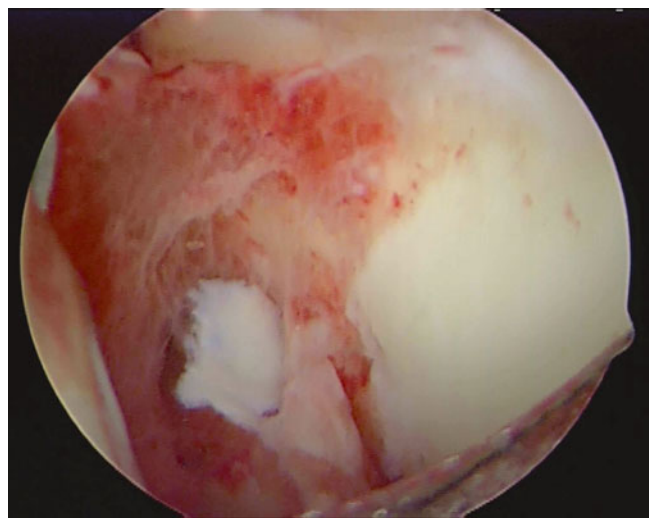


Fig. 33.2 A view from the proximal anterior medial portal of the hematoma often seen in an acute dislocation [Courtesy of Dr. Felix H. Savoie, III]

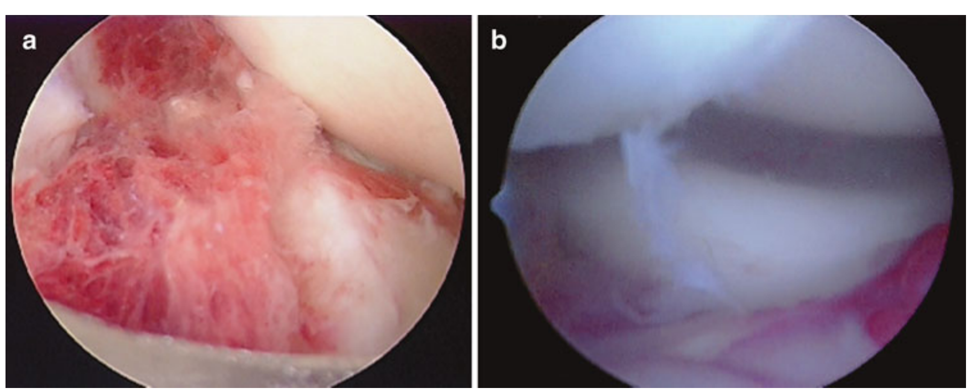


Fig. 33.3 (**a**) The arthroscopic view of the damaged brachialis and torn anterior capsule often noted in acute dislocations. (**b**) The laxity seen in the annular ligament and the displacement of the radial head from the capitellum in acute and chronic PLRI is visualized from the medial portal [Courtesy of Dr. Felix H. Savoie, III]

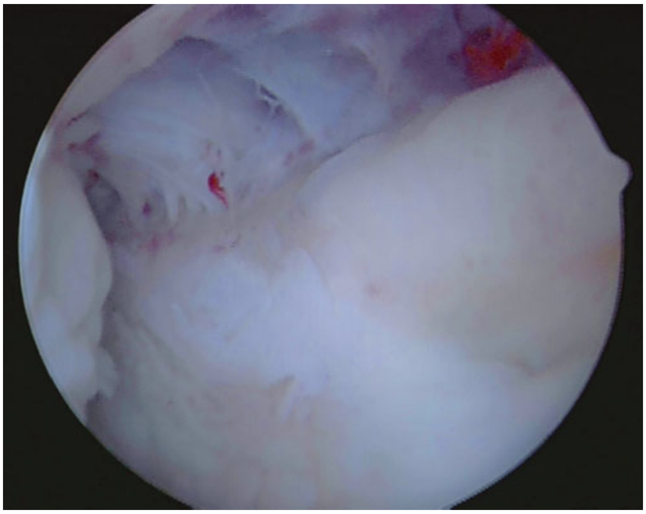


Fig. 33.4 The concomitant tearing of the capsule of the medial capsule in acute instability is visualized from a posterior portal [Courtesy of Dr. Felix H. Savoie, III]

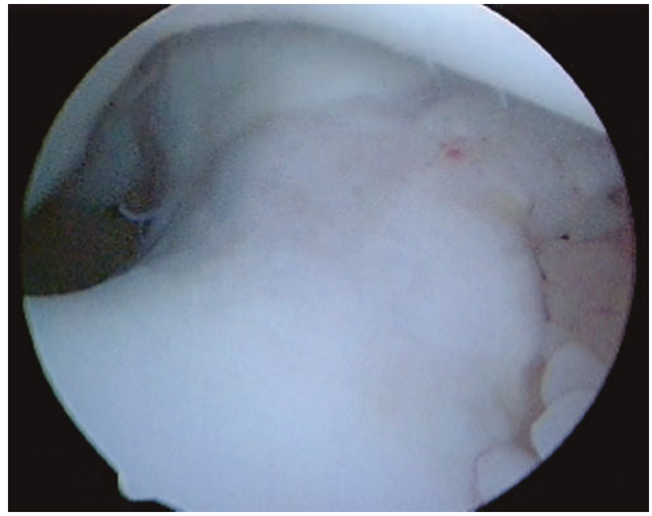


Fig. 33.5 The "drive through sign" of the elbow is performed by placing the arthroscope into the lateral gutter and moving it straight across the ulnohumeral articulation into the medial gutter [Courtesy of Dr. Felix H. Savoie, III]

radiocapitellar joint. Of importance is to view the annular ligament for damage and place a suture in it if necessary. Valgus load and forearm supination demonstrates posterolateral rotatory instability with the radial head subluxating off the capitellum, indicative of injury to the RUHL. One can also view "around the corner" of the proximal capitellum for damage to the collateral ligament part of the radial ulnohumeral ligament complex. On the medial side, an arthroscopic valgus stress test can be performed to evaluate for incompetence of the medial ulnar collateral ligament (MUCL). During evacuation of hematoma, great care is taken not to resect or damage the LCL complex.

The arthroscope is next placed into the posterior central portal, and the hematoma in the posterior compartment of the elbow is evacuated via a proximal posterior lateral portal. Both of these portals need to be relatively proximal to allow for the later repair of the ligament, usually at least 3 cm above the olecrenon tip. A view of the medial gutter will show hemorrhage, and sometimes tearing of the capsule, near the posterior aspect of the medial epicondyle (Fig. 33.4).

One common finding is the ability to move an arthroscope placed down the posterolateral gutter from the posterior central portal straight across the ulnohumeral articulation into the medial gutter. This maneuver is not possible in a stable elbow, and is termed the "drive through sign of the elbow" (Fig. 33.5). It is somewhat analogous to the "drive through sign" in shoulder instability. The elimination of the laxity that allows this maneuver is one of the key aspects of confirming an adequate arthroscopic reconstruction in patients with PLRI.

The lateral gutter and capsule is evaluated next. The arthroscope is easily advanced down the lateral gutter, owing to incompetence of the LCL complex. It is very important to

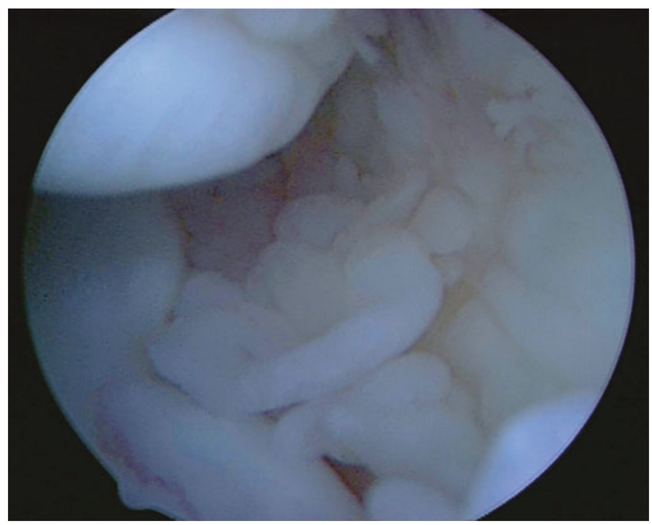


Fig. 33.6 The bone and soft tissue fragments often seen in the lateral gutter in acute dislocation [Courtesy of Dr. Felix H. Savoie, III]

stay close to the ulna as the lateral gutter is evaluated and the hematoma debrided, as the avulsed ligament and bone fragments are displaced distally and may inadvertently be removed by the shaver (Fig. 33.6). The origin of the LCL complex on the posterior aspect of the lateral epicondyle can be visualized as a bare area where the ligament has avulsed off of the humerus. It is usually directly lateral and slightly inferior to the center of the olecrenon fossa. This area on the posterior humerus should be lightly debrided with a motorized shaver.

Once the area of damage has been defined, an arthroscopic anchor may be placed into the humerus at the site of origin of the RUHL (Fig. 33.7). A percutaneous suture passer is placed

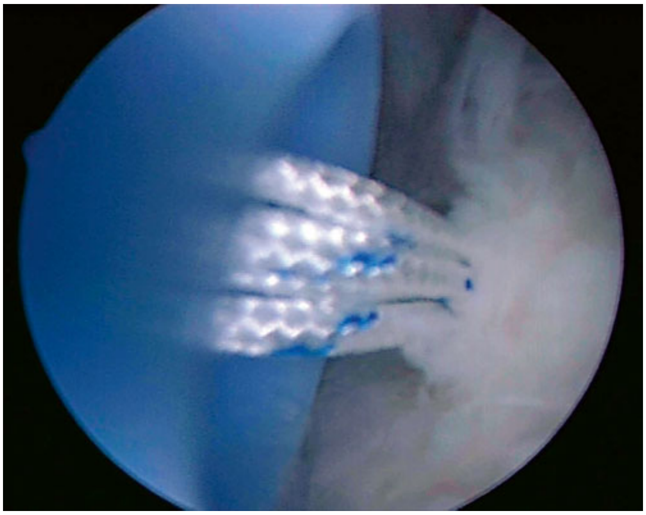


Fig. 33.7 The site of anchor placement into the humerus just lateral to the olecrenon fossa of the humerus as viewed from the posterior portal [Courtesy of Dr. Felix H. Savoie, III]

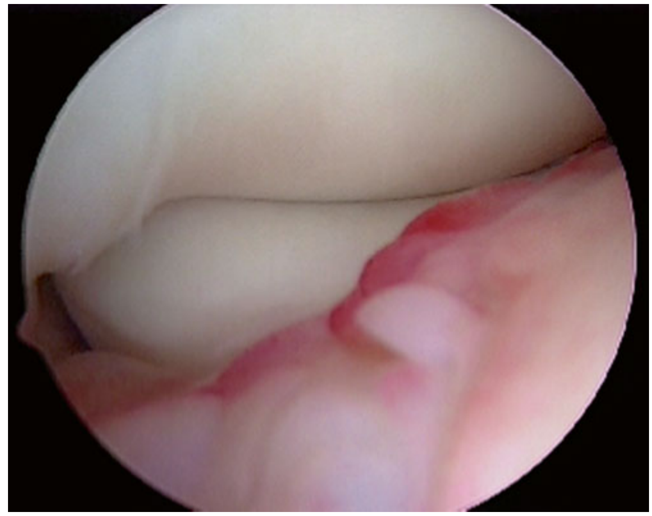


Fig. 33.9 The repaired ligament is visualized from the posterior portal [Courtesy of Dr. Felix H. Savoie, III]

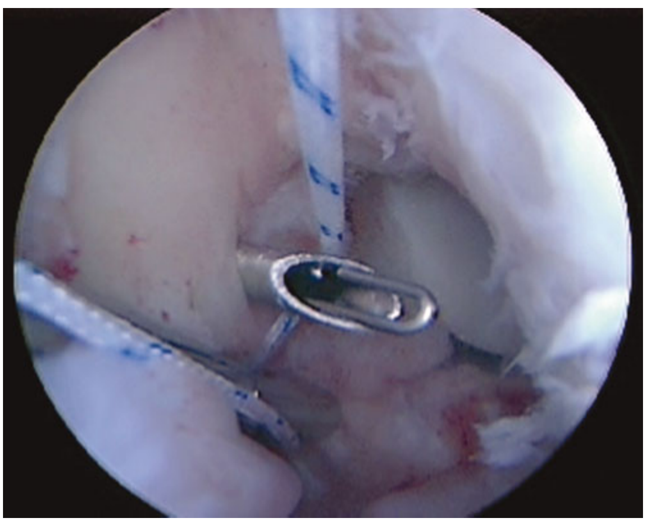


Fig. 33.8 Once an adequate anchor has been placed, the sutures are retrieved though the torn radio-ulnohumeral ligament in preparation for repair [Courtesy of Dr. Felix H. Savoie, III]

through a "soft spot" portal to retrieve the sutures. The limbs of the suture are retrieved to place two horizontal mattress sutures through the non-injured part of the ligament. In the case of a bony avulsion, we place one set of sutures around the bone fragment and the other distal to the fragment (Fig. 33.8). The sutures are tensioned while viewing with the arthroscope down the lateral gutter, which should have the effect of pushing the arthroscope out of the lateral gutter as tension is restored to the LCL complex. The elbow is extended and the sutures are tied beneath the anconeus muscle, tightening the ligament. Motion and stability are evaluated with the arthroscope back in the anterior compartment (Fig. 33.9), confirming tension has been restored to the annular ligament.

Arthroscopic Plication

The development of an arthroscopic technique for the treatment of chronic PLRI was described by Smith et al. in 2001 [4]. Chronic posterolateral instability of the elbow is more readily seen during examination under anesthesia and on arthroscopic evaluation. While viewing from the proximal anterior medial portal, the ulna and radial head can be seen to subluxate posterolaterally during the performance of a pivot shift test. In most cases, the annular ligament is intact as the entire proximal radio-ulnar joint shifts on the humerus.

The arthroscopic technique for chronic instability has two key features: plication of the two major components of the complex and repair of the complex to the humerus. We believe both components can be managed via arthroscopic techniques if there is enough ligamentous and capsular tissue. This assessment is in part determined by the preoperative evaluation, including palpation of the structures in the area to be reconstructed, the amount of prior surgery, and the tissue present on MRI arthrography.

If adequate lateral tissue is present, the tissue in the posterolateral gutter is assessed arthroscopically and prepared with a shaver or rasp. Four to seven absorbable sutures are then placed in oblique fashion beginning at the most distal extent of the RUHL complex attachment to the ulna. The sutures are placed into the lateral gutter via an 18 gauge spinal needle that slides along the radial border of the ulna. The first suture is delivered into the joint through the mid-portion of the annular ligament (Fig. 33.10a). Subsequent sutures are brought into the joint in a progressively more proximal position. Each suture is immediately retrieved with a retrograde suture retriever that passes into the joint from the posterior lateral aspect of the lateral epicondyle (Fig. 33.10b).

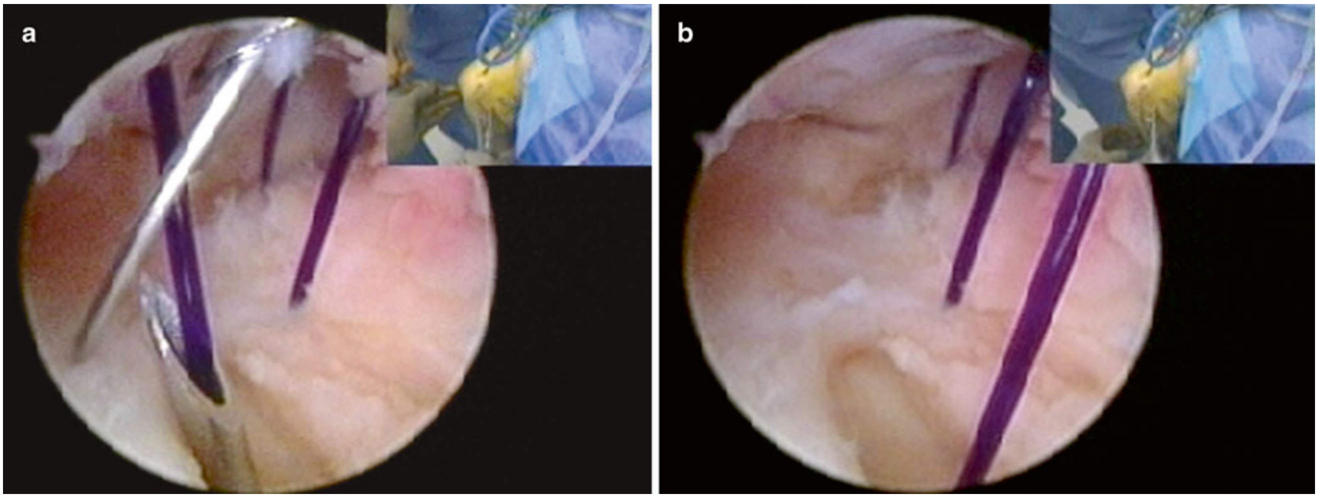


Fig. 33.10 (**a**) The suture is retrieved using a retrograde retriever introduced along the posterior aspect of the lateral epicondyle and under the proximal end of the RUHL complex. (**b**) The views of the closed radial gutter once all the sutures are placed and just before the sutures are tensioned [Courtesy of Dr. Felix H. Savoie, III]

It is quite important that the retrograde retriever comes under the entire RUHL near its proximal attachment to the humerus.

Once all the sutures have been placed, they are retrieved one at a time percutaneously through the existing skin portals and pulled to tension the sutures and evaluate the plication. If the reconstruction has been properly performed and the tissue is adequate for plication, the arthroscope is driven out of the lateral gutter as this tensioning occurs. The arthroscope is then removed, the elbow extended and the sutures are tied individually from distal to proximal.

The exam under anesthesia is repeated with the arthroscope placed first in the posterior central portal, and then in the proximal anterior medial portal, while the pivot shift test is performed to evaluate the adequacy of the reconstruction. If there is laxity or subluxation still present after the sutures are pre-tensioned, an anchor can be placed at the isometric point of the lateral epicondyle to further tension the LCL complex to the humerus. An anchor is placed as in the acute repairs, and one limb of suture is passed under all of the loops of the plication sutures to a retriever and then retrieved back over the plicated sutures to pull the entire plicated complex back to the humerus. This is usually noted as part of the preoperative planning and is accomplished before the plication sutures are tied.

