J. Menetrey · S. Zaffagnini
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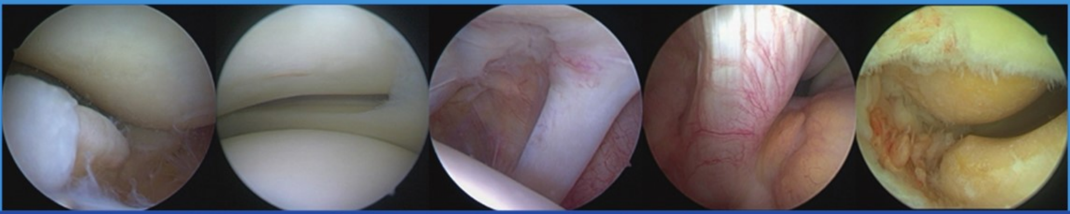
Editors



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Jacques Menetrey • Stefano Zaffagnini
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EUROPEAN SOCIETY OF SPORTS TRAUMATOLOGY, KNEE SURGERY AND ARTHROSCOPY
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Tips and Tricks in Arthroscopic Surgery

1

Mohsen Hussein, Jürgen Höher, Rainer Sieboldl,
Peter Faunø, Svend Erik Christiansen, Bent Lund,
and Martin Lind

Contents

1.1 Anatomic ACL Reconstruction

1.1.1 Operative Technique

Mohsen Hussein, M.D.

Many studies show that anatomic ACL reconstruction (single and double bundle) is significantly superior to conventional single-bundle ACL reconstruction. In this surgical video, we present anatomic ACL reconstruction.

Incision: The anterolateral portal placed higher to the inferior pole of the patella at its lateral border. The anteromedial portal placed very low just medial to the medial edge of the patella tendon. Finally, an accessory inferior medial portal placed medial to the inferomedial portal slightly above the meniscus.

Harvesting: The semitendinosus and gracilis tendons were harvested with closed tendon stripper through longitudinal anteromedial incision on the medial side of the proximal tibia.

Identification: Next, the rupture pattern of the AM and PL bundle was carefully evaluated using a thermal device, and the insertion sites of the AM

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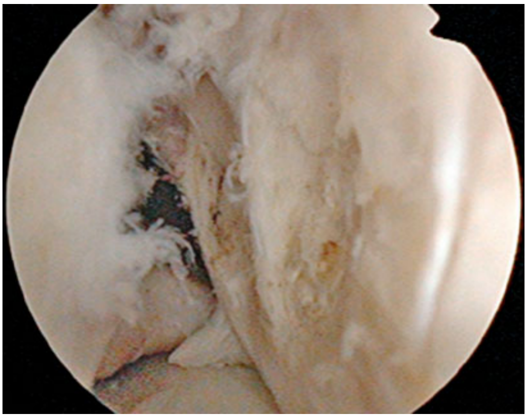

Fig. 1.1 View of lateral intercondylar wall with femoral ACL insertion

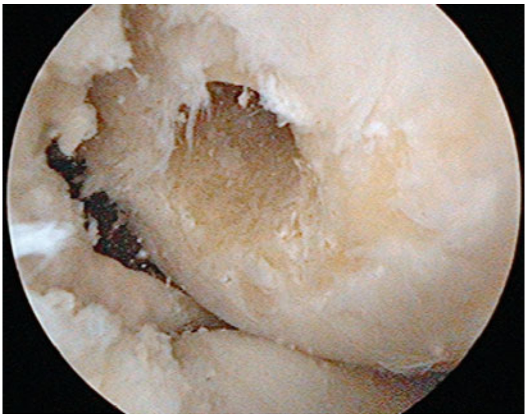

Fig. 1.2 Position of femoral bone tunnel

and PL bundle were very carefully visualized and measured through the lateral and medial portal. Then we visualized and identified the bony landmarks, especially the lateral intercondylar ridge and the lateral bifurcate ridge. Then we marked the location of the native femoral and tibial footprint (Fig. 1.1).

Decision making (ASB or ADB): It depends on the insertion site dimension and notch width.

1.1.1.1 Anatomic Single-Bundle Reconstruction

We addressed the femoral tunnel first and performed it through the accessory medial portal. But we placed the femoral tunnel in the center of the marked insertion sites. The position of the femoral tunnel was between the target point of the AM bundle and PL bundle in the double-bundle ACL reconstruction (Fig. 1.2). In chronic cases, we placed it below the lateral intercondylar ridge, at the lateral bifurcate ridge. If these bonny landmarks could not be identified, we placed it in the lower third of the medial wall of the lateral femoral condyle. The knee was held in 90° flexion for this step, since the position of the femoral insertion sites changes with the knee flexion angle. Following verification of correct pin position, the knee was flexed to 120°, and the pin was malleted into place. An acorn reamer was inserted over the guide wire with special attention taken to avoid injury to the articular surface of the medial femoral condyle. The tunnel was drilled to a depth of 25 mm and, depending on overall tunnel length, may later be hand-drilled to a final length. The far cortex was breached using a 4.5-mm EndoButton drill, and total tunnel length was measured with a depth gauge. Next, attention was turned to the tibial tunnels. An ACL tibial tunnel director guide (DePuy Mitek, Raynham, MA) set at 55° is placed in the center of the ACL tibial insertion site, based on anatomic landmarks and previous marking (Fig. 1.3). The position of the director guide on the tibial cortex was 3 cm medial to the tibial tubercle. The tibial guide pin was placed, and both pin positions were verified

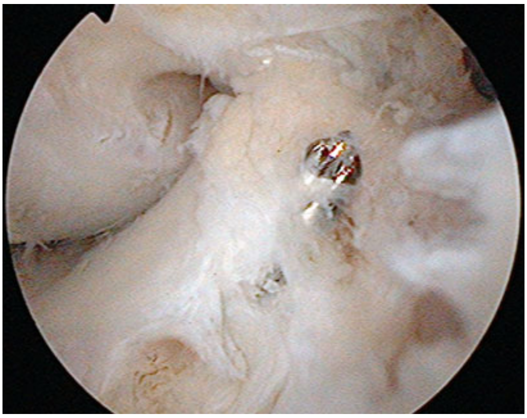

Fig. 1.3 Position of tibial bone tunnel

prior to tunnel drilling. For graft passage, a Beath pin with a long loop suture attached was passed through the accessory medial portal, femoral tunnel and lateral thigh, with the knee hyperflexed to protect the peroneal nerve. The suture was retrieved through the PL tibial tunnel using an arthroscopic suture grasper.

Graft passage and fixation: The graft was then passed, and the EndoButton was flipped in the standard fashion for femoral fixation. The knee was cycled from 0° to 120° approximately 25 times for preconditioning of graft. Graft was fixed using a bioabsorbable interference screw (DePuy Mitek, Raynham, MA) with the knee at full extension with a forced posterior drawer (Fig. 1.4).

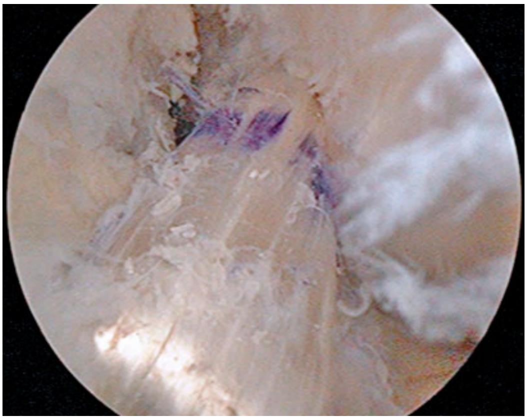

Fig. 1.4 Single bundle ACL reconstruction with hamstrings

1.2 Repair of Medial Meniscus Bucket Handle Tear

1.2.1 Operative Technique

Jürgen Höher, M.D.

In order to preserve the function of the meniscus as a cushion on the medial side of the joint, a medial meniscus bucket handle tear should be attempted to be repaired whenever possible. This video will focus on the arthroscopically assisted treatment of a dislocated bucket handle tear of the medial meniscus.

The surgical technique includes the following steps:

1. Evaluation and reduction of the tear
2. Debridement and blood stimulation
3. Passing of arthroscopic sutures in the anterior horn and the midportion of the meniscus and additional skin incision at the medial aspect of the knee
4. Posterior horn meniscus repair using all-inside suture systems

The decision if repair of a meniscal tear is indicated is based on a thorough diagnostic revision of the knee joint and a probe examination of the meniscus. Duration of the tear, degenerative changes and quality of the tissue as well as the extent and location of the tear have to be evaluated.

When the decision for a meniscus repair is made, reduction of the tear should be performed which is usually possible with the knee near full extension by pushing the dislocated tissue posteriorly with a blunt trocar. Following this, the rim of the lesion has to be debrided. If the red-white zone is involved, the introduction of an additional fibrin clot into the lesion may increase the chance of healing. We recommend trephination of the tissue from outside-in to provoke bleeding and vascularization. Abrasion of the synovia at the base of the meniscus appears to also have a positive effect on the healing rate. For better visualization, the posterior fibers of the medial collateral ligament (MCL) may be incised with a spinal needle percutaneously to allow better joint space opening.

We then prefer arthroscopic suturing techniques for the repair of the meniscus. In all cases, suture material is passed through the meniscal tissue under arthroscopic control followed by tying the knots through an additional skin incision at the medial or lateral aspect of the knee. For inside-out sutures, a curved cannula is used in a joystick manner to reduce the meniscus tear. Flexible needles with a suture attached to its ends are then passed through the cannula, to the outside of the capsule.

For the outside-in technique, regular spinal needles can be passed through the capsule from outside-in so that sutures can be passed through the cannulas and be retrieved inside the joint using small grasping instruments. Using shuttle techniques, the sutures can be passed across the meniscus lesion to complete the reduction of the lesion. When repairing a bucket handle tear on the medial side after reduction and debridement usually repair starts anteriorly with sutures being passed every 5 mm alternating upper and lower rim. We prefer vertical sutures whenever possible as they provide better biomechanical strength to the repair.

Next, the extruding sutures at the medial aspect of the knee need to be tied. Substantial complications of the inside-out technique may occur when tying the sutures over a soft tissue bridge, thus compressing the neurovascular structures. Specifically, the saphenous nerve and its infrapatellar branch are at risk and may cause tremendous, postoperative pain. Therefore, the sutures have to be meticulously prepared and should be tied directly over the capsule under visual control.

For the posterior horn, we prefer all-inside meniscus repair system (e.g., Fastfix, Smith & Nephew). With this device, two tiny anchors are passed through the meniscus and are placed behind the capsule of the joint. Pulling a preknoted suture sling allows adaptation of the tissue in between the two anchors. Using this device, the meniscus tear can be meticulously repaired in various ways in the far posterior region using vertical or horizontal suture. Curved and reverse threaded cannulas can facilitate passing to the suture at the lower surface of the meniscus. All together, a bucket handle tear usually requires 3–6 sutures and 1–3 all-inside repair systems.

After surgery, we immobilize the joint near full extension and partial weight bearing for about a week until skin incisions have healed. Passive flexion to 60–90° may be allowed depending on the localization of the tear. We prefer use of a range of motion brace (e.g., Collamed, Medi corp.) after 1 week with weight bearing as tolerated until full weight bearing. Return to sports activity is allowed after 3–6 months.

1.3 Arthroscopic Autologous Chondrocyte Transplantation at Patella

1.3.1 Operative Technique

Rainer Siebold, M.D.

Full size retropatellar cartilage lesions are troublesome conditions to treat, and an autologous chondrocyte implantation (ACI) with or without scaffold, matrix or periosteal flap may be performed to treat these lesions. An arthrotomy with patella eversion is usually needed to access the retropatellar cartilage, which may associated with a significant parapatellar soft tissue trauma, pain, slow rehabilitation, scar tissue formation, and persistent loss of patella mobility.

This surgical video describes an arthroscopic approach to treat full size contained articular cartilage defects at the patella by ACT using chondrospheres® (co.don Teltow/Berlin, Germany). In prone position (Fig. 1.5), two arthroscopic parapatellar portals are established. The retropatellar articular defect is visualized and is carefully debrided with the use of a shaver and curettes (Fig. 1.6). It is important to establish a stable and healthy cartilage shoulder. The cartilage defect is carefully cleaned up to the subchondral bone without injuring it to prevent bleeding from the bone (Fig. 1.6). The arthroscopic fluid is withdrawn by suction, and the defect is dried arthroscopically with small sponges. The chondrospheres® consisting of approximately 200,000 autologous chondrocytes each are delivered in the retropatellar cartilage defect by an arthroscopic siring-like transport system (Fig. 1.7). A probe is necessary to distribute the chondrospheres® throughout the cartilage defect under arthroscopic control (Fig. 1.8). Figure 1.9 shows the arthroscopic aspect at the patella 4.5 months after implantation.

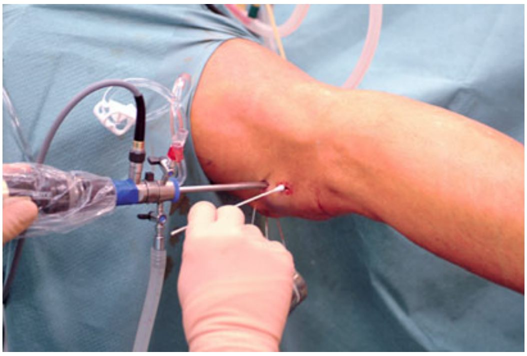

Fig. 1.5 Retropatellar cartilage lesion grade 4 (patient in prone position)

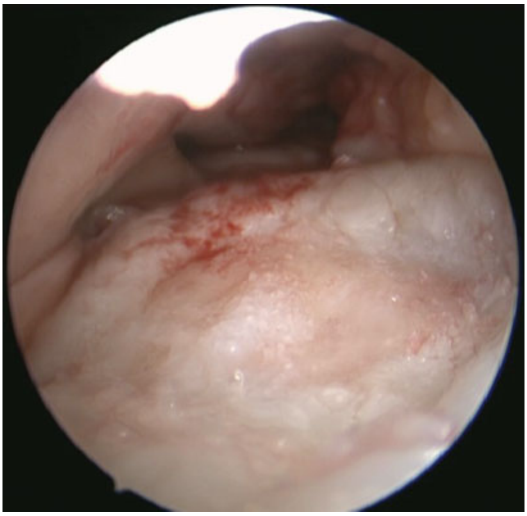

Fig. 1.6 Arthroscopic implantation of spheroids into retropatellar cartilage lesion (patient in prone position)

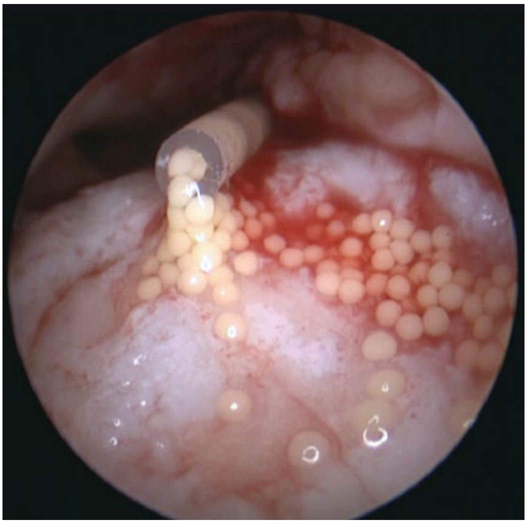

Fig. 1.7 Outside view with patient in prone position

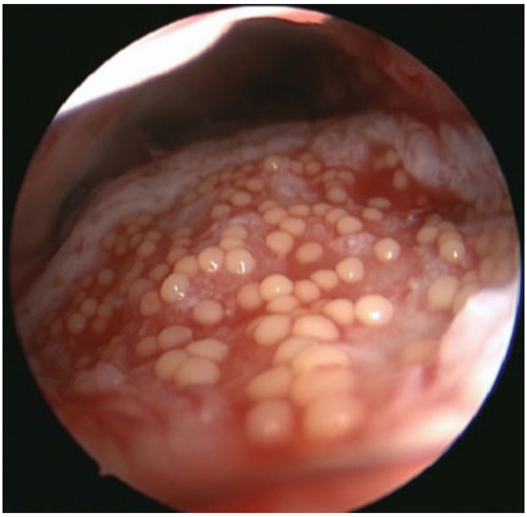

Fig. 1.8 Final result after implantation of spheroids

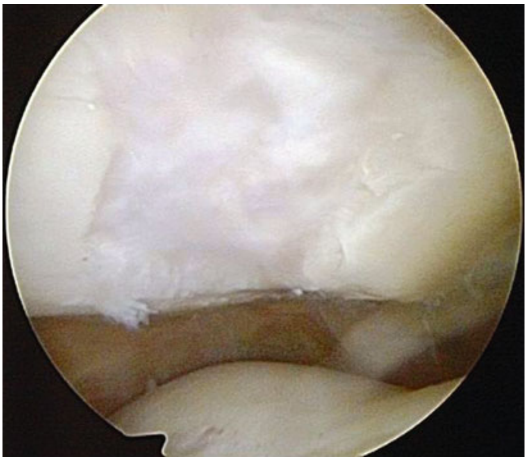

Fig. 1.9 Arthroscopic aspect of cartilage healing 4.5 months after implantation of spheroids at patella

Alternatively, when performing the surgery with a scaffold, matrix or periosteal flap, a parapatellar mini-open incision is used to access the retropatellar cartilage defect and to perform the surgery under direct visualization with the patient in prone position.

1.4 Reconstruction of the Medial Patellofemoral Ligament with Double-Bundle Gracilis Tendon

Peter Faunø, Svend Erik Christiansen,
Bent Lund, and Martin Lind

The medial patellofemoral ligament (MPFL) is the primary medial restraining structure against lateralization of the patella, and rupture of the MPFL is the most important lesion after patellar dislocation [1]. Reconstruction of the MPFL has been advocated as surgical treatment for chronic patella instability, and many techniques with promising results have been described [2].

Amis et al. have demonstrated that an anatomical double-bundle reconstruction imitating the fan-shaped original MPFL provides stronger restraining system [3]. Excellent results after anatomical reconstruction using two-tunnel implant-free patellar fixation and femoral screw fixation in one tunnel have been published from our department [4]. This presentation shows in details how we perform the surgical technique.

1. Graft preparation: The gracilis tendon is harvested through a 2–3-cm incision over the pes anserinus. Each end of the tendon is baseball sutured with nonabsorbable 0 Fibrewire.
2. Patella drill holes: One horizontal 4–5-cm incision is made at the medial aspects of the patella over the line dividing the proximal and middle one-third of the patella. Two 5–8-mm deep holes are made in the medial edge of the patella with a 3.2 drill. The holes are placed in the proximal 2/3 of the patella 10–15 mm apart. Figure 1.10 the tunnels are placed parallel with and between the chondral surface and superficial cortex. Hereafter, the tip of an artery placed in the drill holes is used for aiming while drilling the rest of the tunnel from the anterior side of the patella in an oblique direction toward the tunnel end creating two V-shaped tunnels at the medial edge of the patella.
3. Femoral drill hole: The adductor tubercle is exposed, via a 2–3-cm longitudinal incision, and identified at the medial femoral condyle. The natural MPFL insertion point is just distal to the tubercle. A K-wire is inserted at that point, and an isometry test is performed with a looped 0 Vicryl sutures from the K-wire through the two patella holes to test isometry through the motion arc. Excessive tensions at flexion should be avoided and can be solved by a slightly more distal placement of the condyle K-wire. When proper K-wire placement is achieved, a 7-mm drill hole is made at the femoral condyle.
4. Graft passage and fixation: The gracilis tendon is passed through the patella holes in a looped fashion (Fig. 1.10). The free end of the tendon is passed under the fascia to femoral drill hole. Both tendon ends are tightened into the femoral drill hole using Beath pin pullout technique. The tension of the reconstruction is tested through the arc of motion, and the tendons are fixed in the femoral condyle with a biointerference screw. The tendons are tensioned at 45° of flexion so that the patella still can be lateralized manually 10 mm. It is important not to over

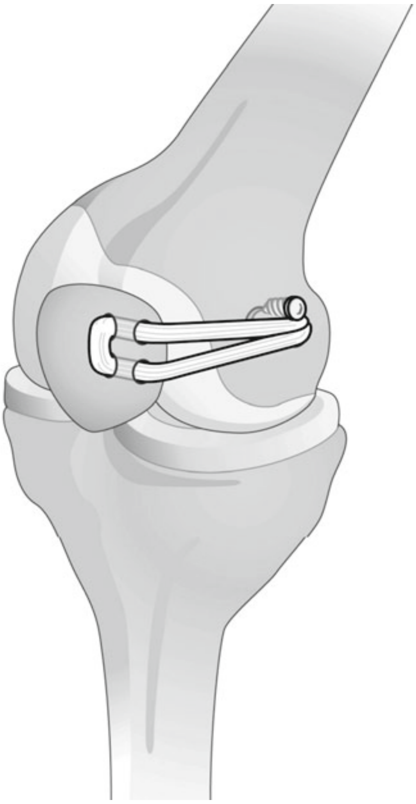

Fig. 1.10 Surgical technique of MPFL reconstruction

constrain the reconstruction, thereby creating chondral overload in flexion.

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2

Management and Consequences of the Rotator Cuff Calcific Tendinopathy

Gregorz Adamczyk, Maciej Miszczak, Mustafa Karahan, Radovan Mihelic, Manos Antonogiannakis, Vojtech Havlas, Jakub Kautzner, Oksana Sevastyanova, and Pietro Randelli

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2.1 Introduction

Calcific tendinopathy of the rotator cuff represents a treatment challenge since there is no consensus on its treatment. Unfortunately, up to 38% of the calcifications do not disappear with time. The persistence of the calcification is detrimental to the tendon biology and resistance. Thus, it is mandatory to follow up the calcification and to treat it in case it would not reabsorb spontaneously. Nonsteroidal anti-inflammatory drugs, rest, exercises, physiotherapy, and shock wave therapy are being used with varying results. Those who have not benefited from the conservative measures are indicated for nonsurgical invasive interventions or surgical treatment. Invasive interventions include steroid/anesthetic injection, barbotage (multiple needle punctures), aspiration, and ultrasound lavage. Surgical (arthroscopic) treatment should be reserved for chronic cases or for cuff ruptures due to the deposit.

2.2 Pathophysiology and Classification

Grzegorz Adamczyk and Maciej Miszczak

Shoulder pain is a common complaint with the occurrence of more than 20% of population. Calcifying tendinitis (calcific tendinitis, calcific tendinopathy) of the rotator cuff has a prevelance of 2.7–7.3% in asymptomatic population (Fig. 2.1). It accounts for approximately 10% of all painful shoulder consultations. Mainly, it occurs in women's shoulders, dominantly in patients over the age of 50. The relation of the rotator cuff tears and calcifications is very low; the long-term follow-up after complete disappearance of deposits shows only 3.9% rate of full-thickness tears. Supraspinatus and infraspinatus tendons are most commonly affected. Genetic data show increased expression of tissue transglutaminase (tTG2) and osteoponin. The increased HLA-A1 incidence is observed. In the resorbtive phase, the amount of multinucleated giant cell is elevated [1]. The underlying cause is still not fully understood however. There are no proofs for the connection of the calcifying tendinitis with any of systemic diseases. There are also no direct relations with the incidence of frozen shoulder.

2.2.1 Staging

The histopathological findings of calcifying tendinitis have been reported by Uhthoff [2], who described three distinctive stages through which the disease process progresses. The first, the precalcific stage, represents metaplasia of the tendinous tissue into fibrocartilage. The second, the calcific stage, consists of a phase of formation and a phase of resorbtion. And the last, the postcalcific stage, is a resorbtion of the calcium deposit and tendon reconstitution.

Additional injuries occurring with calcifying tendinitis are similar to general population in similar age and are biggest in the partial RC ruptures group. The acromion index and type seems to have no influence in occurrence of calcifying tendinitis [6].

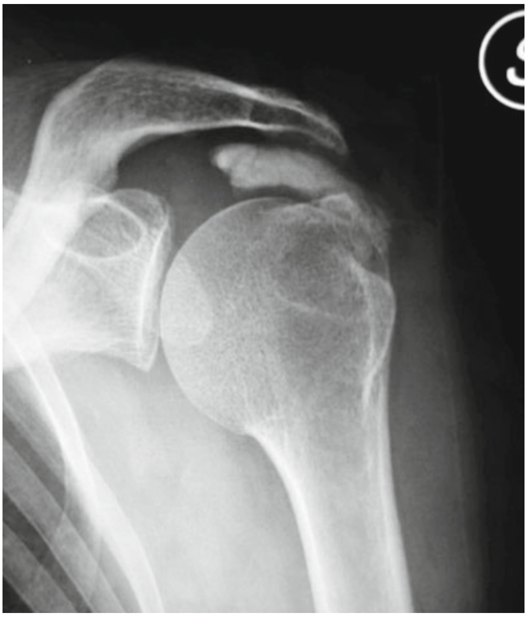

Fig. 2.1 X-ray findings of calcifying tendinitis

2.2.2 Classifications of the Radiological Changes

Radiological morphology of Calcifying Tendinitis by Molé (1993) [3]

(a) Calcification dense homogenous with clear contours
(b) Calcification dense split/separated with clear contours
(c) Calcification nonhomogenous with serrated contours
(d) Dystrophic calcification of the insertion in continuity with the tuberosity

Radiological classification of Calcifying Tendinitis by Gartner and Heyer [4]:

Type 1: Clearly circumscribed and dense, formative
Type 2: Clearly circumscribed, translucent, cloudy and dense
Type 3: Cloudy and translucent, resorptive

Bosworth's radiological classification of Calcifying Tendinitis [5]:

Small: Barely visible on fluoroscopy
Medium: < 1.5 cm
Large: > 1.5 cm

2.3 Conservative Management Overview

Mustafa Karahan

2.3.1 Introduction

Calcific tendinitis of the rotator cuff has been a painful issue around the shoulder. Nonsteroidal anti-inflammatory drugs, rest, exercises, and physical therapy have been used with varying results [5, 7, 8].

2.3.2 Medication and Physiotherapy

Throughout the years, rest (immobilization), heat, nonsteroidal medication, and physical therapy have been used to decrease pain. There have been varying reports over the success of these measures. Nonsteroidal anti-inflammatory drugs are the initial treatment line, and subacromial steroid injection may be helpful if some of the symptoms come from impingement [9]. A formal physical therapy program or gentle exercises may help maintain range of motion. There is mixed evidence that active therapeutic ultrasound is more effective than placebo ultrasound [10]. In a well-designed, randomized, double-blind comparison study of ultrasonography and insonation in patients with symptomatic calcific tendinitis, ultrasound treatment resulted in greater decreases in pain and greater improvements in quality of life in addition to radiographic decrease in calcium deposit size [11].

2.3.3 Noninvasive Nonsurgical Methods

Extracorporeal shock wave therapy has originated from Europe. Loew et al. [8] randomly assigned patients to control, low-energy, high-energy groups, and high-energy groups that received either one or two sessions. The results showed energy-dependent success, with relief of pain ranging from 5% in the control group to 58% after two high-energy sessions. Daecke et al. [12] determined long-term effects and complications. They concluded that the level of success was energy dependent and that there were significant differences in radiologic changes between the groups in a prospective study evaluating 115 patients at 4-year follow-up. At the end of the 4 years, 20% of the entire patient population had undergone surgery on the involved shoulder.

2.3.4 Invasive Nonsurgical Methods

If pain is not controlled with the measures stated above, invasive interventions or surgical methods are considered. The invasive interventions include steroid/anesthetic injection, barbotage (multiple needle punctures), aspiration, and irrigation [11, 13]. Needle lavage technique is best used in patients with an acutely painful shoulder in the resorptive phase, and it helps decrease the intratendinous pressure that results in pain. Treatment with modified ultrasound-guided fine needle technique has been shown to be an effective therapy with a significant clinical response and perhaps greater precision [13]. Using ultrasound-guided needle puncture, Farin et al. [14] found favorable results in more than 70% of patients.

2.3.5 Conclusion

Although it has been reported that calcific deposits in the rotator cuff can be asymptomatic, symptomatic conservative and invasive management is reported to provide relief of shoulder symptoms [15].

2.4 Extracorporeal Shock-Wave Therapy

Radovan Mihelic

2.4.1 Introduction

Extracorporeal shock-wave therapy (ESWT) has been reported to be effective in the treatment of many tendinopathies, including rotator cuff calcific tendinopathy [8, 16–18]. Some publications find mostly placebo effect, yet the majority of authors agree that there is a positive effect of this treatment regarding night pain, ability scales, and improvement of function [19–22]. The position of the shoulder during the treatment can play a role to achieve more effective result [23]. There is little difference in the therapy effect with high-energy and low-energy ESWT [24].

Meta-analysis of ESWT showed significantly better results in pain relief, range of motion, and deposit resorption [25]. However, these results are susceptible to bias due to differences of wave sources, dosage, etc.

2.4.2 Author's Recent Study

We have done a prospective randomized study of 40 patients with calcified tendinosis of supraspinatus muscle treated with ESWT. The therapy was performed via electromagnetic generator (EMSE, or electromagnetic shock wave emitter).

2.4.2.1 Material and Methods

The patients were treated with three low-energy doses in 1-week interval, using 600–3,000 shocks, 0.21 mj/mm². The therapy was focused on the supraspinatus region in the first session, including later treatment combined with anterior flexion and external rotation. The patients were randomly selected from the group of patients with calcified tendionosis who were previously treated with standard physical therapy. All had more than 6 months history of calcific tendinosis. The primary outcome measures were changes in Constant and ASES score as well as VAS. The diagnosis was confirmed by radiography and ultrasound (US). Patients were reevaluated 2 and 8 months after the treatment.

2.4.2.2 Results

Our results show better ASES and Constant score in treated patients. There was a significant pain relief measured on VAS. US control showed partial deposit resorption only in 40% of cases.

2.4.2.3 Conclusion

In our experience, ESWT showed good clinical results in matter of pain relief and range of motion, although calcium deposit was still present. Higher energy doses of shock wave should be considered to provoke the calcium deposit resorption in further treatment.

Noninvasive ESWT is considered an alternative method to operative treatment. Future investigations with higher numbers of cases, good randomization, blinding, and treatment provider bias exclusion are needed [9].

2.5 Percutaneous Needle Lavage Technique

Mustafa Karahan

2.5.1 Introduction

Percutaneous needle lavage technique is a good alternative in the management of calcified tendinitis. Ultrasonographic intervention seems to be more feasible than fluoroscopic guidance. The technique is described in detail in the following text. When conservative medical treatment fails, percutaneous needle lavage technique may be performed. A technique consisting of percutaneous needle aspiration of calcium deposits with fluoroscopic guidance was introduced by Comfort et al. [26]. Later, it was shown that ultrasonography (US) has a high sensitivity to accurately depict and localize rotator cuff calcifications without radiation exposure from fluoroscopy [27]. It was also shown that it is feasible to treat the calcification [28].

2.5.2 Technique

The percutaneous needle lavage technique routinely used represents puncturing the calcium deposited in the rotator cuff up to 15–20 times to break it into pieces and eventually aspirate the calcification during a single procedure. The shoulder is evaluated for the presence of accompanying tear, bursitis, or other associated conditions before initiation of the procedure [13]. Two needles (18–19 gauge) are used simultaneously; saline solution is injected for lavage through one needle and reaspirated through the other needle [28]. The lavage is continued until the aspirate is cleaned of calcified material followed by water-soluble cortisone injection into the subacromial-subdeltoid bursa.

2.5.3 Results

The technique provides quick and significant pain relief in about two-thirds of the cases, with clinical success rates varying from 60% to 74% [29, 30]. Because the punctures in the tendon are manipulated through ultrasonographic guidance, there is concern for potential injury to the tendon.

The results of US-guided percutaneous treatment of calcified tendinitis is better than those of calcium lavage under fluoroscopic monitoring [26, 29, 30]. US intervention has the advantage of avoiding radiation and having direct real-time three-dimensional imaging of the needle tip on the calcification during the procedure.

2.5.4 Conclusion

Residual status of the tendon fibers after repeated punctures may be a concern. Repetitive needle puncturing of the tendon to extract the calcium may potentially damage the tendon fibers and increase the risk of a rotator cuff tear [28]. The risk of a tear is no clear, as data about long-term follow-up of the tendon is not present in the literature. Short-term follow-up studies are not sufficient to show the effect of percutaneous treatment of rotator cuff calcifications on the rotator cuff tendon in the long run.

2.6 Indications for Surgery

Manos Antonogiannakis

2.6.1 Introduction

In those patients who have not benefited from the conservative measures above, invasive interventions and/or surgical treatment methods are considered. Surgery includes either open revision or arthroscopic procedure involving deposits removal and/or treatment of any other concomitant pathologies (rupture, impingement, etc.) [5, 7, 8, 31].

2.6.2 Indications

1. Symptomatic patients after failed conservative treatment following the chronic stage of calcification. In that case, arthroscopic removal of the calcium deposits brings pain relief. Acute inflammatory crisis may be responsive to needle lavage.
2. Patients with diagnosed rotator cuff tears based on calcific tendinopathy.
3. Calcifying tendinitis complicated by adhesive capsulitis is considered another indication for surgery [5, 7, 31–33].

2.6.3 Outcomes

The pain relief is not immediate; it usually occurs after months, and the strength improvement comes even later. Bursectomy and possible acromioplasty seems to improve the long-lasting result and are fully indicated in arthroscopic procedure. Approximately 15–35% of patients demonstrate persistence of some degree of postoperative stiffness [32].

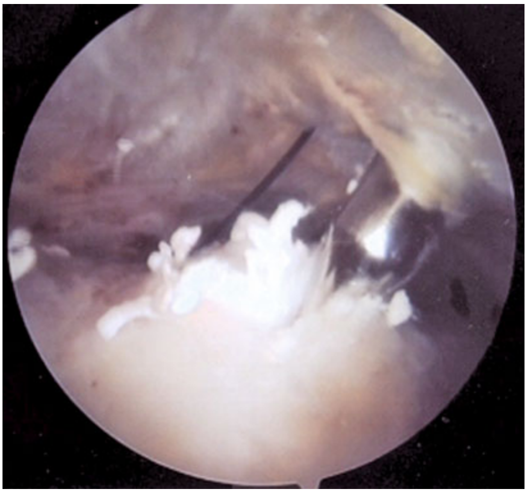

Fig. 2.2 Supraspinatus calcific tendinopathy – arthroscopic view

2.6.4 Conclusion

Although open removal of the calcium deposits can be considered, arthroscopic removal nowadays is the treatment of the choice. There are still controversies concerning the need for complete removal of the deposits and the need for repairing the tendon after deposit removal [5, 7, 31] (Fig. 2.2).

2.7 Surgical Treatment: Arthroscopic Versus Open Surgery

Vojtech Havlas, Jakub Kautzner,
and Oksana Sevastyanova

2.7.1 Introduction

In the treatment algorithm, surgical treatment of the calcific tendinopathy should be reserved for patients with chronic appearance nonresponding to conservative treatment measures, while majority of cases are satisfactorily cured conservatively [7, 33–35]. Open surgical treatment is proven to reduce the size of calcific deposits on radiographic examination as well as the symptoms [36]. Arthroscopic treatment provides good clinical results when combined with rotator cuff reconstruction [37] and provides less invasive method compared to open surgery.

2.7.2 Surgical Treatment Methods

There are several treatment options; these may be performed either by means of open surgery or arthroscopically.

2.7.3 Open Surgery

Deltoid split approach is used to perform calcific deposit excision through a longitudinal incision through the rotator cuff. This procedure is usually combined with acromioplasty to avoid further impingement of the tendon. Eventual rotator cuff reconstruction with side-to-side sutures may be performed if necessary [35]. It is a technically simple and fast method of treatment. A disadvantage of open method is the relatively large surgical exposure with a risk of postoperative complications such as deltoid hypotrophy or wound infection.

2.7.4 Arthroscopic Surgery

With the development of arthroscopic techniques, arthroscopically assisted procedures produce very good clinical results [33] (Fig. 2.2). Arthroscopic methods are less invasive, and earlier functional outcome is regained. The disadvantage may be longer surgical time and certain technical demands. Learning curve of arthroscopic procedures is longer compared to open procedures.

The most commonly used treatment method is calcific deposit removal. At first, calcific deposit is localized using needle under direct arthroscopic view or using fluoroscopy; after localization of calcific lesion, it is perforated by needle or knife tip. If the calcific deposit has a paste-like structure, then a needle or blunt curette is used to evacuate the calcific deposit. If the deposit is hard, a soft tissue shaver is used to remove it.

Acromioplasty is performed after excision of subacromial bursa using a burr. The indication of acromioplasty is discussed. Marder [38] found that the removal of the calcific deposits without acromioplasty has better clinical outcomes. Therefore, acromioplasty should be performed in patients with intraoperative or radiological evidence of impingement.

Rotator cuff repair is indicated if rotator cuff tear is diagnosed during surgical procedure, or there is residual defect after deposit removal. Simple techniques should be preferred to allow faster postoperative recovery. Simple side-to-side suture or suture anchor reconstruction methods are used [37].

2.7.5 Arthroscopic Radiofrequency Stimulation: Author's Own Technique

A new technique, using previously published technique [39] of subscapularis tendon stimulation by bipolar radiofrequency-based microtenotomy (microdebridement), can be used in attempt to improve the healing potential after the arthroscopic

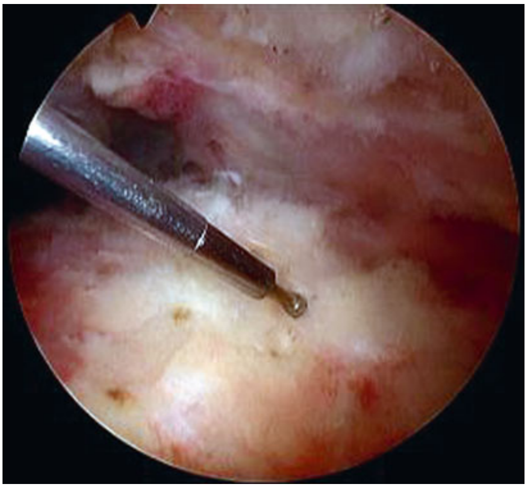

Fig. 2.3 Bursal side view of the left rotator cuff with a radiofrequency wand

treatment (Fig. 2.3). In a prospective study comparing the standard arthroscopic needle technique with a technique using radiofrequency-induced plasma microtenotomy as enhancement of the arthroscopic treatment of the calcific tendonitis on cohort of 20 patients, results measured by Constant score showed significantly better outcome in a group of patients after combined – arthroscopic and radiofrequency stimulation technique compared to a simple arthroscopic deposit removal [40].

2.7.6 Results

Clinical results of surgical treatment are very good, there is a significant improvement in shoulder function according to Constant score [34]; however, the postoperative recovery is very irregular and may take several months to complete recovery regardless of selected surgical technique [35, 41]. Long-term clinical results of rotator cuff surgery are comparable for both the open and the arthroscopic techniques, while short- and mid-term functional outcomes are better for arthroscopic treatment [7].

2.7.7 Conclusion

Surgical treatment is reserved for chronic cases not responding to conservative therapy. The treatment involves calcific deposit removal and rotator cuff reconstruction where necessary. Arthroscopic approach is preferred as it is less invasive and enables faster postoperative recovery compared to the open surgery. Radiofrequency stimulation of the affected tendon in addition to primary arthroscopic procedure shows better clinical outcome as documented on a small cohort of patients [40].

2.8 Practical Treatment Algorithm

Pietro Randelli

2.8.1 Introduction

Calcific tendinitis represents a treatment challenge since there is no consensus on its treatment. Uthoff [42] described three different phases: precalcific, calcific, and postcalcific. He postulated that, finally, the calcification reabsorbs and the tendon is able to restore.

Unfortunately, we know that up to 38% of the calcification do not disappear with time [43].

In particular, medial and anterior localization of the calcification is a negative prognostic factor for self reabsorption of the deposit [44].

The persistence of the calcification is detrimental to the tendon biology and resistance.

Thus, it is mandatory to follow up the calcification and to treat it in case it would not reabsorb spontaneously.

2.8.2 Diagnosis

Actually, X-ray represents the gold standard as diagnostic tool in calcific tendinitis (Fig. 2.1), together with the ultrasound. MRI can lead to diagnostic errors; thus, we do not suggest its use as a single tool.

2.8.3 Methods of Treatment

Several methods of treatment are listed in the literature. Among the most known are shock waves [45], US lavage [46, 47], needling [15], and arthroscopy [48] (Fig. 2.2).

Patient compliance is the key in the treatment algorithm for this disease. As a matter of fact, shock waves are not well tolerated by patients, as like as the surgical treatment is not well perceived. Recently, US-guided lavage offers an easy way of treatment of the tendinitis, washing out the entire deposit. Unfortunately, US lavage is suitable only in acute calcific tendinitis when the deposit is pretty fluid. On the other hand, the arthroscopic treatment allows to repair a cuff tear related to a chronic calcific tendinitis.

2.8.4 Practical Treatment Algorithm

We developed a practical treatment algorithm following the main concepts of:

1. Pain reduction
2. Treatment of the tendon avoiding a subsequent cuff tear

In case of acute onset of calcific tendonitis diagnosed by X-rays, the patients are sent to the radiology department for US lavage. The lavage is performed in local anesthesia and in an outpatient way. Two days after the treatment, the patients start physical therapy for passive range of motion (ROM) exercises, with a full ROM recovery at 7 days after treatment. Active ROM exercises will start only 15–20 days after treatment, depending on the residual pain.

The patients will repeat an X-ray at 2 months after treatment plus an MRI in case of persistent pain.

If the tendon is torn, the patients are scheduled for surgery; if not, they continue follow-up surveillance. In case of chronic calcific tendonitis, we suggest an arthroscopic treatment with or without rotator cuff repair.

2.8.5 Conclusion

Calcific tendinopathy should be treated to avoid subsequent cuff damages.

A well-accepted and successful technique is the US lavage. Arthroscopic treatment should be reserved for chronic cases or for cuff ruptures due to the deposit.

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Biceps Pathology, Global Visions, Evaluation, and Treatment Option

3

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3.1 Introduction

With development of shoulder arthroscopy, the long head of the biceps brachii (LHB) is seen from different prospective. Not only various anatomical variants are described, but also several pathological changes and pain mechanisms are detected and explained. Arthroscopy thus greatly improved diagnostics in addition to other diagnostic modalities such as MRI and CT arthrography or US. Biomechanical and EMG studies still cannot define exact role of LHB because of its different relative position to the GH joint. This is also a reason that so many different treatment options are described. Apart from anatomical reconstruction of the anchor pathology of LHB (SLAP), there are two major surgical techniques: tenotomy and different kinds of tenodesis. Tenodesis is further divided into soft tissue, bony, and intraosseous fixation. One of the weakest points of mostly used evaluation scores for rotator cuff pathology is assessment of LHB. This is also the reason why we cannot compare adequately the clinical results of various surgical techniques. Recently, new scores for LHB assessment are described but still not widely used.

In the next subsections, there are some up-to-date answers and explanations to the already mentioned LHB problems.

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3.1.1 Intra-articular Variations of the Long Head of the Biceps Tendon

Ulunay Kanatli, M.D.

The long head of the biceps tendon (LHB) generally runs free through its course in the glenohumeral joint. It can rarely be seen as attached to the joint capsule or the rotator cuff in different patterns.

It was in the middle of the last century that the first study regarding the biceps tendon's intra-articular variations was published [1]. Following this, new studies were carried out reporting different kinds of variations including the complete absence of the tendon [2–6], a split tendon morphology [7], and its various synovial adherences to the capsule and the rotator cuff [8–10].

Intra-articular variations of the long head of the biceps tendon can be classified into seven groups. These include vinculum, cord, pulley, partial synovial tunnel, complete synovial tunnel, proximal adherent, and distal adherent variations. Also, LHB can be absent totally.

Bearing in mind that the intra-articular variations of LHB are different morphological forms that arise due to the cessation of the tendon migration into the joint at different stages of fetal life, these may be related with some labral pathologies. Although these variations were mostly considered harmless in the literature, the same question was previously asked by some authors. In their report of three cases, Ghalayini et al. [3] suggested that the absence of biceps tendon might predispose to secondary pathologies such as instability. Similar to this, Sayeed et al. [6] and Keefe and Lowe [4] published two individual case reports in which they concluded that the absence of biceps tendon might be responsible for posterior and superior labral tears. Dierickx et al. [11] suggested that the lateral adhesions (distally adherent type) may cause an hourglass-type impingement as suggested by Boileau et al. [12] since the medial portion of the tendon relaxes and the adhesion becomes taut during abduction. LHB variants may alter the intra-articular biomechanics that leads some pathologic lesions. Kanatli et al. [13] reported that the labral pathologies were encountered at a significantly higher rate in the pulley-type variant group than the total population. They concluded that this association may be attributed to an increase in traction stresses that the anterior labrum is subjected to and hypothesized a new physiopathological mechanism for this condition: "The double-pulley traction."

The prevalence of embryological variations of the biceps tendon may be higher than common presumptions, and patients identified with these variations during shoulder arthroscopy should be evaluated carefully in terms of labral pathologies.

3.1.2 Do We Need LHB? Function and Diagnostic Investigations of LHB Pathology

Antonioa Cartucho

The LHB is an intra-articular, extrasynovial structure on the surface of the humeral head and courses into the intertubercular groove.

The role of the long head of the biceps in the shoulder has yet to be defined as it is for some a vestigial structure that can be easily excised or tenodesed when symptomatic. The function of the biceps at the elbow has been well described, and it is generally accepted that the biceps brachii is predominantly a supinator of the forearm and a weak flexor at the elbow. Some authors have hypothesized that the long head of the biceps may be a stabilizer of the glenohumeral joint [14–17].

Although many EMG studies have confirmed that the long head of the biceps is active in the shoulder, other EMG studies have shown that the biceps has no activity in the shoulder when the elbow and forearm motions are controlled [18–23]. Kim et al. [20] found that the biceps play an active compensatory role in the unstable shoulder in the abducted, externally rotated position but is silent in stable shoulders. The various positions of the long head of biceps in relation to the glenohumeral joint according to arm position and presence of pathology may determine the different EMG data.

Itoi et al. [24] found that the moment arm of muscles crossing the glenohumeral joint changes with arm rotation, this effect was more significant for the long head of the biceps than for any other muscles. This might be because the long head of the biceps tendon shifts from one side of the center of glenohumeral rotation to the other with rotation of the arm.

Kuhn et al. [21] reported that the long head of the biceps tendon is a significant dynamic restraint near the end of rotation in the abducted position. He concluded extreme external rotation may load the long head of the biceps tendon, leading to biceps or biceps-labrum complex injuries in throwing athletes.

Glousman et al. [18] observed that the electromyographic activity of the biceps during throwing motion increased in patients with chronic anterior instability of the shoulder compared with those without instability. However, even without any EMG activity in the shoulder and assuming only a tenodesis effect, the long head of the biceps is positioned at the extremes of glenohumeral rotation to act as a ligament limiting glenohumeral translation. This function of the biceps may become more important in overhead throwing athletes, who have hypermobility and in patients with glenohumeral instability. Biceps tenotomy or tenodesis should be approached with caution in these cases. On the other hand, hypertrophy of the biceps tendon commonly occurs after the rotator cuff tears [14, 15, 20]. Such hypertrophy could represent an attempt to constrain the humeral head through the secondary restraint of the biceps tendon confirming a depressor effect of the LHB.

In summary, the different relative position of the LHB to the glenohumeral joint leads to a difficult analysis of electromyographic activity. Nevertheless, it is considered that even inactive, the LHB may limit glenohumeral translation, and active, may be a head depressor and induce a centering effect.

Physical examination is difficult in the diagnosis of LHB pathology. Anterior shoulder tenderness may be present. The belly press, Speed's, and Yergason's tests have only moderate specificity [25, 26]. The bear hug and upper cut tests are highly sensitive but have low specificity [26]. In patients with rotator cuff tears, the physical examination is even less reliable in the detection of LHB tendon disorders [27]. A combination of tests with strong specificity or sensibility is the key to optimize clinical diagnosis.

Clinical diagnosis must be confirmed by imaging. Noncontrast MRI may detect LHB tendon tears with only 52% sensitivity [28]. MRI arthrography may raise the sensitivity to 90%. Computed tomography arthrogram has a poor sensitivity of this (31–46%), but a good specificity (95–99%) [28, 29].

Ultrasound imaging may reliably detect complete rupture and dislocation of the LHB tendon but poorly detects partial-thickness tears of the LHB tendon [30].

Arthroscopy is the gold standard for detection of LHB tendon disorders. A thorough arthroscopic examination of the LHB tendon includes using an arthroscopic probe to pull the extra-articular portion of the biceps into the glenohumeral joint to allow complete visualization of the tendon. The extra-articular segment of the LHB may be affected by tendinopathy or partial-thickness tearing and can only be examined by probing the tendon into the joint. Surgeons should look for an abrasion of the cartilage of the humeral head near the bicipital groove, which may be a sign of biceps pathology [31].

3.1.3 LHB Pathology with Intact Cuff

Angel Calvo, M.D.

Biceps tenotomy is a fast, easy, effective, cheap, and widely used technique around LHB pathology, but in young people, hard workers, and sportsmen with a painful, unstable biceps or pulley lesions, tenodesis should be considered.

Biceps tenodesis is an effective procedure that relieves pain, prevents cosmetic deformity observed with tenotomy, and preserves strength of the elbow. Due to the boom of shoulder arthroscopy, there have been several arthroscopic techniques for biceps tenodesis described that differ in the type of fixation and hardware needed. The different types of fixation and techniques reported include suture anchor [32], interference screw fixation [33–35], the percutaneous intra-articular transtendon technique [36], and the arthroscopic transfer of the biceps to the conjoint tendon [37].

The choice of tenodesis technique is controversial. The fixation has to be stable and the procedure easy and reproducible. Biomechanical studies have shown that the interference screw is superior in fixation strength than suture anchors and keyhole technique [38]. Richards et al. [39] compared interference screws and double suture anchors. Screw fixation showed better traction and fixation strength.

Screw fixation is a reproducible technique but is technically difficult and we have occasionally had problems in the moment of inserting the interference screw because the implant damaged the biceps tendon.

Trying to achieve the objectives of simplicity, reproducible technique, and stable fixation, we used the suspensory fixation in the same form as it has been used in the knee. The posterior cortex of the humerus gives us an excellent traction resistance.

This technique has been performed on 65 patients with very satisfactory results. We have checked that technique is safe in relation to the axillary nerve, and the fixation obtained was very stable.

3.1.4 LHB Pathology Related to Rotator Cuff Tears

Boris Poberaj, M.D.

The long head of the biceps (LHB) is in the most intimate relationship with rotator cuff in its way to the entrance of the bicipital groove. A soft tissue sling, the so-called pulley system, stabilizes its course at this point. As described by histoanatomic study [40], superior glenohumeral ligament (SGHL) and fasciculus obliquus are the most important ligamentous reinforcements of a stabilizing sling. Fibers of supraspinatus tendon join the posterosuperior part of sling, whereas subscapularis tendon is not involved in this suspensory mechanism.

Traumatic anterosuperior cuff tear is well associated with pulley rupture and concomitant LHB subluxation or dislocation. Anteromedial (AM) instability of the LHB is described in subscapularis lesions while posterolateral (PL) instability is related to supraspinatus lesions [41].

Articular-sided partial tearing of supraspinatus tendon can lead to lesion of SGHL, which subsequently allows anterior subluxation of LHB and thus cause articular-sided partial tear of the subscapularis tendon [42, 43].

Biomechanical evaluation of shear forces during different arm position [44] exhibits the highest shear force values on pulley system with internal and neutral rotation in the forward flexion and internal rotation at the neutral position.

Pathologic abnormalities of the LHB, including tendinosis, tenosynovitis, fraying, hourglass biceps, partial tears, and even SLAP lesions have significant association with tears of pulley complex [45].

Pulley tears were also more common in older patients with a positive correlation between PL pulley tears and lesions of the supraspinatus tendon, which may indicate a degenerative process that affects both structures [45].

Optimal treatment of LHB lesions in the setting of rotator cuff tears is still controversial and usually described as different tenodesis techniques and tenotomy. Generally, tenodesis can be divided into soft tissue, osseous, and intraosseous fixation techniques.

Newly developed LHB scoring system [46] for clinical evaluation of treatment includes evaluation of pain and cramps, cosmetic result and measurement of elbow flexion strength. The authors recommend a bony fixation over soft tissue fixation.

Another study [47] which compares tenotomy and suture tenodesis concludes that the only clinical difference between the two modalities is less Popeye deformity in the tenodesis technique.

Ideal treatment would consist of strong fixation without restriction of elbow function during early rehabilitation period, fast and low-cost surgery. Preliminary results of author’s new technique, implantless suprapectoral intraosseous cortical bridge LHB tenodesis (SICT), have shown excellent clinical results with high scores assessed by new LHB scoring system.

Conclusion

Different anatomical variants of LHB, its relationship to nearby tissue structures, mechanism of shoulder injury, and clinical and diagnostic assessment are important factors in treatment algorithm of LHB pathology. Because of yet not clearly defined function, the age limit for tenodesis procedure in case of tendon pathology is getting lower. So far, neither tenodesis nor tenotomy negatively affects the shoulder function. There is still debate at what age to decide to do simple tenotomy and also what kind of tenodesis technique to use. With the newly described techniques of LHB tenodesis, advantage of strong fixation with early rehabilitation phase is emphasized as well as lower costs and less surgery time in comparison to other techniques.

Newly developed LHB scoring systems still have to be validated but already represent great help in evaluation of LHB treatment options.

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4

Unicompartmental Knee Arthroplasty in Medial Osteoarthritis: The Basics

G. Deschamps, C. Dodd, P. Hernigou, A. Franz,
S. Parratte, J.M. Aubaniac, Jean-Noël Argenson,
and M. Ollivier

Contents

4.1 Modern Indications of Unicompartmental Knee Arthroplasty (UKA)

G. Deschamps

Unicompartmental knee arthroplasty (UKA) is designed for patients presenting isolated degenerative unicompartmental medial or lateral femorotibial wear or wear related to aseptic osteonecrosis of the femoral condyle, most frequently medial.

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Fig. 4.1 An ideal case for UKA with isolated medial wear without excessive bone deformity. Absence of anterior tibial translation on the lateral weight-bearing x-ray predicting a healthy ACL

The indication is based on strict criteria (Argenson et al. 2002) [1, 2] (Deschamps and Chol 1997):

- Wear must stem from degenerative osteoarthritis (Fig. 4.1) or be secondary to aseptic necrosis of the medial condyle (inflammatory rheumatism is a contraindication). The symptoms associated with this feature, and particularly pain, must be localized on the index compartment and recognized by the patient as its own and usual pain.
- Age and activity level should be compatible with an indication for arthroplasty.
- The body mass index should be less than 30 kg/m^2.
- The ligament system must be intact, particularly both cruciate ligaments.
- Any preexisting axis deformity should be moderate and the residual axis deformity, after correction of wear with a UKA acting as a spacer, should not exceed 7–10° varus or valgus.

These highly restrictive conditions result in the ideal indications for UKA suitable for no more than 15–20% of knee arthroplasty candidates for most surgeons experienced in this procedure (Stern et al. 1995).

Although the results of certain early series worried potential users [3], today it can be asserted that recent series whose indications and technique correspond to modern use criteria have shown results that are as reliable as those of total knee arthroplasty (TKA) at a 10-year follow-up [4–7]. Beyond this time frame, the risk of polyethylene wear related to the technical restrictions of the UKA is another consideration [8, 9]. Indeed, to prevent the risk of rapid extension of osteoarthritis to the opposite compartment, the procedure should be limited to restoring the patient's constitutional axis before wear phenomena had set in (Fig. 4.2). This makes UKA a surgical procedure at risk of failure due to wear phenomena.

Therefore, today, we can propose instructions for this intervention (Deschamps and Chol 1997), whose value compared to TKA is expressed not only in easier postoperative recovery but also because the flexion and function obtained at completion are highly advantageous compared to TKAs [10]. These arguments, which several recent publications have emphasized (Argenson et al. 2002) [1, 9], explain the renewed interest in this procedure and the refinement of modern rules for its indications and use.

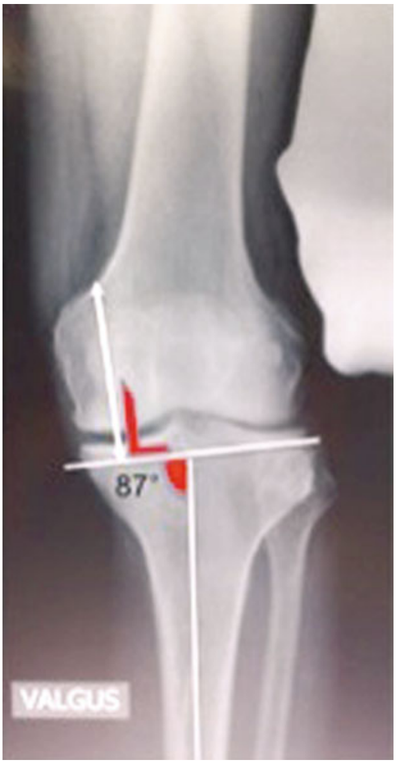

Fig. 4.2 Frontal stress x-ray demonstrating that UKA can be used to wedge the cartilage loss and to plan the ideal direction of the tibial cut

4.2 Basic Technique: Balancing in Mobile UKA

C. Dodd

1. The prime indication (>90%) for the Oxford mobile-bearing UKR is a pathoanatomical condition where there is advanced medial compartment osteoarthritis centered in the anterior aspect with preserved posterior cartilage, intact ligaments, and a functionally intact lateral compartment. The disease is limited to the anterior part of the medial compartment and is therefore called anteromedial osteoarthritis (AMOA) (White et al. 1995). Stress radiography is the investigation of choice in the preoperative assessment of these patients [11]. Given these normal ligaments, the technique therefore never releases any ligaments. The preserved cartilage in flexion is used to align the components in flexion. In extension, the anatomy is damaged and the normal ligaments are used to align the components in extension.
2. A stylus system accurately and reproducibly resects the correct level of tibial bone in order to insert the tibial plateau and a 3- or 4-mm bearing (Fig. 4.3). There is a slotted shim which allows accurate resection of the horizontal cut.
3. An IM rod and a link pin accurately orientate the low profile femoral drill guide referenced from the normal femoral posterior cartilage, thus reproducibly restoring the joint line (Fig. 4.4). The femoral component is spherical and is very forgiving of up to 10° of femoral component malalignment and up to 5° of tibial component malalignment in any direction [12]. The device is therefore very tolerant of rotational malalignment.
4. A sophisticated technique employing a mill acting over a series of spigots with collars of differing thickness allows for incremental milling, thereby accurately balancing the flexion and extension gaps to within +/− 1mm and restoring the predisease alignment to +/− 1°. This technique also accurately restores normal ligament tension and normal kinematics [13].
5. An anti-impingement system removes anterior and posterior femoral bone, thus preventing dislocation of the mobile bearing [14].

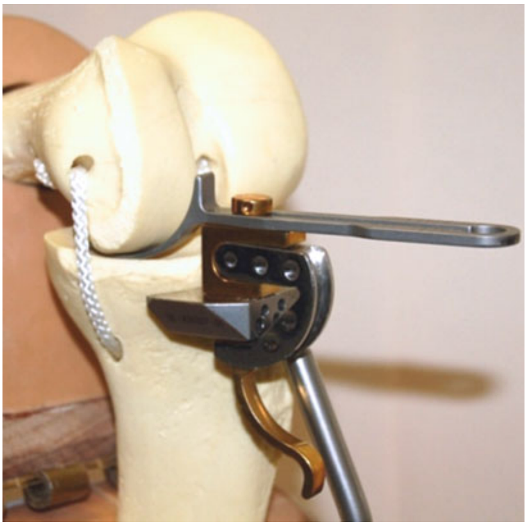

Fig. 4.3 The operative view showing how the system accurately and reproducibly resects the correct level of tibial bone in order to insert the tibial plateau and a 3- or 4-mm bearing

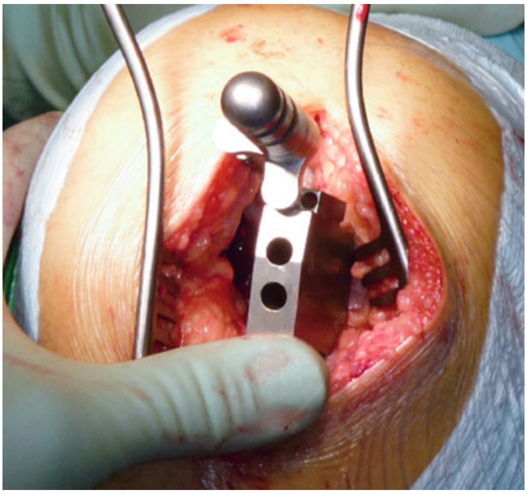

Fig. 4.4 An operative view showing the IM rod and a link pin accurately orientating the low profile femoral drill guide referenced from the normal femoral posterior cartilage

4.3 Basic Technique: Surgical Principles in Fixed UKA

P. Hernigou

4.3.1 Femoral Component Sizing and Final Distal Femoral Preparation

The femoral component size is selected by placing the foot of the femoral finishing guide underneath the posterior femoral condyle and selecting the largest size that will not overhang the junction between the remaining articular cartilage and the cut end of the distal femur. If the component overhangs and extends beyond this point, the native patella can impinge upon the femoral component. Thus, if the surgeon is choosing between sizes, in general the smaller size is selected. It is important to recognize that this is a posterior referencing system, and thus femoral component size does not affect flexion and extension gap balancing. In other words, the amount of bone removed from the posterior femoral condyle is the same regardless of the femoral component size selected with a resection that is equivalent to the thickness of the posterior condyle of the component. When placing the femoral finishing guide on the cut end of the distal femur, care is taken to ensure it is rotated appropriately so that the final femoral component will track centrally on the tibial tray. The removal of osteophytes from the intercondylar notch can also assist the surgeon in appropriately rotating this guide. The guide is then affixed to the femur with multiple pins, and the lugholes for the femoral component are drilled. The femoral chamfer and posterior femoral cuts are then made with an oscillating saw.

4.3.2 Tibial Component Sizing

The remainder of the posterior horn of the medial meniscus and any other remaining soft tissues are removed from the posterior aspect of the joint. The largest size that will not overhang the cut surface of the tibia is selected using the sizing guides; if the tibial cut was removed as a single piece, this can aid in tibial sizing. The trial tibial component is positioned into place.

4.3.3 Trial Reduction

The trial femoral component is inserted along with the trial polyethylene insert. The knee is brought through a range of motion to ensure that the femoral component tracks centrally on the tibial component throughout a range of motion and that the femur does not impinge against the patella. At this point, the knee is extended fully, and there should be 2 mm of laxity in this position. With the knee in extension, the 2-mm side of the spacer should be able to be inserted into the extension space. The knee is now flexed to 90° and the 3-mm side of the plastic spacer should be able to be placed between the trial femoral component and polyethylene spacer. If the flexion and extension spaces are unequal with the trials in place, balancing the extension and flexion space is necessary.

4.3.4 Balancing the Extension and Flexion Space

The technique for fixed-bearing UKA includes resection of the same amount of distal femur as is replaced by the femoral component. However, preoperative assessment of the patient's flexion and extension can aid in adjusting the slope of the tibial resection, which assists in creating appropriate flexion and extension gaps. In a knee with both full extension and good flexion, the slope of the tibial resection should match the slope of the native tibia. With the leg in extension, and after the distal femur and proximal tibial have been resected, the extension side of the spacer is inserted. The thicker extension side of the spacer simulates the thickness of the distal femoral component combined with the tibial component and polyethylene liner. Therefore, at a minimum, the 10-mm block should fit into that space. This will then simulate the thickness of the femoral component with the thickness of the smallest tibial polyethylene liner and allow for 2 mm of laxity in extension, the appropriate amount of residual laxity for a UKA. Once the extension space is appropriately measured, the knee is flexed up to 90°. In 90° of flexion, the flexion side of the spacer (the thin side) is inserted into the flexion gap. This spacer simulates the thickness of the tibial component and the polyethylene liner, without resection of the posterior femoral condyle. At a minimum, a 10-mm spacer block should be able to fit into this space. Usually, the flexion and extension spaces will be similar or equal at this point. However, due to variations in the patient's preoperative ligament balance or bony anatomy or if the bony resections have not been performed accurately, a mismatch between the flexion and extension spaces may be present. The goal at this point is to have the flexion space approximately 1 mm larger than the extension space for a properly balanced medial UKA. The most common problem encountered is to have the extension space tighter than the flexion space. This is usually a residual of a preoperative flexion contracture. Several steps can fix these mismatched spaces. First, as is done routinely in a TKA, removal of posterior condylar osteophytes and the posterior capsule with a curved osteotome can increase the size of the extension gap. If this maneuver does not remedy the problem, the tibia can be recut with slightly less slope as previously described. Finally, the distal femur can be recut by a millimeter or two which will selectively increase the size of the extension space; this is typically required only in cases where initial distal femoral resection was inadequate (less than 6 mm of distal femur was resected). The final alternative is to move the femoral cutting block posteriorly, reducing the amount of posterior femoral condyle resected and thus reducing the size of the flexion space; balance is subsequently achieved by using a smaller polyethylene spacer. The less common scenario is to have the flexion space smaller than the extension space. When this occurs, the tibia can be recut with slightly more posterior slope as previously described. If this does not remedy the problem, the posterior femoral condyle can be shaved with a saw, by a millimeter or two, prior to fitting and sizing the femoral component. This additional resection of the posterior femoral condyle will move the femoral component anteriorly, enlarging the flexion space. The process of balancing the flexions and extension spaces can be an iterative process where slight corrections are made until the flexion and extension spaces are equal and of appropriate size (at least 10 mm) to allow for proper knee kinematics.

4.4 Fix Versus Mobile: Full Poly Versus Metal Back

A. Franz

In the three decades since its introduction, unicompartmental knee arthroplasty (UKA) has become an increasingly common treatment and is now capable of producing superior outcomes to total knee arthroplasty [15]. However, consistent debate surrounds the issue of whether mobile- or fixed-bearing designs are preferable in UKA. Meta-analysis data indicate that there in fact may be no significant difference in clinical outcomes or complication rates between mobile- and fixed-bearing UKA [16], a conclusion that is in accordance with both a recent clinical study [17] and a comprehensive review of research in the field [18]. However, individual studies do point to limitations for each design. Despite several authors reporting robust survival rates at more than 10 years with mobile-bearing designs, other studies with less favorable results have cited the difficult surgical technique required for these devices, the presence of radiolucent lines, and a potential for bearing dislocation as reasons for their inferiority in comparison with fixed-bearing components [18]. Additionally, a recent in vitro analysis, observed that mobile-bearing components exhibited significantly higher wear rates than their fixed-bearing counterparts [19]. In terms of fixed-bearing components, results appear highly dependent on the tibial component utilized. Whereas metal-backed components commonly result in survival rates comparable with the most encouraging studies with mobile-bearing designs, outcomes with all-polyethylene components are not so consistent. Although certain all-polyethylene designs have resulted in excellent medium-term survival, others led to notable complications such as increased rates of loosening and failure [18].