Postoperative Management

In both acute and chronic cases, patients are immediately placed into a splint or hinged brace with the elbow in approximately 30° of extension to relax tension on the repair. Fluoroscopy or radiographs should be obtained to check the reduction after the splint or brace is applied, as additional flexion may be necessary to tighten the reconstruction and keep the joint reduced. The first postoperative visit usually takes place within 3–5 days of the surgery, and the patient is placed into a hinged elbow brace that allows comfortable movement, usually 0°–45°. Shoulder, peri-scapular, wrist and hand exercises are initiated and allowed as long as they do not produce pain in the elbow.

The patient is seen at 2 week intervals and motion slowly increased as pain and swelling allows. Once the repair begins to mature, usually between 6 and 8 weeks, physical therapy is initiated to include more aggressive upper extremity and core strengthening exercises with the elbow brace in place. Full range of motion of the elbow should be obtained by 8 weeks postoperatively, if not sooner. Depending on individual progression, patients are allowed to start strengthening exercises out of brace at 10–12 weeks. They must be able to perform all strengthening exercises pain-free in the brace, prior to progression out of the brace.

Open Technique

The open technique for plication and repair is similar to that described by O’Driscoll [1]. After diagnostic arthroscopy confirms the presence of instability and the absence of associated pathology, an extensile posterolateral approach is used and the anconeus muscle split or retracted anteriorly to access the RUHL complex. If adequate tissue is found to allow repair, the ligaments are plicated and repaired back to the humerus, as described in the above section on arthroscopic repair.

In revision surgery, or in patients with inadequate tissue for repair, a palmaris autograft or gracilis allograft may be used to reconstruct the lateral ligament complex.

The supinator crest of the ulna just posterior to the radial neck is dissected free and the insertion site identified. A 4 mm bone tunnel is created at the supinator crest, at the ulnar attachment of the RUHL. A Beath pin is drilled from this point out the ulnar side of the ulna, and a passing suture is used to pull the mid-portion of the graft into the ulna. The graft is secured using an interference screw technique. The two free graft limbs are then brought proximally, pulling one under the annular ligament and one over the ligament, and attached to the isometric point on the posterior aspect of the lateral epicondyle. The graft should be slightly lax in extension and tighten with flexion (Fig. 33.11).

Patient Data Outcomes, Combined Open and Arthroscopic Reconstruction

Material and Methods

A retrospective chart review was performed on all patients with elbow instability treated surgically by the senior authors. Sixty-one patients with posterolateral elbow reconstructions were identified. Of those patients treated operatively, 54 (89 %) had complete data available for review. All patients were evaluated for Andrews–Carson scores, length of follow-up, surgical technique employed (open versus arthroscopic), age, sex, and previous elbow surgery [9].

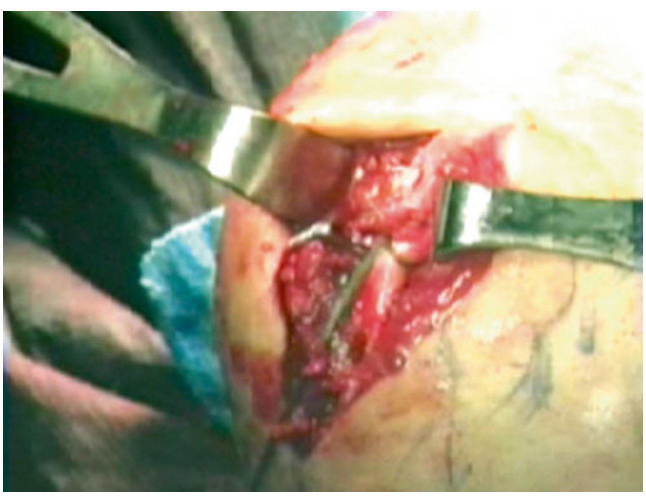


Fig. 33.11 Anatomical picture of the graft reconstruction for PLRI [Courtesy of Dr. Felix H. Savoie, III]

Results

All 54 patients had a PLRI repair, plication or graft performed. Forty-one patients (20 arthroscopic and 21 open) had a combined plication and repair, ten patients (6 open, 4 arthroscopic) had acute or subacute repairs for recurrent elbow instability, and three patients (all open) were reconstructed with a free tendon graft. Ten of the twenty arthroscopically treated and eleven of the twenty-one open plication/repair patients had the addition of an anchor to supplement the arthroscopic suture plication.

The average follow-up was 41 months (range 12–103 months). Overall Andrews–Carson scores for all repairs improved from 145 to 180 ($p<0.0001$) [9] (Table 33.1). Subjective scores improved from 57 to 85 ($p<0.0001$) and objective scores improved from 88 to 95 ($p=0.008$). Subdividing the technique yielded these overall results: arthroscopic repairs improved from 146 to 176 ($p=0.0001$) and open repairs 144–182 ($p<0.001$). Acute repairs performed the best, with nine of ten returning to normal activities, and one to near normal. There was no statistically significance difference between the results of open versus arthroscopic repair.

Patient Data Outcomes, All Arthroscopic Reconstruction

Material and Methods

A separate patient cohort was identified consisting of 14 consecutive patients who underwent all-arthroscopic RUHL reconstruction utilizing the same surgical technique in the acute (less than 3 weeks) or subacute (less than 3 months) period following elbow dislocation. All patients participated in athletics and underwent RUHL repair utilizing suture anchors in the humerus. Patients were evaluated with Mayo Elbow Performance scores (MEPS), and length of follow-up, age, sex, and return to sport were determined.

Results

All 14 patients underwent an all-arthroscopic PLRI reconstruction by repairing the RUHL to the humerus with suture anchors. Outcome scores as determined by the Mayo Elbow

Table 33.1 Comparison of Andrews–Carson scores

Andrews–Carson scores	Subjective		Objective		Overall		Average F/U months
	Pre-Op	Post-Op	Pre-Op	Post-Op	Pre-Op	Post-Op	
Arthroscopic	55	83	91	93	146	176	33
Open	58	86	86	96	144	182	44
Total	57	85	88	95	145	180	41

Performance Score were excellent in all 14 patients. All returned to sport at their previous level of activity with no resulting instability.

Discussion

The diagnosis of PLRI is made by patient history and physical examination and confirmed with radiologic findings. The diagnosis may be supplemented by arthroscopic confirmation of instability including abnormal movement of the radial head and proximal radio-ulnar joint on the humerus, varus opening, and the arthroscopic "drive through sign of the elbow." The posterolateral pivot shift test described by O'Driscoll may be performed both supine and prone, and when combined with the internal rotation push-up and chair lift tests of Regan give a clear clinical picture of instability [1, 6].

Instability findings may coexist with the standard examination findings of lateral epicondylitis, radial tunnel syndrome, and posterolateral plica syndrome. Indeed, as noted by Kalainov, PLRI may actually be a cause of these other problems of the elbow [5]. It is interesting to note that 25 % of patients in our study had previous surgery for chronic recurrent lateral epicondylitis. We believe that uncorrected posterolateral instability of the elbow may result in increased tension on the lateral musculature as it attempts to stabilize the elbow, thereby producing a secondary lateral epicondylitis. Other tertiary findings such as an inflamed posterolateral plica and inflammation of the posterior interosseous nerve in or near the radial tunnel may also occur with the instability. A high index of suspicion for the instability is necessary to fully evaluate the elbow of patients with all of these findings. The clinical examination recommended by O'Driscoll and by Regan certainly will assist in the determination of coexisting instability in the setting of lateral elbow pain [1, 6].

Additionally, the close proximity of the extensor carpi radialis brevis to the radial ulnohumeral ligament and lateral collateral ligament complex may potentially contribute to the iatrogenic development of PLRI during lateral epicondylitis procedures. In performing a standard ECRB release and repair for recalcitrant lateral epicondylitis, the treating surgeon must remain on the anterior aspect of the lateral epicondyle to avoid damage to the RUHL.

In most of our patients, repair and plication, whether open or arthroscopic, seemed to be an effective method of managing the instability. Although grafting was necessary in only three of the patients in the first cohort, one should always be prepared to utilize a supplemental graft. In our patients, we used a gracilis allograft with satisfactory results. We have found the number of previous surgeries and the time from the initial injury to definitive treatment to be the best predictors of the need for a graft. However, our low numbers prevent any meaningful recommendation of this technique.

Furthermore, the second patient cohort demonstrates the excellent results that may be obtained from an arthroscopic repair in the first 3 months following injury. All patients in this cohort were able to return to sport at the same level that they previously participated. Early arthroscopic repair may be indicated in young athletes following elbow dislocation to allow them faster return to play.

In summary, we have described four clinical tests for posterolateral rotatory instability of the elbow: (1) supine pivot shift, (2) prone pivot shift, (3) internal rotation wall push-up, and (4) chair push-up. We recommend MRI arthrography to assist in the preoperative evaluation. In surgical cases, arthroscopic confirmation of instability by the "drive through sign of the elbow" from the posterior portal, and the abnormal movement of the radial head on the humeral capitellum while viewing from the proximal anterior medial portal, confirm the presence of the instability. Finally, a ligament repair and a plication technique have been described that can be performed either arthroscopically or open with a high rate of success.

The current studies show that arthroscopic repair and/or plication of the RUHL complex can be as successful as open repair. This technique is technically demanding and requires speed and precision with a thorough understanding of elbow anatomy. Despite these concerns, arthroscopic repair and plication of the RUHL can effectively stabilize an elbow with acute or chronic PLRI and produce a high degree of patient satisfaction.

References

1. O'Driscoll SW, Bell DF, Morrey BF. Posterolateral rotatory instability of the elbow. J Bone Joint Surg Am. 1991;73(3):440–6.
2. Dunning CE, Zarzour ZD, Patterson SD, et al. Ligamentous stabilizers against posterolateral rotator instability of the elbow. J Bone Joint Surg Am. 2001;83A(12):1823–8.
3. Seki A, Olsen BS, Jensen SL, et al. Functional anatomy of the lateral collateral ligament complex of the elbow: configuration of Y and its role. J Shoulder Elbow Surg. 2002;11(1):53–9.
4. Smith JP, Savoie FH, Field LD. Posterolateral rotatory instability of the elbow. Clin Sports Med. 2001;20(1):47–58.
5. Kalainov DM, Cohen MS. Posterolateral rotatory instability of the elbow in association with lateral epicondylitis. A report of three cases. J Bone Joint Surg Am. 2005;87(5):1120–5.
6. Regan W, Lapner PC. Prospective evaluation of two diagnostic apprehension signs for posterolateral instability of the elbow. J Shoulder Elbow Surg. 2006;15(3):344–6.
7. Yadao MA, Savoie FH, Field LD. Posterolateral rotator instability of the elbow. Inst Course Lect. 2004;53:607–14.
8. Potter HG, Weiland AJ, Schatz JA, et al. Posterolateral rotator instability of the elbow: usefulness of MR imaging in diagnosis. Radiology. 1997;204(1):185–9.
9. Andrews JR, Carson WG. Arthroscopy of the elbow. Arthroscopy. 1985;1(2):97–107.

Arthroscopic Management of Osteochondritis Dissecans of the Capitellum

34

Noah C. Marks and Larry D. Field

Osteochondritis dissecans (OCD) is an increasing cause of elbow dysfunction and pain in the adolescent athlete. The most common site of osteochondritis dissecans of the elbow is the capitellum. This condition is a potentially sport-ending injury for an athlete, with possible long-term sequelae such as degenerative arthritis. Although no single cause of capitellum osteochondritis dissecans has been universally accepted, patients with this pathology do have common findings in regards to history and physical exam. In this chapter, radiographic findings consistent with OCD of the capitellum are discussed in detail. In order to provide the reader with a base to guide both clinical and operative decision-making, the conservative and operative treatment indications and options are discussed based on a review of the literature and our personal experience. As arthroscopic technique has advanced, arthroscopic surgery has become the standard procedure for surgical treatment of capitellar osteochondritis dissecans. This procedure is technically demanding and requires a thorough understanding of elbow arthroscopy portals in order to be able to assess and treat this pathology utilizing arthroscopic technique. We will discuss in detail our preferred arthroscopic technique for treatment of osteochondritis dissecans of the capitellum.

Osteochondritis dissecans (OCD) is an increasing cause of elbow dysfunction and pain in the adolescent athlete. It is a localized condition involving the articular surface that results in the separation of a segment of articular cartilage and subchondral bone. The most common site of osteochondritis dissecans of the elbow is the capitellum. However, lesions have also been reported in the trochlea, radial head, as well as the olecranon and olecranon fossa [1–4].

The true cause and natural history of capitellum OCD remain unknown, and the optimal treatment remains controversial. This can be attributed, in part, to the relative infrequency of the condition. Additionally, other conditions involving the immature elbow have been confused with a true OCD. These conditions include but are not limited to osteonecrosis, osteochondral fractures, hereditary epiphyseal dysplasia, little league elbow, and Panner's disease [5–7].

Osteochondritis dissecans generally occurs in athletes aged 11–21 years who report a history of overuse [5, 6]. The osteonecrotic lesion usually involves only a segment of capitellum, located primarily at a central or anterolateral position [8, 9]. This condition is a potentially sport-ending injury for an athlete, with possible long-term sequelae such as degenerative arthritis [9, 10].

Pathogenesis

No single cause of osteochondritis dissecans has been universally accepted [5]. There have been a number of hypotheses proposed put forward regarding the etiology of osteochondritis dissecans including trauma, genetics, ischemia, and disordered ossification [11, 12].

There is a relatively high prevalence of OCD among young baseball players and gymnasts [13]. The elbow is subjected to a high valgus stress during the late cocking and early acceleration phases of throwing. In gymnastics, there are high impact and shear forces applied through the elbow [14]. These mechanisms lend support for the proposed role microtrauma plays in this pathologic entity. Additionally, the blood supply to the capitellum is supplied by one or two end vessels with minimal collateral flow [15]. This likely predisposes the developing chondroepiphysis to an avascular state in the setting of repeated microtrauma [14, 16].

The actual cause of OCD of the capitellum may indeed be multifactorial. However, the most influential factors in

N.C. Marks, M.D.
Mississippi Sports Medicine & Orthopaedic Center, Jackson, MS, USA

L.D. Field, M.D. (✉)
Upper Extremity, Mississippi Sports Medicine and Orthopaedic Center, 1325 East Fortification Street, Jackson, MS 39202, USA
e-mail: lfield@msmoc.com

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*,
DOI 10.1007/978-1-4614-1596-1_34, © Springer Science+Business Media New York 2015

the development of OCD seem to be related to repetitive microtrauma and overuse to a chondroepiphysis that is vulnerable secondary to its blood supply [5, 7, 14].

Preoperative Considerations

History

Osteochondritis dissecans is primarily a disorder of the young athlete and rarely occurs in adults. The typical patient is usually between the ages of 11 and 21, with the majority developing symptoms between 12 and 14 years [5, 6, 17]. Males are more commonly affected, but this disorder is also prevalent among female gymnasts. The dominant arm is almost always involved, and bilateral involvement has been reported in some 5–20 % [18]. History of overuse is often described with common sport activities such as baseball, gymnastics, weightlifting, racquet sports, and cheerleading [19]. The initial complaint is of pain and stiffness in the elbow that is often relieved by rest. There is usually no history of a specific traumatic event. Symptoms may also include catching, popping, or locking. Pain is often localized over the lateral aspect of the elbow, but it may also be poorly defined [18].

Physical Examination

The most common finding on physical examination is tenderness over the radiocapitellar joint [20]. It is also not uncommon for the patient to exhibit flexion contractures of between 5 and 30° [5, 20–23]. Clicking, catching, grinding, or locking suggests fragment instability or loose bodies. Crepitus and an effusion may be present as well [5, 6, 18, 19]. Provocative tests such as the active radiocapitellar compression test may help to confirm the diagnosis [24]. In this test, the patient actively pronates and supinates the forearm with the elbow in full extension. The resultant muscle contraction compress the radiocapitellar joint and elicits lateral compartment pain in a positive test. Since valgus overload can cause both capitellum OCD and tears in the medial ulnar collateral ligament (MUCL), the integrity of the MUCL should be examined as well.

Imaging

Radiographs are the initial diagnostic test of choice. Standard anteroposterior (AP) and lateral views of the elbow will usually show the classic findings associated with OCD. The addition of an AP view with the elbow in 45° of flexion may improve the ability to detect radiographic finding associated with OCD [25]. Early in the disease process, radiographs may be negative. As the condition progresses, there is capitellar flattening and radiolucency. A rim of sclerotic bone often surrounds the radiolucent crater, which is typically located in the central or anterolateral aspect of the capitellum (Fig. 34.1). Late findings can include radial head enlargement and osteophyte formation, and loose bodies may be present if the necrotic segment becomes detached.

MRI has become the standard modality for further evaluation [5, 25]. Not only can MRI assess the articular surface, but it can also define both size and extent of the lesion (Fig. 34.2). Early, stable lesions show changes on T1-weighted images, but T2-weighted images may remain normal. On the other hand, advanced lesions show changes on both T1 and T2-weighted images [5, 26]. Loose in situ lesions may demonstrate a cyst under the lesion. MR arthrography can provide further information as to the extent of the injury [25, 26]. Contrast can show separation of a detached or partially detached piece from subchondral bone. Progressive healing can also be followed via plain radiographs or MRI. If the fragment remains stable, the central sclerotic fragment gradually becomes less distinct and the surrounding area of radiolucency slowly ossifies [5, 9].