4.5 Bicompartmental UKA and Patellofemoral Joint Replacement

S. Parratte, J.M. Aubaniac, and
Jean-Noël Argenson

Outcome and kinematic studies suggest that maintaining the anterior cruciate ligament in bi- and tricompartmental knee arthroplasty may be advantageous in terms of survivorship, stair climbing ability, patient satisfaction, and joint kinematics (Argenson et al. 2002). Considering these results and as bicompartmental arthritis of the knee is not rare, bicompartmental knee arthroplasties have been proposed to bridge the gap between UKA and TKA [20]. There is a renewal of interest for bicompartmental knee arthroplasties, including combined medial UKA and femoropatellar arthroplasty [21]. Smaller implant size, less operative trauma, the preservation of both cruciate ligaments and bone stock, and a more "physiologic" knee joint are considered advantageous over total knee replacement. Patient selection includes a clinical and radiological analysis [5]. Range of motion and stability in the frontal and in the sagittal planes should be analyzed. Radiological analysis including full-length radiographs of the considered knee and stress x-rays should confirm that the wear is limited to the two concerned compartments and that there is no excessive bony deformation. If there is any doubt concerning the status of the ACL, an MRI should be performed to confirm that the ACL is intact. The procedure is performed under general anesthesia without any tourniquet. A subvastus approach is systematically performed to preserve the quadriceps. The trochlea is prepared first using a dedicated instrumentation to perform an anterior femoral cut first. The rotation is controlled relatively to the Whiteside line and the high of the cut relatively to the anterior cortex of the femur. The UKA is then performed using a metal-backed fixed-bearing implant. All the implants are cemented in one step starting with the UKA. Weight-bearing and full-range of motion rehabilitation is stated the day after surgery. It is important to consider systematically the use of two independent implants (Fig. 4.5) to set properly the rotation of each implant [22].

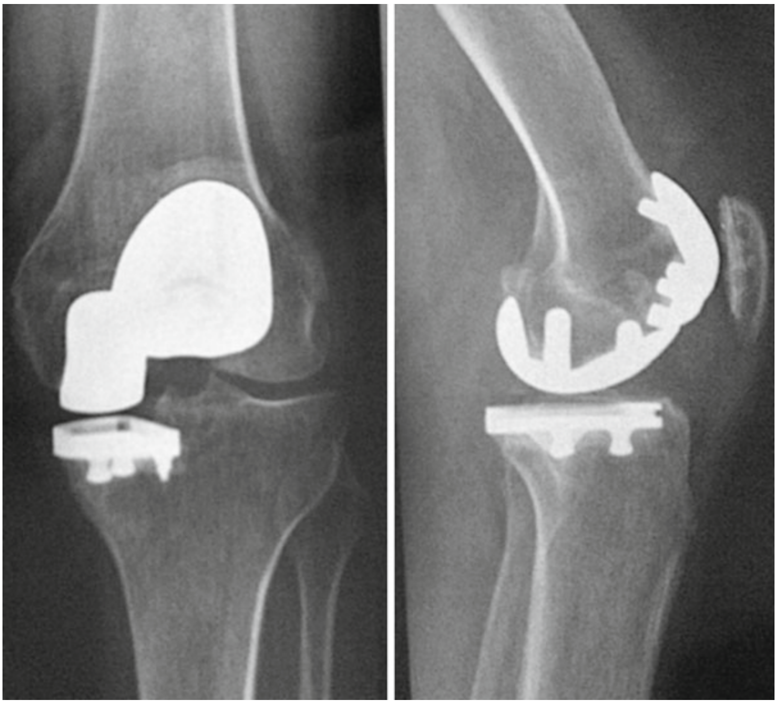

Fig. 4.5 The use of two independent implants, medial UKA and patellofemoral replacement as shown on the frontal and lateral views, is routinely decided in order to set properly the rotation of each implant

4.6 Anterior Cruciate Ligament and UKA

M. Ollivier, S. Parratte,
and Jean-Noël Argenson

Some patients have isolated unicompartmental arthritis of the knee. But the association with an ACL deficiency is frequent [23]. A total knee arthroplasty will be preferred in these cases because of the increased failure rate reported after UKA when the ACL is not efficient [24]. Patients with an intact contralateral and femoropatellar compartment may however not require total knee arthroplasty. The knee kinematics is significantly different when the anterior cruciate ligament (ACL) is deficient (Argenson et al. 2002). Komistek et al. concluded in 2002 that a deficient anterior cruciate ligament conduced to a more posterior contact between femur and tibia during the flexion and more sliding movements than in normal knees [25]. The actual techniques of reconstruction of the ACL are promising and may restore the knee stability to almost normal. Some combined techniques of surgery have been developed in order to associate UKA and ACL reconstruction with very good short-term results [26]. In case of clinical laxity of the ACL in young patients, plain radiographs with anteroposterior and lateral view and long-leg standing radiographs must be performed. Stress radiographs may be additionally realized in order to verify the anterior instability. MRI is also recommended in order to evaluate accurately the ACL. We use both semitendinosus and gracilis tends for the ACL reconstruction. A subvastus approach can be performed to preserve the quadriceps. Osteophytes are removed from the joint particularly in the intercondylar notch to avoid late impingement with the graft on the notch. This point is very important to preserve the graft and avoid any so-called Marie Antoinette effect on the graft. We first prepare the tibial and femoral component of the UKA as described previously. Second, we reconstruct the ACL. We locate the tibial canal position using a 55° guide set to and placed into the anatomical footprint of the tibial insertion. Then we prepare the femoral tunnel with guide wire placed "over the top" in a 2 or 10 o'clock position according to side of the knee. The ACL graft is finally pulled into the femur via the tibial canal and is fixed on both sides (tibial and femoral site) after cycling the graft by repeated flexion/extension. Rehabilitation is started the day after surgery and a clinical and radiological evaluation performed every 6 months. For young patients

Fig. 4.6 The full leg frontal view at 14-year follow-up of a 42-year-old female patient who had UKA combined to ACL reconstruction using at that time patellar tendon grafting

presenting with both instability and pain, this combined solution may delay the time for total knee arthroplasty (Fig. 4.6).

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5

Instructional Course Lecture Posterior Ankle Arthroscopy: What Are the Limits?

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5.1 Introduction

In 1931, Burman found the ankle joint unsuitable for arthroscopy because of its typical anatomy [1]. Tagaki and later Watanabe made considerable contributions to arthroscopic surgery, and the latter published a series of 28 ankle arthroscopies in 1972 [2]. Since the late 1970s, numerous publications have followed. Over the last 30 years, arthroscopy of the ankle joint has become an important procedure with numerous indications for both anterior as well as posterior pathology and pathology of tendons. Endoscopic surgery offers the possible advantages of direct visualization of structures, improved assessment of articular cartilage, less postoperative morbidity, faster and functional rehabilitation, earlier resumption of sports and outpatient treatment [3–5]. The value of diagnostic arthroscopy nowadays is considered limited [6, 7]. Posterior ankle problems pose a diagnostic and therapeutic challenge because of their nature and the deep location of hindfoot structures. This makes direct access more difficult. Historically, the hindfoot was approached by a three-portal technique, i.e. the anteromedial, anterolateral and posterolateral portals, with the patient in the supine position [8–10]. The traditional posteromedial portal is associated with potential damage to the tibial nerve, the posterior tibial artery and local tendons [11]. A two-portal endoscopic approach with the patient in the prone position was introduced in 2000 [12]. This technique has shown to give excellent access to the posterior ankle compartment, the subtalar joint and extra-articular structures [12–14].

In this instructional course lecture, specific attention to the posterior ankle arthroscopy is provided. The lecture is divided in five parts: P. Golano highlights the specific anatomical structures important for the posterior ankle arthroscopy. Anatomical knowledge is an important element for proper surgery and will directly influence the outcome with respect to complication rates. The anatomy also determines where to position the portals which will be discussed by P.A.J. de Leeuw. T. Ögüt presents three typical cases which were treated by means of the posterior ankle arthroscopic technique. P. d’Hooghe discusses the endoscopic subtalar arthrodesis and GMMJ Kerkhoffs introduces a new indication for posterior ankle arthroscopy: arthroscopic ankle arthrodesis.

5.2 ICL 1: Anatomy of the Hindfoot

P. Golanó, M.D. and J. Vega, M.D.

The anatomical knowledge is particularly important in the arthroscopy of the ankle because of the significant risk of associated complications which can be prevented or decreased only by profound familiarity with the anatomy of the region. Adequate knowledge of the anatomy of the joint to be treated should cover not only the most common anatomical configurations (extra-articular and intra-articular) in statistical terms but also the possible anatomical variations to avoid confusion and serious technical errors.

The main anatomical structure for the orientation and for determining the safe working area is the flexor hallucis longus tendon. Just medial to this tendon runs the posterior neurovascular bundle (tibial nerve and posterior tibial artery and veins). The posterior ankle arthroscopy should therefore routinely be performed lateral to the flexor hallucis longus tendon (Fig. 5.1). Proper positioning of the ankle and the hallux results in better visualization of the tendinous portion of the flexor hallucis longus muscle and avoids unnecessary resection of some of the muscle fibres that reach the lateral tendinous border in a semipeniform morphology [15]. Plantar flexion of the ankle or hallux flexion facilitates visualization of the flexor hallucis longus tendon proximal to the lateral talar process.

The posterior ankle ligaments are also important for the orientation during the posterior ankle arthroscopy. These ligaments include the posterior talofibular ligament, the posterior intermalleolar ligament, also called the tibial slip in the arthroscopic literature and the posterior tibiofibular ligament which is composed of a superficial and deep component or transverse ligament.

When the posterior ankle compartment is visualized arthroscopically, at first the location of the flexor hallucis longus tendon should be determined. Then, the detailed anatomy of the posterior ankle can be identified more carefully (Fig. 5.2).

The posterior talofibular ligament, component of the lateral collateral ligament, originates from the malleolar fossa, located on the medial surface of the lateral malleolus, coursing almost horizontally to insert in the posterolateral surface of the talus. This ligament is also an important reference in posterior ankle arthroscopy. Its location is important to know the site of the different working areas: subtalar and talocrural. The posterior subtalar recess is plantar to this ligament and the talocrural joint is located dorsally.

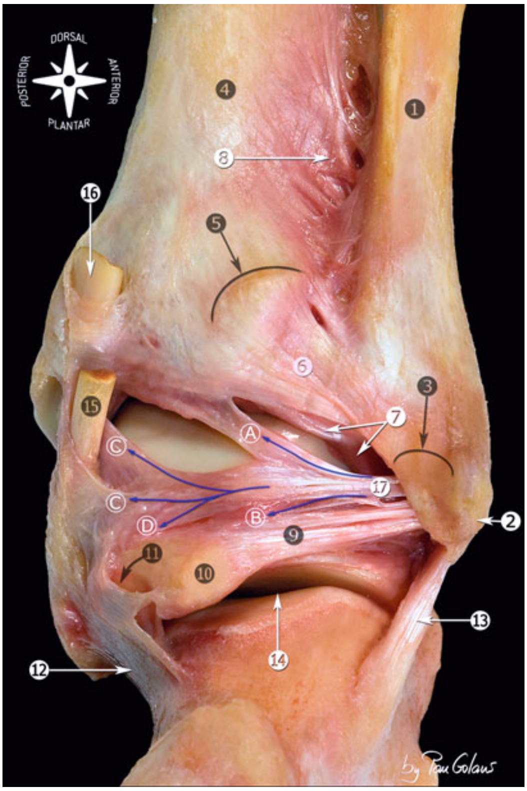


Fig. 5.1 Transverse section of the ankle at the syndesmotic level. *1* tibia; *2* anterior tubercle; *3* posterior tubercle; *4* fibular notch; *5* lateral malleolus; *6* anterior tibiofibular ligament; *7* posterior tibiofibular ligament; *8* peroneus brevis tendon and peroneus longus tendon; *9* tibialis posterior tendon; *10* flexor digitorum longus; *11* flexor hallucis tendon (musculotendinous); *12* calcaneal tendon; *13* posterior neurovascular bundle (posterior tibial nerve and posterior tibial artery and veins); *14* sural nerve and small saphenous vein; *15* tibialis anterior tendon; *16* extensor hallucis longus tendon; *17* extensor digitorum longus and peroneus tertius tendons; *18* anterior neurovascular bundle (deep peroneal nerve and anterior tibial artery and veins); *19* saphenous nerve and great saphenous vein

The posterior intermalleolar ligament has been the subject of recent studies because of its involvement in the posterior soft-tissue impingement syndrome of the ankle [16, 17]. Its prevalence of occurrence both in radiological and in anatomical

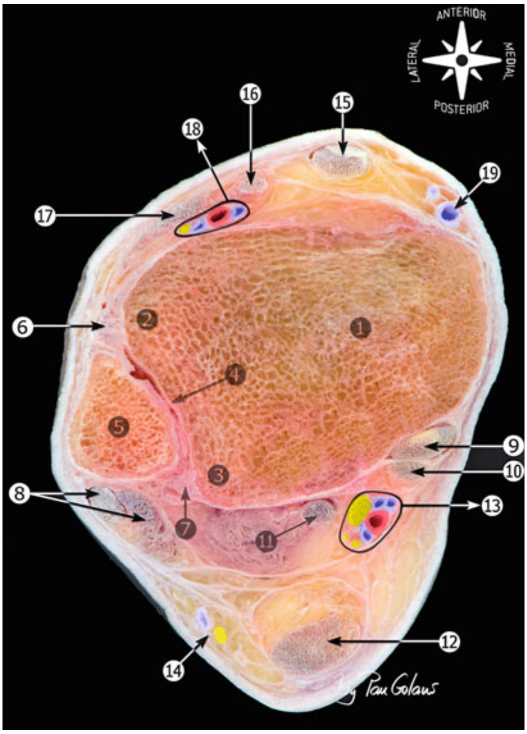


Fig. 5.2 Posterior view of the anatomical dissection of the ankle ligaments showing the posterior intermalleolar ligament with its relation to the surrounding anatomy. *1* fibula; *2* tip of the fibula; *3* peroneal groove of the fibula; *4* tibia; *5* posterior tubercle of the tibia; *6* superficial component of the posterior tibiofibular ligament; *7* deep component of the posterior tibiofibular ligament or transverse ligament; *8* interosseous membrane; *9* posterior talofibular ligament; *10* lateral talar process; *11* tunnel for flexor hallucis longus tendon; *12* flexor hallucis longus retinaculum; *13* calcaneofibular ligament; *14* subtalar joint; *15* flexor digitorum longus tendon (cut); *16* tibialis posterior tendon (cut); *17* posterior intermalleolar ligament: *A* tibial insertion (tibial slip in arthroscopic view), *B* talar insertion (lateral talar process), *C* tibial malleolar insertion through the septum between the flexor digitorum longus and posterior tibial tendons, *D* talar insertion (medial talar process) through the joint capsule (Extracted from the Knee Surg Sports Traumatol Arthrosc (2010) 18:557–569, Golano et al.)

studies varies widely, ranging from 19% up to 100% [17–19]. In my dissections, though, it is a consistent finding. In the posterior view, the posterior intermalleolar ligament is situated between the transverse ligament or deep component of posterior tibiofibular ligament and the posterior talofibular ligament and runs obliquely from lateral to medial and from downwards to upwards. The shape of the posterior intermalleolar ligament is variable. These variations depend on its medial arising sites, the number of composing fibre bundles and the degree of the bundle compactness. The medial arising sites of the ligament included the lateral border of the medial malleolar sulcus, the medial border of the medial malleolar sulcus through the septum between the flexor digitorum longus and posterior tibial tendons, the posterior distal margin of the tibia and the posterior process of the talus through the joint capsule reinforcement. This ligament is commonly resected during the posterior ankle arthroscopy. Although there is no study which determines this claim, it seems that resection has no significance in the talocrural joint stability. However, unnecessary resection may increase the occurrence of a talocrural arthrofibrosis.

Posterior or Posteror Inferior Tibiofibular Ligament. As is frequently observed, also for this rather strong compact syndesmotic ligament, numerous terminologies have been postulated [20], which is particularly evident in the arthroscopic literature [21]. This ligament is basically formed by two independent components, the superficial and deep component. The superficial component originates at the posterior edge of the lateral malleolus and directs proximally and medially to insert in the posterior tibial tubercle. This component would be homologous to the anterior tibiofibular ligament. The deep component is cone shaped and originates in the proximal area of the malleolar fossa to insert in the posterior edge of the tibia. Its insertion is immediately posterior to the cartilaginous covering of the inferior tibial articular surface; the fibres may reach the medial malleolus. This component is also known as the transverse ligament, forming a true labrum [22] to provide talocrural joint stability and to prevent posterior talar translation [23]. The transverse ligament or deep component should be routinely explored to assess its normal insertion on the tibia which may be affected, especially in trauma patients.

5.3 ICL 2: Surgical Anatomy of the Hindfoot Endoscopy

P.A.J. de Leeuw, M.D., P. Golano, M.D.,
and C.N. van Dijk, M.D., Ph.D.

Hindfoot endoscopy was originally described by the senior author in 2000 [12], thereby enabling the surgeon to more easily assess the posterior ankle compartment. Originally treatment of the os trigonum and flexor hallucis longus pathology was the main indication to perform a posterior ankle arthroscopy; nowadays, however, numerous pathologies can be treated and still indications are added.

The patient is positioned in the prone position with a tourniquet above the knee at the affected side, which should be carefully marked preoperatively. The affected ankle is positioned just over the edge of the operation table and is supported to allow free ankle movement (Fig. 5.3).

The anatomical landmarks for portal placement are the sole of the foot, the lateral malleolus and the medial and lateral borders of the Achilles tendon. With the ankle in the neutral position (90°), a straight line, parallel to the sole of the foot, is drawn from the tip of the lateral malleolus to the Achilles tendon and is extended over the Achilles tendon to the medial side. The posterolateral portal is located just proximal to, and 5 mm anterior to, the intersection of the straight line with the lateral border of the Achilles tendon. The posteromedial portal is located at the same level as the posterolateral portal, but on the medial side of the Achilles tendon (Fig. 5.4a, b).

The posterolateral portal is made as a vertical stab incision, and the subcutaneous layer is spread with a mosquito clamp [24]. The foot is now in a slightly (relaxed) plantar-flexed position. The clamp is directed anteriorly, towards the interdigital webspace between the first and second toes. When the tip of the clamp touches bone, it is exchanged for a 4.5-mm arthroscopic cannula with the blunt trocar pointing in the same direction. The trocar is situated extra-articularly at the level of the posterior talar process and is exchanged for the 4.0-mm 30° arthroscope, directed laterally. At this time, the scope is still outside the joint in the fatty tissue overlying the capsule.

Subsequently, the posteromedial portal is made with a vertical stab incision, and a mosquito clamp is introduced through the posteromedial portal and directed towards the arthroscope shaft at a right angle until the clamp contacts the arthroscope. The ankle is still in a slight plantar-flexed position, and the arthroscope has remained in position through the posterolateral portal, directed towards the first interdigital webspace. The arthroscope shaft is used as a guide for the mosquito clamp to travel anteriorly. While in contact with the arthroscope shaft, the clamp glides over

Fig. 5.3 For posterior ankle arthroscopy, the patient is placed in a prone position. A tourniquet is applied around the upper leg, and a small support is placed under the lower leg, making it possible to move the ankle freely. A support is placed at the ipsilateral side of the pelvis to safely rotate the operating table slightly when needed

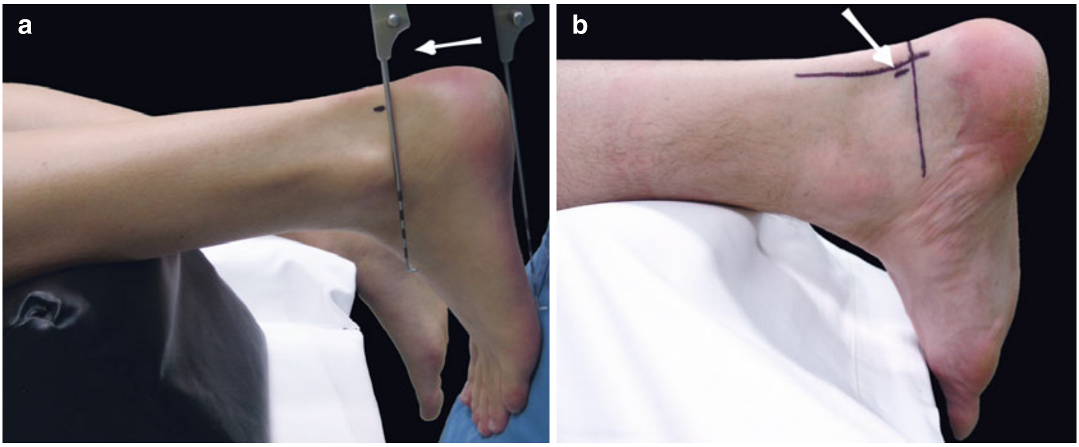


Fig. 5.4 (**a**) The portals are made with the ankle in a neutral (90°) position. An endoscopic probe can be very useful to determine the exact location of the posterolateral portal. The hook is "hooked" under the tip of the lateral malleolus. The hook is placed parallel to the foot sole (with the foot in a 90° position). A straight line is drawn from the tip of the lateral malleolus to the Achilles tendon, parallel to the foot sole. The posterolateral portal (*arrow*) is made just above the line from the tip of the lateral malleolus and 1 cm anterior to the Achilles tendon. (**b**) The posteromedial portal (*arrow*) is located at the same level as the posterolateral portal, just anterior to the Achilles tendon. An imaginary line can be drawn from the level of the posterolateral portal over the Achilles tendon to determine the location of the posteromedial portal

the shaft towards the ankle joint until bone is reached. Once the arthroscope and clamp are both touching bone, the mosquito clamp is left in position and the arthroscope is pulled slightly backward and tilted until the tip of the clamp comes into view. The soft-tissue layer covering the joints consists of fatty tissue and the deep crural fascia. At the lateral side, a specialized part of the crural fascia can be recognized, which is called the Rouvière ligament.

After penetrating this ligament, the lateral part of the subtalar joint can be visualized. Now the mosquito clamp is exchanged for a shaver. Introduction of the shaver should be performed exactly similar to the way the mosquito clamp was. While visualizing the lateral part of the subtalar joint, the soft tissue medially is resected with the shaver. While shaving medially, the head of the shaver should be facing the arthroscope, thereby avoiding damage to the flexor hallucis longus tendon. Before addressing any pathology, this tendon should be localized since, just medially to it, the posterior neurovascular bundle is located. The flexor hallucis longus tendon determines the working area, basically only lateral to this tendon.

Now the pathology can be addressed, ranging from debridement of soft tissue, removal of an os trigonum, addressing the Cedell fracture, release of the flexor hallucis longus tendon or performing a groove deepening in case of recurrent peroneal tendon dislocation, etc.

5.4 ICL 3: Particular Posterior Impingement Cases

T. Ögüt, M.D.

5.4.1 Introduction

Posterior ankle impingement is a pain syndrome. The patient experiences posterior ankle pain mainly on forced plantar flexion. It is caused by overuse or trauma, and the first one has a better prognosis. Posterior ankle impingement is very common in ballet dancers and runners.

Potential causes of deep posterior ankle pain are soft-tissue injuries (e.g. flexor hallucis longus (FHL) tenosynovitis, synovitis due to rheumatological or tumoral diseases), bony or osteochondral injuries (e.g. os trigonum syndrome, osteochondral defects, intraosseous talar cysts, tarsal coalition) and neurovascular injuries (e.g. sural nerve entrapment, tarsal tunnel syndrome). Today, most of them can be treated endoscopically [25].

In this lecture, four ankles of three cases will be presented with their arthroscopic videos and preoperative pictures.

5.4.2 Case Presentations

The main complain of all three cases was deep posterior ankle pain, and they all revealed positive posterior impingement test.

Cystic lesions of different sizes in the posterior portion of talus were detected in four ankles of three patients. The bilateral case (case 1) was treated with a sole operation. On MR imaging, one patient (case 3) revealed suspected pigmented villonodular synovitis (PVNS) of posterior ankle compartment additionally. All patients had flexor hallucis longus (FHL) tendinitis diagnosed from *clinical and radiological* evaluations [26]. The FHL tendon was painful for all patients upon physical examination. In addition, radiographs revealed os trigoni in all affected ankles. On MRI sections, FHL tendons in all ankles and os trigoni in three ankles were oedematous. In case 3, FHL tendon was affected by suspected PVNS, beginning from subtalar joint level and extending until 4 cm proximal to it. Preoperative conservative treatment was ineffective for all patients. The median preoperative AOFAS score was 62 points.

According to clinical and radiological findings, the cause of symptoms was unable to be attributed to one specific pathology (os trigonum, FHL tendinitis or talar cystic lesion). Therefore, all patients underwent a single hindfoot endoscopic procedure in order to treat all possible pathologies [24].

Case 1: A 35-year-old male. He had bilateral talar cysts and treated with a sole operation. The preoperative radiological diagnoses of cystic lesions were intraosseous ganglia (Figs. 5.5a–d and 5.6a–d).

Case 2: A 32-year-old male. He had a big talar cyst in his right talus. The preoperative radiological diagnosis of cystic lesion was simple bone cyst (Fig. 5.7a–c).

Case 3: A 22-year-old female. She had a talar cyst in posterior part of his right talus and severe, lobulated tenosynovitis around the FHL tendon arising from fibro-osseous tunnel orifice, extending 4 cm long proximally (Fig. 5.8a–e). The preoperative radiological diagnosis was PVNS localized to the posterior compartment of the ankle joint and invasing the posterior part of the talus.

5.4.3 Surgical Technique

Surgeries were performed under general anaesthesia as outpatient procedures. The patients were placed in the prone position, and a tourniquet was applied at the level of the thigh. Standard posteromedial and posterolateral arthroscopic portals were used to access the talus [25]. A 4.0-mm arthroscope with a 30° viewing angle was utilized to visualize the site. In all patients, there were adhesions and scar tissue around the FHL tendon which were debrided with a 4.5-mm shaver. Os trigonum was excised by partially cutting the posterior talofibular ligament with a punch. Soft-tissue debridement was completed by the removal of

Fig. 5.5 (**a**–**d**) Case 1: left side: X-ray and MR images

hypertrophic synovial and adhesive tissues around the FHL tendon with a 3.5-mm shaver which freed the FHL from the surrounding scar tissue and the stenosing retinaculum (Fig. 5.9a–d). In case 3, the FHL tendon was surrounded with pigmented synovitis along its entire visible length. Posterior ankle compartment was also covered by a pigmented villonodular tissue (Fig. 5.10a–c). Following debridement of all the pigmented tissues, a window was opened on the posterior wall of the talar process with a 3.5-mm drill (Fig. 5.10d). Localization of the lesions was determined from MRI. If the window was obstructed by the FHL tendon, a thin and blunt retractor was introduced from the posteromedial portal to retract the tendon medially. A third accessory portal was opened 0.5–1.0 cm proximal to the posteromedial or posterolateral portal depending on the case. The retractor was always kept on the posteromedial side, and the shaver or curette was consistently used through the posterolateral portal. The scope was introduced

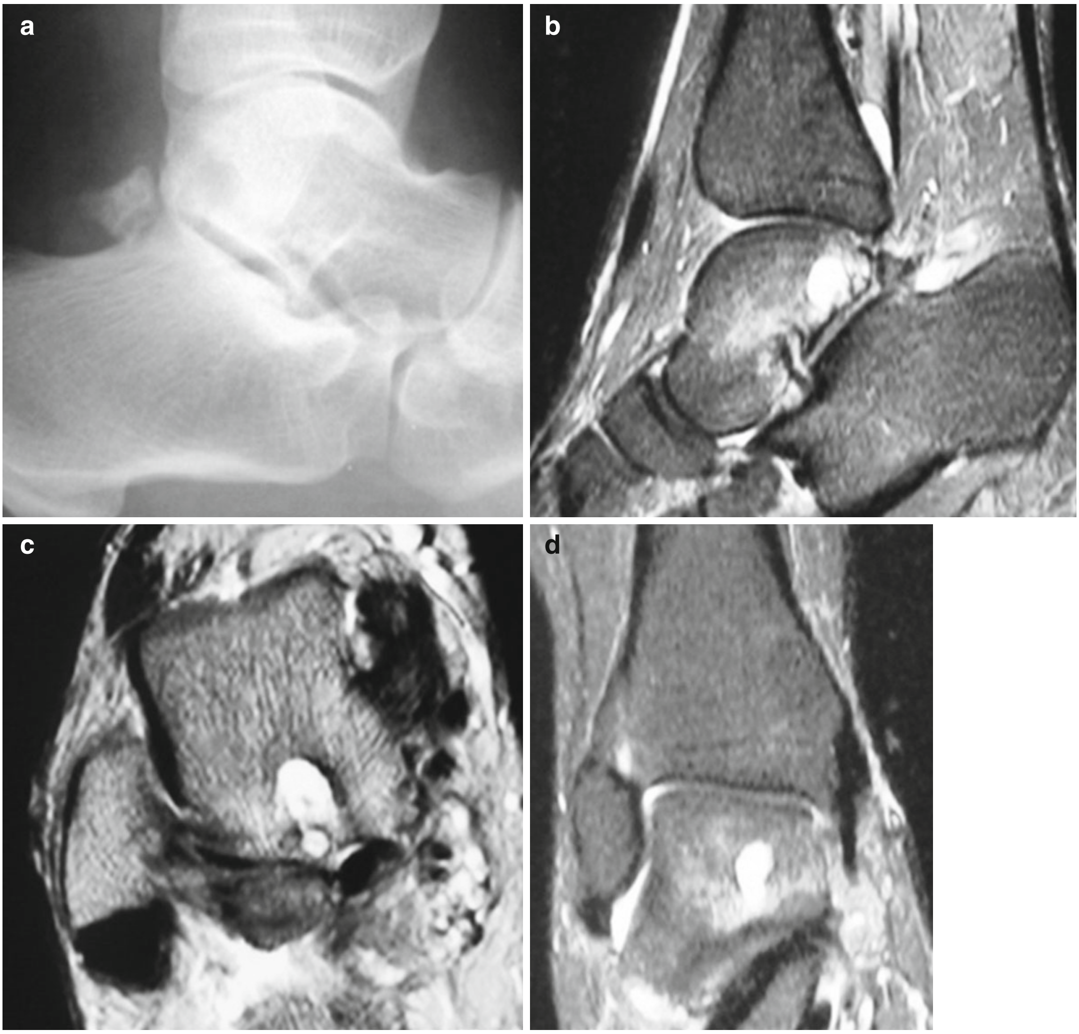


Fig. 5.6 (**a**–**d**) Case 1: right side: X-ray and MR images

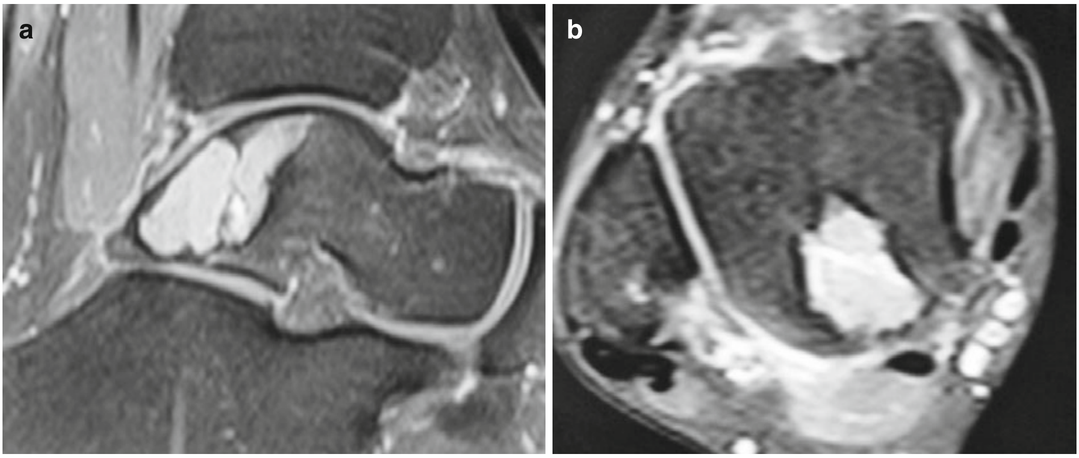


Fig. 5.7 (**a**–**c**) Case 2: MR images of the lesion

Fig. 5.7 (continued)

through the third distal portal on the posteromedial or posterolateral side depending on the case (Fig. 5.11). Cyst content was extruded with a curette; further debridement was performed with a burr and multiple drill holes opened via Kirschner wire in the interior wall of the cyst cavity (Fig. 5.12a–d). A trocar was introduced through a portal, and the cavities were filled with autografts which had been harvested from the posterior superior iliac spine (PSIS) in all patients except one. In case 3, hydroxyapatite (TriPore™ HA – synthetic porous hydroxyapatite) was used (Fig. 5.10e). The cavity was then impacted tightly with grafts to prevent migration during ankle motion (Fig. 5.13a–d) [25].

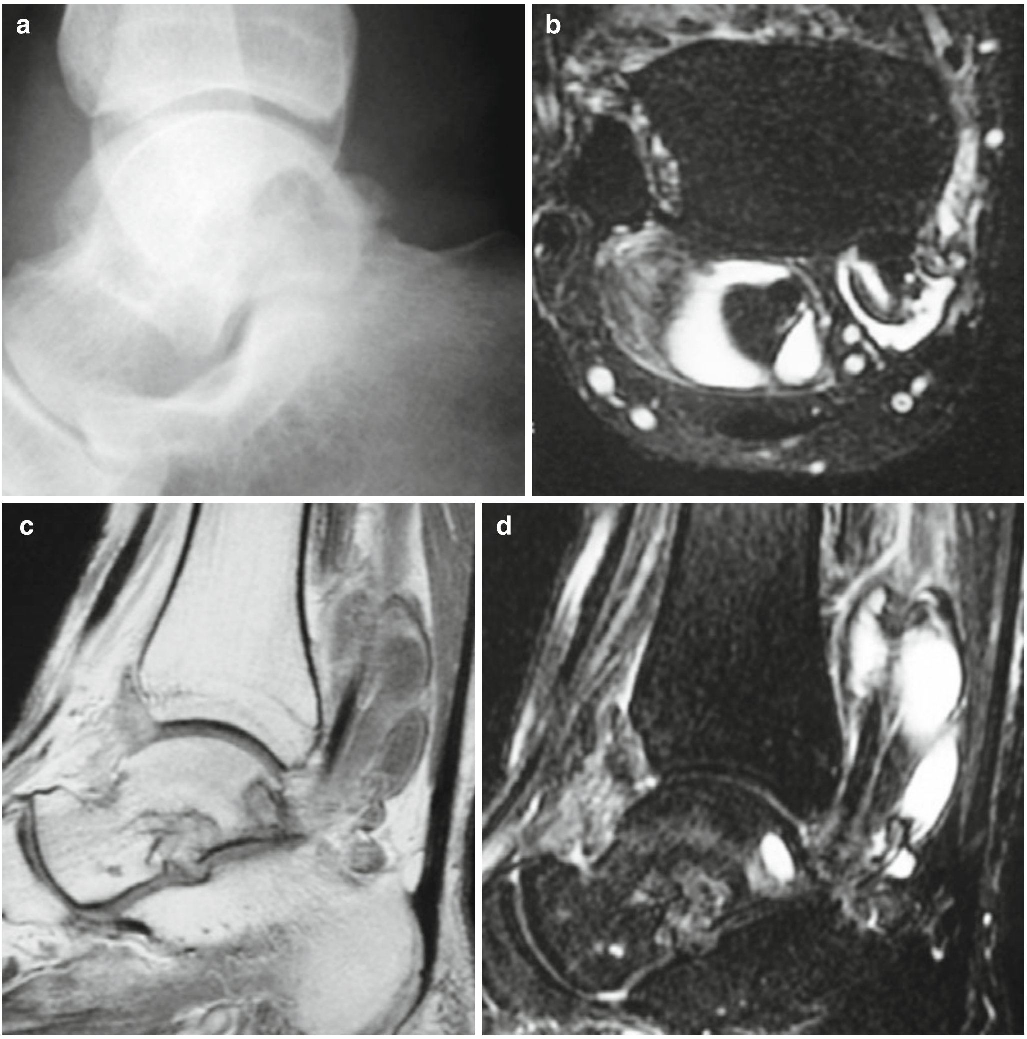


Fig. 5.8 (**a**–**e**) Case 3: X-ray and MR images of the lesion

Fig. 5.8 (continued)

5.4.4 Results

Following histological examination, the preoperative diagnoses were unchanged postoperatively. After a median postoperative follow-up time of 36 months, the median AOFAS score was improved to 93 points. All patients were free from moderate or severe pain at their final physical examination. Graft union was demonstrated by CT scan in all patients (Figs. 5.14a–c, 5.15a, b, and 5.16a–e). There were no complications during surgery or in the postoperative follow-up period.

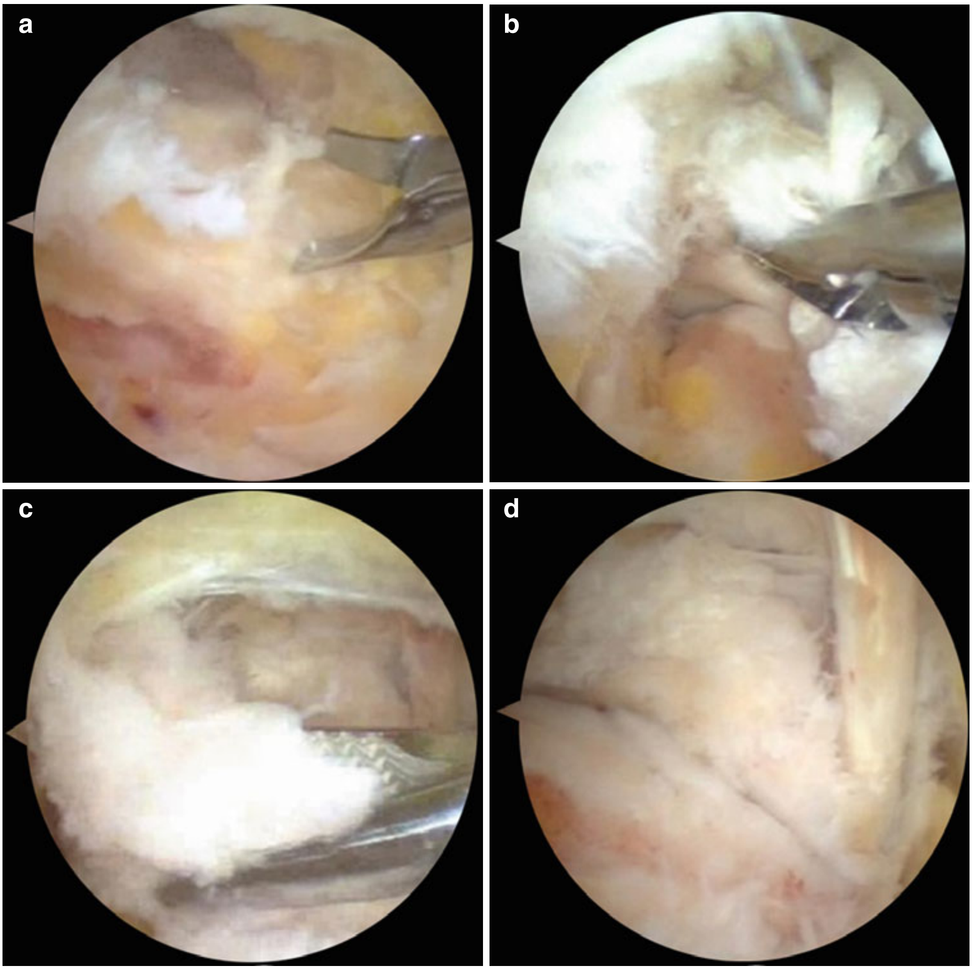


Fig. 5.9 Left ankle of case 1. (**a**–**c**) Os trigonum removal and debridement of scar tissue; (**d**) released FHL tendon, posterior ankle and subtalar joints

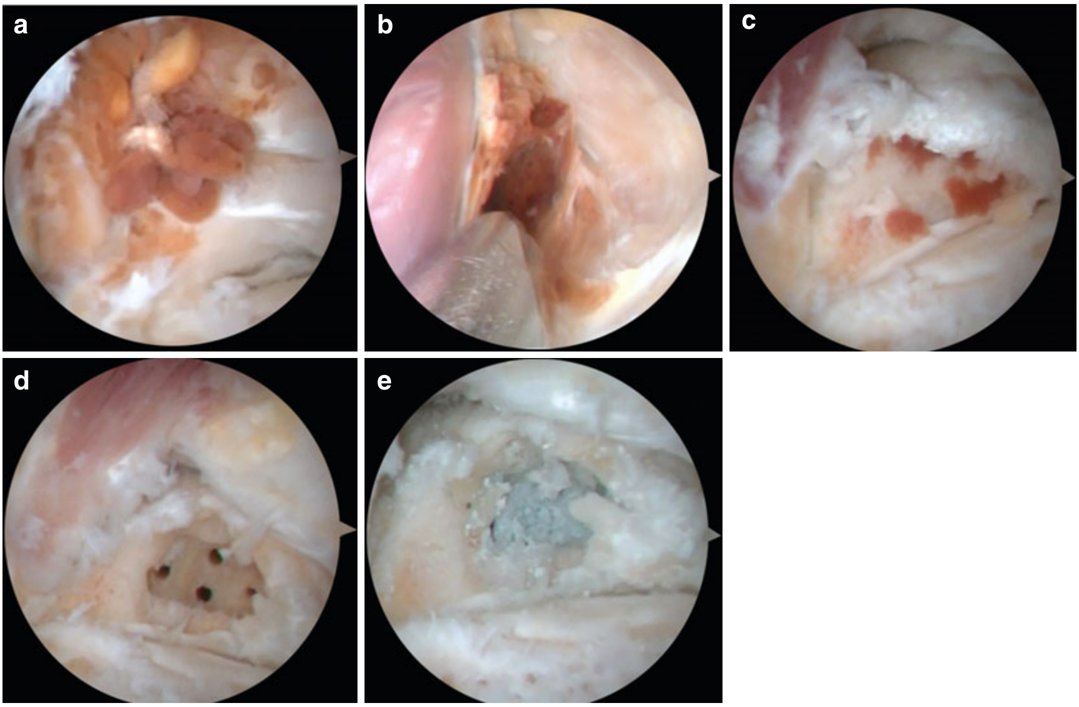


Fig. 5.10 Endoscopic views of case 3. (**a**) Pigmented villonodular synovitis on the FHL tendon, which hides the tendon; (**b**) the shaver is in the recess of the FHL muscle sheath, at 4 cm proximal to the subtalar joint level, shaving the pigmented synovitis around the muscle; (**c**) after fenestration in to the cyst, a similar pigmented tissue came out of the cyst; the FHL tendon and muscle can be recognized after shaving of the surrounded synovitis; (**d**) the view after debridement of all the synovitis and pigmented tissues, curettage of the cyst and drilling of the cyst wall; (**e**) cyst filled with hydroxyapatite

Fig. 5.11 Right ankle of case 2. Retractor in posteromedial portal retracts the FHL tendon medially, while scope and shaver are used through two posterolateral portals. The tip of retractor is thin and blunt

5.4.5 Discussion

Hindfoot endoscopy can be used for the treatment of intraosseous talar cysts that are posteriorly localized and for PVNS which is localized to the posterior ankle compartment even if it is invasing the posterior part of the talus and extends proximally along the FHL tendon sheath. Significant advantages of this method include lower morbidity and shorter postoperative hospitalization time. Hindfoot endoscopy is a safe and effective method for treating posterior talar cystic lesions and is an attractive alternative to open surgery for experienced arthroscopic surgeons.

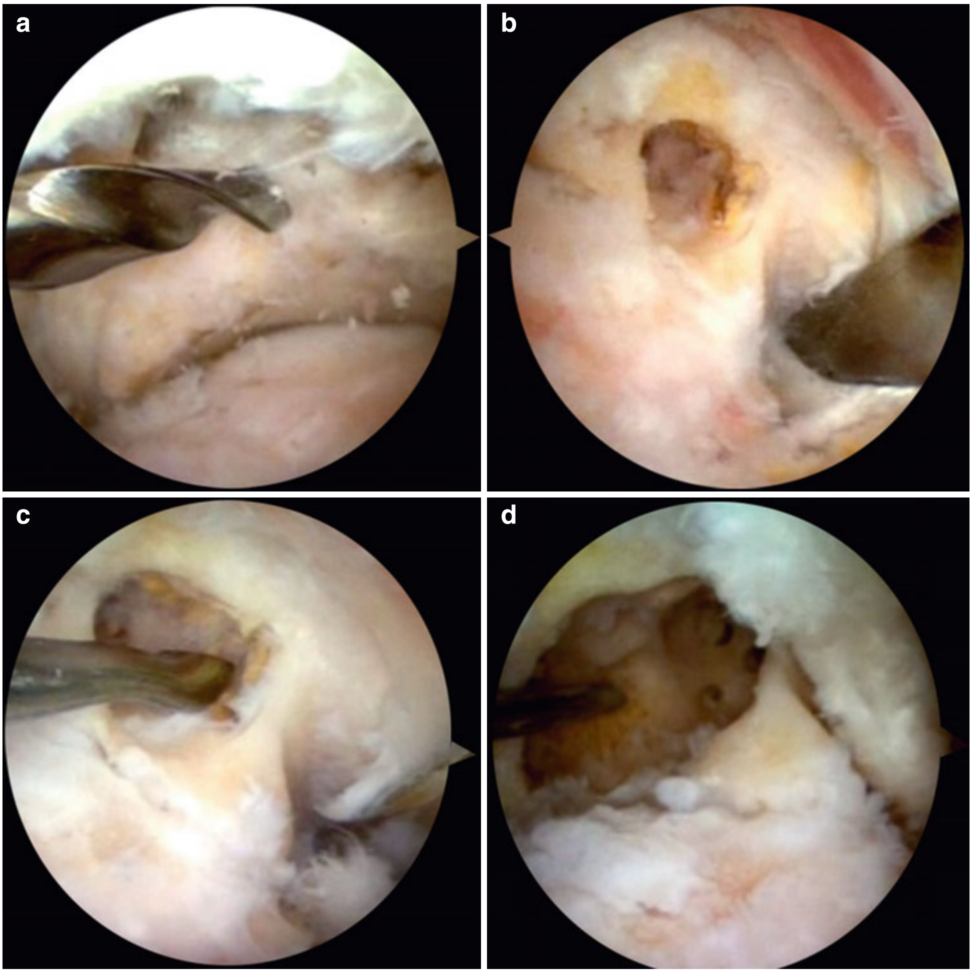


Fig. 5.12 (**a**) Fenestration of the cyst, (**b**) retraction of FHL tendon, (**c**) curretage of the cyst, (**d**) drilling of the cyst wall

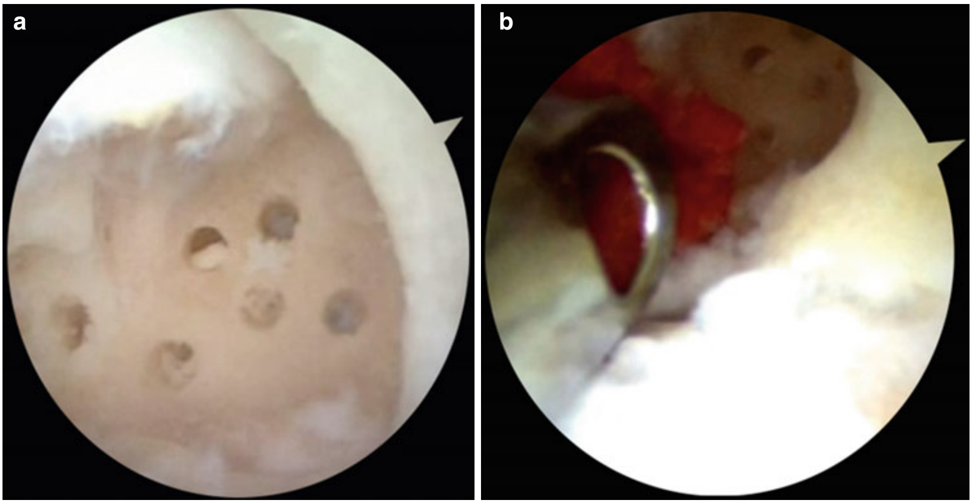


Fig. 5.13 (**a**) Drilled cyst wall, (**b**) filling autografts through a trocar, (**c**) impaction of the cavity with autografts, (**d**) end view

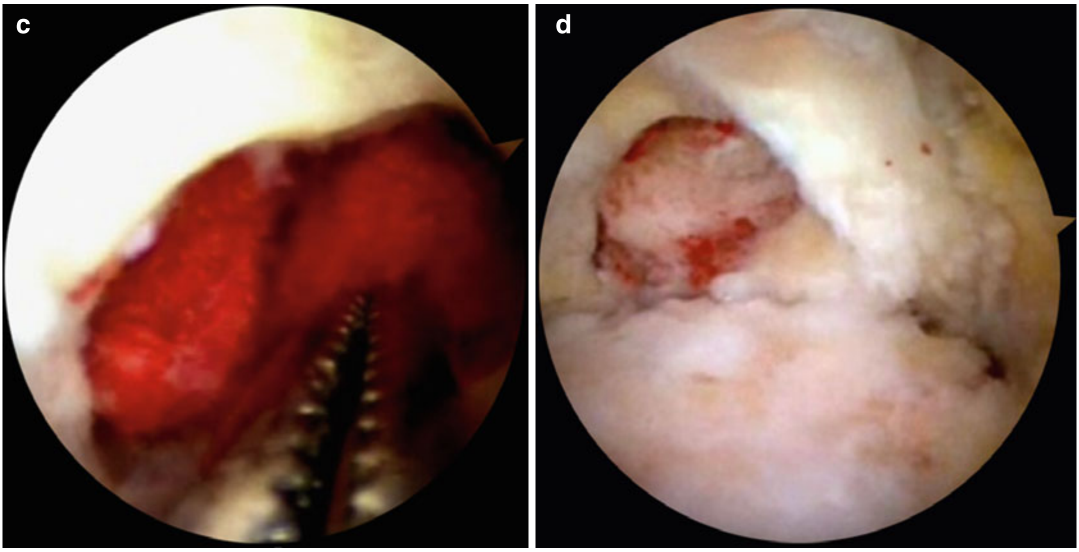


Fig. 5.13 (continued)

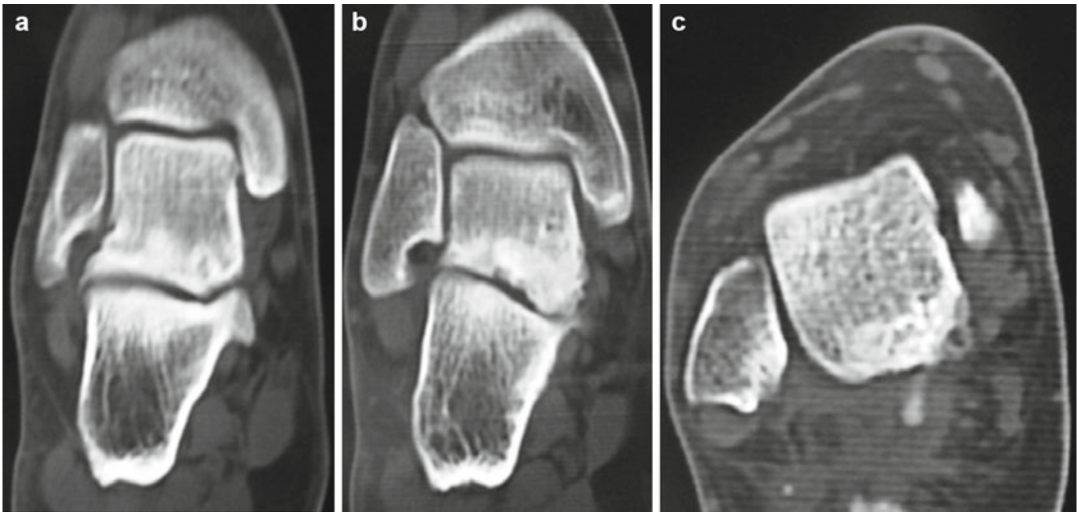


Fig. 5.14 (**a**–**c**) CT scans of case 1 left side, 20 months postoperatively

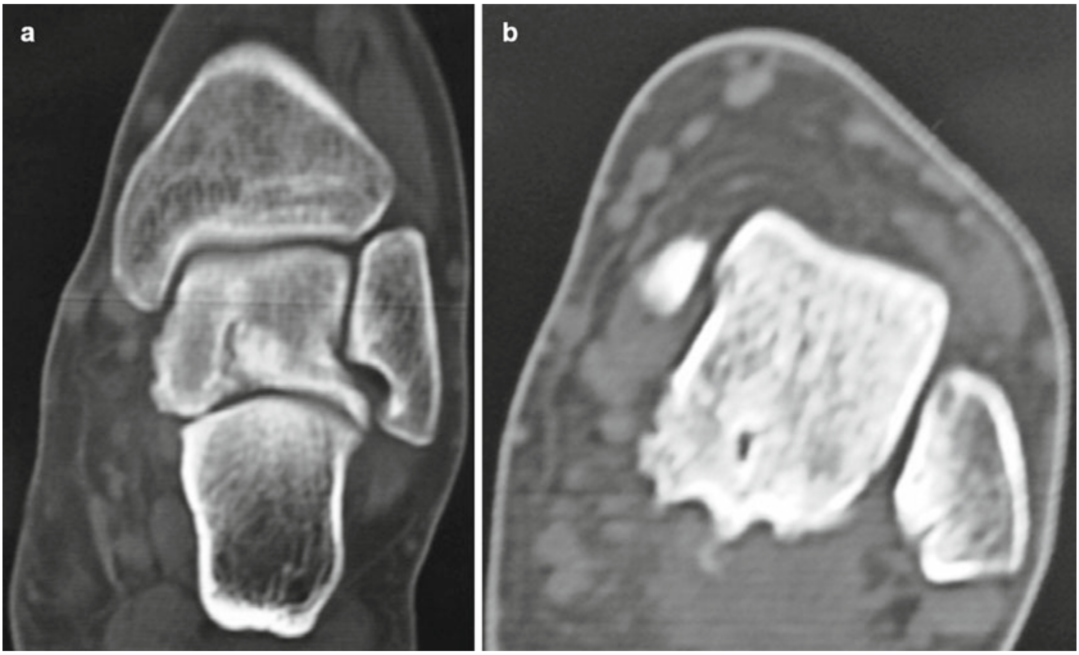


Fig. 5.15 (**a**, **b**) CT scans of case 1 *right* side, 20 months postoperatively

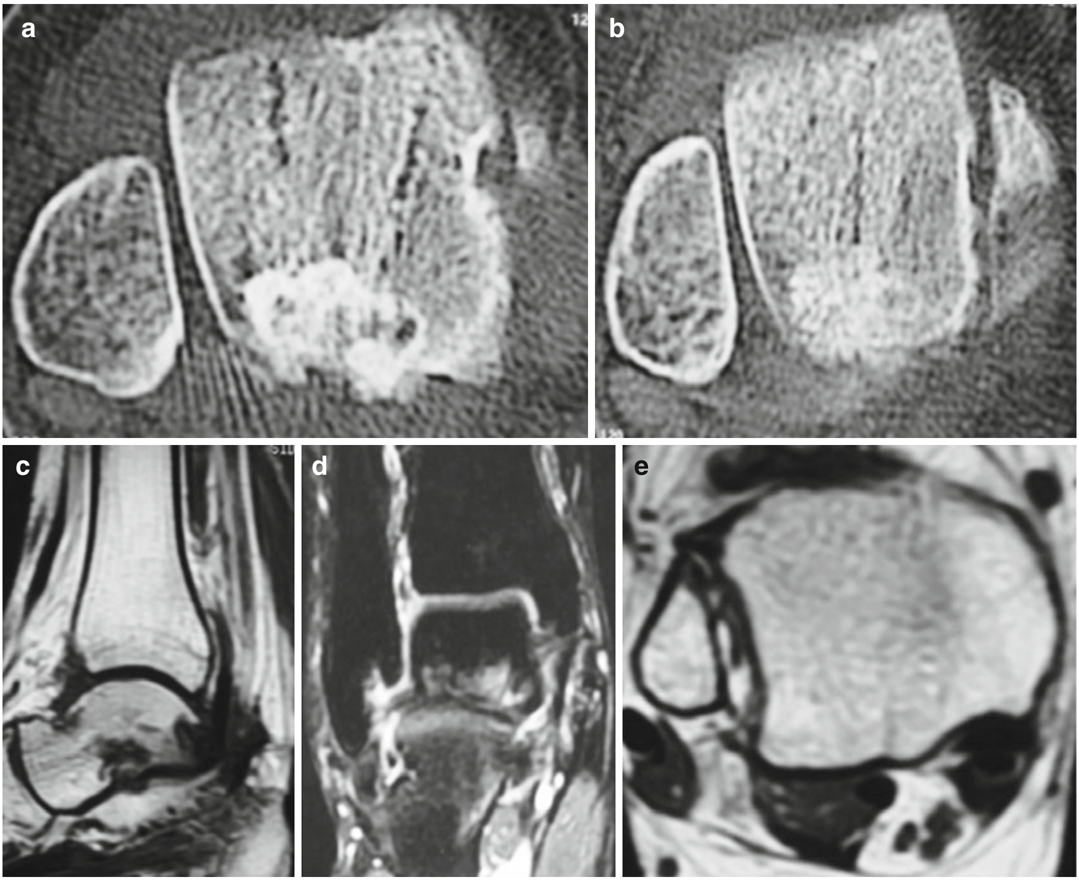


Fig. 5.16 (**a**–**e**) CT scans (**a**, **b**) and MR images (**c**–**e**) of case 3, 1 year postoperatively

5.5 ICL 4: Arthroscopic Subtalar Arthrodesis

P. d'Hooghe, M.D.

The subtalar joint is a complex joint that is functionally responsible for inversion and eversion of the hindfoot. Treatment options are limited when hindfoot discomfort can be isolated to the subtalar joint without radiographic evidence of arthrosis. Medication, physical therapy and orthoses have a limited role.

With the introduction of small instruments and precise techniques, arthroscopy of the subtalar joint has expanded over the past decade.

In 1905, subtalar arthrodesis was first described by *Nieny*. In 1985, arthroscopy of the subtalar joint was first described by Parisien and *Vangsness* [27]. Arthroscopic subtalar arthrodesis was then consequently introduced by *Tasto* in 1992 [28].

The further techniques that followed fine-tuned this procedure, with emphasis on:

- The intention to yield *less morbidity* and preserve *blood supply.*
- The intention to preserve *proprioception and neurosensory input.*
- Increase the *fusion rate and* decrease the *time until fusion.*
- The decrease in significant complications.

In 2009, a three-portal approach for arthroscopic subtalar arthrodesis was introduced to offer full exposure and treatment on the posterior facet of the subtalar joint [29] (Fig. 5.17).

The advantages of the arthroscopic subtalar arthrodesis technique are:

- Bony union after 6 weeks.
- Prone position during the procedure offers excellent exposure for alignment positioning and screw placement.
- Time-efficient technique.
- The full posterior facet of the subtalar joint can be addressed by using the third accessory portal.

The limitations of the procedure are:

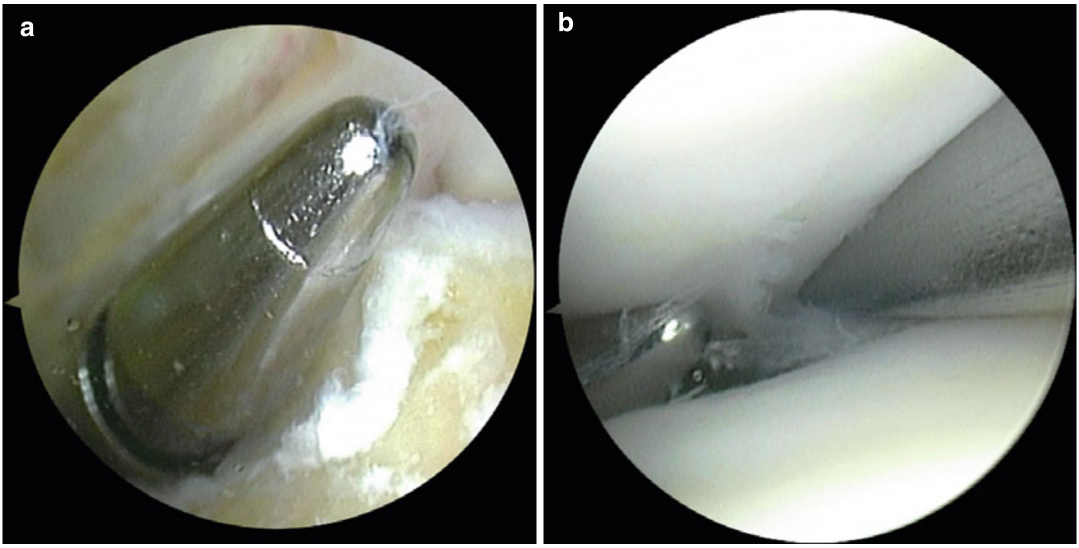


Fig. 5.17 (**a**–**g**) Intra-operative views of arthroscopic subtalar arthrodesis in a patient with a talocalcaneal coalition. (**a**) The blunt trocar is positioned laterally of the subtalar joint via the accessory sinus tarsi portal. (**b**) The blunt trocar is sidewards forced into the subtalar joint. Using a small size chisel, an attempt is made to destruct the medially located talocalcaneal bar. (**c**) and (**d**) Ring curettes are used for removal of articular cartilage from the posterior subtalar joint. (**e**) It is important to remove all cartilage from the posterior subtalar joint. A bone cutter shaver may also be used for this purpose. (**f**) Longitudinal grooves are cut in the subchondral bone of the talus and calcaneus using the small size chisel. (**g**) Under arthroscopic view, the screws are tightened, and coaptation of the posterior subtalar joint surfaces is seen (Extracted from [29])

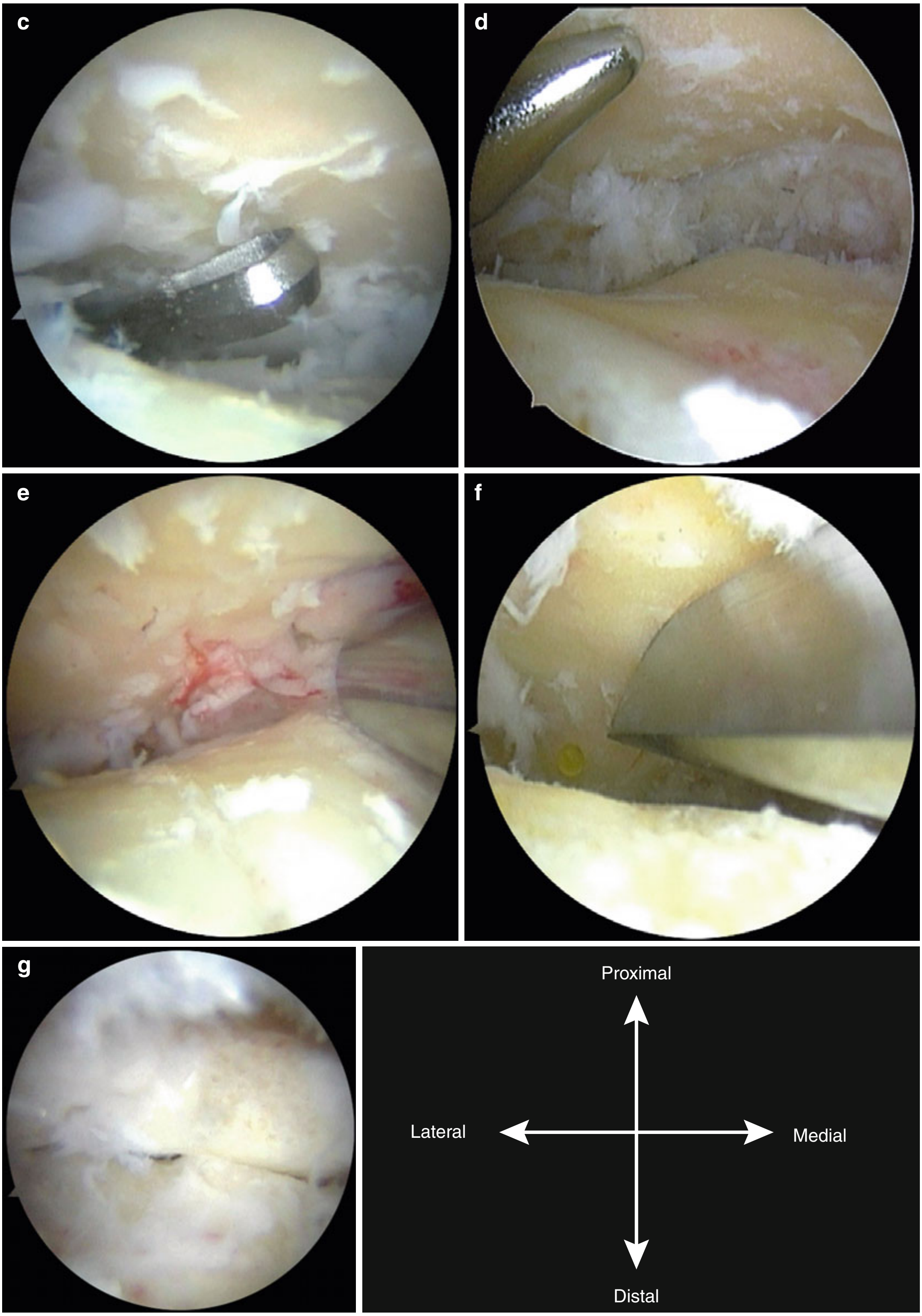


Fig. 5.17 (continued)

- The technical challenges, especially in the lateral coalition cases.
- Only the posterior facet of the subtalar joint can be treated.
- There is not always a macroscopic idea on the level and amount of resection.

Regarding indications and results in athletes, best improvement in AOFAS and Tegner score for this procedure was seen in talocalcaneal coalition cases with full return to play after 4–7 months. The described three portal technique is therefore nowadays routinely used for this indication by van Dijk. [29])

Further studies are required to search for the impact of this treatment on the ankle and its function, especially in the athlete's ankle.

5.6 ICL 5: Posterior Ankle Arthroscopic Arthrodesis

G.M.M.J. Kerkhoffs, M.D., Ph.D., R.P. Hendrickx, M.D. and C.N. van Dijk, M.D., Ph.D.