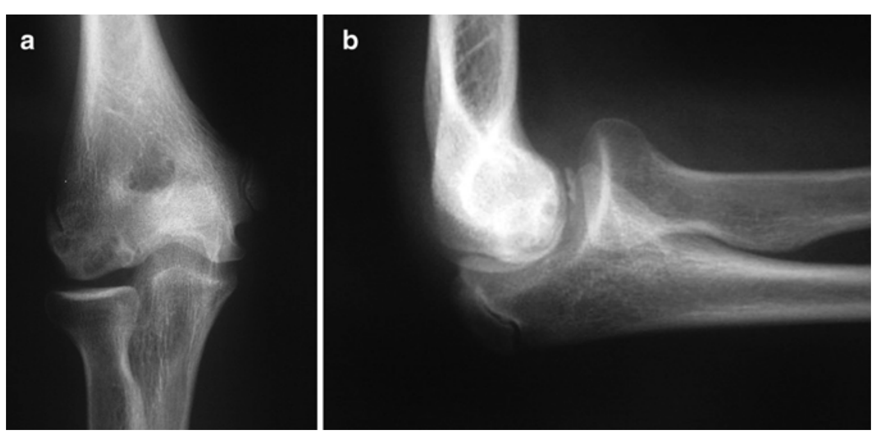


Fig. 34.1 Anteroposterior (**a**) and lateral (**b**) radiographs demonstrating radiolucency and rarefaction typical of osteochondritis dissecans of the elbow

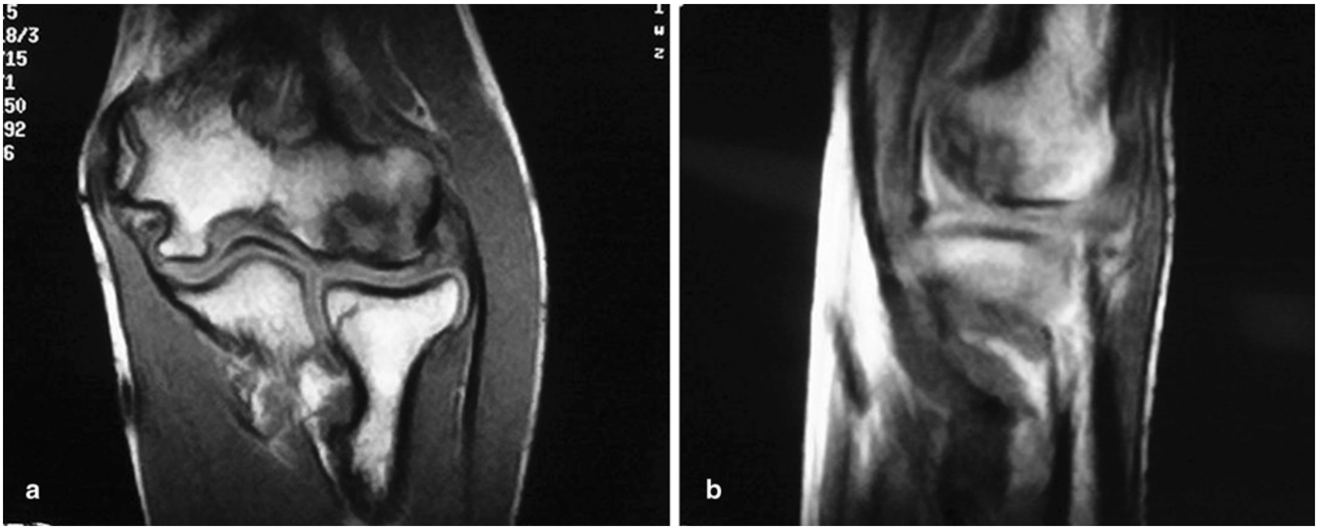


Fig. 34.2 Coronal (**a**) and sagittal (**b**) MR images of the same lesion shown in Fig. 34.1. Increased signal of the T2 image indicates disruption of the articular surface

Treatment Options

Options for the surgical management of symptomatic OCD include nonoperative measures, fragment excision, fragment fixation, and osteochondral autograft reconstruction of the lesion. Management decisions are based primarily on the integrity of the articular cartilage and status of the involved segment; whether it is stable, unstable but attached, or detached and loose. The size and location of the lesion as well as the status of the capitellar physis also affect decision making [21, 27, 28].

Stable lesions with intact cartilage and in situ subchondral fragments are managed conservatively [5, 18, 25]. Surgical indications include persistent or worsening symptoms despite prolonged conservative care, loose bodies, or evidence of instability including violation of intact cartilage or detachment [5, 18, 29, 30].

Conservative Management

Recently, some literature suggests that radiographic information alone is not sufficient to determine if a lesion can be successfully treated nonoperatively. Specifically, Takahara et al. [28, 31] retrospectively reviewed 106 cases of capitellar OCD with an average 7 year follow-up in a level II study. They found that lesions that healed completely with nonoperative treatment had the following characteristics on initial presentation: open capitellar physis, good elbow motion, and radiographic findings of localized flattening or lucency of the subchondral bone. Lesions that fit that criteria were classified as stable.

Nonsurgical treatment is typically selected for patients with intact, nondisplaced, stable lesions, and it involves activity modification with cessation of sports participation [28, 32, 33]. Sports and other aggravating activities are avoided until symptoms subside, approximately for 3–6 weeks. We recommend protecting the elbow in a hinged elbow brace during that time. The straight hinges function to off load the capitellum by correcting the normal valgus tilt of the elbow. As symptoms decrease, physical therapy can begin. Gentle range of motion exercises followed by strengthening are instituted as symptoms dictate. The athlete can usually return to unrestricted sports activities within 3–6 months after treatment has begun [19]. Patients with intact lesions caught early and treated conservatively have the best prognosis. However, it is prudent for the clinician to inform the patient and family of possible long-term sequelae [9, 10, 14, 16, 18, 23, 25].

Surgical Treatment

Operative intervention is indicated for patients that do not improve with appropriate nonoperative treatment have, the presence of loose bodies with mechanical symptoms, or an unstable lesion [7, 13]. Takahara et al. [28, 31] found that conservative treatment failed when patients with unstable lesions had one of the following findings at presentation: a closed capitellum physis, fragmentation, or restriction of elbow motion greater than 20°.

Multiple operative procedures have been described for treating these lesions including drilling of the defect [13], fragment removal with or without curettage/drilling of the

Fig. 34.3 Common arthroscopic elbow portals

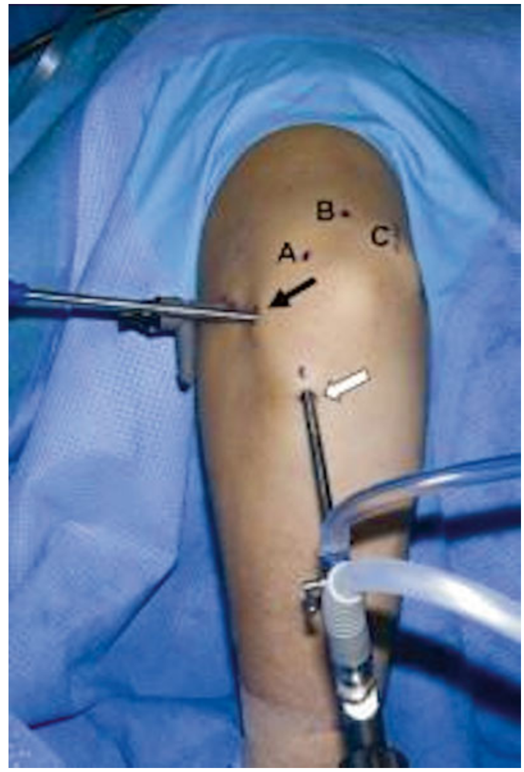


Fig. 34.4 The distal ulnar portal approximately 3–4 cm distal to radiocapitellar joint and just lateral to the palpable posterior edge of the ulna

residual defect [9, 10, 13, 16, 23, 34, 35], fragment fixation by a variety of methods [13, 36–39], reconstruction with osteochondral autograft [13, 38, 40–43], autologous chondrocyte implantation [13, 44], and closing-wedge osteotomy of the lateral condyle [13, 45]. Comparisons of the results of the various operative techniques, however, are difficult because of their largely retrospective nature, different outcome measures, and the relative infrequency of osteochondritis dissecans [13].

Arthroscopic surgery is becoming the standard procedure for the surgical treatment of capitellar osteochondritis dissecans [46, 47]. Advantages include the minimally invasive nature of the procedure with the potential for early rehabilitation, access to the lesion and the entire elbow joint, and ability to identify and treat concurrent lesions including the removal of loose bodies [13]. Studies on arthroscopic debridement and abrasion arthroplasty have shown encouraging short- and mid-term results [9, 21, 22, 28, 35, 47–50]. Recently a level III review of the literature by de Graff et al. [51] suggested that both good short term and long term results can be achieved in a majority of patients treated arthroscopically for OCD of the capitellum. However, their review also emphasized the need for enhanced methodology and longer follow-up. Studies Miyake et al. [52] recently retrospectively evaluated 106 patients who underwent arthroscopic debridement of a capitellar OCD lesion. They found patients with large lesions and open proximal radial physes had both poor radiographic and clinic outcomes. Excellent short term results were obtained in the remaining patient groups.

To treat OCD lesions arthroscopically, the angle of approach through portal access is of utmost importance in order to thoroughly debride, drill, or place osteochondral plugs. Most surgeons use a variation of a 6-portal approach [13, 21, 46, 53] (Fig. 34.3). These portals include standard anteromedial, anterolateral, direct posterior, posterolateral, and direct lateral portals [13, 53]. Baumgarten et al. [21] identified the use of 2 direct lateral portals as the key to effective arthroscopic treatment of osteochondritis dissecans of the capitellum. Davis et al. [53] performed a cadaveric study evaluating the dual direct lateral portals and found that 78 % of the entire capitellar surface area was accessible through these portals. In addition, the portals remain safely proximal and posterior to the lateral ligamentous complex [53]. A distal ulnar portal (Fig. 34.4) has recently been described and is placed approximately 3–4 cm distal to the posterior aspect of the radiocapitellar joint and just lateral to the palpable posterior edge of the ulna [47]. This portal is typically used as a viewing portal, while the standard soft-spot portal is used as a working portal [47]. Some authors have described an arthroscopic-assisted drilling method, using a hole drilled through the radius shaft [54]. In this novel approach to drilling of an OCD lesion, a 1.8 mm K-wire is drilled into the radial head from approximately

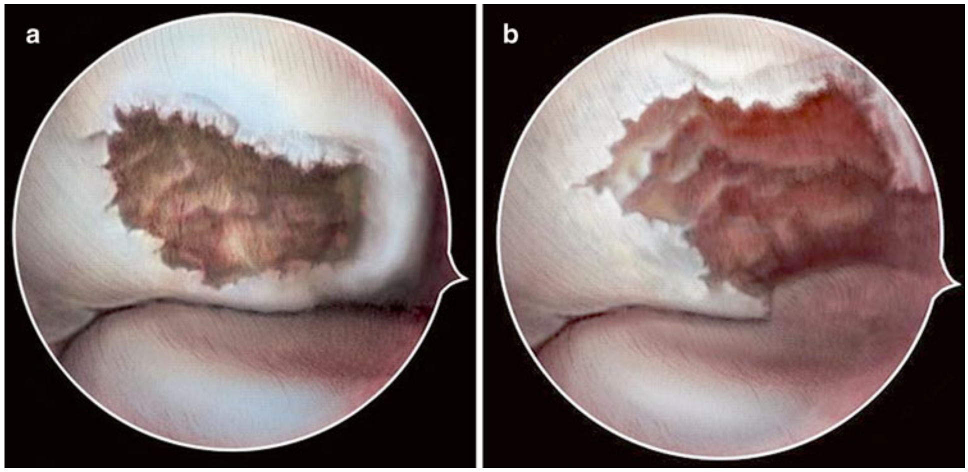


Fig. 34.5 View of osteochondritis dissecans lesion of capitellum in right elbow of patient in prone position viewing from posterolateral portal. Contained osteochondritis dissecans lesion (**a**) with circumferential healthy cartilage present. Similar lesion with loss of lateral column support (**b**)

3 cm distal. The OCD lesion can usually be completely accessed by altering the flexion angle in both pronation and supination [54]. The angle of approach, however, can be in close proximity to the posterior interosseous nerve. Also, this procedure requires drilling across the normal cartilage surface of the radius [47, 54].

The surgical treatment of unstable lesions depends on the size and location of the lesion. Smaller lesions can be debrided with good pain relief. There is still debate over treatment of larger lesions with debridement versus repair versus osteochondral autografts. Shimada et al. [55] suggested that lesions less than 1 cm^2 could be treated with debridement, chondroplasty, and possibly microfracture or drilling, and lesions greater than 1 cm^2 should be treated with osteochondral autograft or fixation. Takahara et al. [9, 28] found lesions with defects greater than 50 % of the capitellar width had a poorer prognosis after fragment removal alone.

Poor results after treatment have been noted in lesions that extend through the lateral margin of the capitellum resulting in the absence of a complete circumferential border of healthy articular cartilage and subchondral bone [13, 22, 34] (Fig. 34.5). Byrd and Jones [34] postulated that the lateral fragment noted in the study by Ruch et al. [22] is similarly associated with loss of the lateral border of the capitellum and portends a possible poor prognosis [13]. The lateral column of the capitellum supports compressive forces when the elbow undergoes either a valgus stress or an axial load. The lack of a lateral buttress impedes the formation of fibrocartilage by subjecting the defect to increased radiocapitellar forces. In a similar fashion, engagement of the radial head into the defect compromises healing. This situation may also lead to accelerated radiocapitellar arthrosis. ElAttrache and Ahmad et al. [56] stated that more than 6–7 mm of lateral column involvement may not be best treated by microfracture alone. They did report successfully treating lesions that were an average of 1.32 cm^2 with microfracture alone provided there was no lateral column involvement. Interestingly, this is in contrast to the suggestion by Shimada et al. [55] that lesions >1 cm^2 should be treated with osteochondral autograft or fixation. Perhaps, this is demonstrates that, to an extent, involvement of the lateral column may more important than the absolute size of the lesion when choosing treatment methods.

Osteochondral autograft transplantation has been recently introduced as another treatment option for capitellum osteochondritis dissecans [13, 38, 40–43]. Indications for this procedure have included lesions involving over 50 % of the articular surface area, disruption of the lateral buttress (Fig. 34.5), and engagement of the radial head [28, 33, 57]. Cylindrical osteochondral grafts are harvested from a donor site, typically the lateral femoral condyle. The plug is inserted perpendicular to the subchondral bone (Fig. 34.6) [31, 40]. These authors have suggested that the procedure may reduce the progression to osteoarthritis and lead to better long-term results [47]. Several reports have described success with osteochondral autograft transfer and osteochondral mosaicplasty [13, 41, 43, 55, 58–61] (Table 34.1).

Authors' Preferred Technique

Arthroscopic Excision and Drilling

The authors utilize general anesthesia and the prone position for arthroscopic evaluation and treatment of the elbow. The patient is placed prone on the operating table over chest rolls to ensure adequate ventilation. The shoulder is abducted to 90° and the arm is supported by an arm positioner or an arm board (Fig. 34.7). The arm board is placed parallel to the operating table, centered at the shoulder. A sandbag, foam support, or rolled blankets are placed under the upper arm to elevate the shoulder and allow the elbow to rest in 90° of flexion.

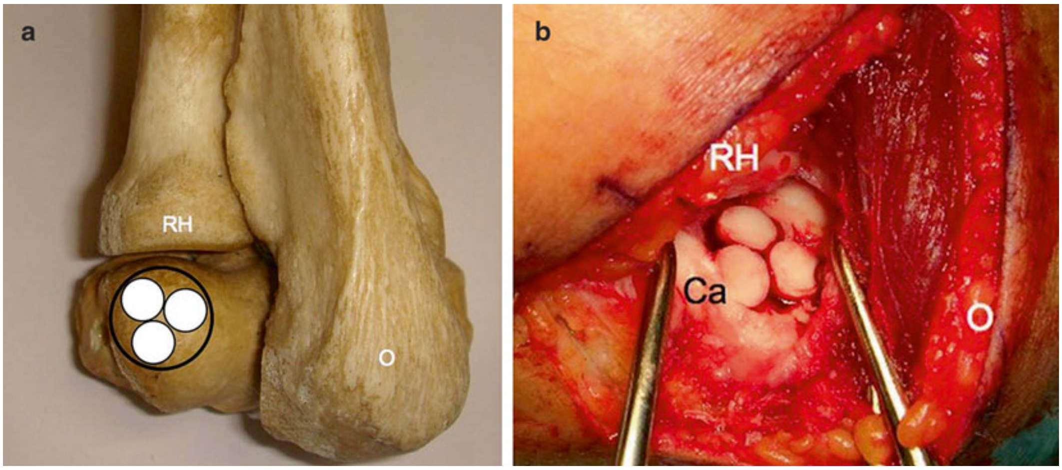


Fig. 34.6 Osteochondral autograft reconstruction of osteochondritis dissecans lesion of the capitellum: Schematic drawing (**a**) and intraoperative view (**b**)

Table 34.1 Results of osteochondral autograft transfer and mosaicplasty for OCD of the capitellum

Author	Mean follow-up	Mean score (points)	Number of patients	Pain free at final follow-up	Patients return to sport level
Tsuda et al. [58] 2005	16 months	193 (Timmerman, 200 max)	3	3	3
Shimada et al. [55] 2005	25.5 months	93.8 (Japanese Orthopaedic Association, 100 max)	10	8	8
Yamamoto et al. [43] 2006	3.5 years	–	18	–	14
Iswasaki et al. [59] 2006	24 months	183 (Timmerman, 200 max)	8	7	6
Iswasaki et al. [41] 2009	45 months	191 (Timmerman, 200 max)	19	18	17
Ovesen et al. [60] 2011	30 months	93.5 (mayo, max 100)	10	8	10
		92.5 (constant, max 100)			
Shimada et al. [61] 2012	36 months	180 (Timmerman, 200 max)	26	–	26

Fig. 34.7 Prone position for arthroscopic treatment of the elbow

Surface landmarks are marked on the skin prior to creating portals. Important landmarks to outline are the radial head, olecranon, lateral epicondyle, medial epicondyle, and ulnar nerve (Fig. 34.3). Prior to making portals, the joint should be distended with 20–30 ml of sterile saline. Placing an 18-gauge spinal needle either in the olecranon fossa or the soft spot bounded by the lateral epicondyle, olecranon, and radial head can provide access to the elbow joint. Neurovascular structures are displaced away from the joint with distention of the joint, which gives an additional margin of safety [20, 62].

The arthroscope is introduced through the proximal anteromedial portal. This portal is located 2 cm proximal to the medial epicondyle and just anterior to the medial intermuscular septum (Fig. 34.8). The medial intermuscular septum is identified by palpation, and the portal is made anterior to the septum so that the ulnar nerve is not injured. The blunt trocar is introduced into the portal, anterior to the septum, and aimed toward the radial head while maintaining contact with the anterior surface of the humerus. This allows the brachialis muscle to remain anterior and protect the median nerve and brachial artery. The trocar enters the elbow through the tendinous origin of the flexor-pronator group and medial capsule. Once entrance into the joint is confirmed, the anterolateral portal is established under direct visualization. The proximal anterolateral portal is positioned 2 cm proximal and 1–2 cm anterior to the lateral epicondyle (Fig. 34.9), and in some cases may be used as the initial portal in elbow

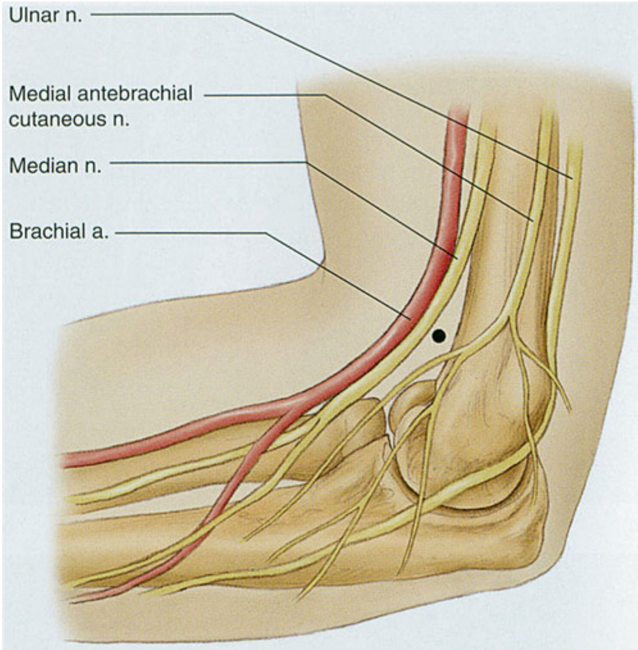


Fig. 34.8 Illustration demonstrating anatomic positioning of the proximal anteromedial portal

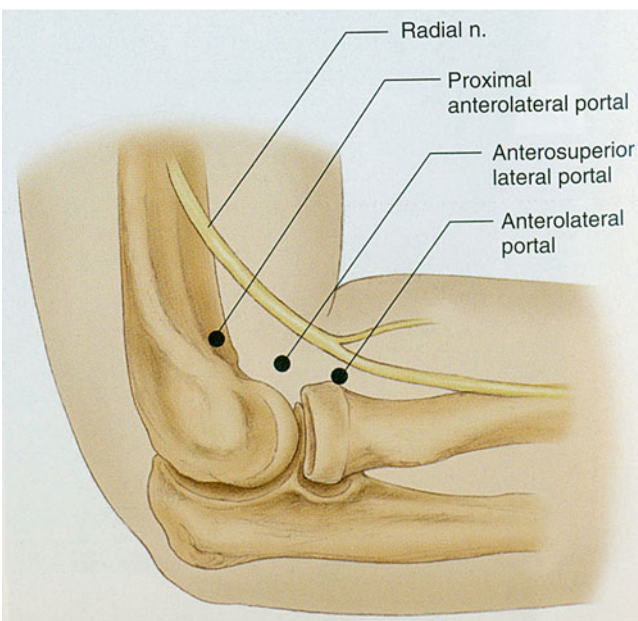


Fig. 34.9 Illustration demonstrating anatomic positioning of common lateral arthroscopic portals

arthroscopy. The blunt trocar is aimed towards the center of the joint while maintaining contact with the anterior humerus, and pierces the brachioradialis muscle, brachialis muscle, and lateral joint capsule before entering the anterior compartment. The coronoid fossa is a common place for loose bodies to be localized (Fig. 34.10). Although the osteochondritic lesion may be noted on the anterior aspect of

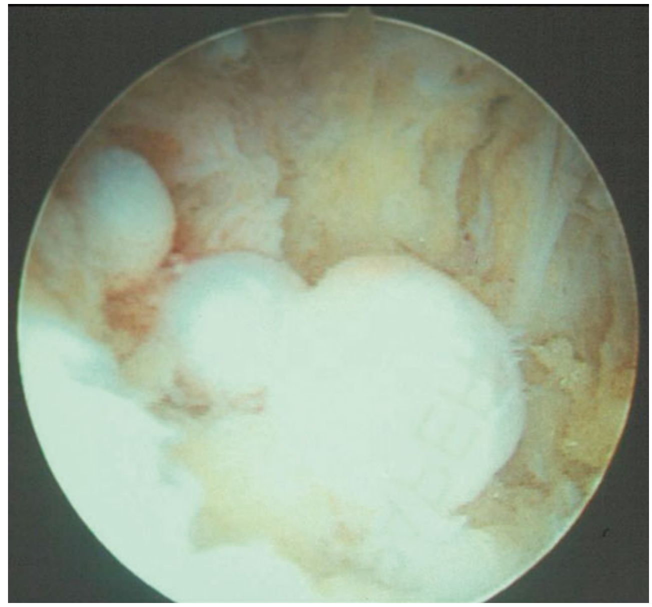


Fig. 34.10 Loose bodies found in the anterior compartment of the elbow

the capitellum, it is most commonly identified at the posterior aspect of the capitellum. One should always perform a varus and valgus stress test while the scope is in the anterior portal to document any concomitant instability of the elbow. Once a complete diagnostic arthroscopy of the anterior compartment of the elbow with removal of any associated loose bodies has been completed, the inflow is left in the proximal anteromedial portal and the scope is transferred to a straight posterior portal. The straight posterior or trans-triceps portal is located 3 cm proximal to the tip of the olecranon in the midline posteriorly [34, 63] (Fig. 34.3). This portal allows visualization of the entire posterior compartment as well as the medial and lateral gutters. The blunt trocar is advanced toward the olecranon fossa through the triceps tendon and posterior joint capsule. The medial gutter is evaluated initially along with the olecranon fossa, and any loose bodies noted in either of these are removed. The arthroscope is then continued into the lateral compartment, and a soft spot portal is established. In most cases of osteochondritis, a relatively large, inflamed posterolateral plica will be noted, along with synovitis in this lateral compartment (Fig. 34.11). The soft spot portal is located in the center of the triangular area bordered by the olecranon, lateral epicondyle, and the radial head. This portal is also known as the direct lateral portal or midlateral portal (Fig. 34.3). The blunt trocar passes through the anconeous muscle and the posterior capsule and into the joint. This inflammatory tissue is excised through a posterior soft spot portal. At this point the 30° arthroscope is removed and a 70° arthroscope is substituted through the posterior central portal. Utilization of the 70° arthroscope may be allows complete evaluation of the osteochondritis dissecans

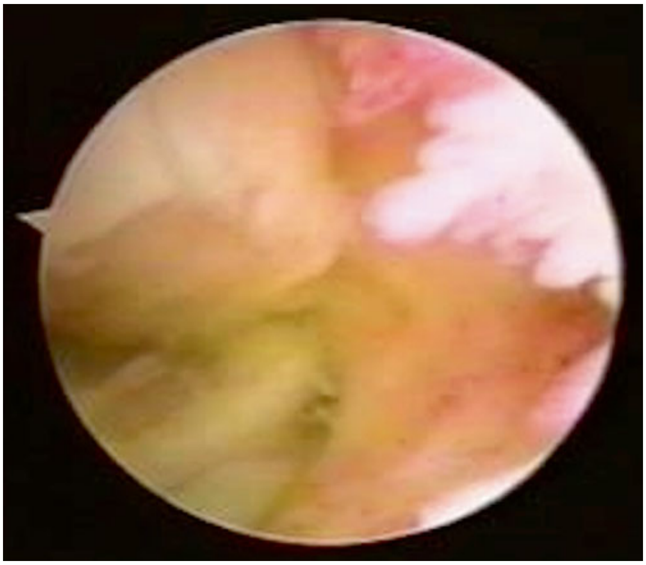


Fig. 34.11 Posterolateral gutter of a patient with osteochondritis dissecans demonstrating the synovitis and inflamed posterolateral plica

Fig. 34.12 Arthroscopic management of a detached osteochondritic lesion of the capitellum viewed from the anteromedial portal. The loose fragment is temporarily stabilized with a spinal needle before excised with a grasper from the anterolateral portal

lesion of the capitellum (Fig. 34.12). The shaver is placed through the soft spot portal and any loose fragments of the osteochondritic area are debrided. The necrotic bone is then removed and, in an attempt to stimulate blood flow, multiple drill holes are placed into the main body of the capitellum using either a drill or an awl (Fig. 34.13).

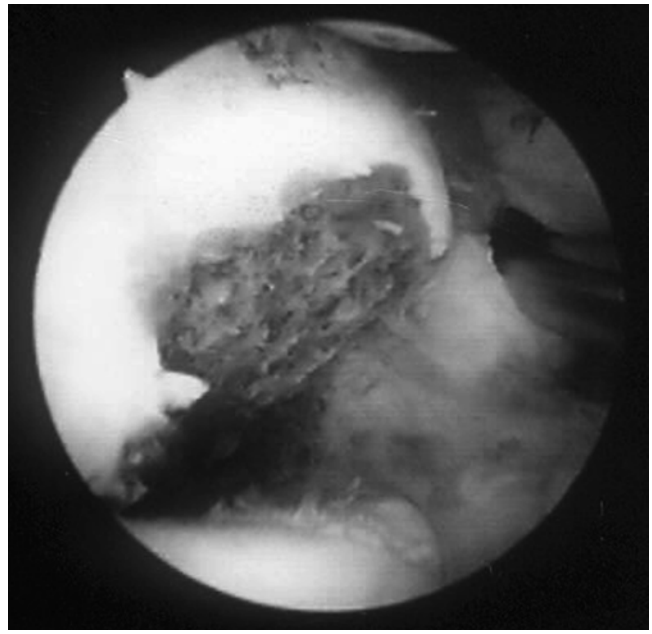


Fig. 34.13 The subchondral base after excision of the fragment and debridement with a shaver

Postoperative Considerations

Rehabilitation

Rehabilitation following arthroscopic treatment begins within a week with the patient placed in a double-hinged elbow brace. Gentle range of motion exercises are started initially and, as swelling and pain subside, patients are slowly allowed to resume athletic activities in the brace. The brace is gradually weaned after 8–12 weeks postoperatively as long as the patient remains free of significant pain or any mechanical symptoms. Generally, full return to activities and sports is possible after approximately 12–16 weeks.

References

1. Joji S, Murakami T, Murao T. Osteochondritis dissecans developing in the trochlea humeri: a case report. J Shoulder Elbow Surg. 2001;10:295–7.
2. Patel N, Weiner SD. Osteochondritis dissecans involving the trochlea: report of two patients (three elbows) and review of the literature. J Pediatr Orthop. 2002;22:48–51.
3. Vanthournout I, Rudelli A, Valenti P, Montagne JP. Osteochondritis dissecans of the trochlea of the humerus. Pediatr Radiol. 1991;21:600–1.
4. Mitsunaga MM, Adishian DA, Bianco Jr AJ. Osteochondritis dissecans of the capitellum. J Trauma. 1982;22:53–5.
5. Bradley J, Petrie R. Osteochondritis dissecans of the humeral capitellum: diagnosis and treatment. Clin Sports Med. 2001;20:565–90.
6. Schenck Jr RC, Goodnight JM. Osteochondritis dissecans. J Bone Joint Surg Am. 1996;78:439–56.

7. Yadao MA, Field LD, Savoie III FH. Osteochondritis dissecans of the elbow. Instr Course Lect. 2004;53:599–606.
8. Konig F. Ueber freie Korper in den Gelenken. Deutsche Zeitschr Chir. 1887;27:90–109.
9. Takahara M, Ogino T, Sasaki I, et al. Long term outcome of osteochondritis dissecans of the humeral capitellum. Clin Orthop. 1999;363:108–15.
10. Bauer M, Jonsson K, Josefsson PO, et al. Osteochondritis dissecans of the elbow: a long-term follow up study. Clin Orthop. 1992;284: 156–60.
11. Gardiner TB. Osteochondritis dissecans in three members of one family. J Bone Joint Surg Br. 1955;37:139–41.
12. Stougaard J. Familial occurrence of osteochondritis dissecans. J Bone Joint Surg Br. 1964;46:542–3.
13. Baker 3rd CL, Romeo AA, Baker Jr CL. Osteochondritis dissecans of the capitellum. Am J Sports Med. 2010;38(9):1917–28.
14. Singer KM, Roy SP. Osteochondrosis of the humeral capitellum. Am J Sports Med. 1984;12:351–60.
15. Haraldsson S. On osteochondrosis deformans juvenilis capituli humeri including investigation of intra-osseous vasculature in distal humerus. Acta Orthop Scand. 1959;38(suppl):1–232.
16. Jackson DW, Silvino N, Reiman P. Osteochondritis in the female gymnast's elbow. Arthroscopy. 1989;5:129–36.
17. Pappas AM. Osteochondritis dissecans. Clin Orthop. 1981;158:59–69.
18. Shaughnessy WJ. Osteochondritis dissecans. In: Morrey BF, editor. The elbow and its disorders. 3rd ed. Philadelphia, PA: WB Saunders; 2000. p. 255–60.
19. Peterson RK, Savoie III FH, Field LD. Osteochondritis dissecans of the elbow. Instr Course Lect. 1998;48:393–8.
20. McManama Jr GB, Micheli LJ, Berry MV, et al. The surgical treatment of osteochondritis of the capitellum. Am J Sports Med. 1985;13:11–21.
21. Baumgarten T, Andrews J, Satterwhite Y. The arthroscopic classification and treatment of osteochondritis dissecans of the capitellum. Am J Sports Med. 1998;26:520–3.
22. Ruch D, Cory J, Poehling G. The arthroscopic management of osteochondritis dissecans of the adolescent elbow. Arthroscopy. 1998;14:797–803.
23. Woodward AH, Bianco Jr AJ. Osteochondritis dissecans of the elbow. Clin Orthop. 1975;110:35–41.
24. Baumgarten TE. Osteochondritis dissecans of the capitellum. Sports Med Arthr Rev. 1995;3:219–23.
25. Takahara M, Shundo M, Kondo M, et al. Early detection of osteochondritis dissecans of the capitellum in young baseball players: report of three cases. J Bone Joint Surg Am. 1998;80:892–7.
26. Fritz RC, Stoller DW. The elbow. In: Stoller DW, editor. Magnetic resonance imaging in orthopedics & sports medicine. 2nd ed. Philadelphia, PA: Lippincott-Raven; 1997. p. 743–849.
27. Mihara K, Tsutsui H, Nishinaka N, Yamaguchi K. Nonoperative treatment for osteochondritis dissecans of the capitellum. Am J Sports Med. 2009;37(2):298–304.
28. Takahara M, Mura N, Sasaki J, Harada M, Ogino T. Classification, treatment, and outcome of osteochondritis dissecans of the humeral capitellum. J Bone Joint Surg Am. 2007;89:1205–14.
29. Chess D. Osteochondritis. In: Savoie III FH, Field LD, editors. Arthroscopy of the elbow. New York, NY: Churchill Livingstone; 1996. p. 77–86.
30. Nagura S. The so-called osteochondritis dissecans of Konig. Clin Orthop. 1960;18:100–22.
31. Takahara M, Mura N, Sasaki J, Harada M, Ogino T. Classification, treatment, and outcome of osteochondritis dissecans of the humeral capitellum: surgical technique. J Bone Joint Surg Am. 2008; 90(Suppl 2, Part 1):47–62.
32. Mihara K, Suzuki K, Makiuchi D, Nishinaka N, Yamaguchi K, Tsutsui H. Surgical treatment for osteochondritis dissecans of the humeral capitellum. J Shoulder Elbow Surg. 2010;19:31–7.
33. Ruchelsman DE, Hall MP, Youm T. Osteochondritis dissecans of the capitellum: current concepts. J Am Acad Orthop Surg. 2010; 18:557–67.
34. Byrd T, Jones K. Arthroscopic surgery for isolated capitellar osteochondritis dissecans in adolescent baseball players: minimum three-year follow-up. Am J Sports Med. 2002;30:474–8.
35. Tivnon MC, Anzel SH, Waugh TR. Surgical management of osteochondritis dissecans of the capitellum. Am J Sports Med. 1976;4:121–8.
36. Harada M, Ogino T, Takahara M, et al. Fragment fixation with a bone graft and dynamic staples for osteochondritis dissecans of the humeral capitellum. J Shoulder Elbow Surg. 2002;11:368–72.
37. Kuwahata Y, Inoue G. Osteochondritis Dissecans of the elbow managed by Herbert screw fixation. Orthopedics. 1998;21:449–51.
38. Oka Y, Ikeda M. Treatment of severe osteochondritis dissecans of the elbow using osteochondral grafts from a rib. J Bone Joint Surg Br. 2001;83:838–9.
39. Takeda H, Watarai K, Matsushita T, et al. A surgical treatment for unstable osteochondritis dissecans lesions of the humeral capitellum in adolescent baseball players. Am J Sports Med. 2002; 30:713–7.
40. Iwasaki N, Kato H, Ishikawa J, Masuko T, Funakoshi T, Minami A. Autologous osteochondral mosaicplasty for osteochondritis dissecans of the elbow in teenage athlete: surgical technique. J Bone Joint Surg Am. 2010;92(Suppl 1, Part 2):208–16.
41. Iwasaki N, Kato H, Ishikawa J, Masuko T, Funakoshi T, Minami A. Autologous osteochondral mosaicplasty for osteochondritis dissecans of the elbow in teenage athletes. J Bone Joint Surg Am. 2009;91(10):2359–66.
42. Nakagawa Y, Matsusue Y, Ikeda N, et al. Osteochondral grafting and arthroplasty for end-stage osteochondritis dissecans of the capitellum: a case report and review of the literature. Am J Sports Med. 2001;29:650–5.
43. Yamamoto Y, Ishibashi Y, Tsuda E, Sato H, Toh S. Osteochondral autograft transplantation for osteochondritis dissecans of the elbow in juvenile baseball players: minimum 2-year follow-up. Am J Sports Med. 2006;34(5):714–20.
44. Iwasaki N, Yamane S, Nishida K, Masuko T, Funakoshi T, Kamishima T, Minami A. Transplantation of tissue-engineered cartilage for the treatment of osteochondritis dissecans in the elbow: outcomes over a four-year follow-up in two patients. J Shoulder Elbow Surg. 2010;19:e1–6.
45. Kiyoshige Y, Takagi M, Yuasa K, Hamasaki M. Closed-wedge osteotomy for osteochondritis dissecans of the capitellum: a 7-to 12-year follow-up. Am J Sports Med. 2000;28(4):534–7.
46. Savoie FH. Guidelines to becoming an expert elbow arthroscopist. Arthroscopy. 2007;23:1237–40.
47. Van Den Ende KI, McIntosh A, Adams J, Steinmann S. Osteochondritis dissecans of the capitellum: a review of the literature and a distal ulnar portal. Arthroscopy. 2011;27(1):122–8.
48. Bojanic I, Ivkovic A, Boric I. Arthroscopy and microfracture technique in the treatment of osteochondritis dissecans of the humeral capitellum: report of three adolescent gymnasts. Knee Surg Sports Traumatol Arthrosc. 2006;14(5):491–6.
49. Brownlow HC, O'Connor-Read LM, Perko M. Arthroscopic treatment of osteochondritis dissecans of the capitellum. Knee Surg Sports Traumatol Arthrosc. 2006;14(2):198–202.
50. Rahusen FT, Brinkman JM, Eygendaal D. Results of arthroscopic debridement for osteochondritis dissecans of the elbow. Br J Sports Med. 2006;40(12):966–9.
51. de Graaff F, Krijnen MR, Poolman RW, Willems WJ. Arthroscopic surgery in athletes with osteochondritis dissecans of the elbow. Arthroscopy. 2011;27(7):986–93.
52. Miyake J, Masatomi T. Arthroscopic debridement of the humeral capitellum for osteochondritis dissecans: radiographic and clinical outcomes. J Hand Surg Am. 2011;36(8):133–1338.