5.6.1 Introduction

Several methods have been described for fusion of the ankle joint. Secure fusion can be accomplished arthroscopically, open or using a so-called mini-open technique [4, 30–34]. An open procedure allows for an easier realignment of the foot when significant deformity is present. Arthroscopically assisted fusion is becoming more popular with rising union rates and lower complication rate compared to open surgery [30, 33, 34]. A number of different fixation techniques have been described in literature. Laboratory and finite-element studies advocate that screw fixation results in a highly resistant construction. Screws crossing above the fusion point positioned in a 30° angle on the tibial axis seem to be beneficial in producing rigid fixation [35–37]. Parallel placed screws, however, tend to allow for greater compression [38]. The use of flat cuts allows better correction in severely deformed ankle joint. However, in vitro experiments demonstrate improved initial stability when contour-shaped joint surfaces are used [37, 39, 40]. We developed an arthroscopic technique that combines the best compression with an improved initial stability.

5.6.2 Methods

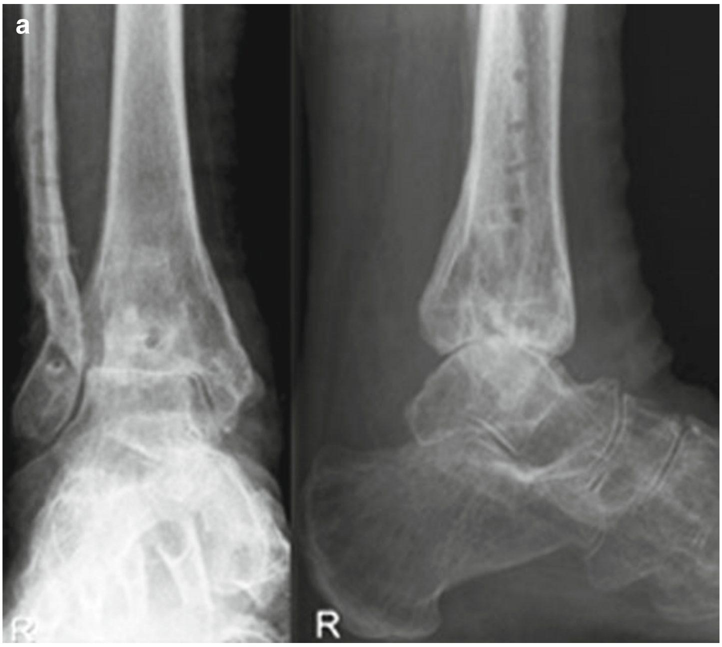
A prospective study was started with approval of the local Research Ethics Committee. The inclusion criterion was patients with end-stage osteoarthritis of the ankle. All but one (CVD) procedures were performed by a single surgeon (GK). The primary exclusion criterion was re-arthrodesis. The secondary exclusion criterion was inability to understand the patient information and the questionnaires. From January 2010 to December 2011, a total of 20 patients (20 ankles) were operated using the arthroscopically assisted technique. All patients are assessed using AOFAS and FAAM questionnaires before surgery and yearly after surgery. Clinical assessment is performed in the outpatient clinic using a standardized follow-up protocol. Radiographic investigation for the assessment of fusion is performed at 6 and 12 weeks postoperatively.

5.6.3 Operative Treatment

A standard technique for posterior ankle arthroscopy [12, 24] is used for debridement of the tibiotalar joint surfaces with an additional anteromedial ankle portal to be able to distract the ankle joint and to be able to debride the anterior distal tibial and anterior talar surface if this cannot be reached from posterior. The cartilage, of both the talus and tibia, is removed and the subchondral plate damaged (Fig. 5.18a–d). Then under fluoroscopic control, two 6.5-mm cancellous screw are inserted through the Achilles tendon with the ankle in the desired position [41, 42].

5.6.4 Results

The data on the first nine patients are presented in this publication. The male to female ratio is 3:6. Mean age at surgery was 57 years (range 38–80). There are six post-traumatic cases, two primary and one postinfectious. Mean body mass index was 27 (range 20–41). The preoperative AOFAS ankle hindfoot score was 32 (range 16–58), and postoperative score at 1-year follow-up was 74 (range 55–84). The preoperative pain perceived with daily activities was graded 8 (range 2–10) on a visual analogue scale, and postoperative score at 1-year follow-up was 1 (range 0–3). Mean operation time was 84 min (range 66–100). At 3 months following surgery, eight ankles showed solid fusion. One ankle was clinically fused, although radiologically fusion was graded “progressive”. No complications during surgery, no infections, and one screw was removed after 6 months.



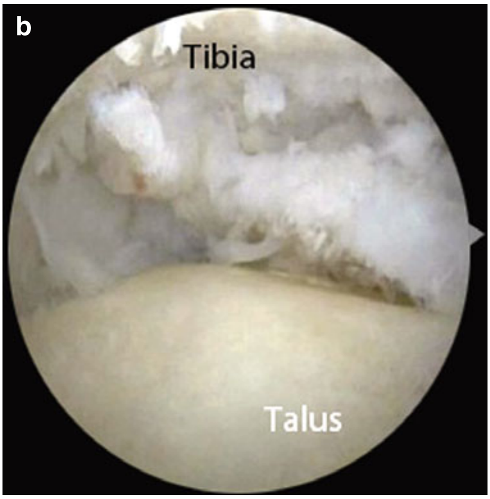


Fig. 5.18 (**a**–**d**) Case presentation: A 65-year-old female patient sustained a trimalleolar right ankle fracture in 2010, treated with an open reduction and internal fixation. The postoperative period was complicated by an osteomyelitis of both the medial and lateral malleolus. In the follow-up period, the patient complains of progressive pain and stiffness despite removal of the hardware. (**a**) Anterior to posterior radiographs indicating post-traumatic/infectious osteoarthritis. (**b**) Preoperative arthroscopic image; postinfectious tissue has been removed on talar surface through the posteromedial – and lateral portal; tibial side shows postinfectious tissue before removal. The anteromedial portal was used to distract the ankle joint. (**c**) Postoperative radiographs; two 6.5-mm cancellous screws are in position. (**d**) 6-week follow-up radiographs; fusion of the ankle joint

Fig. 5.18 (continued)

5.6.5 Conclusion

Posterior ankle arthroscopic arthrodesis is a challenging, but safe and effective technique.

Conclusion

Posterior ankle arthroscopy was first reported in 2000 and has proven to be a reliable endoscopic technique to treat a wide variety of ankle pathologies. The initial indications included flexor hallucis longus pathology and the os trigonum. Nowadays, however, the technique is used, with or without an additional portal, for an increasing amount of pathologies, and the limits are not yet reached.

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6

Anatomy – Biomechanics – Novel Imaging of the Native PCL

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6.1 Anatomy and Biomechanics

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The PCL is considered an intra-articular and extra-synovial structure and its dimensions have been well described. Its length is 32–38 mm with a cross-sectional area of 11 mm^2, and the bony insertion sites are three times larger than its mid-substance [11]. The average area of the femoral footprint of the anterolateral (AL) bundle is 118 ± 23.95 and of the posteromedial (PM) bundle is 90 ± 16.13 [23]. The distance from the medial articular cartilage has been found at 13 mm posteriorly and inferiorly [33]. The average area of the tibial footprint of the AL bundle is 93.1 ± 16.6 and of the PM bundle is 150.8 ± 31 [48]. The distance from the medial articular cartilage has been found at 8 mm posteriorly and 20 mm inferiorly. Both bundles insert as a unique tendon on the posterior aspect of the tibia approximately 1–1.5 cm distal to the joint line and their centre is located, medial to lateral, 48% of the width of the tibial plateau [8].

The meniscofemoral ligaments originate from the posterior horn of the lateral meniscus and insert on the medial femoral condyle anteriorly (ligament of Humphrey) and posteriorly (Wrisberg) to the PCL. The combined cross-sectional area of the anterior and posterior meniscofemoral ligaments makes up 17.2% of the PCL complex cross-sectional area [34]. It has been reported that the meniscofemoral ligaments play a role as a secondary stabilizer of the knee against posterior tibial translation [6].

It has been found that the mean ultimate load for the AL bundle is 1.120 ± 362 N and for the PM bundle 419 ± 128 N [14]. Knowledge of the biomechanics obtained from flexibility-approach experiments has shown that the PCL provides the primary restraint to posterior tibial translation at all angles of flexion of the knee with a maximum at 90° of flexion. In contrast, isolated sectioning of the ligament did not increase external rotation and varus angulation. However, combined sectioning of the PCL, lateral collateral ligament and structures of the posterolateral corner led to increased posterior translation at 30° of flexion, varus angulation at all angles of flexion and increased external rotation at 60° and 90° of flexion [12]. Moreover, other biomechanical studies have shown that the PCL is a non-isometric structure; the AL bundle becomes longer and more vertical from 0° to 120° of flexion, while PM bundle becomes shorter and more horizontal [1]. Regarding the meniscofemoral ligaments, it has been postulated that they function as additional stabilizers of the knee resisting posterior translation, particularly when the PCL has been ruptured [32].

6.2 Study on Its Bony and Soft Tissue Anatomy Using Novel 3D CT Technology

6.2.1 Introduction

The insertion sites of the PCL have been studied and described extensively using 2D technology such as macroscopic images, plain x-ray, computerized tomography (CT) and MRI.

Recently, 3D imaging and segmentation technology has been introduced into the orthopaedic field to improve our understanding of the complex *bony* anatomy of the human knee. Such information has led to better understanding of the bony insertion sites of the native cruciate ligament and has been translated recently into the clinical practice as the anatomical ligament reconstruction concept. The definition of anatomical ligament reconstruction only includes bony references such as a centre-tibial footprint to centre-femoral footprint tunnel position and at least 80% footprint coverage. This concept, however, does not take into account soft tissue references such as the course and volume of the native ligament, as 3D visualization of *soft tissue* anatomical structures such as the PCL has not yet been performed using CT images.

The purpose of this study is to visualize both the tibial and femoral bony insertion sites but also the soft tissue anatomy of the native PCL using novel 3D CT imaging. In addition, new concepts of best-fit cylinder and central axis are introduced

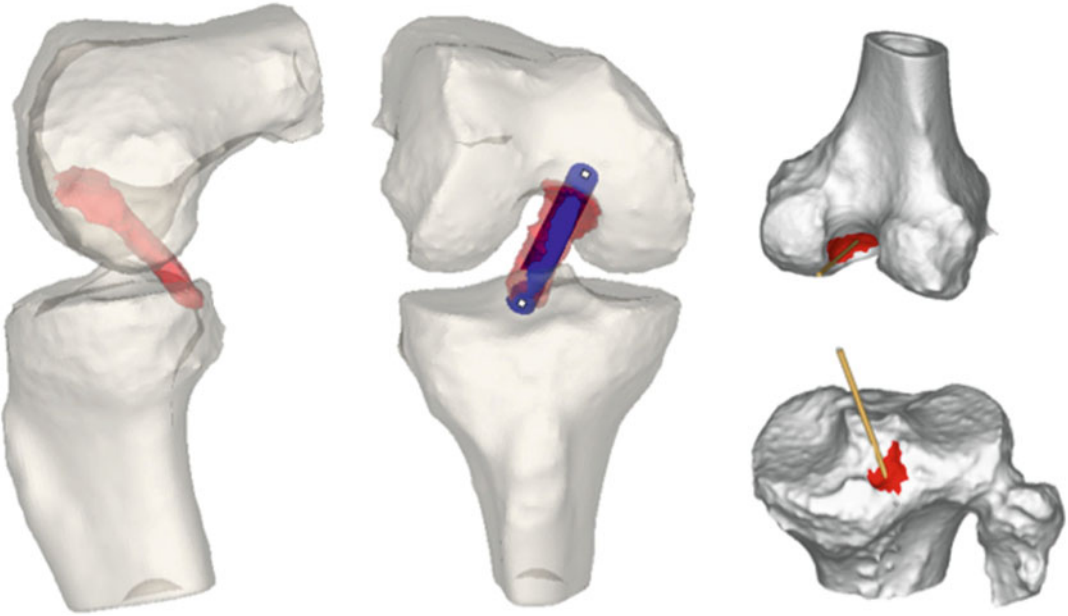

Fig. 6.1

and evaluated. The central axis represents the best-fit cylinder around the native PCL fibres as determined by an automated computerized process. The central axis bony insertion therefore depicts the ideal tunnel position to enclose the majority of ligament fibres. This information can be useful for ligament reconstructive purposes.

6.2.2 Results

6.2.2.1 Anatomical Description

Based on anatomical dissection, interpretation of specific collagen tissue contrasted CT, 3D reconstructions of the native PCL and tibial plateau and intersection area, we found that the posterior cruciate ligament was attached to the posterior intercondylar area between the tibial plateaus and posteriorly of the intercondylar eminences.

In line with the topographical studies of Forsythe et al. (2009) and Tajima et al. (2009), we also found the PCL consisting of two bundles inserting in different planes on the posterior intercondylar area. In almost every 3D native PCL, the anterolateral and posteromedial bundle is clearly detectable. Two slopes can be identified on insertion area of the PCL: (1) an anterolateral slope, located at the superolateral aspect of the posterior intercondylar area, to which the anterolateral bundle is attached and (2) a posteromedial slope, in the inferomedial aspect of the fossa, which is the insertion area for the posteromedial bundle.

In cranial direction, the PCL inserts on the lateral surface of the medial femoral condyle in the intercondylar fossa. This insertion area is bounded caudally by the rim of the articular surface of the medial condyle and cranially by the medial intercondylar ridge depicted in most knee samples. The medial bifurcate ridge, described in Forsythe et al. (2009) as a small osseus prominence between the anterolateral and posteromedial bundles of the PCL, was not visible on the bony surfaces of the CT datasets and 3D reconstructions in the current study. On the other hand, it was possible to distinguish the anterolateral and posteromedial bundles in the 3D native PCL at the femoral insertion site.

6.2.2.2 Measurement of PCL Footprint

Mean footprint surface area of the tibial and femoral footprint were 189.1 mm² (SD ± 63.0, range 68.6–263.4) and 293.3 mm² (SD ± 65.2, range

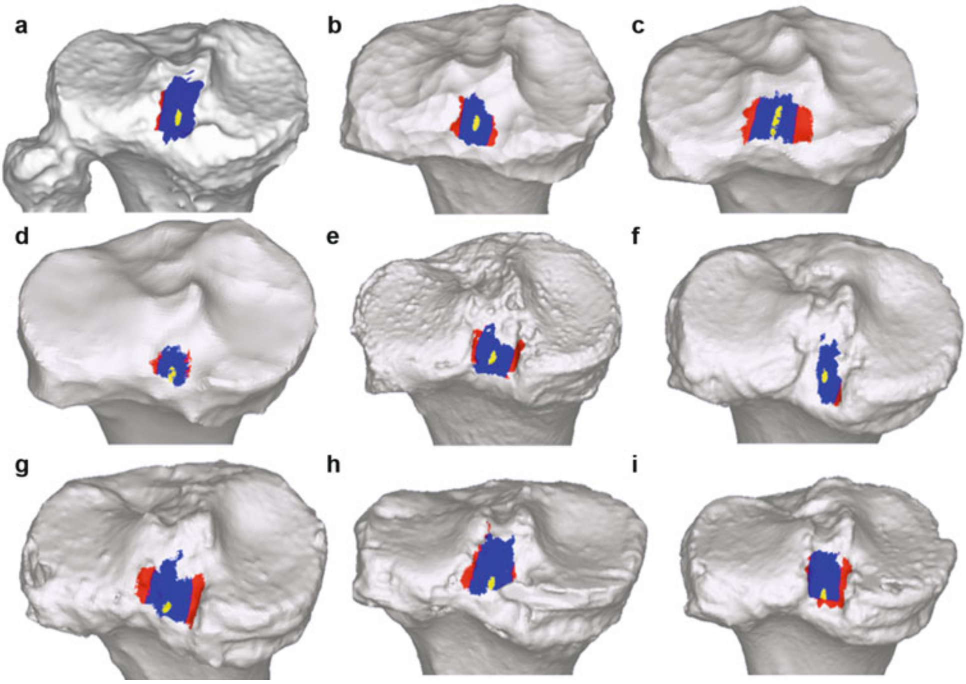

Fig. 6.2

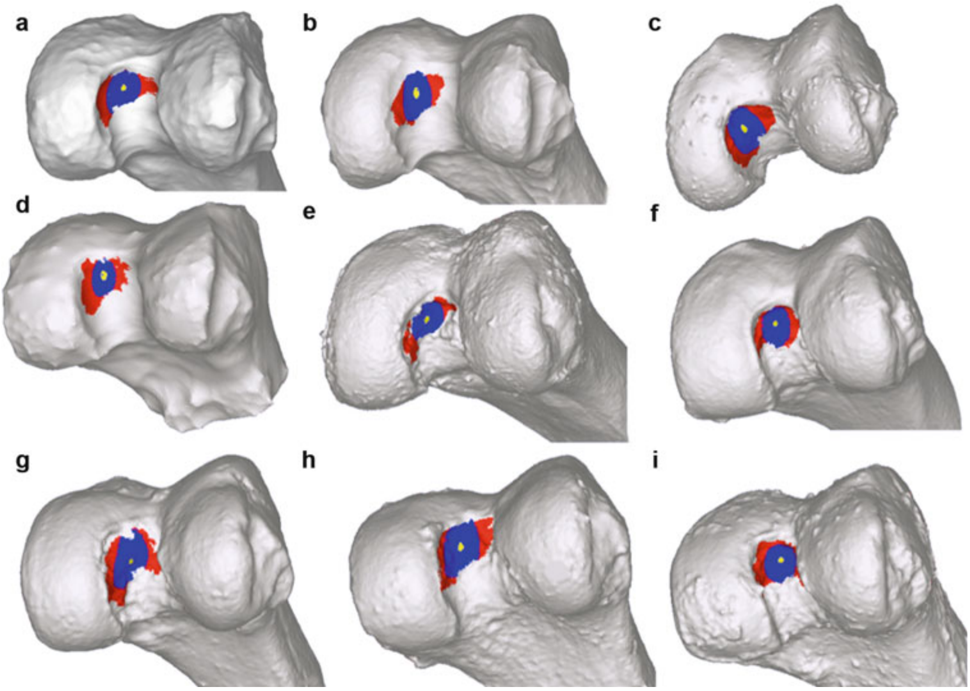

Fig. 6.3

193.7–400.5), respectively. A high inter-patient variability was observed.

6.2.2.3 Fitting of Cylinders Through the PCL

The mean diameter of the best-fit cylinder was 10.4811 mm ± 1.299. The mean coverage of the best-fit cylinder on the tibial and femoral footprint was 76.5 ± 11.7% and 46.5 ± 6.3%, respectively. The best-fit cylinder central axis was located in the anterolateral bundle footprint on the femur and more centrally in the PCL footprint on the tibia.

6.2.3 Discussion

This study is the first to describe the detailed anatomy of the human PCL with respect to its course and footprints using a direct contrast-enhanced visualization methodology based on CT imaging in combination with a 3D approach. This unique approach offers valuable bony insertion site information but also offers new insights into optimal tunnel placement based on the new concept of best-fit tunnel and central axis. The latter technology is only possible through soft tissue visualization and allows maximum ligament soft tissue coverage in contrast to the mid-footprint anatomical approach which allows maximum footprint coverage. However, maximum footprint coverage does not necessarily encompass maximum soft tissue coverage. It is well known that the anterolateral bundle of the PCL is both functionally and anatomically more important. A midfootprint approach however will only incorporate equal parts of the AL and PM bundle and therefore underestimate the importance of the AL bundle. In contrast, the best-fit cylinder approach would suggest a more balanced evaluation as it is not based on the mid-position of the footprints but rather on the bulk of the soft tissues of the PCL. Thus, since the bulk tissue of the AL bundle is larger than the PM bundle, the best-fit cylinder central axis will be closer to the AL bundle. This is confirmed by the observations made in this study. Nevertheless, while a mean best-fit cylinder of 10 mm diameter will cover almost 80% of the tibial footprint, it will only cover 50% of the femoral footprint. This observation suggests that single-bundle PCL reconstruction is never able to be considered anatomical on the femoral side. In addition, increasing the diameter of the PCL cylinder in order to increase femoral footprint coverage would probably result in overstuffing the soft tissue compartment of the PCL and would result in impingement with the ACL.

This study also confirms the large difference between the tibial and femoral footprint area with the former being significantly smaller. Nevertheless, the anatomy of the tibial footprint was characterized in all cases by 2 different planes. In contrast with a number of studies, we, however, were unable to discern the bony eminence in between the AL and PM bundle. In addition, a large inter-patient variability concerning footprint area is observed. Although most anatomical studies are limited by a low number of samples and thus low generalizability of these observations, such high variability should be incorporated into the treatment algorithm of PCL reconstruction as it can influence the graft choice and graft diameter.

In conclusion, the best-fit cylinder and central axus concept offer additional insights into the optimal tunnel placement at the tibia and femoral footprint to cover the largest portion of the native PCL soft tissue.

6.3 Posterior Cruciate Ligament

6.3.1 Clinical Examination

Jacques Menetrey, M.D., PD

6.3.1.1 Definition

Posterior instability is defined as an abnormal posterior laxity of the tibia which results, for the patient, in an insecurity, sensation of uncontrolled hyperextension, ‘feeling of weakness’ in the knee and sometimes in anterior knee pain. This posterior laxity depends upon the degree of injury of the PCL, the degree of injury of the posterolateral capsulo-ligamentous structures and the degree of injury of the posteromedial capsulo-ligamentous structures.

A PCL evaluation should always start with the determination of the mechanism of injury which can provide important information as to the potential severity of the injury. The most common mechanism of injury to the PCL is an anterior blow to the proximal tibia (the so-called ‘dashboard’ injury) [2]. Hyperflexion is the most common mechanism of injury [3] and has a tendency to result in a lesion on the tibial side of the ligament. Other mechanism of injury implies hyperextension with a loaded foot, and extension injuries are commonly located on the femoral side of the ligament [4]. PCL and other structures are also injured in different knee dislocation mechanism: hyperextension, varus-internal rotation, valgus-external rotation, posterolateral and posterior.

Partial PCL rupture is defined as a continuity of remaining ligament fibres or a retention of fibres that are observed to resist tension, while complete PCL rupture is defined as none or a few remaining intact fibres that are non-functional to resist posterior load applied on the knee. The PCL is the primary restraint to posterior drawer in flexion [5]; therefore, a PCL injury results in a posterior drawer in flexion. Thus, a PCL injury is defined as an abnormal posterior laxity at 80–90° of flexion. This posterior laxity should be defined in millimetres.

Lesion of the posterolateral corner (PLC) implies injury of either the lateral collateral ligament, the popliteo-fibular ligament, the popliteus tendon, the three popliteo-meniscal fascicles (ant-inf, post-inf, post-sup), the mid-third capsular ligament, the biceps femoris (long/short head) and the ilio-tibial band.

Lesion of the posteromedial corner (PMC) implies injury of the superficial medial collateral ligament (MCL), the deep MCL (ligament meniscofemoral), the posterior oblique ligament (POL) and the posteromedial capsule.

6.3.2 Clinical Evaluation

6.3.2.1 Clinical Evaluation and Physical Examination

Patients suffering from a PCL injury may be seen in an emergency department with multiple trauma, on a sport field after a seemingly benign injury or even limp to your office several days to weeks after the initial trauma. A patient suffering from a PCL injury shows a moderate swelling, a slight limp and a range of motion that will lack 10–20° of flexion [6]. The patient will usually have discomfort with flexion and the posterior drawer examination will be positive with a posterior subluxation of the tibia of various degrees [6]. Often, in case of combined injury, the soft tissues around the knee will be especially swollen, and ecchymosis might be seen near the joint. This appearance is very similar to a knee dislocation, and this diagnostic must always be ruled out.

The most accurate clinical test is the posterior drawer test at 90° of flexion [7, 8]. It is critical to develop a system to quantify the posterior subluxation of the tibia, and one way to do it is to determine the ‘step-off’. The ‘step-off’ is determined as the distance of the medial tibial plateau from the medial femoral condyle at 90° of flexion

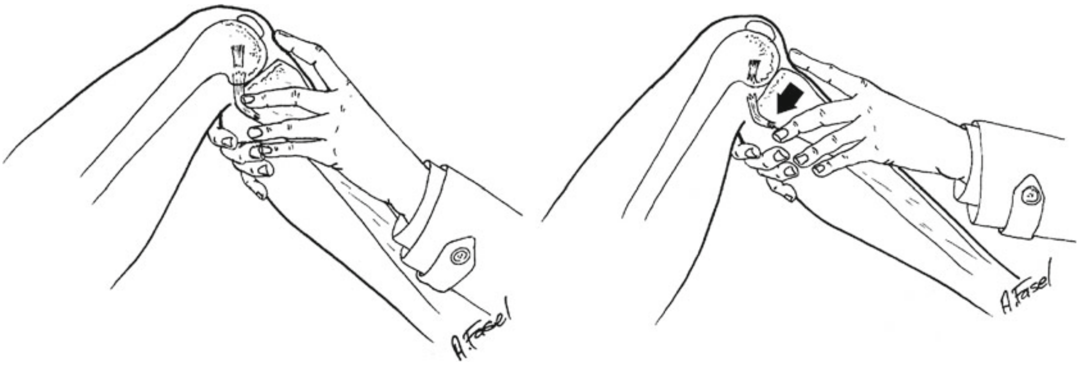

Fig. 6.4 The knee placed at 90° of flexion, the 'step-off' is determined by the distance from the anteromedial margin of the tibia to the medial femoral condyle. *A*: on the normal knee (usually 10 mm). *B*: on the injured knee. This test allocates a good evaluation of the posterior drawer starting from the neutral point, drawer reduced, followed by the application of a posterior load causing the tibial subluxation beyond the femur. The diminution of the 'step-off' under the finger allows for the clinical measurement of the posterior drawer

Fig. 6.5 Posterior sag (Godfrey test). A tangential view of the anterior tibial tubercle allows for the visualization of a posterior sag of the involved side

(usually 10 mm). The physician's index finger is placed onto the anteromedial joint line with the tip of the finger applied on the medial femoral condyle (Fig. 6.4) When a posterior load (posterior drawer) is put on the tibia, the physician can palpate the posterior sag of the tibia relative to the medial femoral condyle ([6], Miller et al.) (Fig. 6.5). According to Harner and Höher [6], a clinical grade I injury has a palpable but diminished 'step-off' (0–5 mm). A grade II injury has lost their 'step-off', but the medial tibial plateau cannot be pushed beyond the medial femoral condyle (posterior laxity of 5–10 mm). A grade III injury has also lost its 'step-off', but the tibia can be pushed beyond the medial femoral condyle (corresponds to a posterior laxity > 10 mm). Another sign is the posterior sag (Godfrey test) [9] observed at 90° of flexion. A tangential view of the anterior tibial tubercle allows the visualization of a posterior sag of the involved side (Fig. 6.5).

A critical point from the initial examination is the involvement of the posterolateral corner. In case of a posterior tibial translation greater than 10 mm (elimination of the 'step-off'), one must rule out an involvement of the posterolateral corner [6]. This may be difficult to detect because posterior tibial subluxation may diminish or even negate posterolateral corner laxity [1, 6, 8, 10, 11]. It is therefore important in this situation to reduce the tibia to the 'neutral position' and then test the posterolateral corner at both 90° and 30° of flexion (Fig. 6.6) [6]. The most important tests for isolated and combined PCL injuries are the posterior drawer tests at 90° of flexion, dial tests and posterolateral drawer tests at 90° and 30° of flexion, the reverse pivot shift and the varus/valgus tests (Table 6.1).

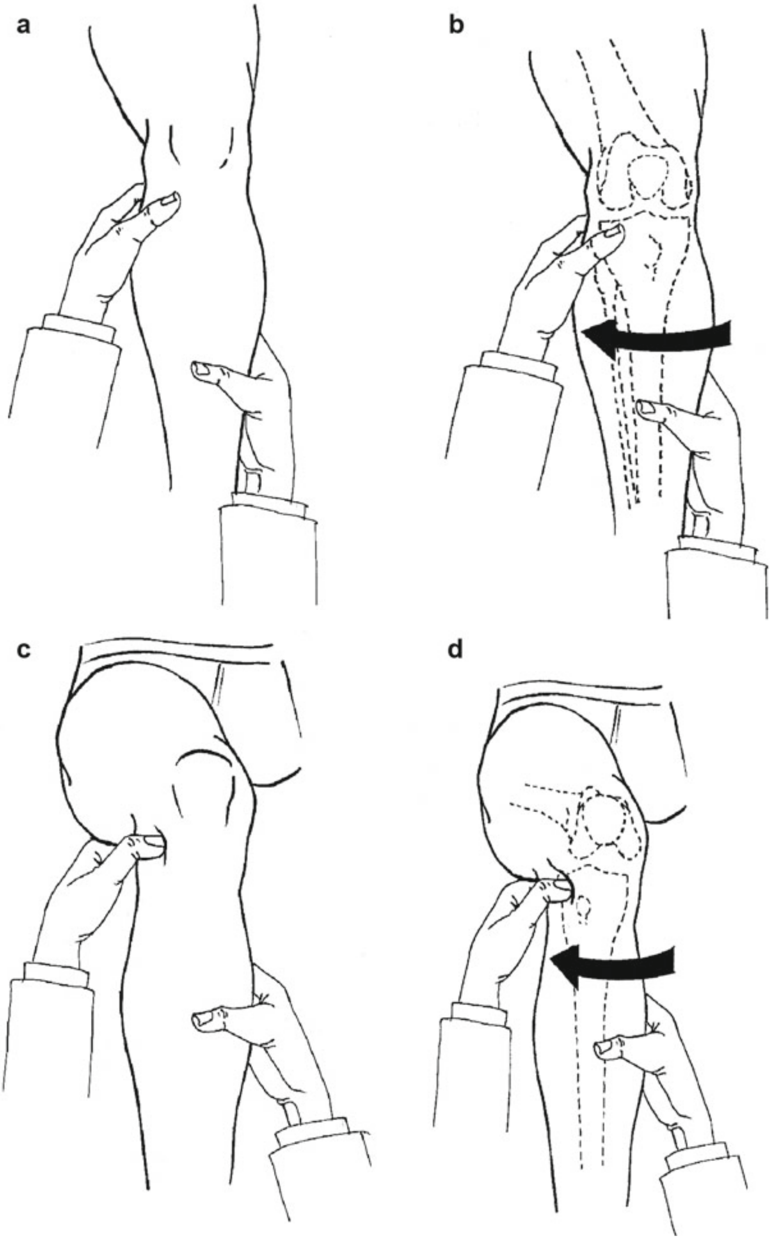

Fig. 6.6 The posterolateral drawer test is performed at 30° (**a**, **b**) and at 90° (**c**, **d**) of knee flexion. The examiner applies a posterior load and a load in external rotation on the tibia. It is important to reduce the tibia to the 'neutral position' before testing the posterolateral corner

Table 6.1 Clinical evaluation for PCL injury – check list

Posterior tibial drawer test at 90° of flexion – step-off
Varus laxity in extension
Posterolateral drawer test at 30° and 90° of flexion (foot externally rotated 15°)
Dial test at 30° and 90° of flexion
External rotational recurvatum test
Reverse pivot shift test
Varus thrust (in chronic cases)
Posteromedial drawer test at 90° of flexion (foot internally rotated 15°)

In case of combined ligament injuries, it is critical to check the pulses in the feet (dorsalis pedis, tibialis posterior) and to perform a meticulous neurological examination (especially sensory and motor modalities in the peroneal nerve territory). If one detects a diminished pulse by palpation, an arteriogram (angio-Ct) should be obtained immediately.

6.4 Imaging Plus Complementary Investigation

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6.4.1 Introduction

Appropriate imaging techniques are required to precisely diagnose injury or insufficiency of the posterior cruciate ligament (PCL). The choice of imaging strongly depends on the type of injury. Acute injuries require different imaging techniques than chronic ones.

6.4.2 Acute PCL Injury

Patients with an acute injury of the PCL usually suffer a direct tibial blow in a flexed knee position or endure a hyperextension trauma [1, 12]. Swelling will occur in minutes after the injury with a hematoma developing at the back of the knee joint and contusion marks at the front of the tibia. Typically, a *conventional x-ray*, ap and lateral, is taken to exclude fractures of the tibia and femur. Sometimes, a posterior sag of the tibia relative to the femur can be observed. If PCL injury is suspected and no substantial swelling is present, the patient should be examined under *dynamic fluoroscopy* on both knee joints for anterior and posterior translation in 90° flexion. If swelling has already occurred, pain will prevent precise examination with the patient awake. If the patient will have to undergo immediate surgery due to related injuries, this examination should be performed in the operation room prior to surgery.

In the acute setting, MRI analysis is highly sensitive and specific for PCL injury. Location of the injury can be easily depicted by the edema and swelling of the structure of the PCL [9] (Fig. 6.7). Associated injuries of intra-articular and extra-articular structures can identified, which can be crucial for the differentiation between a monoligamentous and multi-ligamentous injury. This will have direct consequences for the ensuing treatment regimen.

Since PCL injury often requires a substantial trauma to the knee joint and associated injuries are frequent, vascular injuries must be excluded [7]. Doppler ultrasound examinations should be performed at the time of injury and repeated at 24 and 48 h to exclude intima lesions that often present with timely delay.

Stress x-rays are not indicated in the acute setting. Swelling and pain will stop patients from relaxing the hamstrings, which prevents valid measurements of true anterior-posterior translation.

6.4.3 Chronic PCL Injury

In chronic PCL insufficiency, it is detrimental to quantify the extent of posterior instability, especially when differentiating isolated from combined chronic injuries. Objective quantification and comparison of posterior translation of the tibia relative to the femur between both knee joints are of crucial importance [3, 7, 9]. *Conventional stress x-rays* allow such analysis on exact lateral views (Fig. 6.5) with different imaging methods being described [8]. Jung et al. found that kneeling [5] and Telos techniques [13] proved to be

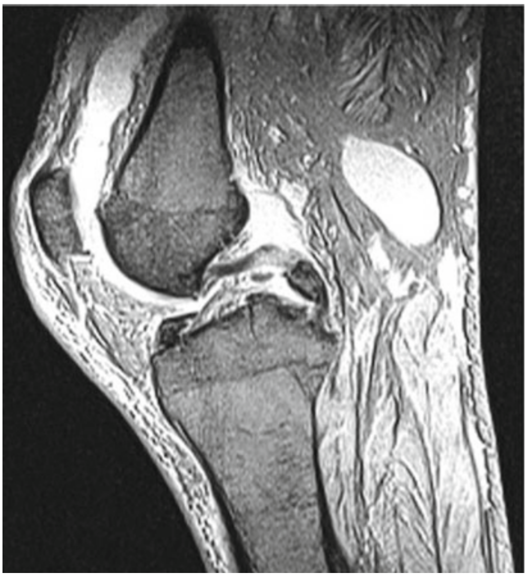

Fig. 6.7 MRI of an acute intraligamentous rupture of the posterior cruciate ligament

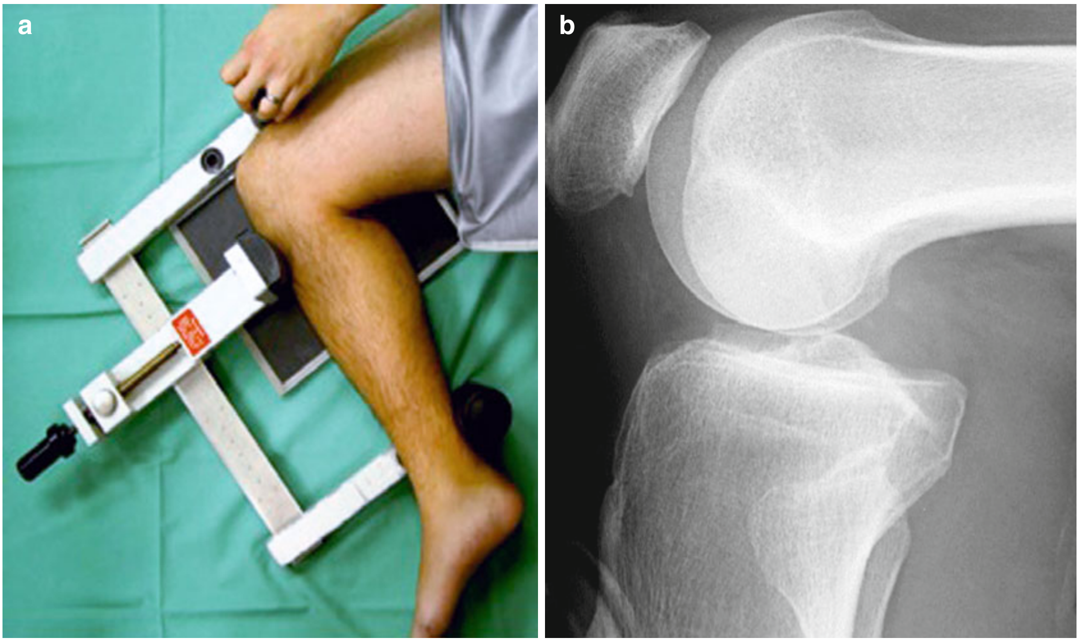

Fig. 6.8 (**a**, **b**) Telos stress x-ray for quantification of posterior translation

most repetitive and reliable in determining accurate posterior translation [8]. Strobel et al. [6, 14] found out that side-to-side differences (SSD) of 12 mm or more in posterior translation were suggestive of combined instability, most likely of the PCL and the posterolateral structures. SSD in posterior translations below 10 mm were indicative of isolated chronic PCL insufficiency. Therefore, stress x-rays are very useful in separating isolated from combined injuries, which is crucial for the decision on surgical treatment and ultimate clinical outcome.

Another important phenomenon is the so-called 'fixed posterior subluxation' [2]. This describes the observation that patients with chronic PCL insufficiency present with permanent posterior tibial subluxation without the possibility of fully restoring anterior-posterior translation. This observation is made in up to 44% of patients with chronic PCL deficiency [2]. If these patients undergo PCL surgery, the knee will be stabilized in a posteriorly subluxed position, resulting into rapid development of patellofemoral pain and arthrosis [2]. Therefore, it is essential that not only posterior but also anterior translations are compared with stress x-rays between the PCL-deficient and PCL intact knee joint. A difference in SSD of 3 mm or more in reduced anterior translation of the PCL-deficient knee is indicative of fixed posterior subluxation on anterior stress x-rays. Such quantification has only been shown until now using Telos technique [2]. If a fixed posterior subluxation is found on anterior stress x-rays, full restoration of anterior-posterior translation must be achieved prior to PCL surgery.

While MRI analysis has been proven to be very helpful in the diagnosis of acute PCL injury, its use is limited in patients with chronic PCL insufficiency. It has been shown that the PCL has a high potential to heal. Often, if appropriate reduction of the knee joint is not achieved right after injury, healing will result into an elongated PCL. While clinical instability and patellofemoral pain will develop over time, MRI imaging will show a fully healed PCL with a signal intensity that does not vary from the uninjured PCL [15, 16] (Fig. 6.9). Only subtle tibial posterior

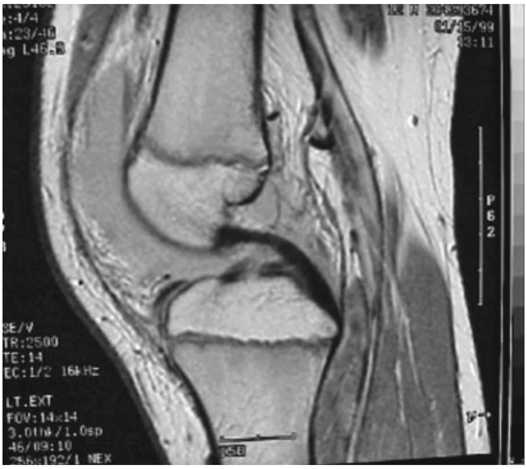

Fig. 6.9 MRI of PCL in chronic PCL-deficient knee joint

subluxation can be depicted with the knee joint usually examined in extension in a prone position. However, these differences are small and no MRI technique currently exists that will allow for quantifying posterior instability between both knee joints. Therefore, MRI imaging has its main use in to visualize concomitant injuries, especially to the cartilage of the patellofemoral and medial joint compartment, which are often associated with long-lasting PCL deficiency.

In summary, important differences exist in the imaging of acute and chronic PCL injuries. While imaging methods in the acute injury situation focus on determining the extent of comorbidities, especially of the peripheral ligamentous and vascular structures in order to decide the best sequence and necessity of surgical intervention. It is more important in the chronic PCL-deficient knee to visualize and quantify the extent of posterior instability and the concomitant changes in relative tibiofemoral position and possible damage to other structures than the PCL. These information are required to decide on the appropriate surgical treatment to obtain optimal long-term outcome.

6.5 Treatment of Acute PCL Injuries

Patrick Djian and Konstantinos G. Makridis

6.5.1 Introduction

Posterior cruciate ligament (PCL) injuries represent 3% to 40% of all knee ligamentous injuries, but the true incidence remains unknown because many isolated lesions often are misdiagnosed at initial evaluation [17, 18]. Most of PCL injuries are caused by high-energy mechanism acting on the flexed knee. Hyperextension and varus or valgus injuries usually result in combined ligamentous lesions involving the anterior cruciate ligament, collateral ligaments and structures of the posterolateral corner [10, 14, 19]. Accurate diagnosis and differentiation of an isolated from a combined injury are the key objectives in the successful management of PCL ruptures.

Treatment recommendations have evolved and several therapeutic algorithms have been proposed by many authors [20–23]. However, there is no consensus on the optimal treatment, and few controversies remain to clarify the ideal indications between the non-operative and surgical management of the acute PCL ruptures.

6.5.2 Acute PCL Injury

There is no consensus in the literature concerning its incidence, natural history and indications for conservative or surgical treatment.

6.5.2.1 Non-operative Treatment

The choice of treatment of an acute PCL injury depends on the severity of the injury, the associated ligamentous structures and the activity level of the patients. Current indications of non-operative treatment are isolated, grade I (posterior translation 1–5 mm) and grade II (posterior translation 6–10 mm) PCL injuries, as well as small avulsion fractures with posterior tibial translation <10 mm [24]. If there are meniscal or chondral injuries that are amenable to repair, arthroscopy should be performed to evaluate the status of the articular cartilage and deal with the meniscal lesion. Once these injuries have been treated, a rehabilitation program can be started. An understanding of the posterior tibiofemoral shear forces during daily living and during rehabilitation exercises is important to minimize the amount of stress applied to the injured PCL. An extension splint is useful for a short period of time (3–4 weeks) in order to reduce the inflammatory process, decrease tension on the anterolateral bundle fibres and minimize the antagonistic effect on the hamstring muscles [5]. Protected weight bearing and early range of motion training begin immediately. Open-kinetic-chain exercises are better to be avoided, since there is a high risk of stressing the patellofemoral joint. The strength of quadriceps is important to counteract posterior tibial subluxation, and this can be achieved by closed-kinetic-chain exercises [25]. The patients can return to athletic activity when the muscular strength of the injured knee is 90% as compared with the normal side.

The evolution of a PCL-deficient knee has been extensively investigated. Many authors have reported 80–90% satisfaction of the patients and ability to return to their previous activities [14, 22, 26]. All of them have concluded that quadriceps muscle strength is a critical factor to achieve good stability of the knee and normal knee function. Shelbourne et al. [27] evaluated patients with acute, isolated grade I/II PCL tears, and they concluded that the subjective function of the knee is irrelevant to the PCL laxity, which appears with time after injury. However, it has been well documented that the PCL-deficient knee results in altered loads and kinematics during functional activities. Several biomechanical and clinical studies have shown changes in tibiofemoral mechanics and overloading of the medial and patella-femoral compartments of the knee [28–30]. In addition to the degenerative alterations, other authors have reported an increased risk for injury of the posterolateral corner in a PCL-deficient knee, since the synergistic action of PCL bundles no longer exists and the loads are transferred to the adjacent structures of the knee [31].

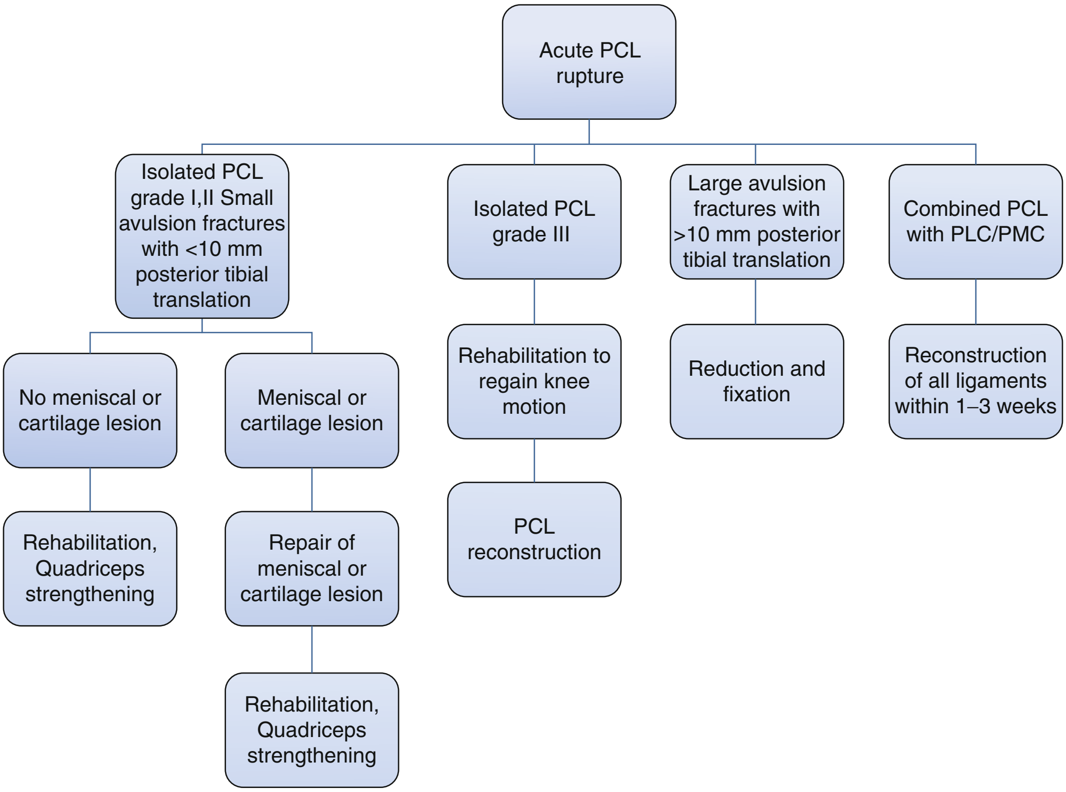

Fig. 6.10 Treatment algorithm for acute PCl injuries

6.5.2.2 Operative Treatment

Current surgical indications for the acute PCL injuries include grade III posterior tibial laxity (>10–15 mm), combined ligamentous lesions and bony avulsion fractures with posterior tibial translation > 10 mm (Fig. 6.10) [23, 24, 32].

The timing of PCL reconstruction, choice and fixation of the graft and selection of the PCL reconstruction technique are important factors for the treatment outcome and are still on debate.

In isolated, grade III, PCL ruptures, it is highly recommended to the patients to undergo a rehabilitation program in order to regain knee range of motion and strengthen the quadriceps and hamstring muscles prior to surgery, which usually takes place 4–6 weeks after the injury. In combined ligamentous injuries, it is better to perform surgery within 1–3 weeks, thus avoiding capsular scarring and maximizing healing potential [33].

Appropriate graft choice still remains controversial, although a variety of grafts exist for PCL reconstruction surgery. The most common of them are the bone-patellar tendon-bone (BPTB), hamstring tendons (HT), quadriceps tendon (QT) and Achilles tendon allograft (AT). Many studies have compared the failure load of fixation, mechanical properties and length of the various grafts [3, 7, 34, 35]. The BPTB graft presents good incorporation but has the disadvantage of graft site morbidity such as patellar fracture, quadriceps weakness and patellofemoral joint problems. The multiple-strand hamstrings graft is biomechanically superior to single-strand graft and must always be used to the reconstruction of PCL [36]. This graft has a wider cross-sectional area and higher ultimate failure load than BPTB and lower donor site morbidity. Its disadvantage is the inferior fixation strength and longer tendon-bone healing period, so post-fixation technique is always recommended. The QT graft has similar biomechanical properties with BPTB, good tibial incorporation and no complications from patellar tendon. Similar to BPTB, the optimal position for the bone block is flush with the posterior tibial opening [37]. The AT allograft has an intermediate ultimate failure load between HT and BPTB grafts and lack of donor site problem. However, there is always the risk of unknown disease transmission and antigenic host reaction [38].

The optimal surgical technique for PCL reconstruction is still under investigation, and no consensus exists on which technique is superior between single-bundle and double-bundle reconstruction as well as between trans-tibial and tibial inlay reconstruction.

It has been shown that the AL bundle is approximately twice the width of the PM bundle and is also stiffer having a higher ultimate load to tensile failure [39]. So, many procedures have been performed trying to reconstruct just the AL bundle. However, other cadaveric and clinical studies have been published, showing that double-bundle reconstruction provides superior biomechanical and functional results. Race and Amis stated that a double-bundle graft could restore normal knee laxity [40], while Harner evaluated in cadaveric knees that posterior tibial translation was close to normal after reconstruction of both bundles [2]. Whiddon demonstrated superior results with double-bundle technique regarding posterior and rotational stability in PCL/PLC combined injuries. In contrast, with the PLC intact, there were no benefits using the double-bundle reconstruction [41]. Similarly, Bergfeld found no difference in posterior tibial translation with respect to the number of bundles [15].

The most common method used for tibial fixation during PCL reconstruction is the trans-tibial technique. The graft passes proximally and posteriorly through the tibial tunnel, and after making 90° bend (killer turn), it enters the knee joint. It has been shown that this curve creates a ‘sawing phenomenon’ producing high internal graft pressures, elongation and failure [17]. To avoid these complications, some authors proposed fixation of the graft in order to be flush to the posterior edge of the tibial tunnel (aperture fixation) and creation of a tibial tunnel with rounded, smooth edges [37, 42]. In addition, Margheritini studied the kinematics of PCL with the use of trans-tibial reconstruction in cadaveric knees [43]. The study revealed that combined tibial fixation (proximal interference screw and distal post-screw) results in significantly less posterior translation at 30°, 90° and 120° of knee flexion; less graft motion; and increased graft stiffness.

The tibial inlay technique was popularized by Berg as an alternative to the trans-tibial method in order to avoid the complications of the ‘killer turn’ and the difficulties to achieve an aperture fixation [8]. The initial technique involved the arthroscopic placement of the femoral tunnel and open fixation of the graft in the posterior tibia, while later all-arthroscopic techniques described [44]. Different studies were performed comparing the trans-tibial with the tibial inlay technique. Bergfeld found less anteroposterior laxity in the tibial inlay group, and Markolf showed that the tibial inlay reconstruction is superior to the trans-tibial reconstruction when subjected to cyclic loading [3, 45]. In contrast, Zehms and Kim found no differences between the two techniques regarding the functional and biomechanical outcome [11, 46].

Every patient with PCL rupture must be suspected for having an injury to the posteromedial (PMC) and/or posterolateral (PLC) corners of the knee. Left untreated, these injuries may result in increased loads in the PCL graft and subsequent failure. It has been shown that failure to restore associated ligament instabilities and incorrect tunnel placement were major factors contributing to surgical failure. PLC injuries are best treated in the acute stage (within 3 weeks after initial trauma) in order to avoid capsular scarring and soft tissue stretching. Numerous techniques, non-anatomic and anatomic, have been used to restore the structures of posterolateral corner [18, 47–50]. Although many studies show favourable short-term results for anatomic PLC reconstruction, it remains unclear which type of repair is superior.

In comparison with posterolateral corner injuries, PMC lesions are studied less often. Similarly, left untreated these lesions place additional valgus strain on the PCL graft and can contribute to late graft failure. A combined PCL and medial-sided injury is considered one indication for surgical reconstruction of both ligaments. Low-grade medial injuries (grade I, II) can be allowed to heal before PCL repair with an extension knee brace and physiotherapy [51]. However, in the setting of combined grade III medial collateral ligament (MCL) and PMC injuries, repair or reconstruction is indicated [52]. Because the posteromedial structures depend on each surrounding structure, a systematic, deep-to-superficial approach is important. If there is a meniscal lesion, it is repaired first and suturing of the posteromedial capsule follows the procedure. The superficial MCL can be repaired with screws and soft tissue washers or nonabsorbable sutures tied over a post [19]. When a reconstruction technique is chosen, autografts (semitendinosus) or allografts can be used. Repair or reconstruction of posterior oblique ligament (POL) is crucial and must be always performed [6]. The POL acts as a primary stabilizer to internal rotation and secondary stabilizer to valgus stress.

Post-operatively, the reconstructed knee is immobilized in a hinged knee brace locked in extension in order to minimize the effects of gravity and hamstrings. Patients are usually allowed to walk with partial weight bearing for the first 6 weeks. The brace is unlocked for range of motion and closed-chain exercises and primarily quadriceps strengthening. The brace is discontinued when the range of motion and quadriceps force has been restored. Physical therapy continues with emphasis on restoration of normal gait, gradual recovery of muscle strength and proprioception. A gradual return to athletic participation is achieved at approximately 10–12 months post-operatively for isolated PCL injuries and 12–18 months after surgery for combined injuries.

6.5.3 Conclusion

Continuous anatomical and biomechanical studies have improved our knowledge of the PCL and the ability to reproduce its anatomy and function during reconstruction. Treatment indications for the acute PCL injuries are more clearly defined, although debate still remains on the optimal treatment method. Isolated, grade I and II PCL injuries, as well as small avulsion fractures with posterior tibial translation <10 mm, can be treated without surgery following a staged rehabilitation protocol, which emphasizes on quadriceps muscle strengthening. Grade III PCL injuries, multiligamentous lesions and bony avulsion fractures with posterior tibial translation >10 mm are absolute indications for surgery.

Single-bundle and double-bundle techniques can equally be used depending on the convenience and experience of the surgeon. Trans-tibial reconstruction offers sufficient fixation, is easier and is recommended for primary acute PCL injuries. Tibial inlay technique has the advantage of avoiding the ‘killer turn’; however, it is technically demanding and is better indicated for revision PCL reconstruction. Proximal and distal fixation of the tibial component is strongly recommended, since it provides superior fixation and increased graft stiffness. PLC and PMC combined injuries must always be suspected and treated simultaneously with PCL within 1–3 weeks after the initial injury.

Although satisfactory results are generally reported, long-term studies suggest that normal stability is not restored with current techniques.

6.6 Treatment of Chronic Posterior Cruciate Ligament Instability

Fabrizio Margheritini, M.D.

6.6.1 Introduction

Isolated injuries of the posterior cruciate ligament (PCL) and combined ligamentous injuries of the knee involving the PCL are far less common than other lesions of the knee.

With an incidence of PCL injuries historically reported to be as low as 3% in the general population to as high as 37% of all patients presenting with knee hemarthroses in a major trauma centre, treatment option has been widely debated in the recent past. A non-operative approach to isolated PCL injury has traditionally been recommended because of the capacity of the ligament to heal. With isolated PCL injury, the patient often is able to compensate for the change in joint kinematics resulting from ligamentous disruption.

This adaptation is most likely to occur through compensatory muscle function developed through a carefully guided physical therapy program.

The approach to non-operative treatment revolves around adequate knee stabilization that facilitates healing and return of the ligament's primary function in resisting excessive posterior tibial translation.

However, surgical treatment has gained great popularity in the most recent past.

Surgical treatment of the chronic PCL-deficient knee is recommended for patients with persistent symptomatic complaints, such as pain or discomfort that fails to improve with an appropriate physiotherapeutic program. The rationale for performing a reconstruction is to restore normal joint kinematics and forces, thus minimizing the deleterious effects, such as early cartilage degeneration, that a PCL deficiency is likely to have on the knee.

6.6.2 Surgical Technique

Numerous PCL reconstruction techniques are described in the literature. Since its introduction by Clancy et al. [1] in 1983, single-bundle PCL reconstruction has become a popular surgical option. Its focus is on reconstruction of the larger, stiffer anterolateral bundle via arthroscopic assistance. More recently, to more accurately reproduce the anterolateral and posteromedial bundles of the native PCL, the double-bundle technique has been proposed.

Biomechanically, Harner et al. [7] showed that double-bundle reconstruction is better able to reproduce normal knee kinematics between 0° and 120° of knee flexion. Current biomechanical data support the use of double-bundle reconstruction, suggesting that the technique is better than the single-bundle approach in restoring normal knee kinematics and joint forces.

However, clinical studies providing long-term results obtained with single- and double-bundle reconstructions are still lacking. Hermans et al. [8] conducted a long-term follow-up study to determine which factors impact the results of isolated, arthroscopically assisted reconstruction of the PCL's anterolateral bundle. After a mean follow-up period of 9.1 years, 25 patients treated with a variety of graft including bone-patellar tendon-bone autografts, autologous hamstring autografts and an Achilles tendon allograft.

Functional scores for patients who received either BPTB or STG reconstruction were not significantly different. Final functional results were significantly better in patients with no cartilage damage at the time of surgery and in those who underwent surgery within 1 year postinjury.

Tibial inlay reconstruction, in which both an arthroscopic and a posterior open approach are used, was presented in the late 1990s as an alternative technique to the trans-tibial tunnel single-bundle technique [3, 15].

Rather than creating a tunnel for tibial attachment, the tibial inlay technique uses a bone trough at the tibial site of PCL insertion to which the bone block of the graft is directly fixed. This type of reconstruction has the specific aim of restoring normal knee kinematics by achieving a more anatomical tibial fixation and by avoiding what has been described as the 'killer turn', i.e., the sharp bend in the graft that occurs at the proximal margin of the tibial tunnel.

At least theoretically, the killer turn causes increased graft stress and friction, which are thought to contribute to graft elongation or failure

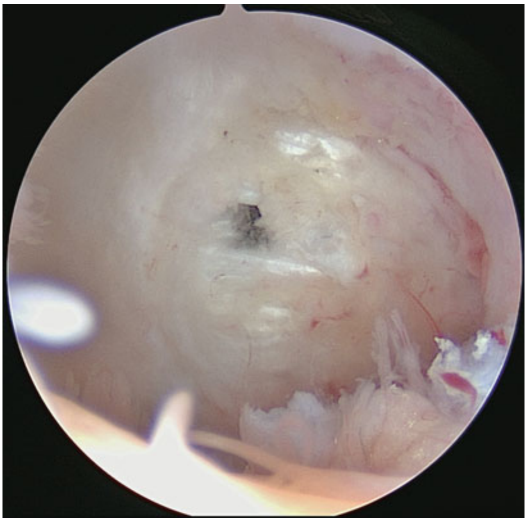

Fig. 6.11 Arthroscopic view of a PCL femoral tunnel with the augmentation technique. Note the preservation of the majority of the AL bundle fibres

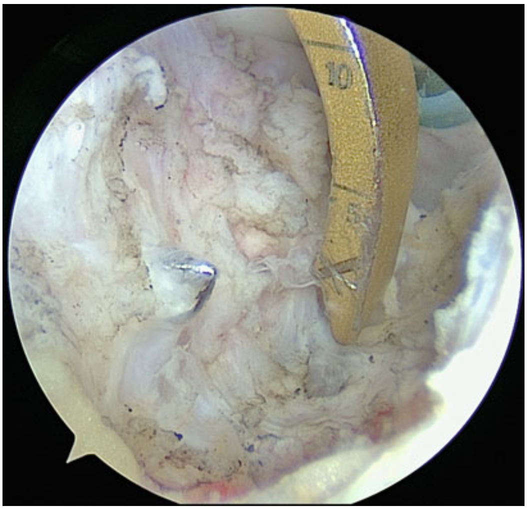

Fig. 6.12 Arthroscopic view via transeptal technique of the tibial tunnel placement. The scope is placed in the posterolateral portal

following fixation. However, no clear evidence of biomechanical superiority has been demonstrated either from a biomechanical or a clinical standpoint [5, 9].

Out of the techniques preferred by the surgeon, there are some tips that may be helpful in the surgical management.

Preservation of the remnant bundle significantly improves the posterior stability and proprioception of the reconstructed knee joint, integrating graft with remnant fibres [6, 16].

In this way, it could be possible to perform a true augmentation technique, which combines the advantage of preserving the bulk of the PCL fibres with the use of a soft tissue graft such as the hamstring or the tibialis anterior, which makes the surgery very straight forward (Fig. 6.11). One more point is to use an adequate fixation system when securing the graft on the tibial side. It has been shown that the average bone density at the posterior tibial epiphysis is less pronounced than elsewhere in the tibia. That means that a double fixation system, such as the combination of an intra-tunnel screw and staple/post on the anterior tibial cortex, may reduce the micromotion of the graft within the tunnel, increasing the stiffness of the whole construct. If using an arthroscopic technique, the use of a transeptal approach is recommended. This technique has been introduced by Ahn at the early 2000 and allows, with the removal of the posterior septum, the creation of a wide posterior chamber reducing the need of the intraoperative fluoroscopic control and increasing the accuracy of posterior tibial tunnel placement (Fig. 6.12).

More recently, an arthroscopic full tibial and femoral inlay have been presented [53, 54]. The rationale of the authors is to combine the advantage of an anatomical placement of the graft and the reduction of the killer turn frequently seen either at the tibial of femoral side with a safe arthroscopic approach.

Finally, certain cases of chronic PCL/PLC instability may require high tibial osteotomy to correct bony varus deformity prior to ligament reconstruction. This since failure to correct the bony varus deformity exposes the ligament reconstruction to high tensile loads, increasing the risk of ligament reconstruction failure. Furthermore, it has been shown that increasing the tibial lateral slope reduces the posterior instability when an axial load is applied [13], preventing the posterior sag and diminishing the biomechanical effects.

As up to 60% of PCL injuries also involve the PLS [2], recent studies have evaluated the benefit of PLS reconstruction in the setting of operative

PCL tears. Techniques for PLS repair described in the literature have been reported to restore external and varus rotational stability compromised in PLS deficiency [4].

Harner et al. [34] reported that PLS deficiency increases the in situ forces exerted on the PCL replacement graft, compared with a knee with intact PLS. These data suggest that PLS deficiency in the setting of PCL reconstruction predisposes the patient to early graft elongation or failure. Thus, in cases of combined injury of the PCL and PLS, reconstruction of the PLS is recommended when the decision is made to proceed with surgical treatment of the PCL. This combined reconstruction offers the best chance of restoring normal knee kinematics and thereby preventing graft failure.

Post-operatively, a 2- to 4-week period of immobilization with the knee in full extension is suggested. This position results in reduction of the tibia, p of gravity and hamstring muscle contraction on tibial translation. The use of a knee brace equipped with either a fixed posterior support or a spring mechanism that allows the tibia to be pushed anteriorly can further enhance the healing process.

During this period, strengthening exercises targeting the quadriceps muscles are encouraged, whereas use of the hamstring muscles is prohibited, to minimize posterior tibial load up to even 6 months.

6.6.3 Conclusions

PCL injuries, although less common than other knee injuries, can result in significant disability in both the athletic and trauma populations. Current management of PCL injuries unfortunately can yield relatively poor clinical outcomes, whether surgically or conservatively treated. However, surgical reconstruction of the PCL chronic lesion has been achieving an increasing popularity. In patients with severe symptomatic laxity (grade III) or combined injury, surgical reconstruction is necessary. Single-bundle reconstruction through a tibial tunnel has had variable results, but outcomes appear to be improving with improved surgical techniques and more defined patient selection. Although newer methods of reconstruction may possess certain theoretical biomechanical advantages over single-bundle repair, there is not enough evidence to endorse their clinical superiority.

Further studies are necessary to define the natural history of the PCL-deficient knee and determine optimal surgical technique for patients requiring reconstruction.

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Revision Anterior Cruciate Ligament

7

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Contents

7.1 Diagnosis, Causes of Failure, and Planning in Revision ACL Reconstruction

C. Hantes

The incidence rate of ACL rupture in young patients (15–40 years) has recently been reported to be 85 per 100,000 person-year, and it is estimated that approximately 250,000 ACL reconstructions are performed yearly in Europe and the United States. Although ACL reconstruction is a successful operation with satisfactory outcomes, an overall clinical failure rate of 10% to 25% has been reported. Therefore, an increasing number of patients are requiring revision ACL reconstruction. Indeed, the number of

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revision ACL reconstructions has almost doubled during the past 10 years according to national registries.

There is no consensus and there is no strict definition what constitutes failure after ACL reconstruction. Postoperative complications, like infection, arthrofibrosis (or motion loss), extensor mechanism dysfunction, and a painful knee because of cartilage deterioration, could result to an unsatisfactory outcome and, therefore, a failure of the reconstruction. However, the vast majority of performed revision ACL reconstruction is due to recurrent knee instability. Diagnosis of recurrent knee instability after ACL reconstruction is based on history, clinical examination, and imaging.

Usually, patients have a subjective sensation of instability, giving way, and they have functional limitations that affect daily or sports activities. Instability may be accompanied by knee pain and swelling in some patients. Knee stability and graft function are assessed by physical examination using both the Lachman and the pivot-shift test which may demonstrate excessive laxity. In addition, objective laxity can be measured using the KT-1000 arthrometer. According to IKDC classification, a side-to-side difference of more than 2 mm is considered not normal. However, many patients with a 3–4-mm side-to-side difference do not complain of symptoms of instability. Definitely, a side-to-side difference of more than 5 mm is not acceptable and is correlated with poor functional result. It is important to document recurrent knee instability using both subjective and objective criteria since many studies demonstrated that 32% of ACL reconstructed knees had positive findings on a Lachman test and 22% had positive findings on the pivot-shift test despite satisfactory subjective outcomes.

Causes of graft failure and recurrent instability are (1) technical errors, (2) failure of graft incorporation, (3) a new trauma to the knee and the graft, and (4) failure to recognize and treat concomitant laxity.

The most common technical error is improper tunnel placement. A nonanatomic graft placement (failure to place the graft in the native femoral and tibial footprints) will result in graft impingement, stretching of the graft, and eventual laxity. A common scenario of poor graft placement is a vertically oriented graft in the coronal plane when the transtibial technique is used. In this way, anteroposterior stability may be restored, but not the rotational stability. Poor graft quality, inadequate graft tensioning, and failure of graft fixation may be also causes of failure because of poor surgical technique and technical errors. Although technical errors is mainly the primary reason for ACL failure, traumatic reinjury is considered to be the most common mode of failure after ACL reconstruction according to recent studies. Failure of graft incorporation is suspected when there is no history of new trauma and the graft is well positioned.

Imaging of the knee using plain X-rays, which are the most simple and useful investigations, will contribute to diagnosis and help to define the cause of failure as well as planning the revision. Preoperative radiographs will show tunnel position and widening and the presence of metal hardware. The necessity for removal of metallic hardware, options for graft fixation, and if a single- or two-stage procedure (because of tunnel expansion) can be decided by the surgeon by using simple X-rays, in most of the cases. Finally, a computed tomography can be obtained if additional information regarding tunnel placement and expansion are needed.