53. Davis JT, Idjadi JA, Siskosky MJ, ElAttrache NS. Dual direct lateral portals for treatment of osteochondritis dissecans of the capitellum: an anatomic study. Arthroscopy. 2007;23:723–8.
54. Aria Y, Hara K, Fujiwara H, Minami G, Nakagawa S, Kubo T. A new arthroscopic-assisted drilling method through the radius in a distal-to-proximal direction for osteochondritis dissecans of the elbow. Arthroscopy. 2008;24:237e1–4.
55. Shimada K, Yoshida T, Nakata K, Hamada M, Akita S. Reconstruction with an osteochondral autograft for advanced osteochondritis dissecans of the elbow. Clin Orthop Relat Res. 2005;435:140–7.
56. Gonzalez-Lomas G, Ahmad C, Wanich T, ElAttrache N. Osteochondritis dissecans of the elbow. In: Ryu RKN, editor. AANA advanced arthroscopy: the elbow and wrist. 1st ed. Philadelphia, PA: Saunders Elsevier; 2010. p. 40–54.
57. Ahmad C, ElAttrache N. Treatment of capitellar osteochondritis dissecans. Tech Should Elbow Surg. 2006;7(4):169–74.
58. Tsuda E, Ishibashi Y, Sato H, Yamamoto Y, Toh S. Osteochondral autograft transplantation for osteochondritis dissecans of the capitellum in nonthrowing athletes. Arthroscopy. 2005;21:1270–2.
59. Iwasaki N, Kato H, Ishikawa J, Saitoh S, Minami A. Autologous osteochondral mosaicplasty for capitellar osteochondritis dissecans in teenaged patients. Am J Sports Med. 2006;34:1233–9.
60. Ovesen J, Olsen BS, Johannsen HV. The clinical outcomes of mosaicplasty in the treatment of osteochondritis dissecans of the distal humeral capitellum of young athletes. J Shoulder Elbow Surg. 2011;20:813–8.
61. Shimada K, Tanaka H, Matsumoto T, Miyake J, Higuchi H, Gamo K, et al. Cylindrical costal osteochondral autograft for reconstruction of large defects of the capitellum due to osteochondritis dissecans. J Bone Joint Surg Am. 2012;95(11):992–1002.
62. Brown R, Blazina ME, Kerlan RK, et al. Osteochondritis of the capitellum. J Sports Med. 1974;2:27–46.
63. Menche DS, Vangsness Jr CT, Pitman M, et al. The treatment of isolated articular cartilage lesions in the young individual. Instr Course Lect. 1998;47:505–15.

Arthroscopic Treatment of Elbow Fractures

35

Michael R. Hausman and Steven M. Koehler

Introduction

Recently there has been an increased interest in elbow arthroscopy. Yet elbow arthroscopy is not new. Burman reported the first attempt at elbow arthroscopy in 1931 in the *Journal of Bone and Joint Surgery*. He found the elbow to be "unsuitable for examination, since the joint space is so narrow for the relatively large needle" [1]. One year later, he reversed his opinion and successfully arthroscopically examined ten cadaveric elbows [2]. Yet despite early pioneering work of elbow arthroscopy, interest in elbow arthroscopy did not become widespread until relatively recently. It was not until 1985 that Andrews and Carson reported the first elbow arthroscopy in vivo and described many of the portals used today [3]. Since then, interest in elbow arthroscopy and its indications has rapidly expanded.

Trauma is a more recent application of elbow arthroscopy [4]. Intra-articular fractures of the elbow often occur in conjunction with injury of the collateral ligaments and capsule. The complex osteology of the elbow and close proximity of vital neurovascular structures make exposure challenging and, often, limited. Further complicating exposure is the need to avoid damaging ligaments, which, if sectioned, could potentially exacerbate the initial injury by increasing instability. Consequently malreduction or incomplete reduction is not uncommon and hardware penetration of the articular surface may occur. Elbow arthroscopy may improve the visualization of the articular surface and, via magnification, facilitate accurate reduction and fixation.

M.R. Hausman, M.D. • S.M. Koehler, M.D. (✉)
Department of Orthopaedic Surgery, Mount Sinai Medical Center, 5 East 98th Street, Box 1188, New York, NY 10029, USA
e-mail: Steven.Koehler@mountsinai.org

Considerations

The successful application of elbow arthroscopy to trauma treatment involves several modifications of technique. First, timing is very important. Initially after fracture, there is bleeding from the fracture surfaces that can only be controlled with higher inflow pressures (greater than 35 mmHg). This results in rapid swelling making conversion to open surgery much more difficult. If possible, a delay of 24–36 h after injury allows clot to form on the fractured surfaces and allows the use of lower perfusion pressure (<25–30 mmHg) which minimizes swelling and, thus, extends working time and facilitates conversion to an open procedure, if necessary. Second, a newly fractured elbow comes pre-distended by fracture hematoma, which makes joint entry relatively easy. Third, unlike in other indications for elbow arthroscopy, prior to fracture, the joint was normal with no contractures or deformity. The capsule is supple and thin and easy to penetrate. Thus, entering the joint in a trauma case is, in many ways, easier than for a contracture, where the capsule may be thick and tough and the joint volume markedly constricted. Thus, the challenge is not entering the joint, but patiently lavaging and debriding the hematoma with a small diameter shaver (3.5 mm) directed posteriorly toward the humerus, until good visualization is achieved.

Contraindications

The contraindications in the arthroscopic treatment of elbow arthroscopy are the same as those for all elbow arthroscopic procedures. Submuscular transposition of the ulnar nerve is a contraindication, unless the entire procedure is to be done without medial portals. Arthroscopy is also contraindicated in the event that visualization cannot be achieved and conversion to open, standard techniques would make a procedure easier or provide a more precise reduction.

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*, DOI 10.1007/978-1-4614-1596-1_35, © Springer Science+Business Media New York 2015

Technique

Timing

As mentioned previously, timing of the intervention is very important. A 24–48 h delay avoids the problem of bleeding from the fracture surface, as discussed above [5, 6]. A tourniquet is routinely used.

Positioning

The supine position, described in 1985 by Andrews and Carson, offers maximum flexibility and access for fracture fixation [3]. In our practice, we have modified this position to include an adjustable shoulder positioner, such as the McConnell arm holder (McConnell Orthopaedic Manufacturing Co., Greenville, Texas) (Fig. 35.1). This allows the patient's arm to be placed either across the chest or at the patient's side, conferring multiple advantages: the ability to move the arm in space; easy access for fluoroscopy; easy elevation of the arm to minimize "breakthrough bleeding"; and application of longitudinal traction of the arm, which frequently assists with reduction. The posterior compartment is accessed with the arm across the patient's chest and the anterior compartment is accessed with the shoulder abducted 90° and the humerus parallel to the floor.

Instrumentation

Generally, a 4.0 mm arthroscope with a 30° offset is used. This typically provides excellent visualization for all procedures. Occasionally a 70° arthroscope is useful for viewing the coronoid base or the capitellum and anterior surface of the humerus from the distal posterolateral portal. A smaller 2.7 mm scope can be used for smaller spaces or pediatric patients younger than 5–7 years.

Flow management is vital to the success of elbow arthroscopy, thus special trocars and cannulae without fenestrations should be used to avoid the extravasation of fluid into the subcutaneous layer [1]. Therefore, we also recommend liberal use of switching sticks and cannulae once the portals are established (Fig. 35.2). This also serves to decrease the risk of neurovascular injury by minimizing the number of passes through tissues.

We also find it useful to have special instruments available such as cannulated screws, a small Freer elevator with a hole drilled in the end for passing sutures, modified skin hooks, and 28-gauge stainless steel wire to help in reducing, holding fragments and passing sutures (Fig. 35.2). A variety of graspers, forceps, shavers, and burrs should be available.

Portal Placement

Precautions

Because the elbow is highly constrained, it is necessary to place multiple portals to access and see all parts of the joint [7]. Anatomic studies have demonstrated that flexion of the elbow to 90° minimizes the proximity of the critical neurovascular structures [8–11]. Therefore, all portals should be established from this position. Distention of the capsule further displaces these structures away from arthroscopic instruments. Portals should be made close of the capsular insertion on the supracondylar ridge, to prevent entrapping capsular tissue between the portal and the humerus. Doing so would decrease the joint volume and compromise exposure [12, 13]. Lastly, observing standard technique, a small incision should be used to incise the skin only (no stab incisions). Next, blunt dissection should be performed through the subcutaneous tissue and down to the level of the capsule. This helps to

Fig. 35.1 Our preferred patient positioning for elbow arthroscopy: supine with a McConnell arm positioner. (**a**) Position for access to the posterior compartment. (**b**) Position for anterior elbow access. (**c**) Alternative lateral decubitus position demonstrating access to the anterior compartment

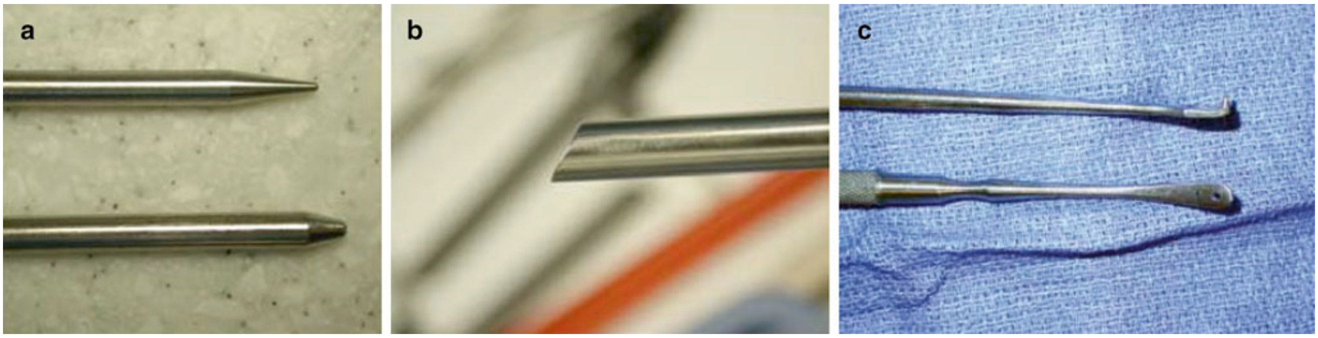


Fig. 35.2 (**a**, **b**) Trocars and nonfenestrated cannulae used for elbow arthroscopy. The use of switching sticks over which a cannula can be threaded is preferable to the customary trocar/cannula combination because there is less soft-tissue drag and, thus, it is easier to enter the joint. (**c**) a hook retractor that has been ground and modified to fit through a small cannula and a Freer elevator with a hole drilled through the end for passing sutures

minimize the risk to the surrounding structures by displacing them out of the proposed path prior to trocar insertion. All trocars should use blunt tips.

Standard Anteromedial Portal

This portal is located 2 cm distal and 2 cm anterior to the medial epicondyle (Fig. 35.3). The arthroscope should be aimed towards the coronoid fossa (not anteriorly), passing through the common flexor origin, posterior to the median nerve and brachial artery, which are protected by the brachialis muscle [3, 9, 10]. This portal allows an excellent view of the entire anterior compartment of the joint, in particular the radiocapitellar joint, coronoid, and trochlea. Pronation and supination will allow a full 260° arc of visibility of the radial head [8]. From this portal, the coronoid process may obstruct the proximal radioulnar joint articulation. Furthermore, the medial ulnohumeral articulation is difficult to see. This portal affords access to the anteromedial coronoid and may be useful, in conjunction with the proximal anteromedial portal, for coronoid reduction and fixation.

The structure at greatest risk is the medial antebrachial cutaneous nerve; it is an average 1 mm away from the trocar and demonstrates considerable variability [8]. The median nerve is an average 7–14 mm away.

Proximal Anteromedial Portal

This portal is often used as the starting point in elbow arthroscopy and offers an optimal view of the entire anterior compartment. It is made 2 cm proximal and 1 cm anterior to the medial epicondyle to avoid injury to ulnar nerve (Fig. 35.3) [11, 14, 15]. When making the portal, a blunt trocar should be used to pierce the flexor pronator mass. The trocar should be slid along the anterior surface of the humerus, aimed toward the radial head [11, 15]. During this approach, the structure most at risk with this portal is the medial antebrachial cutaneous nerve.

Standard Anterolateral Portal

Originally described by Andrews and Carson as 3 cm distal and 1 cm anterior to the lateral epicondyle, this portal is very close to the neurovascular structures and is not recommended (Fig. 35.3) [3]. Similar, less risky visualization has been described via other portals.

Proximal Anterolateral Portal

Located 2 cm proximal and 1–2 cm anterior to the lateral epidondyle, this portal permits a consistent view of the radiocapitellar joint and the medial side of the joint (Fig. 35.3) [16, 17]. To access this portal, the trocar should be directed towards the center of the joint while in contact with the anterior humerus. Because the posterior branch of the lateral antebrachial cutaneous nerve and radial nerve are a safe distance away, this portal has been advocated as a good starting point in elbow arthroscopy [10, 17].

Posterior Radiocapitellar "Soft Spot" Portal

This portal is commonly referred to as the "soft spot" and is located in the center of the triangle created by the lateral epicondyle, olecranon, and radial head (Fig. 35.3). It can be used for visualization of the posterior radiocapitellar and ulnohumeral joints and for distention [18]. The risk of this portal is that the minimal distance between the capsule and the skin increases the risk of fluid extravasation into surrounding soft tissues. Therefore, it is recommended to delay placement of this portal until the procedure has begun via another portal [10]. The only structures relatively at risk from this approach are the lateral antebrachial cutaneous nerve and posterior antebrachial cutaneous nerve [11, 18].

Straight Posterior (Trans-triceps) Portal

The workhorse of the posterior compartment, this portal is located 3 cm proximal to the olecranon tip in the midline of the humerus between the epicondyles (Fig. 35.3) [19]. A #11

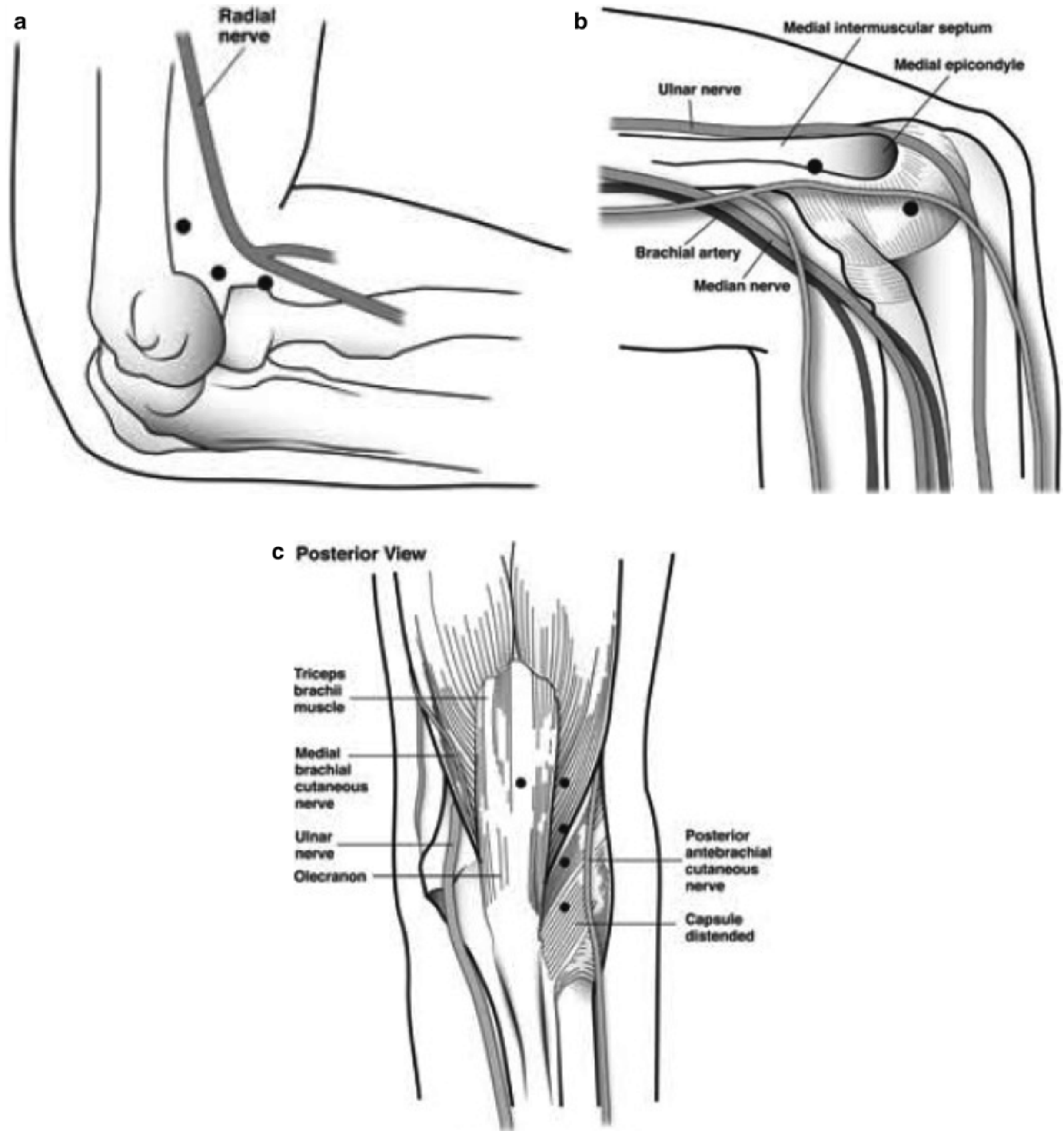


Fig. 35.3 Commonly used (**a**) lateral and (**b**) medial portals. Lateral portals include the proximal anterolateral portal, 2 cm proximal and 1 cm anterior to the lateral epicondyle; anterior radiocapitellar portal directly anterior to the radiocapitellar joint (and closest to the radial nerve) and the posterior radiocapitellar or soft spot portal. Medially, the proximal anterolateral portal is most widely used, 2 cm proximal and anterior to the lateral epicondyle. An additional anteromedial portal can be placed 1 cm distal to the proximal anteromedial portal, but insertion is more difficult because of the more fibrous common flexor origin tendon in the more distal position. (**c**) Posteriorly, the transtriceps portal is supplemented with proximal and distal posterolateral portals for retractors and working instruments. Additional portals can be safely placed along the posterior radioulnar interval

scalpel to make a sharp stab incision into the tendon down to bone. This is safe because the ulnar nerve is palpated and the portal is made well lateral to the course of the nerve. The trocar passes through the triceps tendon and into the olecranon fossa. Complete visualization of the entire posterior compartment and gutters is easily achievable.