7.2 ACL Revision: Graft Selection, Fixation, and Tunnel Placement

Magnus Forssblad, M.D., Ph.D.

In the last annual report from the Swedish ACL register (2010), we can read that Swedish surgeons' first choice for primary ACL reconstruction is hamstring tendons in 98% of all cases. Similar figures are found in both Norway (70% hamstrings) and Denmark (90% hamstrings). The last ACL study group questionnaire from 2010 shows a more modest use of approximately 50% hamstrings. The reasons for this extensive use of hamstrings in Scandinavia are probably due to reduced donor-site problems, less complications, and easy harvesting.

This primary use of hamstrings gives us the following options for revision: patellar tendon, quadriceps tendon, or hamstrings from the contralateral knee. In many clinics, allograft is another option, but in Sweden it's rather difficult to get access to allografts. However, we sometimes use allografts for secondary revisions and multi-ligament knee injuries. The first option for revision in our clinic is to use the patellar tendon as graft. Our opinion is that it's much easier to revise a hamstring tendon ACL reconstruction with a patellar tendon than vice versa. Our standard fixation in a primary hamstrings reconstruction is an endobutton at the femoral side and a screw/post at the tibial side. You don't have to remove the endobutton in case of revision, and it's easy to remove the screw/post from the tibia if necessary. In many cases, you can also leave the fixation devices intact. For revisions with patellar tendon, we mainly use interference screws in both tunnels, but of course there are many other options.

Before any revision, we need to do a proper planning and always have a preoperative X-ray to determine previous fixation methods, tunnel widening, and associated injuries like the grade of osteoarthritis. All fixation methods need a well-documented plan/strategy to be used when to remove the devices. Some of the existing devices in the market don't fulfill this criterion.

If there are signs of tunnel widening, you have to consider a two-stage procedure with bone grafting (maybe this is more common in clinics that use allografts). A two-staged procedure can also be necessary if you have large fixations devices.

In most cases after transtibial primary ACL reconstruction with hamstrings tendon, the femoral tunnel is "too high" compared to the updated technique including drilling through the anteromedial portal with the knee in 120° of flexion. This fact makes a revision very simple on the femoral side. In the opposite case with a well-placed femoral tunnel, you can often redrill the same tunnel and use it again. In addition, it can be an advantage to use, for example, another aimer/drill guide system like the old "rear entry" system. This drill guide can help you have another angle of the femoral tunnel. In some cases, the old tunnel interferes too much with the new planned tunnel – a good advice is then to switch to a two-stage procedure with grafting of the old tunnel with bone if necessary.

Revision surgery for the tibial tunnel is seldom a problem. We can avoid the old tunnel by changing both the angle of the tibia aimer and/or make the tunnel more medial/lateral. We always try to remove an old interference screw but sometimes you can leave it in place.

A good rule is that if everything looks perfect after the primary reconstruction (tunnel placement), you have to reconsider the cause of the failure.

A possible future problem is if all surgeons concentrate on one method – for example, hamstrings procedures. That could lead to a huge lack of knowledge both for primary reconstructions in cases where the hamstrings graft is not sufficient or immature or for revision reconstructions when you have to use different type of grafts.

As a surgeon, you also should have knowledge about different grafts but also about different methods and fixations. My opinion is that we shall concentrate ACL surgery (both primary and revisions) to highly specialized centers to maintain knowledge about different methods. It isn't really acceptable that more than 80% of all American orthopedic surgeons do less than 10 procedures a year. The corresponding rate for Sweden is 50%.

7.3 Single-Staged Revision Anterior Cruciate Ligament Reconstruction: Pros and Cons

Andreas Weiler, M.D., Ph.D.

Revision ACL reconstruction is demanding with respect to tunnel management. Thus, it needs to be decided if revision reconstruction is done directly or in a staged procedure with previous tunnel filling/cancellous bone grafting. For that, a classification of existing tunnels might be helpful. Based on X-ray and/or CT analysis, tunnel can be divided into three different types:

- Correct: existing femoral or tibial tunnels are placed completely correct and can be used again.
- Complete incorrect: existing femoral or tibial tunnels are placed completely incorrect, and a new tunnel can be created in the correct position without touching the old tunnel.
- Incomplete incorrect: existing femoral or tibial tunnels communicate with the new correctly placed tunnels which might lead to large bone defects.

Correctly positioned tunnels measuring less than approximately 8 mm in diameter can be reused if primary reconstruction was performed with a soft tissue graft depending on the desired type of fixation (isolated versus hybrid). In these cases, tunnel preparation includes removal of intratunnel soft tissue using a drill or a shaver followed by drilling or dilation of the recreated tunnel to the desired diameter. The important effect of this procedure is a debridement of the tunnel wall by removing sclerotic bone so that graft incorporation can proceed.

In case of complete incorrect tunnel placement or complete bony replacement of the previous graft (e.g., BPTB), new tunnel preparation can be done as in primary ACL reconstruction. If an old and completely incorrect tunnel shows excessive enlargement, it should be filled with a cancellous bone plug or as an alternative with a biodegradable interference screw prior to graft fixation to prevent collapse between the old and new tunnel.

Surgically, the most demanding cases are those with incomplete incorrectly placed tunnels. Drilling a correctly positioned tunnel in these cases might lead to huge bone defects. To achieve stable tunnel conditions, we suggest initially drilling a correctly placed tunnel with a diameter of only 4–5 mm and then use the serial dilation technique to the desired diameter. This procedure leads to a compaction of cancellous bone from the newly created tunnel into the old tunnel. In critical cases with very large bone defects or low bone density, a biodegradable interference screw or a cancellous bone plug can be placed into the old tunnel prior to dilation. However, if there is only little uncertainty, a two-staged procedure should be performed.

Tunnel direction must be verified in the coronal plane in addition to the tunnel entry position. As many surgeons use a transtibial technique for femoral tunnel creation, the direction of a new tunnel drilled via the anteromedial portal diverges from the old tunnel, which finally improves graft fixation even if the tunnel entry site is enlarged. Thus, the anteromedial portal technique should be recommended routinely in all ACL revision procedures.

If excessive tunnel enlargement can be seen on regular radiographs, a CT scan is indicated to exactly identify its dimensions. Based on CT findings of tunnel enlargement, whether or not a two-staged procedure is necessary directly depends on the desired type of graft and fixation technique.

If a two-staged procedure is indicated, the first step includes autologous or allogenic cancellous bone or bone substitute filling followed by revision ACL reconstruction. On the femoral site, the impaction of a cylindrical iliac crest graft or a cylindrical synthetic filler (beta-TCP) can nicely be performed arthroscopically. The use of bone chips on the femur might require special instruments if performed arthroscopically. On the tibial site, one might use a single or two cylindrical plugs which should be impacted. However, in most cases, a tight filling with this technique is difficult. Thus, we recommend using autologous bone chips, eventually mixed with synthetic materials (beta-TCP) to tightly fill the old tunnel. In this case, one should be aware not to compact to bone chips into the joint cavity. We therefore recommend not to debride soft tissue from the tibial tunnel aperture site, which can later prevent bone chip access to the joint.

A new CT scan before revision ACL reconstruction should be taken to exactly evaluate bony recovery. If filling of the defects was successful, revision ACL reconstruction can be performed using the same methods as for primary reconstruction. The minimum time between bone grafting and revision reconstruction should be 3 months

7.4 ACL Revision : Peripheral (Collateral) Plastic: Yes or No

A. Amendola, M.D.

A. *Introduction: reasons for failed ACL reconstruction*
  1. Painful stiff knee
  2. Recurrent laxity 5–10%
    (a) Related to graft placement/technical
    (b) Traumatic
    (c) Biologic
  3. *Associated pathology*
    (a) Early OA /malalignment/chondral injury
    (b) Postmeniscectomy
    (c) *Collateral/associated laxity*
      i. *Medial*
      ii. *Lateral/posterolateral*

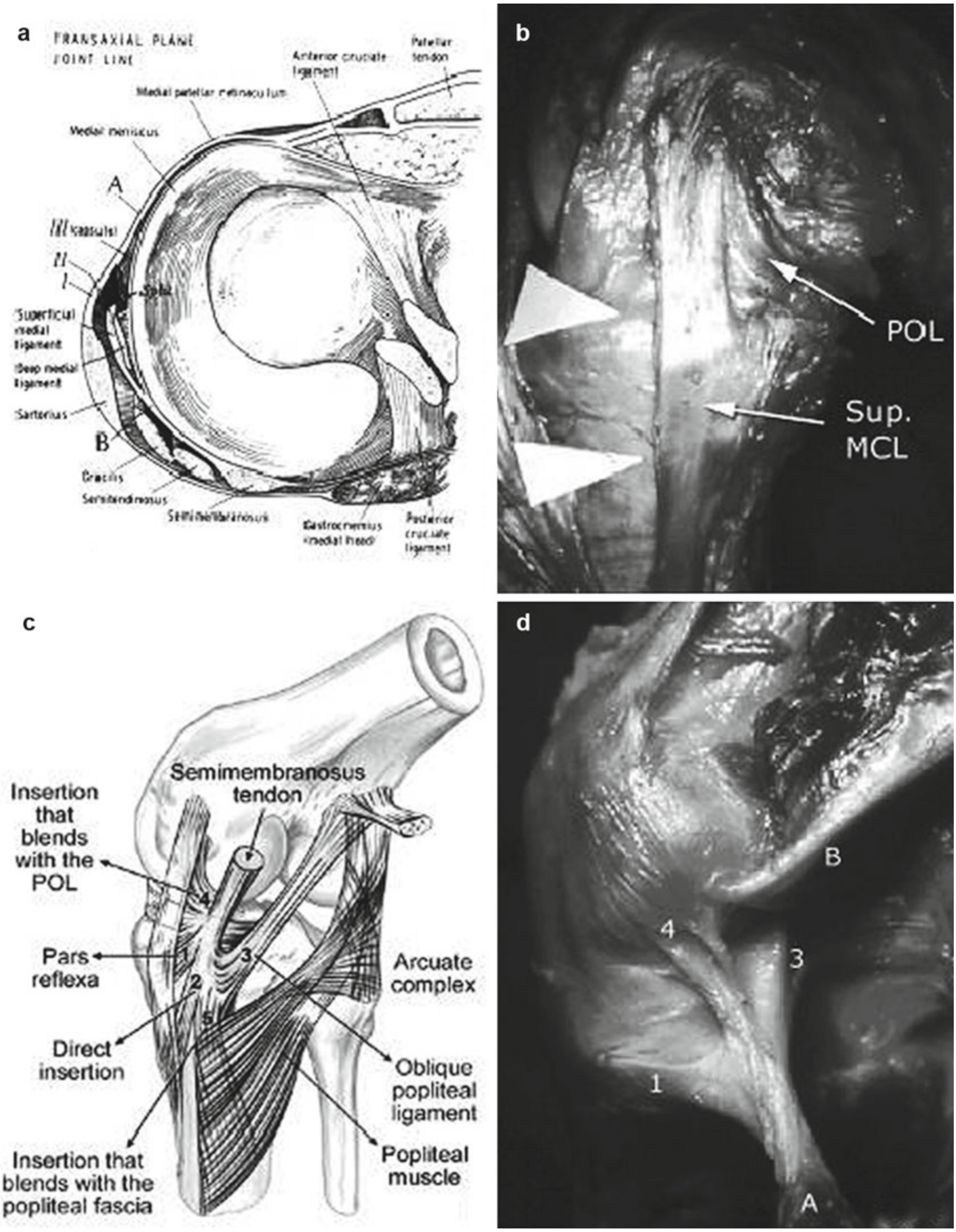
B. *Anatomy and biomechanics*
  1. Medial (valgus stability) (secondary ACL stability)
    (a) MCL deep and superficial layers (Marshall)
    (b) Medial meniscus
    (c) Dynamic: semimembranosus posteromedial stability
      i. Posterior oblique ligament (POL)
  2. ACL and MCL relationship
    (a) Higher risk of ACL injury with increasing valgus laxity
  3. Valgus alignment
    (a) In the face of the valgus knee alignment, isolated MCL and combined MCL/ACL are at higher risk of failure because of the chronic overload.

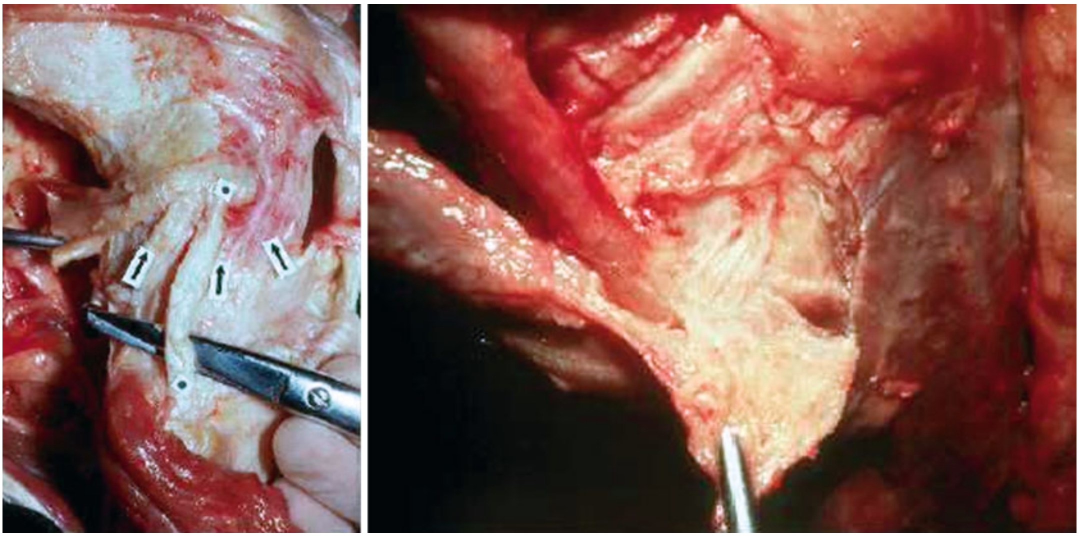
C. *Chronic ACL and MCL laxity*
  (a) If grade 2 laxity does not open in extension with ACLR, late medial repair and PM advancement
  (b) If grade 3 laxity (opens in extension) plan allograft ACLR and open MCL reconstruction with allograft (Achilles or tibialis graft)

D. *Posterolateral anatomy and biomechanics*
  1. Biceps complex
  2. Popliteus
  3. Lateral collateral ligament
  4. Popliteofibular ligament
  5. PL instability is a spectrum of injury and associated with ACL failure.
    (a) Isolated
    (b) Combined
    (c) Varus alignment

E. *ACL revision and lateral tendonesis (PLC stabilization)*
  1. Controversial effect on outcome of ACL revision surgery
  2. Improved stability
  3. Reduced failure rate of revision surgery

F. *Summary: considerations for success*
  1. Identify reasons for failure of ACLR and individualize Rx
  2. Associated pathology to consider for treatment at time of ACL revision
    (a) Alignment
    (b) Meniscal deficiency
    (c) Collateral/extra-articular laxity
  3. If collateral/secondary constraints are lax, should consider repair/reconstruction


a
TRANSAXIAL PLANE
JOINT LINE
Anterior cruciate ligament
Patellar tendon
Medial patellar retinaculum
Medial meniscus
A
III (capsule)
II
I
Split
Superficial medial ligament
Deep medial ligament
Sartorius
B
Gracilis
Semitendinosus
Semimembranosus
Gastrocnemius (medial head)
Posterior cruciate ligament
b
POL
Sup. MCL
c
Semimembranosus tendon
Insertion that blends with the POL
4
Pars reflexa
1
2
3
5
Direct insertion
Insertion that blends with the popliteal fascia
Arcuate complex
Oblique popliteal ligament
Popliteal muscle
d
B
4
3
1
A



7.5 Anterior Cruciate Revision in Varus Knee

M. Denti, C. Bait, M. Cervellin, E. Prospero, A. Quaglia, and P. Volpi

Knee anatomy reveals that approximately 60% of the weight-bearing forces are transmitted through the medial compartment and 40% through the lateral. The varus knee with unicompartmental OA of the medial compartment has an altered limb alignment; more load weighs subsequently on the affected compartment. In addition to this, the medial tibial plateau supports a very prevalent rate of the body weight, and the incorrect alignment accentuates the stress on the damaged articular cartilage, causing further degenerative changes and more severe angular deformity.

The situation is certainly worsened when dealing with an unstable knee, following, for instance, a cruciate ligament lesion or the failure of a cruciate ligament reconstruction associated with a medial meniscectomy.

In this case, the patient's pain symptoms are related to an initial arthritis associated with instability.

This situation may get worse if the patient underwent the failure of an ACL reconstruction.

Indeed, more functional requirements are certainly needed in this case.

A corrective osteotomy in varus asymptomatic knee is not generally required when ACL lesion occurs; on the contrary, ACL reconstruction/revision is often combined to osteotomy in arthritic and unstable varus in a 25–40-year-old patient.

The valgus tibial osteotomy that we usually perform is an open-wedge osteotomy.

The ACL revision graft is generally a duplicated semitendinosus-gracilis in case of autograft (also related to the previous surgery) or an allograft (Achilles tendon or tibialis anterior/posterior tendon).

The surgical timing is:

1. Diagnostic arthroscopy to evaluate the external compartment above all and to treat associated lesions
2. Graft preparation
3. Preparation of the bone tunnels through one incision technique or all-inside technique
4. Performance of the valgus tibial osteotomy and of its fixation with plate and screws
5. Graft fixation

The postoperative does not include any brace with a ROM from 0° to 60° for 7 days, 0–90° for 7 days and then complete, following the stages of ACL revision.

The weight bearing is not allowed for 30 days, and after that a partial weight bearing is allowed for 15 days and then complete, following the protocol of the osteotomy.

Combining ACL reconstruction to osteotomy does not imply therefore anything more demanding during the postoperative protocol.

The only contraindication is about surgical time, which is slightly longer.

We believe that the combination of a valgus osteotomy with an ACL reconstruction, even in case of revision, can lead us to have a correct axis and stable knee.

This combined surgery is obviously reserved to selective patients with instability associated with initial varus arthritis.

7.6 Postoperative Management

Gianluca Melegati

Reconstruction of the anterior cruciate ligament is one of the most common surgical procedures performed by orthopedic surgeons. Despite its wide success, 10% to 15% of patients may experience a failure of their ACL graft.

Most of these failures can be conducted to technical errors by the surgeon, most frequently femoral tunnel malposition. When graft failure occurs, it is necessary to perform an ACL revision procedure.

Revision of ACL reconstruction is a complicated and delicate clinical procedure whose results are theoretically less satisfactory than those of the first operation because further intervention is required in an area where anatomical landmarks may have been altered by previous procedures.

In fact, it is generally believed that the results of revision ACL reconstructions are not as good as the initial ACL, and the goal of the revision is to allow the patient to do their activities of daily living instead of return to competitive athletics. The patient should have realistic goals and understand all of the issues, but can be reassured that with the proper evaluation, treatment, and rehabilitation, a successful outcome can be expected in most cases. Some authors advocate a possible return to sports activities at the same level as before their initial ACL injury.

As following the first ACL reconstruction, the rehabilitation protocol and its timing can make or break the success of revision ACL graft surgery.

The rehabilitation for a revision ACL reconstruction is generally similar to that after the initial reconstruction, but may be lengthier and less aggressive. It must be explained to patients that the results could be less predictable than their initial surgery and that it could be very important that they followed the staged rehabilitation. Each rehabilitation program must be individualized to match the type of revision surgery, graft fixation, and additional surgery that the patient had. Weight bearing is often protected longer, and return to sports is withheld compared to primary ACL reconstruction.

One of the main goals of the rehabilitation after ACL revision surgery is to prevent arthrofibrosis.

If the knee becomes inflamed and regaining range of motion is slower than expected, it is important that the rehabilitation team keep in mind the possibility that adhesions and scar tissue may be forming within the joint cavity. In the early stages of rehabilitation, it is usually possible to arrest this process by appropriate intervention.

Rehabilitation focuses on immediately moving the knee the day after surgery, with the patient regaining full flexion and extension by the 4th–6th week.

If the rehabilitation is too quick or aggressive, the graft may fail or the joint space may become inflamed and trigger arthrofibrosis.

In some cases, when an extension deficit is expected, depending on the preoperative mobility, the patient's leg can be placed into a hinged knee brace locked in extension, with the patient permitted to be weight bearing as tolerated in the brace. The brace can be removed when the patient is not ambulating, and range of motion exercises are begun in the immediate postoperative period. The hinged knee brace can usually be discontinued within 1 week of surgery.

Straight-leg raises and quadriceps sets are initiated immediately after surgery. The patient generally uses crutches for the first 4 weeks, and physical therapy initially concentrates on achievement of full extension and progressive flexion. Full flexion should be reached within 6 weeks. Stationary bike can be started 1 week after surgery, step-simulator exercises at 4–6 weeks, and light jogging without cutting or pivoting in 12 weeks. Gradual return to full activities is achieved 6 months after surgery.

Return to sports activity does not follow temporary rules: it will be allowed when precise goals will be met by the patient: full ROM (equal to contralateral knee), recovery of running patterns without pain, proper isokinetic hamstring eccentric/quadriceps concentric strength ratio, proper single-triple leg-hop test, satisfactory functional agility and flexibility tests, and proper cardiovascular fitness recovery.

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Massive Rotator Cuff Tears and Rotator Cuff Arthropathy

8

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8.1 Introduction: Massive Rotator Cuff Tears (RCT) Criteria

Antonio Cartucho

8.1.1 Incidence and Etiology

Multiple etiologies have been implicated in the pathogenesis of rotator cuff tear mainly of two types: extrinsic, such as subacromial and internal impingement, tensile overload, repetitive stress; intrinsic, such as poor vascularity, alterations in material properties, matrix composition, and aging. The work of Yamamoto [1] statistically identified that the risk factors associated with rotator cuff tears in the general population were a history of trauma, the dominant arm, and age. In subjects who were under 49 years of age, rotator cuff tears were more strongly associated with the dominant arm and a history of trauma. These results indicated that extrinsic factors were more closely associated in the tears of the younger patients. The same study found 6.7 % of patients in their 40s with rotator cuff ruptures, 12.8 % in their 50s, 25.6 % in their 60s, 45.8 % in their 70s, and 50.0 % in their 80s, with the prevalence increasing with age. Despite these results, 16.9 % of the subjects without symptoms have also a rotator cuff rupture.

8.1.2 Classification

Rotator cuff tears are characterized by size, location, type of onset, retraction, muscle atrophy, and fatty degeneration. More recently, the presence of supra scapular nerve pathology has been emphasized by Albrighton [2]. Different authors have proposed various classification systems to define a “massive” tear. Cofield [3], for example, defined massive tears as those whose anterior-posterior dimension exceeds 5 cm. More recently, several authors have defined massive tears as those involving at least two complete tendons. According to the tendons involved on the massive tear, we have two distinct anatomic patterns: posterosuperior, involving the supraspinatus and the infraspinatus (Fig. 8.1) and teres minor; and anterosuperior involving the subscapularis, supraspinatus, and most of the times, the long head of the biceps (Fig. 8.2). Massive tears can be further classified by chronicity and are defined as acute, acute-on-chronic, or chronic. An acute tear is relatively infrequent and occurs after a traumatic event usually in young patients. Acute-on-chronic rotator cuff tear is usually middle-aged patients, and chronic massive tears are found almost exclusively in elderly patients. Muscle atrophy has been classified by Thomaseau [4] in three different degrees, and retraction was classified by Patte also in three different types.

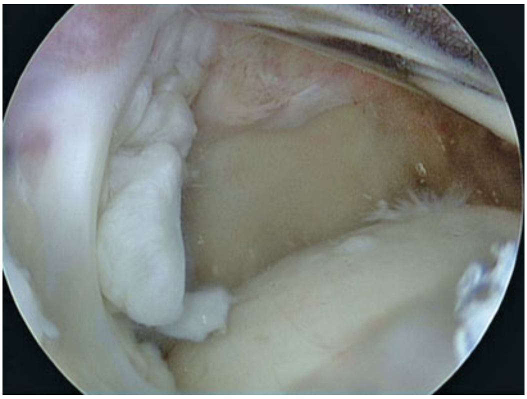


Fig. 8.1

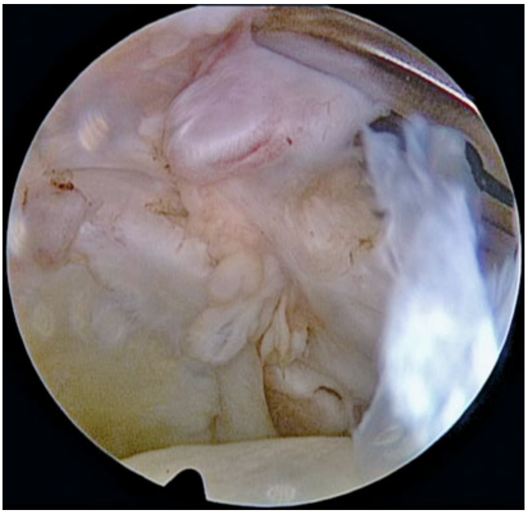


Fig. 8.2

The fatty degeneration, another prognostic factor, has been described by Goutalier [5] in 1990 and classified in four degrees according to the percentage of degenerated muscle belly.

8.1.3 Pathomechanics

With massive rotator cuff tears, there may be an uncoupling of the forces between the cuff and the deltoid that results in unstable kinematics. This fact is especially evident if the tear extends into the anterior or posterior cuff tendons. Despite this fact, patients with chronic massive rotator cuff tears may have a functional range of motion being pain and loss of strength as the major complaints.

8.1.4 General Guidelines for Treatment

Conservative treatment should be the choice in elderly patients with acceptable range of motion for daily living activities and little pain. Young patients with acute traumatic tears should be operated on. In patients with acute-on-chronic tears with poor function and/or with pain, evaluation of muscle atrophy, tendon quality, retraction, and fatty degeneration is the key for treatment choice. Operative treatment options include debridement, partial or complete repair with or without tissue substitutes, and tendon transfers. When glenohumeral joint cuff arthropathy is present, a shoulder replacement surgery, usually with an inverted prosthesis, may be considered.

8.2 Biomechanical Studies with JK Spinnaker Technique

Pascal Gleyze

We think that the current reinsertion techniques, more specifically double-row repairs, generate extended and stiff apposition areas [6–8] that lead to shearing effect in the myotendinous junctions in rotation movements.

The implant size, the spaces needed for a double-row repair, and the lack of flexibility of the suture sliding are all constraining factors that demand a larger size construct, heavy in material, and most of all mechanically far too rigid. We are under the opinion that to adapt to all rupture types, we need a system where the implant positioning can be more freely decided.

We therefore have worked in that direction and are presenting the biological and mechanical advantages of a more dynamic and supple "V" or "W" construct (we call it the Spinnaker Technique in reference to the special shape sail) that follows the principle of a lateral anchor to create a large V effect coupled with a tension-free medial row to secure a quality footprint without generating tendinous shearing effect. For this supple construct, we use the JuggerKnot suture anchor. Of a unique design, this suture anchor has demonstrated pullout strengths that satisfy the highest standards [9–11] (Figs. 8.3 and 8.4). The very nature of the JuggerKnot and its very small size allow an almost absolute flexibility in the insertion decision-making process. The direct result is the optimal biomechanical properties of the anchor spread. The pullout strengths, the shearing effects, and the various force spread patterns have been studied in the most common type constructs.

We most often combine the rotator cuff JuggerKnot 2.9 (referring to the size of the drilled hole) with the smaller JuggerKnot 1.4 initially designed for Bankarts or SLAPS. The JuggerKnot 1.4 is probably insufficient for a full-thickness cuff tear but conveniently completes "on demand" construct built on the JuggerKnot 2.9. For smaller arc-shaped tears, we propose a "V" construct (Fig. 8.5) and a double "V" for bigger tears (Fig. 8.6), and "a la Carte" construct for angulated tears with the possibility of deep partial

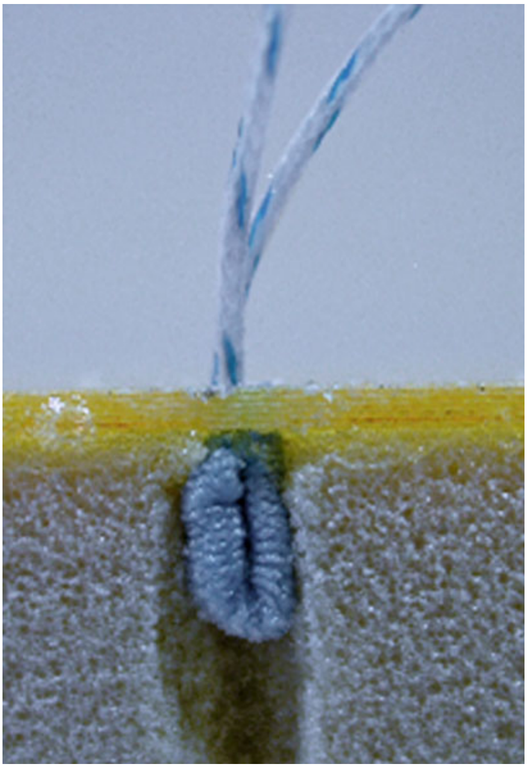


Fig. 8.3

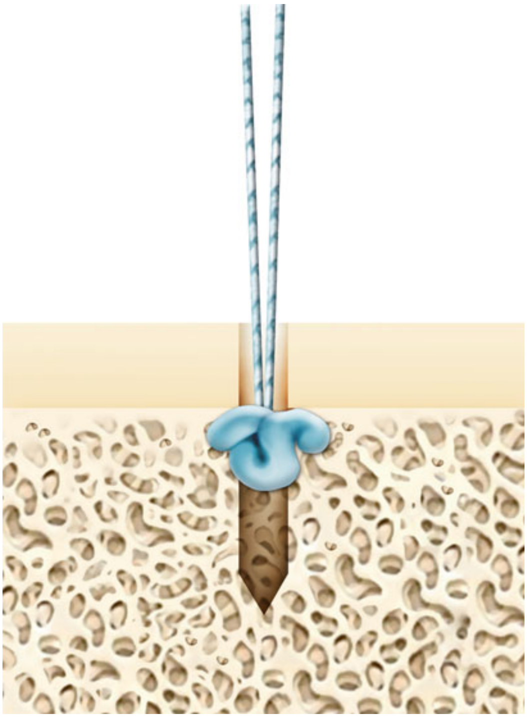
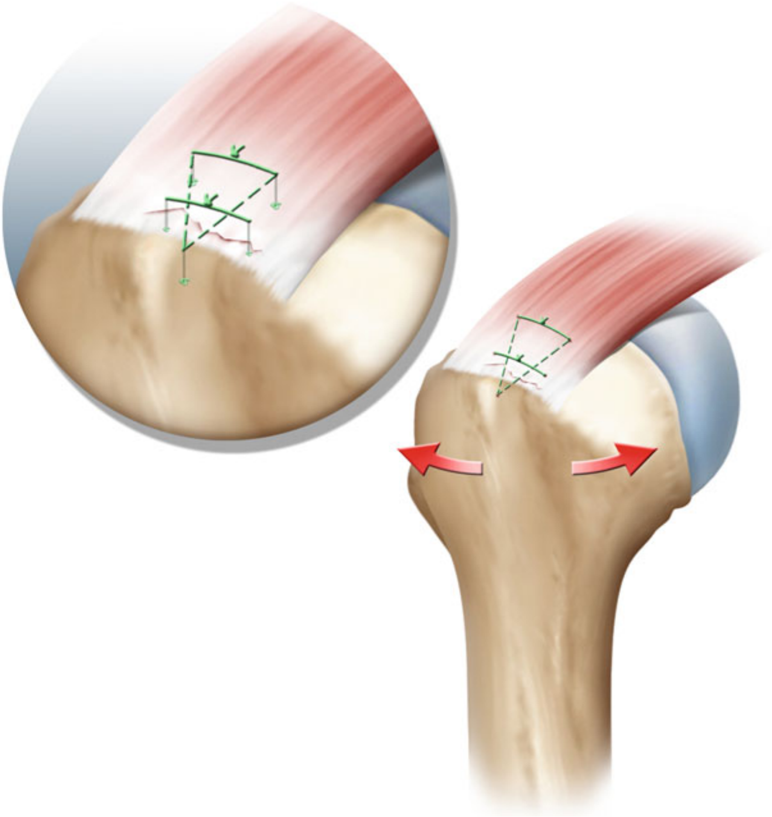


Fig. 8.4

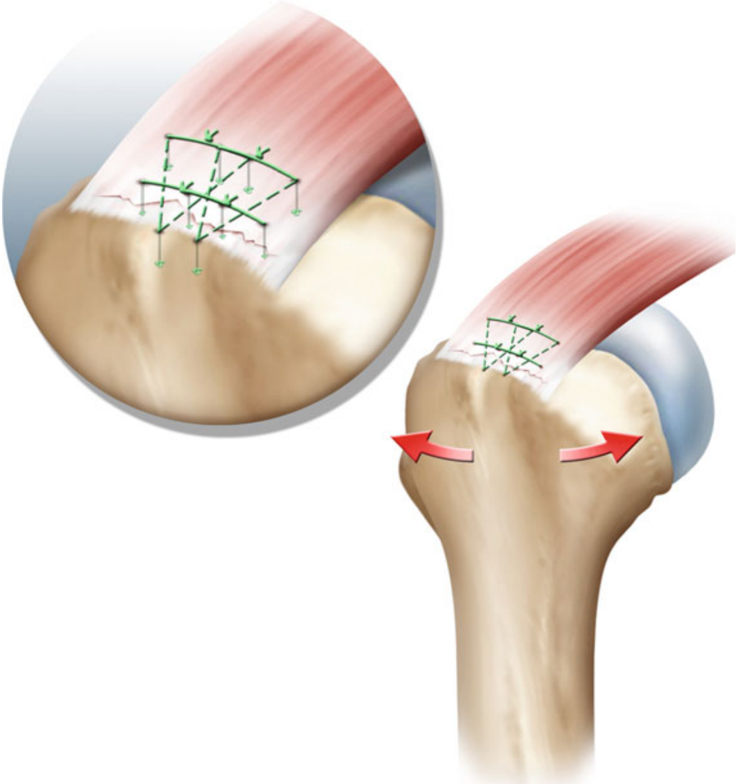
Fig. 8.5



tears repairs with a very small insert (1.4 mm) (Fig. 8.7).