Proximal Posterolateral Portal

This portal is usually placed 3–4 cm proximal to the olecranon tip and just lateral to the palpable edge of the triceps tendon (Fig. 35.3) [18]. The trocar is placed through the posterolateral capsule, just lateral to the tendon and towards the olecranon fossa. It is quite safe with the ulnar nerve, medial

Fig. 35.4 Surface landmarks (**a**) and mapping (**b**) of all common portals prior to commencement of the surgery

and posterior antebrachial cutaneous. We typically use this portal as a working portal in conjunction with the straight posterior portal.

Accessory Distal Posterolateral Portal and Anterior Radiocapitellar Portal

The distal posterolateral portal (Fig. 35.3) is used to view the posterior compartment, lateral gutter, posterior radiocapitellar joint, proximal radioulnar joint, and medial gutter while allowing the transtriceps portal to be used for a shaver or resecting forceps. A useful accessory portal is the anterior radiocapitellar portal just anterior and proximal to the joint. It should only be made under direct localization and visualization from the medial portal as it lies closest to the radial nerve. Extreme caution should be used when inserting the trocar as anterior deflection along the capsule will place the radial nerve at risk [6].

Surface Landmarks

Prior to starting, it is our practice to always mark the major topographic landmarks on the skin. We routinely mark the medial and lateral epicondyles, olecranon and proximal ulnar, radial head, radiocapitellar joint, and the path of the ulnar nerve (Fig. 35.4). We also ensure there is no ulnar subluxation present. Lastly, we mark out our proposed portals, because joint distention will distort the anatomy later in the procedure.

Order of Portal Placement

Portal placement is determined by the procedure to be done. In general, for fracture work, a proximal anteromedial portal is first established and the lateral portals can be located with a 25 guage needle to ensure safe, accurate placement. A posterior portal is useful for checking the posterior wall of the lateral column and the distal reduction of capitellar fractures. Coronoid fractures are fixed through anteromedial and anterolateral portals.

Surgical Tips for Fracture Arthroscopy

1. Do not overdistend the joint. Capsular rupture has been shown to occur with a little as 20 mL [20].
2. Wait 24–36 h for clot to form (if not contraindicated)
3. Enter the joint and lavage with a 3.5 mm shaver directed posteriorly toward the humerus until the hematoma is cleared and an adequate view is established. This takes time and patience, but it is impossible to see anything until this step is completed, so be patient.
4. Leave the ulnar nerve in situ to avoid trauma and additional scarring. Furthermore it preserves the option of later arthroscopic arthrolysis should subsequent elbow release be necessary.

Capitellum and Anterior Coronal Shear Fractures

Due to the difficulty of obtaining adequate exposure and the risks of screw placement in a hemisphere (similar to a subcapital hip fracture or slipped femoral capital epiphysis), capitellar fractures are well suited for arthroscopic treatment. These injuries frequently involve the lateral aspect of the trochlea in addition to the lateral column (Fig. 35.5) [21, 22]. Thus, the entire anterior articular surface as well as the posterior cortex of the lateral column should be inspected.

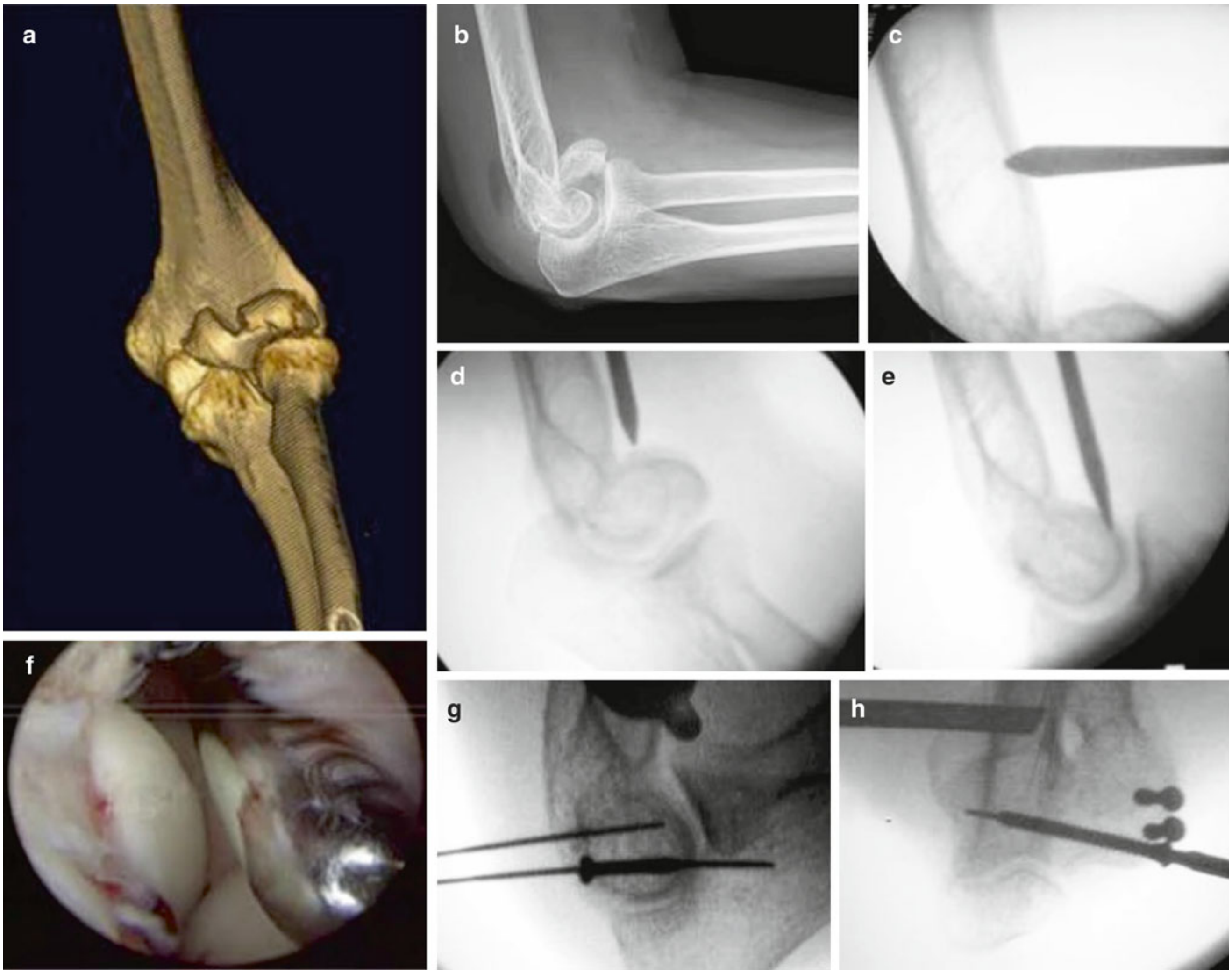


Fig. 35.5 (**a**) CT and (**b**) X-ray demonstrate an anterior coronal shear fracture involving the entire capitellum and lateral trochlea. (**c**) A "high" proximal anterolateral portal is marked out under radiologic guidance and created proximal to the fracture. (**d**, **e**) Extension frequently will reduce the fracture, but in this case a complete reduction does not occur. Therefore, the trocar is used to push the fragment into an anatomic reduction. (**f**) This is confirmed with the arthroscopic view from the anterolateral portal. (**g**) Fixation is achieved with cannulated screws, again using the arthroscope to confirm optimal placement and length. (**h**) Note the use of a transcondylar screw to reinforce the fixation, permitting early use and therapy

This would require extensive exposure and dissection for complete visualization. However, such exposure can be accomplished arthroscopically with minimal trauma. Additionally, direct visualization of the reduction is invaluable in ensuring adequate fixation and the joint surface can be visually monitored to insure correct screw length and placement. We outline our preferred technique below, but various other techniques have been described (Fig. 35.5) [23–25].

As previously described, the proximal anteromedial portal should be established and the hematoma evacuated from the joint. The fracture can frequently be reduced in elbow extension, but because of contact with the radial head, the fracture can redisplace when the elbow is flexed. If this occurs, then we place a trocar in the radiocapitellar joint to help the radial head "ride over" the capitellum as the elbow is flexed (much like a shoehorn is used). A trocar is then placed in a proximal anterolateral portal and is used to push and reduce the anterior coronal shear fragment. This trocar is then interposed in the radiocapitellar joint, to act as a shoehorn to prevent displacement as the elbow is flexed and allow the radial head to "ride over" the capitellum without displacing it. Once flexion more than 90° is obtained, the radial head will then help to maintain the reduction. Fluoroscopic examination will ensure that the capitellar fragment is captured by the radial head and not redisplaced.

Once reduction is achieved, the elbow should be kept flexed, maintaining the reduction. The reduction should be thoroughly visualized, both the anterior aspect of the joint and the distal humerus where there can be comminuted fragments or plastic deformation of the posterior fragment of the distal humerus that prevents a perfect reduction. We utilize a transtriceps or distal posterior lateral portal to visualize the distal humerus. When using a distal posterior lateral portal, we, pass down into the lateral gutter, obtaining a view of the posterior column. It may sometimes be necessary to use the posterior radiocapitellar portal for a 3.5 mm shaver to remove debris in this area, improving visualization. The reduction of the lateral trochlear ridge can also be assessed from the posterior side, advancing the arthroscope down the lateral gutter and directing the optics proximally along the anterior humerus. Occasionally, a 70° arthroscope is helpful for this purpose.

Once an accurate reduction is achieved and confirmed, we prepare the area for fixation. Small posterior incisions are made to insert guide wires for at least two cannulated screws. If necessary, we use an anterior portal or a view from the lateral gutter with a 70° scope to observe the guide wires, thereby confirming the trajectory of the screws and assuring the proper length and position. The guide wires are advanced until just barely visible through the cartilage and a screw 2–4 mm shorter than the measured length is selected. This process ensures that the longest possible screw is being used, instead of undersizing, which may occur when judging the screw length in a sphere on a two-dimensional radiograph. If possible, a lateral to medial transcondylar screw (2.5 or 2.7 mm) will substantially increase the strength of the fixation. Care should be taken to assess the trochlear ridge reduction if the fracture extends medially.

We prefer to start early motion. However if there is comminution or any question about stability, then the elbow should be immobilized. We prioritize healing of the fracture over early motion, as any residual contracture can be treated with a staged arthroscopic contracture release, if necessary.

Unicondylar Fractures (AO Type B) of the Distal Humerus

A unicondylar, intra-articular distal humerus fracture is anatomically similar to a capitellar fracture or pediatric lateral condyle fracture. Triceps sparing or reflecting approaches have been advocated to avoid olecranon osteotomy. However, visualization of the articular surface is severely compromised unless a more extensive soft tissue release performed, thereby contravening the hypothetical advantage of the more limited approach. We prefer a hybrid operation. Our preference is to combine the arthroscopic view of the articular surface (the "exposure") with a combined, extracapsular medial or lateral approach to apply a plate (Fig. 35.6). Arthroscopy may then be used to confirm that articular penetration has not occurred.

Critical to the success of this operation is accurate articular reduction and reassociation of the distal articular surface to the shaft by means of a plate. Established principles of fixation should be observed [26].

Visualization and assessment of the reduction are similar to the capitellum fracture and lateral condyle fracture described above and below. However, a thicker pin (4.5 mm Steinmann pin or even biplanar pins) will be required to manipulate the larger fragment with the attached muscle origins. Once the reduction is evaluated both arthroscopically and radiographically, the fracture is temporarily fixed with the transcondylar wires or pin (our preference is a 3 mm Steinmann pin). Then, a medial or lateral midaxial incision is made for application of the plate. Because of arthroscopic assisted reduction, no additional arthrotomy or musculotendinous dissection is required.

For a medial column fracture, the incision should be made prior to pin placement because of the proximity of the ulnar nerve, which should be identified, retracted, if necessary, and protected as the pin is inserted. When reducing a lateral column fracture, take care not to advance the pin too far medially to protect the ulnar nerve.

The plate is then applied over the K-wires or Steinmann pin in the correct position. The plate is then provisionally fixed and a second distal transcondylar screw is placed though the plate. The initial pin can then be removed and replaced with a transcondylar screw through the plate, thus conforming to O'Driscoll's principles of distal humerus fracture fixation [26]. The remaining proximal and distal screws are then placed.

Postoperatively, we recommend that the onset of range of motion exercises should be determined by the surgeon's confidence in the strength and stability of the fixation, again prioritizing union over early motion. Restoration of lost motion is much more reliable than the treatment of avascular necrosis of the trochlea or lateral condyle.

Coronoid Fractures

As we increase our understanding of the significance of coronoid fractures, the indications for repair continue to evolve. We now understand that the traditional Regan–Morrey classification type I and II coronoid fractures are frequently associated with ligament and soft-tissue injuries that can cause instability even with Type I coronoid fractures [27, 28]. O'Driscoll's and Steinmann and Adams' modifications recognize the association of medial coronoid facet fractures (type II) with varus instability [29, 30]. Doornberg and Ring have demonstrated that this fracture pattern is also associated with posteromedial rotatory instability [31]. Transverse coronoid tip and anterolateral coronoid facet fractures (O'Driscoll type I) can be associated with MCL rupture and

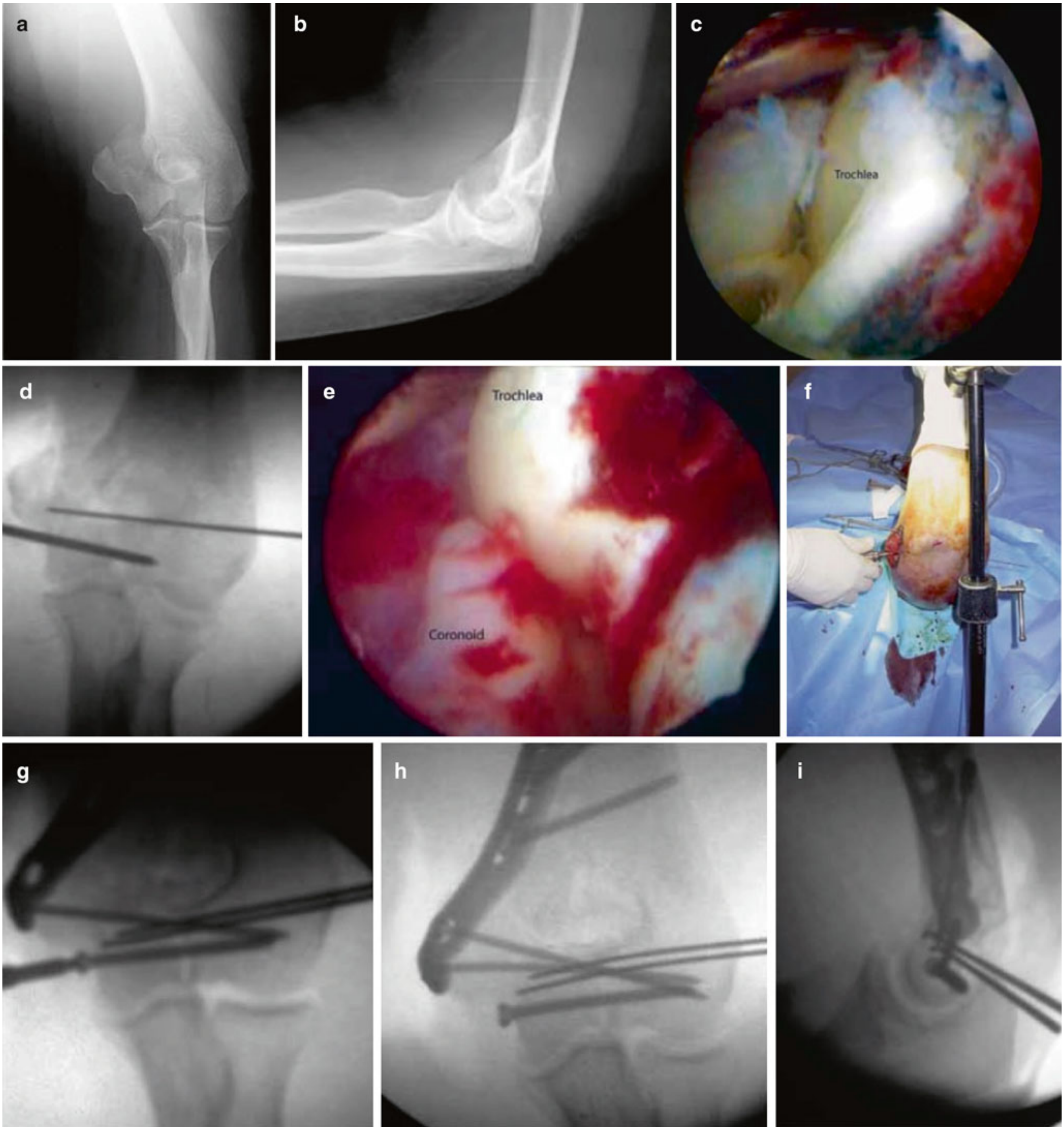


Fig. 35.6 (**a**, **b**) A comminuted medial condyle fracture as seen on X-ray. (**c**) Arthroscopically, the trochlear articular fragment is seen. (**d**, **e**) A limited medial approach is made to protect the ulnar nerve so that a heavy Steinmann pin can be inserted as a joystick to manipulate the fragment into a reduction. K-wires placed from lateral to medial temporarily stabilize the reduction while a transcondylar screw is inserted (in a lag fashion, if necessary) to achieve an anatomic reduction. (**f**, **g**) A medial plate is applied without disturbing the flexor pronator origin. The intact lateral condyle allows an exemption from the usual "4–5" distal screw rule since the intact lateral column acts as a plate, thus achieving four distal screws that secure the articular surface to the shaft. (**h**, **i**) Reduction of a lateral column fracture involves similar steps from the lateral side

posterolateral rotatory instability. Therefore, treatment should be determined by the presence or absence of instability and whether the instability is posterolateral or posteromedial. A medial coronoid facet fracture should not be fixed arthroscopically. Rather a buttress plate should be used to restore this important stabilizer [29]. However, coronoid transverse tip fractures and anterolateral fractures are amenable to arthroscopic reduction and fixation [32]. If there is

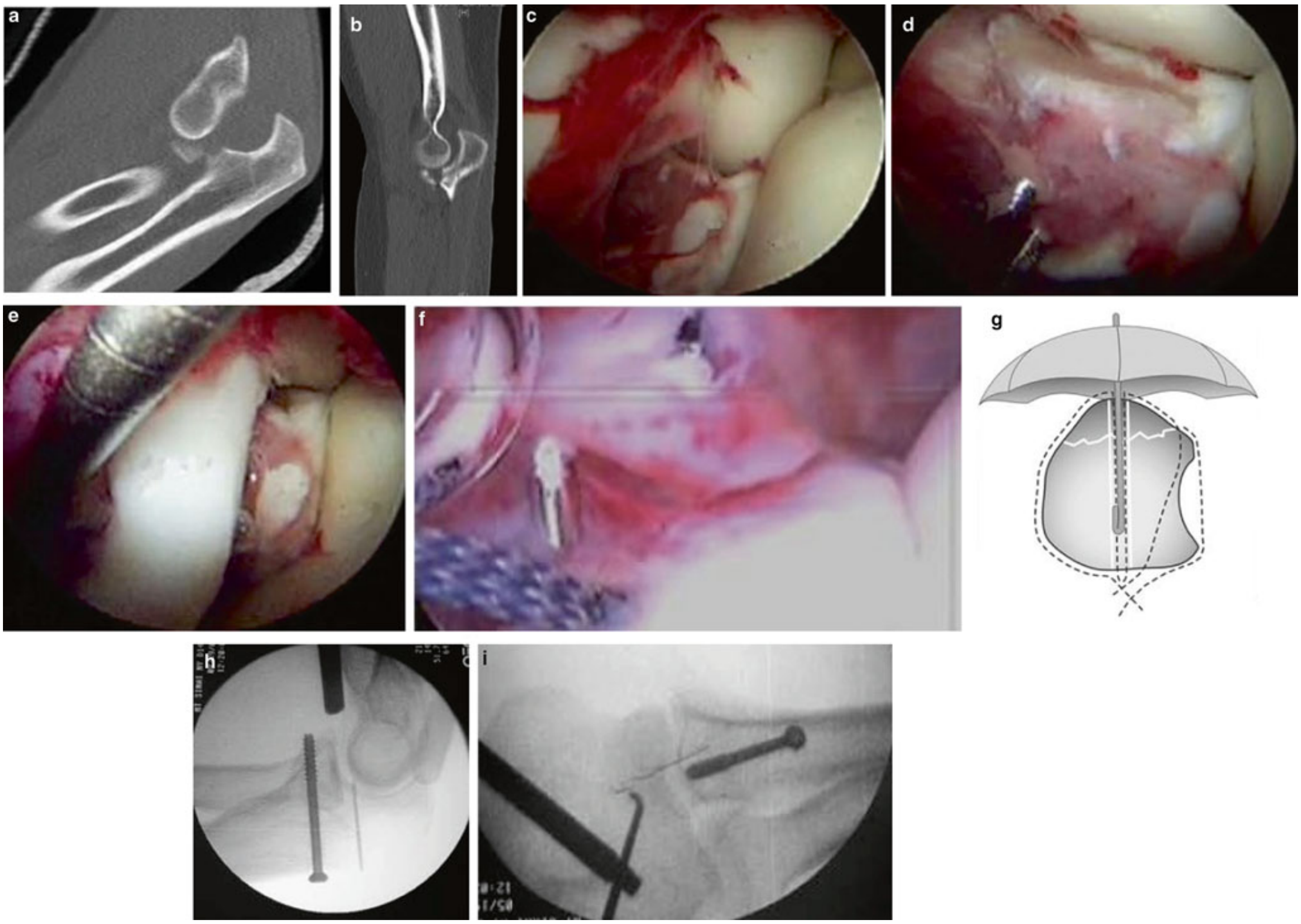


Fig. 35.7 (**a**, **b**) Preoperative CT scanning demonstrates a "terrible triad" injury with an anterior marginal fracture of the radial head, characteristic of posterolateral instability, and an O'Driscoll type I coronoid fracture. There is also anterior ulnohumeral instability, but the anteromedial facet of the coronoid is intact, signifying that posteromedial rotatory instability will not be likely if the other injuries are fixed. The radial head will be preserved in this case, limiting access to the coronoid from the lateral approach, but the anterior ulnohumeral instability is an indication for ARIF of the coronoid. (**c**) The coronoid base is visualized (with a 70° arthroscope, in this case) and (**d**) guide wires are directed from the posterior proximal ulna to the base of the coronoid. (**e**) The tip of the coronoid is then reduced and, under arthroscopic visualization, a guide wire and cannulated screw are placed in the coronoid from the subcutaneous border of the proximal ulna. Fluoroscopy helps determine the approximate entrance point. A second, medial hole is drilled over another guide wire for passage of a cerclage suture using a suture retriever or 28 gauge wire. (**f**, **g**) A Kevlar-reinforced suture is passed through the cannulated screw and through the second hole, then exits to the posterior border of the ulna. This further reinforcement is like an umbrella embracing the tip of the fragment (**h**, **i**) The coronoid cerclage suture is tied after ORIF of the radial head using an arthroscopic sliding knot. The radial head fracture is then fixed through a small, lateral approach

no radial head fracture present or if the radial head is to be preserved, we prefer arthroscopic reduction and fixation of the coronoid, which thereby imparts additional stability and minimizes surgical trauma (Fig. 35.7) [33]. However, if the radial head is resected, access to the coronoid from an open, lateral approach is relatively easy.

We use standard anteromedial and anterolateral portals. Of note, if there is considerable synovitis, an anterior capsule debridement may be necessary in order to visualize the fragment. Taking the extra minutes to debride can facilitate excellent visualization. To facilitate reduction, a small modified skin hook is introduced through a cannula in the anteromedial portal to grab and reduce the coronoid fragment. Using fluoroscopy, guide wires for cannulated screws are placed through the posterior cortex of the proximal ulna just distal to the coronoid process. Two or three wires are placed to engage and temporarily fix the coronoid. They should exit just distal to the coronoid tip, angling distal posteriorly to proximal anteriorly. This way, distally directed forces on the coronoid compress, rather than distract, across the fracture. A drill guide, such as that used in anterior cruciate reconstruction surgery, can be helpful when aiming the guide wires. The arthroscope may be used to observe the correct exit point for the guide wires.

If the fragment is large enough, the placement of two partially threaded cannulated screws is preferred. We augment

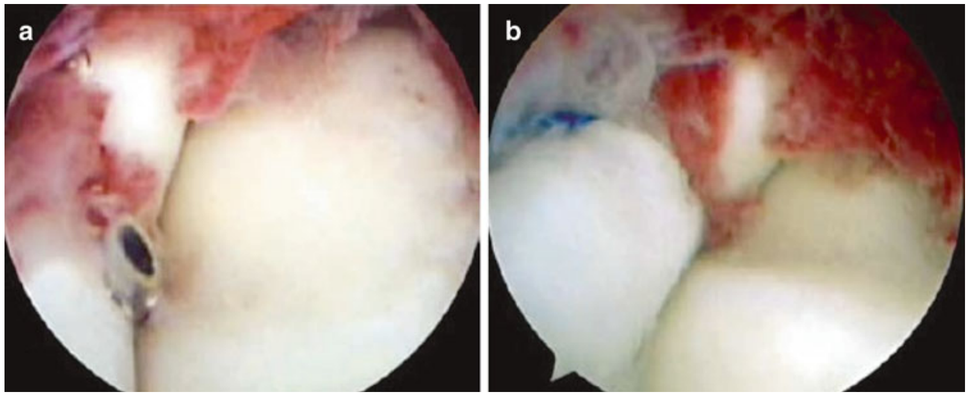


Fig. 35.8 (**a**) This case demonstrates the cerclage suture passing through the proximal radioulnar joint to secure a small anterolateral coronoid fragment. Note the vector of the suture's pull in a proximal direction, securing the fragment in a reduced position against the trochlea. (**b**) The cerclage suture (*blue*) avoids the suture anchor effect of tying to a point and effectively reduces the coronoid

this repair with a cerclage loop of suture passed through the screws, which achieves a mattress suture effect. Unfortunately, most fractures will not accept two screws and a single screw construct must be used. This screw should be placed in the center of the largest dimension of the fragment. We confirm our guide wire position and reduction with both arthroscopy and fluoroscopy. Then, we hold the coronoid fragment in place with the modified skin hook. Additional, auxiliary guide wires may also be used to temporarily stabilize the fracture. The cannulated screw guide wires are grasped with an arthroscopic grasper in the joint to hold the reduction and prevent unintended removal of the pin while drilling with the cannulated drill.

A partially threaded 3.5 mm cannulated screw(s) is then inserted. The screw length is slightly undersized so there is a millimeter of bone between the cortex of the coronoid and the screw, thereby avoiding abrasion of the cerclage suture. We then pass our cerclage suture (Fig. 35.8). If the coronoid fracture is an anterolateral fragment, a spinal needle is placed in the soft spot and a 28 g stainless steel wire is passed and extracted through the lateral portal along with the cerclage suture that has been passed through the screw. We use non-resorbable, braided suture, such as FiberWire (Arthrex, Naples, FL).

If a cerclage of the medial fragment is required, a small Freer elevator with a hole drilled in the end can be passed along the medial border of the proximal ulna. Care must be taken to remain on bone during this maneuver in order to be deep to the ulnar nerve, which lays close to the proximal ulna at the level of the coronoid. We preload this modified Freer with a 28 g stainless steel wire that can be used as a suture shuttle to pass the cerclage suture exiting the cannulated screw.

Our postoperative care is dictated by the presence of other injuries and the potential or presence of elbow instability. For example, posteromedial rotatory instability with an O'Driscoll type II fracture of the medial facet is difficult to stabilize. As a result, stability and healing is prioritized over motion and many patients require a second-stage arthroscopic release to achieve full motion. However, this is preferable to persistent instability.

Type I and III injuries can usually be stabilized well enough to permit early range of motion. Weekly radiographs are obtained to check for any signs of instability. If the radiographs demonstrate instability, a static external fixator should be applied.

Radial Head Fractures

Arthroscopic assisted reduction and fixation of radial head fractures is described [4, 34–37]. However, this is a challenging procedure due to swelling around the injury and thus is not consistent with the principle that the arthroscopy should improve exposure, simplify the procedure or avoid major soft tissue trauma associated with an open exposure. Since most radial head fractures can be exposed and fixed through a limited, non-destructive approach through the common extensor origin (the so-called Kaplan interval), we do not perform ARIF of the radial head.

Described methods visualize the fracture from the proximal anteromedial portal. A shaver is inserted through the proximal anterolateral portal. Reduction is accomplished with a periosteal elevator or percutaneously placed K-wires can also be used through the fracture fragments to joystick them into appropriate position. Once reduction is achieved, these wires can be passed into the radial diaphysis to allow for cannulated headless screw placement, taking care to bury the threads beneath the articular surface to avoid impingement of the proximal radioulnar joint (Fig. 35.9). Percutaneously placed K-wires can also be used through the fracture fragments to joystick them into appropriate position (Fig. 35.9). A soft spot portal allows for a view of the posterior radial head. Additionally, use of the posterolateral portal has been well described as a working portal, as it allows for an optimal angle for screw entry [36, 37]. Dawson and Inostroza have described using this arthroscopic technique to treat an angulated pediatric radial neck fracture in a child as well (Fig. 35.10) [35].

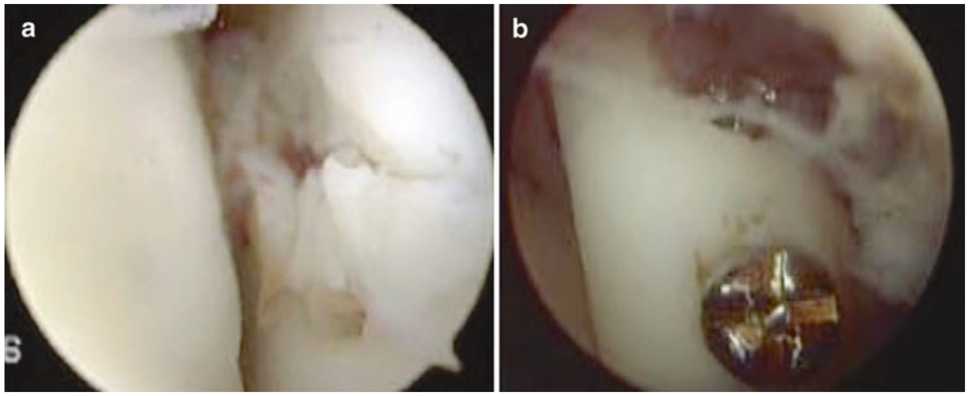


Fig. 35.9 (**a**) A view from the anteromedial portal shows a Mason type II radial head fracture after reduction and (**b**) placement of two cannulated screws

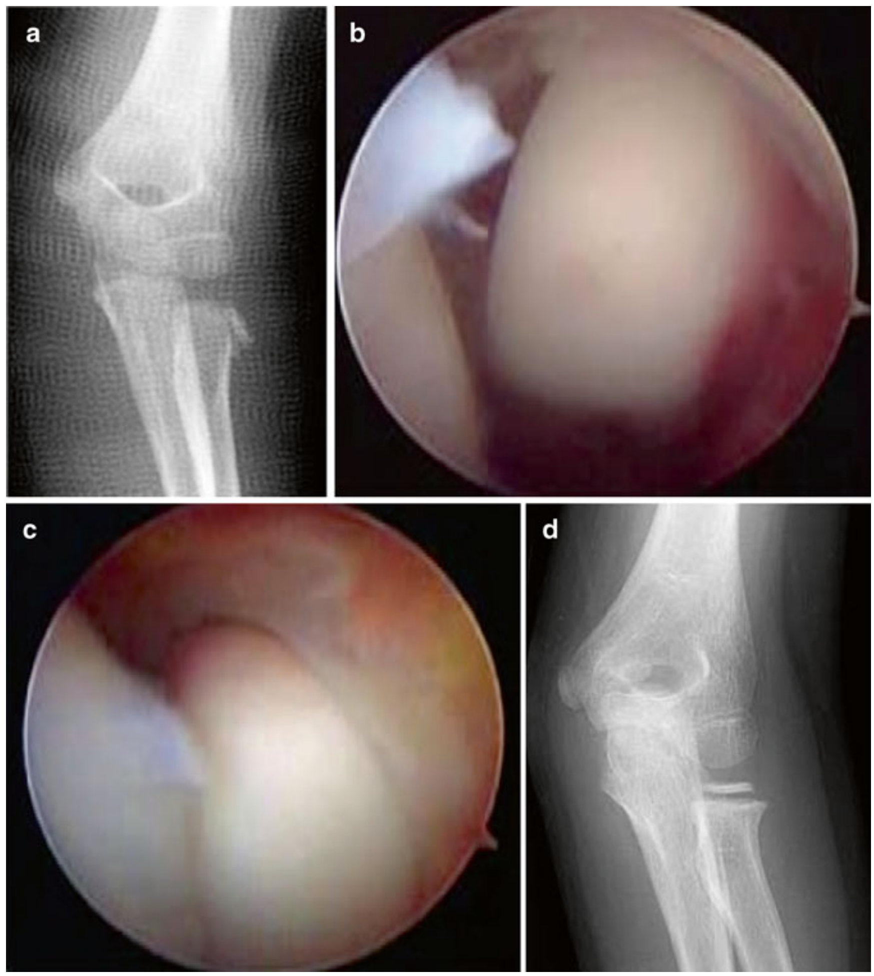


Fig. 35.10 (**a**) The reduction of this angulated, pediatric radial neck fracture is impeded by (**b**) Displacement of the radial head anterolaterally into a capsular recess. (**c**) Following reduction, the radial head is articulating with the capitellum and the intact periosteal sleeve stabilizes the fracture. (**d**) A postoperative X-ray demonstrates a good reduction

Instability

Posterolateral rotatory instability (PLRI) often results from overlooked ligamentous injury in elbow trauma [38]. For instance, as outlined above, coronoid fractures are frequently associated with elbow instability. Furthermore, the combination of an elbow dislocation, radial head fracture, and coronoid fracture (commonly referred to as the "terrible triad" in light of its notoriously poor outcome) can also result in PLRI if the damage to the lateral ligamentous complex is not recognized and treated. McKee described a standard protocol to approaching these injuries. It includes initial fixation or replacement of the radial head, fixation of the coronoid fracture, repair of the lateral collateral ligament complex, and, for residual instability, reconstruction of the medial collateral ligament and/or application of an external fixator [39].

The arthroscopic treatment of posterolateral rotatory instability of the elbow was initially described by Smith et al. in 2001 and further expanded upon by Savoie et al. in 2010 [38, 40]. In both studies, the authors provide a method for confirming the diagnosis of posterolateral rotatory instability of the elbow arthroscopically and an all arthroscopic suture plication of the complex.

First, to confirm the diagnosis, a pivot shift maneuver is performed while visualizing the anterior compartment from the proximal anteromedial portal. The radial head will be seen to sublux posteriorly in the presence of continued PLRI. In addition, the presence of a "drive-through" sign (i.e., the ability to drive the scope into the ulnohumeral joint) is present in the unstable elbow but will correct with appropriate treatment of that instability.

Arthroscopic repair of the lateral ligamentous structures involves suture plication to tighten the posterolateral capsule and the radial ulnohumeral ligament. The lateral gutter is viewed from a posterior portal. At the insertion point of the radial ulnohumeral ligament, a spinal needle is inserted into the joint. Suture is then shuttled into the joint, directly adjacent to the lateral humeral epicondyle. The two ends of the suture exit the joint through a lateral incision. As the sutures are tensioned, the lateral gutter will decrease in volume, representing tightening of the posterolateral ligamentous structures. Finally, the authors note that if a large amount of instability if found or if the ligament has avulsed from the humeral origin, a suture anchor can be placed at the isometric point of the lateral epicondyle in addition to the plication technique described [38].

In a study comparing this procedure to the classic open repair, a high rate of success was measured in both categories, suggesting this as a ready alternative to open surgery [40]. Given this, in addition to direct visualization of posterolateral subluxation of the radial head on the capitellum from the anteromedial portal, arthroscopic plication of the attenuated LUCL complex provides an effective, alternative approach to joint stabilization.

Pediatric Facture of the Lateral Condyle

The visualization of a pediatric lateral condyle fracture via the arthroscope is conceptually similar to the capitellum fractures described earlier. However, because the entire lateral column is involved the type and trajectory of the fixation is different. Our rationale for arthroscopic assistance in these fractures is twofold. First, arthroscopy is provides an excellent visualization the articular surface while avoiding extensive dissection around the lateral condyle. Thus, arthroscopy could minimize compromise of the precarious blood supply to the condyle and, hopefully, minimize the risk of avascular necrosis [41]. Second, we find arthroscopy is useful to confirm the trajectory of the fixation pins. In children whose lateral condyles are largely cartilage, this can be difficult radiographically. Lateral condyle fractures are categorized according to the Milch criteria based on where the fracture line exits in relation to the trochlear groove [42]. Reportedly, nondisplaced Milch type 1 fractures may be treated nonsurgically; however, we have found that truly nondisplaced fractures are extremely rare [43]. Our current treatment protocol is to arthroscopically fix displaced type 1 and all type 2 lateral condyle fractures (Fig. 35.11) [41, 44, 45].

However, if the fragment is very rotated (90° or more) then arthroscopic reduction may be difficult and a small, open approach may be necessary.

Positioning in pediatric patients is similar to adults. A standard proximal anteromedial portal is created. As previously described the hematoma in the joint is evacuated. Once adequate visualization is achieved, the degree and direction of displacement can be seen. A 1.6 mm (0.062 in.) Kirschner wire can be inserted percutaneously into the lateral condylar fragment. To ensure that the pin placement is in the secondary ossification center, the arthroscope can be advanced to the trabecular bone of the secondary ossification center and the cannula placed in contact with the bone. The arthroscope is then withdrawn and the K-wire is advanced through the cannula, into the fragment, and out the skin. As the arthroscope is reinserted in the cannula, the K-wire is withdrawn out the lateral aspect of the elbow until just the tip of the pin is seen in the secondary ossification center. Two or three 1.6 mm pins are placed under direct visualization and are used as a joystick to reduce the fragment. The pins are then alternately advanced. The reduction is inspected both under direct visualization with the arthroscope and using fluoroscopy. The pins are then trimmed and the elbow is casted.

Postoperatively, the elbow is casted 4–6 weeks until there is radiographic evidence of union and exercise is begun.

Complications

The overall complication rate from elbow arthroscopy has been reported at 6–15 % [46]. This includes neurologic injury, compartment syndrome, septic arthritis, superficial infection, arthrofibrosis, thromboembolism, complex regional pain syndrome and persistent portal drainage [13, 47–49]. The most common problem is a portal fistula, which can usually be avoided by careful closure of the portals with multiple sutures. It is also our practice to routinely prep and close drain holes after removal of the drain.

The rate of neurologic injury is cited as 0–14 % [13]. Most injuries are neuropraxias and will resolve with time, but complete transection has also been seen [13]. Injury can occur with injection of local anesthetic, compression due to swelling of the joint or crushing from the instrumentation, direct trauma from trocar insertion, or laceration with a shaver. Minimizing

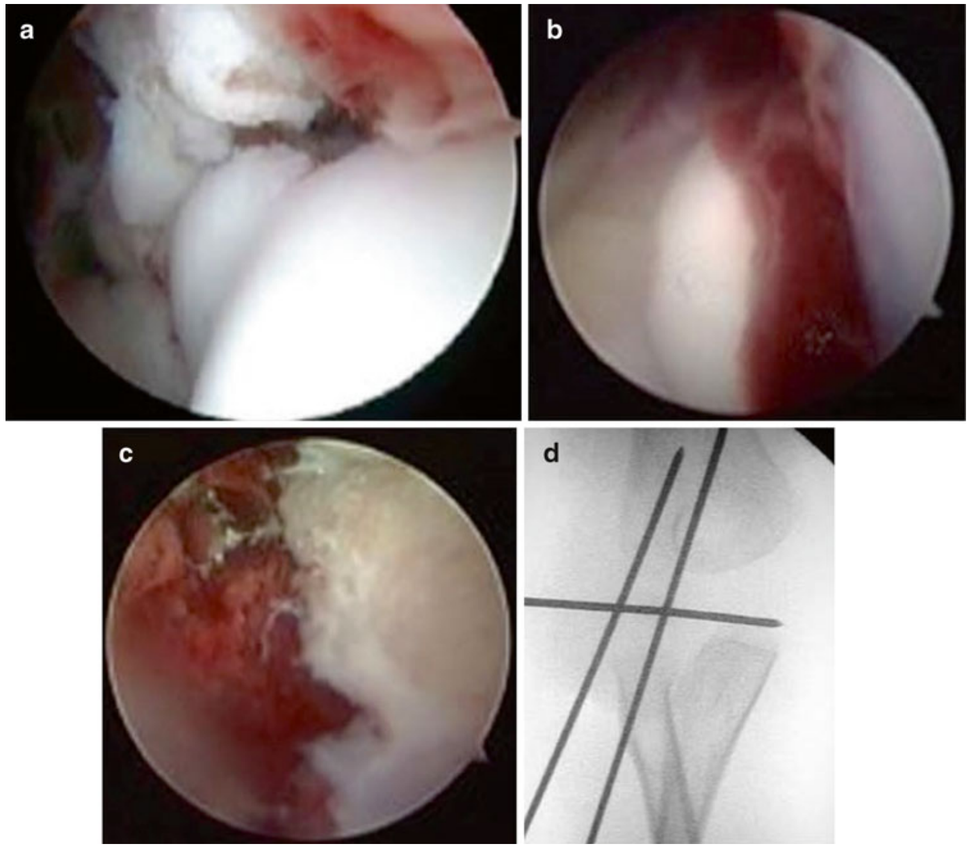


Fig. 35.11 (**a**) An arthroscopic view from the proximal anteromedial portal shows the displaced lateral condyle. (**b**) The cannula and scope are advanced up to the bone of the secondary ossification center; the arthroscope is withdrawn while holding the cannula in position; and a K-wire is advanced through the cannula into the bone. (**c**) The wire is then withdrawn from the lateral aspect of the elbow until it is just piercing the surface of the bone. (**d**) The final position of the fixation pins. Note the use of a transcondylar pin to prevent rotation in addition to the usual oblique pins

this risk requires experience, careful attention to the anatomy and surface landmarks, and an appreciation of the special risks including distorted anatomy, contractures, rheumatoid arthritis, or heterotopic ossification. Any injury, even to cutaneous nerves, can lead to a chronic, possibly disabling condition.

Infection following elbow arthroscopy is infrequent. Superficial postoperative infections are readily treated with oral antibiotics. Septic arthritis has been found more commonly in patients who received intra-articular steroid injection following the procedure [13]. Steroid injections are contraindicated by fractures and ligament injuries. If steroids are used after contracture release, IV administration beginning prior to deflating the tourniquet is maximally effective.

One increasingly reported complication from elbow arthroscopy is heterotopic ossification [50]. Although a rare complication, there is some evidence that it is related to the extensiveness of the procedure [48]. The extent of the injury (e.g., “terrible triad”) and recurrent instability have been implicated as negative prognostic factors [48]. Currently, we do not take any increased precautions during our arthroscopy procedures aside from warning patients of this potential complication. Some surgeons have adopted routine prophylaxis with either indomethacin or a preoperative dose of radiation prior to more-involved arthroscopic surgeries [48, 50–53]. If it does occur, the standard treatment is excision after 3 months [48].

Conclusion

While still evolving, arthroscopy has already established a role in elbow trauma management. It should only be considered a useful adjunct, however, if it facilitates the exposure or makes the reduction and fixation easier, more precise, or safer, as in avoiding inadvertent intra-articular hardware penetration. If after initial debridement, good visualization is not achieved, arthroscopy adds no value and the operation should be converted to a conventional open procedure. Following established arthroscopic techniques, such as using lower inflow pressures and using retractors when necessary, will avoid extravasation of fluid and swelling that would hamper a conversation to an open procedure. In the pediatric patient, arthroscopy is useful for radial neck fractures and moderately displaced lateral condyle fractures. However, if the lateral condyle fragment is spun 90°, open reduction is likely to be necessary. In the adult, arthroscopy has proven consistently helpful with capitellum and anterior coronal shear fractures. Most coronoid fractures that do not involve impaction of the medial facet can also be reduced and stabilized, however, the indications are still evolving and if other open treatment, such as radial head arthroplasty, is required, an open approach is preferred [16, 33].

References

1. Burman MS. Arthroscopy or the direct visualization of joints, an experimental cadaver study. J Bone Joint Surg Am. 1931; VIII(4):669–95.
2. Burman MS. Arthroscopy of the elbow joint, a cadaver study. J Bone Joint Surg Am. 1932;14:349–50.
3. Andrews JR, Carson WG. Arthroscopy of the elbow. Arthroscopy. 1985;1:97–107.
4. Holt SM, Savoie III FH, Field LD, et al. Arthroscopic management of elbow trauma. Hand Clin. 2004;20:485–95.
5. Dodson CC, Nho SJ, Williams 3rd RJ, et al. Elbow arthroscopy. J Am Acad Orthop Surg. 2008;16(10):574–85.
6. Hsu JW, Gould JL, Hausman MH. The emerging role of elbow arthroscopy in chronic use injuries and fracture care. Hand Clin. 2009;25(3):305–21.
7. Ramsey ML, Naranja RJ. Diagnostic arthroscopy of the elbow. In: Baker Jr CL, Plancher KD, editors. Operative treatment of elbow injuries. New York, NY: Springer; 2002. p. 163–9.
8. Adolfsson L. Arthroscopy of the elbow joint: a cadaveric study of portal placement. J Shoulder Elbow Surg. 1994;3:53–61.
9. Lynch GJ, Meyer JF, Whipple TL, Caspari RB. Neurovascular anatomy and elbow arthroscopy: inherent risks. Arthroscopy. 1986;2:190–7.
10. Stothers K, Day B, Regan WR. Arthroscopy of the elbow: anatomy, portal sites, and a description of the proximal lateral portal. Arthroscopy. 1995;11:449–57.
11. Unlu MC, Kesmezacar H, Akgun I, Ogut T, Uzun I. Anatomic relationship between elbow arthroscopy portals and neurovascular structures in different elbow and forearm positions. J Shoulder Elbow Surg. 2006;15:457–62.
12. Gallay SH, Richards RR, O'Driscoll SW. Intraarticular capacity and compliance of stiff and normal elbows. Arthroscopy. 1993;9:9–13.
13. Kelly EW, Morrey BF, O'Driscoll SW. Complications of elbow arthroscopy. J Bone Joint Surg Am. 2001;83A:25–34.
14. Poehling GG, Whipple TL, Sisco L, Goldman B. Elbow arthroscopy: a new technique. Arthroscopy. 1989;5:222–4.
15. Lindenfeld TN. Medial approach in elbow arthroscopy. Am J Sports Med. 1990;18:413–7.
16. Adams JE, Merten SM, Steinmann SP. Arthroscopic-assisted treatment of coronoid fractures. Arthroscopy. 2007;23:1060–5.
17. Field LD, Altchek DW, Warren RF, O'Brien SJ, Skyhar MJ, Wickiewicz TL. Arthroscopic anatomy of the lateral elbow: a comparison of three portals. Arthroscopy. 1994;10:602–7.
18. Baker Jr CL, Jones GL. Arthroscopy of the elbow. Am J Sports Med. 1999;27:251–64.
19. Andrews JR, Craven WM. Lesions of the posterior compartment of the elbow. Clin Sports Med. 1991;10:637–52.
20. O'Driscoll SW, Morrey BF, An KN. Intraarticular pressure and capacity of the elbow. Arthroscopy. 1990;6:100–3.
21. Ring D, Jupiter JB, Gulotta L. Articular fractures of the distal part of the humerus. J Bone Joint Surg Am. 2003;85A:232–8.
22. Guitton TG, Doornberg JN, Raaymakers EL, Ring D, Kloen P. Fractures of the capitellum and trochlea. J Bone Joint Surg Am. 2009;91A:390–7.
23. Kuriyama K, Kawanishi Y, Yamamoto K. Arthroscopic-assisted reduction and percutaneous fixation for coronal shear fractures of the distal humerus: report of two cases. J Hand Surg Am. 2010; 35:1506–9.
24. Hardy P, Menguy F, Guillot S. Arthroscopic treatment of capitellum fractures of the humerus. Arthroscopy. 2002;18:422–6.
25. Mitani M, Nabeshima Y, Ozaki A, Mori H, Issei N, Fujii H, Fujioka H, Doita M. Arthroscopic reduction and percutaneous cannulated screw fixation of a capitellar fracture of the humerus: a case report. J Shoulder Elbow Surg. 2009;18:e6–9.
26. O'Driscoll SW. Optimizing stability in distal humeral fracture fixation. J Shoulder Elbow Surg. 2005;14(1 Suppl S):186S–94.
27. Schneeberger AG, Sadowski MM, Jacob HA. Coronoid process and radial head as posterolateral rotatory stabilizers of the elbow. J Bone Joint Surg Am. 2004;86A:975–82.
28. Closkey RF, Goode JR, Kirschenbaum D, Cody RP. The role of the coronoid process in elbow stability. A biomechanical analysis of axial loading. J Bone Joint Surg Am. 2000;82A:1749–53.
29. O'Driscoll SW, Bell DF, Morrey BF. Posterolateral rotatory instability of the elbow. J Bone Joint Surg Am. 1991;73:440–6.
30. Adams JE, Sanchez-Sotelo J, Kallina 4th CF, Morrey BF, Steinmann SP. Fractures of the coronoid: morphology based upon computer tomography scanning. J Shoulder Elbow Surg. 2012;21(6):782–8.
31. Doornberg JN, Ring D. Coronoid fracture patterns. J Hand Surg Am. 2006;31:45–52.
32. Broberg MA, Morrey BF. Results of treatment of fracture-dislocations of the elbow. Clin Orthop Relat Res. 1987;216: 109–19.
33. Hausman MR, Klug RA, Qureshi S, Goldstein R, Parsons BO. Arthroscopically assisted coronoid fracture fixation: a preliminary report. Clin Orthop Relat Res. 2008;466:3147–52.
34. Michels F, Pouliart N, Handelberg F. Arthroscopic management of Mason type 2 radial head fractures. Knee Surg Sports Traumatol Arthrosc. 2007;15:1244–50.
35. Dawson FA, Inostroza F. Arthroscopic reduction and percutaneous fixation of a radial neck fracture in a child. Arthroscopy. 2004;20 Suppl 2:90–3.
36. Moskal MJ, Savoie 3rd FH, Field LD. Elbow arthroscopy in trauma and reconstruction. Orthop Clin North Am. 1999;30:163–77.
37. Rolla PR, Surace MF, Bini A, Pilato G. Arthroscopic treatment of fractures of the radial head. Arthroscopy. 2006;22:233.e1–6.
38. Smith JP, Savoie FH, Field LD. Posterolateral rotatory instability of the elbow. Clin Sports Med. 2001;20(1):47–58.
39. McKee MD, Pugh DM, Wild LM, Schemitsch EH, King GJ. Standard surgical protocol to treat elbow dislocations with radial head and coronoid fractures. Surgical technique. J Bone Joint Surg Am. 2005;87(Suppl 1, Pt 1):22–32.
40. Savoie FH, O'Brien MJ, Field LD, Gurley DJ. Arthroscopic and open radial ulnohumeral ligament reconstruction for posterolateral rotatory instability of the elbow. Clin Sports Med. 2010; 29(4):611–8.
41. Carro PL, Golano P, Vega J. Arthroscopic-assisted reduction and percutaneous external fixation of lateral condyle fractures of the humerus. Arthroscopy. 2007;23:1131.e1–4.
42. Milch H. Fractures and fracture dislocations of the humeral condyles. J Trauma. 1964;4:592–607.
43. Bast SC, Hoffer MM, Aval S. Nonoperative treatment for minimally and nondisplaced lateral humeral condyle fractures in children. J Pediatr Orthop. 1998;18:448–50.
44. Hausman MR, Qureshi S, Goldstein R, Langford J, Klug RA, Radomisli TE, Parsons BO. Arthroscopically-assisted treatment of pediatric lateral humeral condyle fractures. J Pediatr Orthop. 2007;27:739–42.
45. Hausman MR, Roye B. Pediatric elbow arthroscopy and reconstruction. In: Trumble TE, Budoff JE, editors. Wrist and elbow reconstruction and arthroscopy. Rosemont, IL: American Society for Surgery of the Hand; 2006. p. 377–402.
46. Savoie III FH, Field LD. Arthrofibrosis and complications in arthroscopy of the elbow. Clin Sports Med. 2001;20:123–9.
47. Small NC. Complications in arthroscopic surgery performed by experienced arthroscopists. Arthroscopy. 1988;4:215–21.
48. Gofton WT, King GJ. Heterotopic ossification following elbow arthroscopy. Arthroscopy. 2001;17:1–5.
49. Gay DM, Raphael BS, Weiland AJ. Revision arthroscopic contracture release in the elbow resulting in an ulnar nerve transection. J Bone Joint Surg Am. 2010;92:1246–9.

50. Hughes SC, Hildebrand KA. Heterotopic ossification—a complication of elbow arthroscopy: a case report. J Shoulder Elbow Surg. 2010;19:e1–5.
51. King GJ. Stiffness and ankylosis of the elbow. In: Norris TR, editor. Orthopaedic knowledge update: shoulder and elbow. Rosemont, IL: American Academy of Orthopaedic Surgeons; 1997. p. 325–35.
52. Jupiter JB, Ring D. Fractures of the distal humerus. In: Norris TR, editor. Orthopaedic knowledge update: shoulder and elbow. Rosemont, IL: American Academy of Orthopaedic Surgeons; 1997. p. 397–413.
53. Sodha S, Nagda SH, Sennett BJ. Heterotopic ossification in a throwing athlete after elbow arthroscopy. Arthroscopy. 2006;22:802.e1–3.

Index

W.B. Geissler (ed.), *Wrist and Elbow Arthroscopy: A Practical Surgical Guide to Techniques*,
DOI 10.1007/978-1-4614-1596-1, © Springer Science+Business Media New York 2015

B

E

M

N

O

P

T