This construct refers to sailing, where the sheeting point receives the sail pivoting and a suture row secures the angular tensions. It follows the principle of a fluid mechanical construct, dynamic because of its spread of the various forces, positioned "a la Carte," and little aggressive to the anatomical structures.

Fig. 8.6



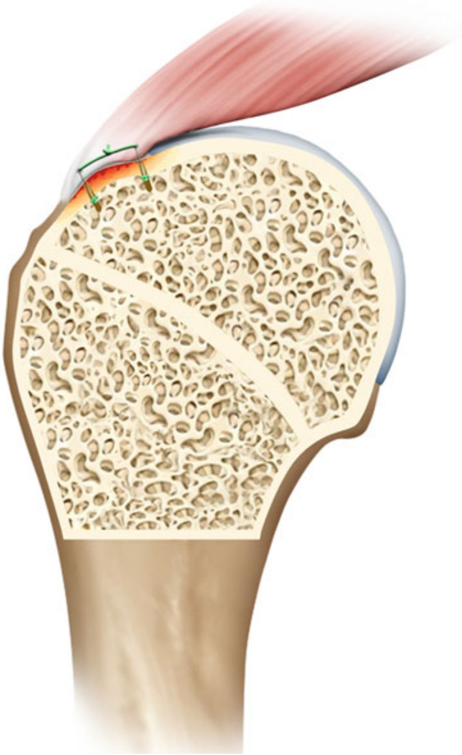


Fig. 8.7

8.3 The Importance of Biology in Rotator Cuff Treatment

Antoon Van Raebroeckx

To improve the outcome of the treatment of rotator cuff tears, different new techniques are being developed. Despite these new fixation techniques, healing rates remain insufficient. Failures are less likely to occur from weak tendon-to-bone fixation but more likely due to biological failure. A lot of research is being done on biological augmentation. Even more important, taking care of the biology of the repair itself using all this new techniques in our daily practice will improve our results.

The biology of a rotator cuff repair starts preoperatively, continues during the surgery, and ends during the revalidation period. There are a lot of factors the surgeon himself can take care of considering the basic principles of tendon-to-bone repair.

Clinical and technical examination will show the degree of fatty infiltration and quality of the muscle and tendon. Communication with the patient regarding these results might clarify the expected result after the repair. The negative effect on potential healing of crystalline glucocorticoid injections in the subacromial bursa needs to be considered if surgery might be necessary in the future. Most important, at this stage, is the importance of biology during the surgery itself. This starts with the examination of the tear and the recognition of the tear pattern. If the tear pattern is not fully understood, the repair will not be anatomical, and biology will fail. Time needs to be taken for a proper debridement of the bursa to have a nice view of the whole rotator cuff. Using a manipulator, the type of tear can be estimated. The importance of restoring the footprint is generally accepted. Time needs to be taken for the preparation of the footprint. For a tendon-to-bone repair, we need as healthy tissue on both sides as possible. All remaining fibers on the footprint need to be removed on an area as large as possible without taking of healthy cuff fibers. Radio-frequency devices are very useful and work quickly. After cleaning with the RF device, all tissue sides that need to heal must be cleaned using a shaver device before the repair, making sure that all death tissue is removed. Using new techniques, an area as big as possible of the footprint should be covered with the tendon. The importance of the tension on the rotator cuff is important, and it is widely accepted that too much tension should be avoided. More studies are needed to support this scientifically.

The importance of the biology continues after the repair. The healing process takes several weeks and can be divided into three stages: the inflammatory stage, the repair stage, and the remodeling stage. The negative effect of nicotine and nonsteroidal anti-inflammatory drugs is very well known. Patients should be asked to stop smoking 8 weeks before and 8 weeks after the repair. Both traditional and cox-2-specific NSAID inhibit tendon-bone healing. A good communication with the general practitioner is obligatory to avoid starting this medication during the period of cuff ingrowth. If possible, glucocorticoid medication should be stopped during the same period. The postoperative rehabilitation protocol should be respecting the healing process during the first 12 weeks. No ingrowth is seen on the first 6 weeks, and it takes up to 12 weeks before the first collagen fibers are strong enough to be loaded. It is generally accepted that active movement on the first 6 weeks should be avoided. There is less agreement on when to start passive motion. In contrast to what many think, to early start the passive motion exercises might lead to stiffness. In general, passive motion exercises should be started between 3 and 6 weeks postoperatively.

Besides all these factors that should be taken care of in our daily practice, a lot of scientific work is being done to further improve the biology of a rotator cuff repair. Tendon augmentation with autograft can be used to decrease the tension on the repair. An extracellular matrix with no cellular components acts as a tissue bridge between tendon and bone or can be used as a reinforcement of a poor-quality tendon in a tendon-to-bone repair. Recently, xenograft, allograft, and synthetic extracellular matrices are being developed and used. While xenografts yield mixed results, allograft extracellular matrices show some promising results. To avoid the inflammatory response to some DNA in the matrix, synthetic grafts are being developed. The next step is the development of ECM autogenic cell constructs, which were autologous cells that are harvested from undamaged sites on the host and cultured with the ECM. Using gene therapy, these constructs can be manipulated to promote fibroblast proliferation and minimize inflammation. Growth factors have been tested individually for their contribution to rotator cuff healing. Different systems are commercially available to augment the repair with platelet-rich plasma. Until now, no significant difference is being reported using these techniques. Results of randomized control studies using PRP as an augmentation to rotator cuff repair versus a conventional repair are waited for.

All these new techniques and promising new developments may not change the focus we need to put on the basic biology of our daily rotator cuff repair.

8.4 Massive Cuff Tear: Suture Bridge Repair

Bruno Toussaint

Massive cuff tears are not common. Even in clinical practices limited to the treatment of shoulder problems, less than one-third of all rotator cuff tears are massive. Massive anterosuperior rotator cuff tears are even less common.

While there is no universal agreement on the definition, in North America Cofield's definition of a massive tear as one with a diameter of 5 cm or greater is used [12], in France Patte's definition of a massive tear as on with three tendons torn or more is used. Massive cuff tear could not be repaired every time. Different factors modify ability to repair massive cuff tear. A number of treatment options are available to the surgeon when a massive defect of the tendons of the rotator cuff is found, but if the full repair is possible, the suture bridge technique is a good option that it restores the cuff footprint as well [13–16].

8.4.1 The Preoperative Assessment of Ability to Repair Massive Cuff Tear

Massive cuff tears classification will need to be updated. Recognition of the geometric tear patterns described in new classification, described by Burkhart, will remain useful and serve as a basis for communication and comparison of treatment methods and outcomes [17–19].

Fatty degeneration of the rotator cuff muscles, as determined on magnetic resonance imaging (MRI) or computed tomography (CT) scan, is frequently invoked as a contraindication, or at least a relative contraindication, to rotator cuff repair. Superior migration of the humeral head is also invoked as a contraindication to rotator cuff repair. Currently, they are relative contraindications [20]. Some authorities believe that rotator cuff repair in shoulders with 50 % or greater fatty degeneration of the infraspinatus (as shown on MRI or CT scan) is doomed to failure. This philosophy is based primarily on the work of Goutallier et al. who stated that patients with rotator cuff tears associated with stage 3 (50 %) or stage 4 (>50 %) fatty degeneration of the infraspinatus did not improve after surgical repair. Although the original imaging studies were CT scans, Gerber et al. [20] have shown that MRI and CT scans are equivalent in their ability to detect fatty degeneration of muscle. Additionally, MRI, because of improved contrast resolution, can better differentiate muscle from fibrous tissue and fat and has widely replaced CT scanning in the majority of centers for shoulder evaluation. Nakagaki et al. have shown that the fatty degeneration correlated well with the size of the cuff defect and the tendon fiber area. The fatty degeneration in the supraspinatus muscle after a cuff tear is associated with retraction of the tendon fiber rather than with reduction of the muscle size. Burkhart et al. [21] have shown what arthroscopic rotator cuff repair in patients with grade 3 or 4 fatty degeneration (≥50 %) can provide significant functional improvement. Those with 50–75 % fatty degeneration show a much greater degree of improvement than those with >75 % fatty degeneration. However, clinical improvement was observed for some patients having >75 % fatty degeneration and for all patients in the 50–75 % group. Pseudoparalysis, which is often a characteristic symptom of large-to-massive rotator cuff tear, has been focused on recently because it is one of the important indication criteria for performing reverse total shoulder arthroplasty. It is also known to be a negative prognostic factor of rotator cuff repair in cases of large-to-massive tears. Therefore, pseudoparalysis is not an irreversible phenomenon. Further, a fairly large number of the patients could elevate their shoulder above horizontal level after rotator cuff repair [22]. A large number of the patients did recover from pseudoparalysis after rotator cuff repair, and postoperative function was favorable. Functional and anatomic outcomes of the pseudoparalytic groups were comparable to nonpseudoparalytic groups. Considering the complications and longevity of reverse total shoulder arthroplasty, rotator cuff repair should be the first-line treatment option for nonarthritic large-to-massive tears regardless of the presence of pseudoparalysis.

Which are the factors that influence the tendon-to-bone healing? Bone quality, tendon quality, and muscle retraction are the main factors [23–27].

Although cuff strength may be compromised by inflammatory arthritis and steroids, the primary cause of tendon degeneration is aging. Like the rest of the body's connective tissues, rotator cuff tendon fibers become weaker with disuse and age; as they become weaker, less force is required to disrupt them. Other authors have shown loss of tendon strength with age. Pettersson provides an excellent summary of the early work on the pathology of degenerative changes in the cuff tendons. Citing the research of Loschke, Wrede, Codman, Schaer, Glatthaar, Wells, and others, he builds a convincing case for primary, age-related degeneration of the tendon manifested by changes in cell arrangement, calcium deposition, fibrinoid thickening, fatty degeneration, necrosis, and rents.

Reparability should be confirmed intraoperatively, not judged solely on preoperative criteria.

The surgical treatment of massive, contracted, immobile rotator cuff tears (of the posterosuperior rotator cuff) can be difficult and demanding.

Tauro was the first to describe an arthroscopic interval slide (anterior interval slide) for improving the mobility of contracted tears. The anterior interval slide improves the mobility of the rotator cuff by releasing the interval between the supraspinatus tendon and the rotator interval, effectively incising the coracohumeral ligament, which commonly becomes contracted in the tear patterns [17, 24, 28, 29].

Burkhart et al. [30] have shown that the double-interval slides have demonstrated significant improvements to reestablish the rotator cuff footprint.

According to the rotator cable and crescent theory, it countered more logical today to preserve the rotator cable which is the most resisting tissue element to fix to the bone. The respect of comma sign anteriorly and the connected fibers of supra- and infraspinatus posteriorly seems the key point of the repair technique. And the mechanical strength of repaired tendons is improved as well as possible.

Glenohumeral joint and subacromial side release are very important to recreate a good rotator tendon mobility. In these cases, because of the propensity of the coracohumeral ligament to rigidly shorten and thereby tether the rotator cuff medially, mobilization techniques are required to allow repair of the rotator cuff to a lateral bone bed in a tension-free manner. The comma sign is made from the superficial layer of the rotator interval established by subscapularis superficial fibers connected with supraspinatus superficial fibers and is often stuck on the coracoid process. It must be totally released from the coracoid process. Posteriorly, the release must be careful to avoid damaging the suprascapular nerve just in front of the scapular spine. The articular capsule must be opened superiorly for 3 o'clock to 7 o'clock to improve the rotator cuff tendon mobility.

Cadaver study has shown that the maximum lateral advancement of the cuff that it permitted by the neurovascular structures is 3 cm [31].

The fixation is made then easily on first-row anchors restarted on the whole footprint as parachute. The second-row anchors apply compression over the footprint of the rotator cuff. All sutures should be passed through the rotator cuff tendon in first and have tied in a second time to improve suture passing.

Although arthroscopic rotator cuff repairs have led to excellent clinical results, there has been some criticism of suture anchor repair constructs. This is because when the rotator cuff is repaired with a single row of suture and anchors, the normal footprint of the rotator cuff is not restored. In an elegant study by Apreleva et al., the effect of reconstruction method on three-dimensional repair site area was evaluated. These authors determined that suture anchor repair constructs restored only 67 % of the original "footprint" of the rotator cuff, whereas transosseous simple suture repairs restored approximately 85 % of the surface area. The technique for double-row suture anchor fixation for arthroscopic rotator cuff repair was first described by Lo and

Burkhart. Those authors proposed that by placing two rows of suture anchors, one on the medial side of the footprint and the other on the lateral side, a more anatomic repair configuration could be achieved. The result, they hypothesized, would be a stronger repair construct and a larger contact area for healing, yielding superior clinical outcomes and a more durable rotator cuff repair. Lafosse et al. have reported a rate of structural failure after double-row fixation was only 11 %, and to our knowledge, this value represents the lowest rate of structural failure after either open or arthroscopic repair as reported in the literature. Galatz et al. [32], in a study on the results of all arthroscopic reconstruction of large or massive rotator cuff tears with use of single-row suture anchors and simple sutures, reported recurrence of the tear in 17 of 18 patients as assessed with ultrasonography. The shoulders with repaired large and massive rotator cuff tears had less strength than those with smaller tears. These findings suggest that the double-row suture anchor configuration may be the optimal repair construct for arthroscopic rotator cuff repair. We believe that the transosseous equivalent versus suture bridge technique provides excellent initial repair strength [16, 24, 33–35]. This strength, as well as the compression applied over the footprint of the cuff, allows for increased surface area and healing. Traditional single-row repairs allow only for healing of the edge of the tendon to bone. Double-row techniques provide excellent strength but lack the compressive effect of the suture bridge. The biomechanical study presented by El Attrache et al. [34] is the first comparison of double- and single-row repair techniques that accounts for the tension differential between the two. The results suggest that, when possible, a double-row repair should be performed for the treatment of retracted tears of the rotator cuff.

Arthroscopic revision rotator cuff repair is a reasonable treatment option, even in cases of massive retear. The good midterm improvement in forward elevation could be explained by deltoid integrity that is essential to achieve satisfactory elevation but also by the systematic repair of the subscapularis that provided restoration of the rotator cable and balanced force couples.

8.5 Double-Row Technique Appliance in Massive RC Tears

Roman Brzoska and Adrian Blasiak

8.5.1 Introduction

Massive rotator cuff injuries are the most common cause of pain and movement impairment of the shoulder. New very successful arthroscopic reconstruction methods of repair of RC rapture have been established in a few last years. It has become possible due to use of stronger bone implants (anchors) with improved surgical sutures as well as improvement in visualization of joint's structures (arthroscopic pump, radiofrequency device). The aim of arthroscopic treatment is to achieve strong and durable junction between bone and tendon while allowing both structures to heal. Single-row implantation technique is simpler, faster, and requires less artificial material. Some believe that using fewer sutures with excellent results of repair is a great advantage of this technique. Double-row technique is more challenging; however, it can produce RC junction similar to anatomical. Physiological movements of shoulder postoperatively are fully restored which was confirmed by biomechanical studies [36, 37]. Unfortunately double-row technique requires more artificial material to build up junction, and for some, it is the disadvantage of the technique. It will also lead to increased cost of operation. Some authors proved that the "watertight closure of the rotator cuff is not needed to obtain successful outcome" [38–40]. The aim of the partial repair is to restore of the proper mechanics of the shoulder through the reconstruction of infraspinatus and subscapularis tendon footprint. Both of them give opposition forces to the deltoid muscle force vector. This partial reconstruction prevents upper migration of the humeral head [41].

8.5.2 Technique

The patient is settled in the "beach-chair" position, under general anesthesia following interscalene block. This position gives the best insight into the subacromial space and allows removing all adhesions between the ruptured tendons and undersurface of the acromion and also performing extensive capsulotomy. These two procedures facilitate to mobilize retracted cuff tendons (Fig. 8.8). The next stage is precise definition of the shape and direction of retraction of the tendon margin. With the tissue grasper, the mobility is tested in order to approximate the tendons to the tuberosity (Fig. 8.9).

From the perspective of healing process, it is very important to prepare bony bed until the bleeding of cortical bone surface. The first double-loaded anchor is situated at the cartilage rim

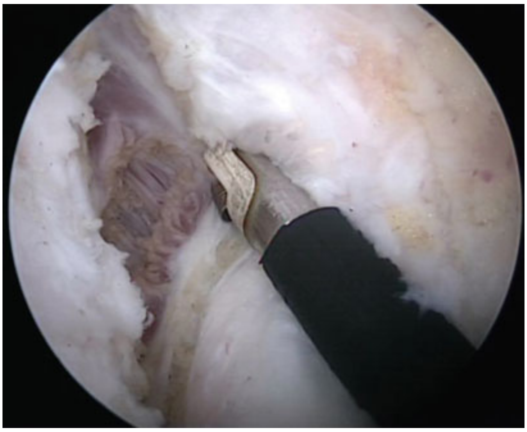


Fig. 8.8

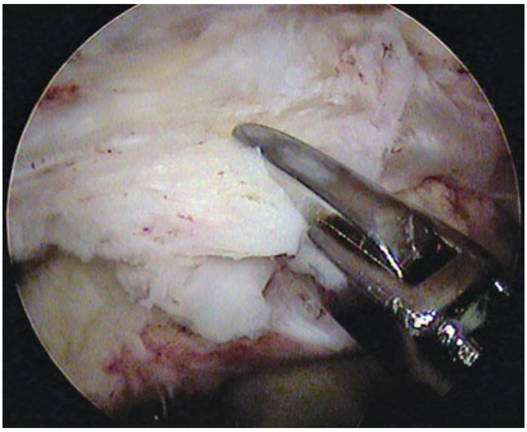


Fig. 8.9

(Fig. 8.10). The most technically demanding step of this procedure is suturing the tendons. The goal of this step is to choose the strongest part of the tendon for passing the sutures, which provides a strong footprint restoration. Using a Clever Hook device, two mattress sutures for each of double-loaded anchors are performed (Fig. 8.11).

Second-row anchor is placed on the lateral aspect of the great tuberosity.

After all anchors are placed and all threads have been passed through the tendon, the cuff is reduced with a locking knot made on the "lasso-loop" stitch at the lateral anchors (Fig. 8.12). After the reduction has been completed, mattress sutures on the medial anchors are tightened [42]. If necessary, acromioplasty and/or acromioclavicular joint resection is performed. No complications were reported during surgeries.

8.5.3 Results

All our patients have been assessed by postoperative Constant score, USG examination, Jobe and Neer tests that were used to evaluate results and recovery postsurgery. From 2006 to 2009, 54 patients (mean age 58 ± 9.3, range 27–79) underwent arthroscopic double-row reconstruction of massive RCT. Results of surgery were assessed 3, 6, and 12 months postoperatively. Massive rupture of supra- and infraspinatus muscle tendon was the most common type of injury. Good results according to Constant score were observed (Table 8.1).

There were twice less reinjuries confirmed by USG examination in 12 months postoperatively in patients with type II infraspinatus retraction (according to Patte classification), comparing with type III injuries of this tendon. Better results in group with smaller infraspinatus ruptures in 3 and 6 months postoperatively according to Constant score suggest less pain and wider range of arm's movements. Older patients (>65 years old) had worst results. Limited movements of arm and pain were still present 12 months postoperatively; however, improvement to preopera-

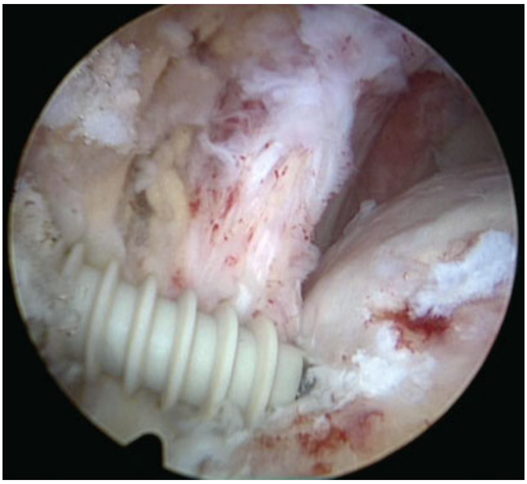


Fig. 8.10

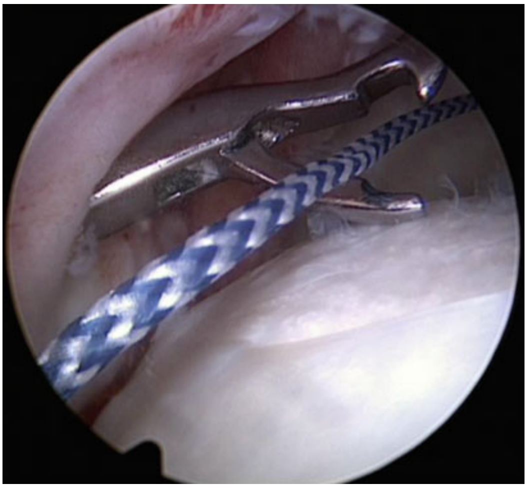


Fig. 8.11

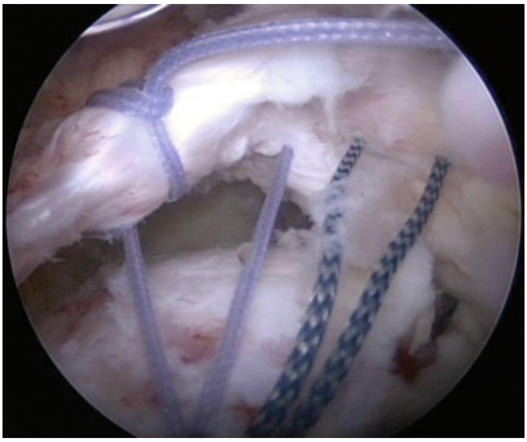
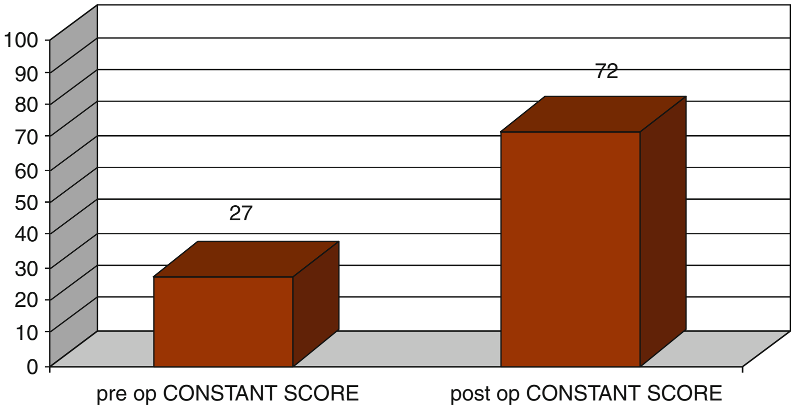


Fig. 8.12



tive status was still satisfactory according to Constant score.

8.5.4 Conclusions

Double-row technique is effective and adequate to the massive RCT repair. However, the condition must be met to obtain a good mobilization of retracted tendons what allows to tie the knots without excessive tension of sutured tissue.

8.6 The Shoestring Bridge

Maarten van der List and Peer van der Zwaal

Historically, the aim of the rotator cuff repair is to mobilize the tendon, close the defect, and anatomically restore the insertion on the footprint. Large U- and L-shaped tears are usually transformed into smaller tears by side-to-side repair with interrupted sutures in a medial to lateral progression (the margin convergence technique). Then the tendon is fixed by a single or double row of corkscrews or suture anchors. In our opinion, this is the method of choice in small, medium, and large mobile tears. However, in large degenerative and nonelastic tears, there is a significant risk that the tendon will fail after mobilization and fixation onto the anatomic footprint – too much tension. The shoestring bridge technique uses a principally different approach for the repair of these rotator cuff tears. It is a solely side-to-side repair without anatomical reconstruction of the footprint. The shoestring configuration using the broad FiberTape evenly distributes the tension over the tendon. This makes the repair more resilient in spite of the poor-quality tissue. We hypothesize that although there is no restoration of the footprint, there is a functional restoration of the cable bridge of Burkhart. We believe this is an important aspect of the procedure.

From a mechanical point of view, it is interesting to conclude that functional repair is possible without insertion onto the footprint.

We think the shoestring bridge can be a valuable technique for the shoulder surgeon in the treatment these challenging cuff ruptures.

8.7 Orthospace InSpace™ Balloon System in Massive Irreparable Rotator Cuff Tears

Vladimir Senekovic, Boris Poberaj, Ladislav Kovacic, Boštjan Sluga Martin Mikek, Ehud Atoun, Eliyau Adar, and Assaf Dekel

8.7.1 Introduction

Rotator cuff tears (RCTs) are among the commonest tendon injuries seen in orthopedic patients resulting in significant community-borne pain and disability.

Irreparable RCTs are defined by the size of the tear, the presence of tendon retraction, chronicity of the injury, the amount of muscle atrophy, and degree of fatty degeneration. In these situations, direct repair at the point of insertion is usually not feasible despite extensive soft-tissue mobilization and release. A range of surgical options are available including debridement (with or without partial tendon repair), tendon transfer, muscle-tendon slide procedures, the utilization of rotator cuff allograft and synthetic graft materials, arthrodesis, reverse arthroplasty, or hemiarthroplasty. It has been reported in massive RCTs that primary repairs will rerupture in between 20 % and 65 % of patients over time. Although patients with massive RCTs may be capable of generating glenohumeral abduction, methods designed to reduce pain will result in significantly improved shoulder kinematics. Our hypothesis is that the deployment of an inflatable balloon into the subacromial space in patients with massive RCTs will prevent impingement during abduction, resulting in painless activation of the scapulohumeral musculature. Moreover, lowering of the humeral head during balloon inflation may provide an improved balance between the subscapularis anteriorly and the infraspinatus posteriorly and permit better deltoid activation and compensation through the arc of motion. This study assesses the safety and clinical outcome of the use of the copolymer InSpace™ (Orthospace Ltd., Israel) balloon in a group of patients diagnosed with a massive irreparable RCT.

8.7.2 Methods

8.7.2.1 Study Design

Patients were enrolled in the study after signing an informed consent. The study was ethically approved by the hospital's Institutional Review Board and Slovenian Competent Authority. The study was designed to assess the initial safety and efficacy of the InSpace ™ balloon system in subjects with massive irreparable tears, to record surgeon satisfaction with the implantation procedure, as well as procedure and device-related adverse effects. Primary endpoints included pain relief over time (along with relief of night pain), improvement in the range of motion, activities of daily living, and shoulder strength using the Constant score recorded at each follow-up visit. Specific contraindications to InSpace™ deployment included patients with significant shoulder osteoarthritis, evidence of glenohumeral instability, prior shoulder surgery, or those with concomitant shoulder infection or immunosuppression. Patients were clinically assessed preoperatively for the presence of a full-thickness massive RCT with supplementary imaging using ultrasound, CT arthrography, and magnetic resonance (MR) imaging as appropriate. Final confirmation of the RCT size, tendon involvement, and reducibility was made during arthroscopy where the surgeon assessed the feasibility of surgical repair. Prospective postoperative assessment of symptoms, complications, and/or device-related adverse events were recorded with prospective determination of the Constant score as well as at hospital discharge 1, 3, and 6 weeks, 3 and 6 months, 1.5 and 3 years postoperatively. Balloon placement and degradation were assessed by sonographic evaluation at 1 week and 3 and 6 months postimplantation.

8.7.2.2 InSpace™ Balloon System

The InSpace™ system is a biodegradable balloon meant for arthroscopic insertion into the subacromial space following bursa excision. The preshaped balloon is comprised of a copolymer of poly-L-lactide-co-ε-caprolactone in a 70:30 ratio which biodegrades over a period of 12 months. Insertion of the balloon is aided by folding it into a cylindrical shape inside an insertion tube. Once positioned in the subacromial

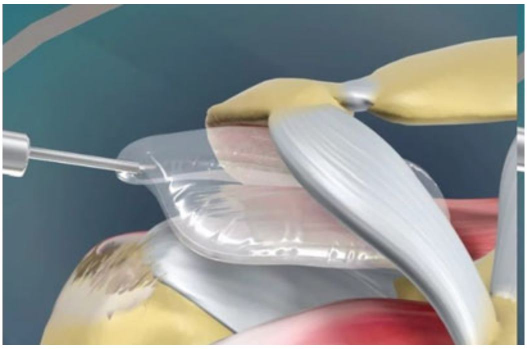


Fig. 8.13 Schematic representation of the InSpace™ balloon deployment and inflation in the subacromial space through an insertion tube (*left* of image)

space, the balloon is inflated with saline permitting frictionless gliding of the humeral head against the acromion. A schematic representation of the balloon deployment is shown in Fig. 8.13a,b. Balloon size (small, medium, or large) is selected based on the surgeon's discretion following measurement of the distance between the lateral border of the acromion and the superior rim of the glenoid as well after defining the extent of any tear extension. The range of motion is determined by balloon inflation and deflation, and the appropriate inflation volume is left in situ by withdrawing the syringe which effectively seals the balloon (Fig. 8.13).

8.7.2.3 Surgical Technique

All operations were performed with the patient in a beach-chair position under general anesthesia using three arthroscopic ports (anterior, lateral, and posterior or posterolateral). After subtotal removal of the subacromial bursa, the tear was debrided, and the rotator cuff was assessed by grasping the edges of the tendons with an arthroscopic clamp in an attempt to draw it to the footprint region. A decision was made to insert the balloon when it was deemed that the RCT was irreparable.

8.7.3 Results

A total of 20 patients (11 males and 9 females; mean age 70.5 years) with massive RCTs were enrolled in the study between the periods of May and October 2008 at the Department of Traumatology at the University Medical Centre Ljubljana and two of its satellite implanting centers, the Valdoltra Orthopedic Hospital and the Department of Surgery at the Novo Mesto General Hospital in Slovenia. In all but one case, where a miniopen approach was used, the balloon was inserted arthroscopically. The mean duration of symptoms prior to surgery was 34.7 months (range 4–95 months) with documented failure of conservative treatment in all patients. The technique of implantation was recorded as relatively straightforward by all surgeons where the approximate time for implantation (from insertion of the InSpace™ balloon to withdrawal of the accessories after deployment) ranged from 2 to 20 min. Two patients were lost from follow-up (one patient died during follow-up from cardiac disease at the time of the 1.5-year visit).

Table 8.2 shows the baseline and follow-up clinical scoring data of the 20 patients analyzed, and Fig. 8.14 shows these changes represented graphically. There was a significant improvement in the subjective pain score (module A of the Constant score), commencing at 1 week following balloon implantation, with a mean change of 2.91 points (95 % CI 1.28–4.54; $P = 0.0021$). This improvement remained statistically significant with a progressive increase throughout the duration of follow-up. At the 3-year visit, the average change reached 6.11 points (95 % CI, 4.34–7.88; $P < .0001$). Night pain statistically improved beginning at 1 week postsurgery (95 % CI 0.41–0.97; $P < 0.0001$) with a sustained statistically significant improvement through to the 3-year follow-up visit (95 % CI 0.69–1.30; $P < 0.0001$). Improvement in night pain was reported in 12/18 patients (66 %) at the first postoperative week, in 14 (77 %) patients at the 1.5-year visit, and sustained at the 3-year follow-up visit (14/18; 77 % patients). One patient had no improvement in pain, where at 6 weeks, an ultrasound showed that the InSpace™ balloon was partially deflated. This patient withdrew consent from further participation in the study and a few months later underwent reverse total shoulder arthroplasty. No other device- or proce-

Table 8.2 Summary of patient efficacy data mean scores (+ SD) from preoperation (baseline) up to 3 years after InSpace balloon deployment

	Baseline N = 20	3 weeks N = 20	6 weeks N = 20	3 months N = 17	6 months N = 18	1.5 years N = 17	3 years N = 17
TCS	33.41 (13.34)	39.05 (13.04)	42.61 (15.00)	44.12 (14.98)	50.36 (19.72)	60.11 (24.30)	60.00 (22.68)
SPS	5.08 (2.76)	7.70 (3.57)	7.70 (3.57)	8.28 (3.94)	8.92 (4.16)	11.56 (4.47)	11.29 (4.09)
Night pain	0.70 (0.66)	1.25 (0.79)	1.30 (0.66)	1.35 (0.49)	1.72 (0.46)	1.53 (0.62)	1.71 (0.47)
Daily activities	7.20 (3.36)	9.77 (4.65)	9.50 (3.44)	10.06 (3.07)	10.94 (3.95)	13.82 (5.36)	15.94 (4.39)
ROM	20.60 (8.95)	21.60 (7.75)	24.70 (9.91)	25.76 (10.27)	27.00 (9.68)	30.00 (11.00)	28.82 (11.94)
Power	0.54 (2.39)	–	–	–	3.50 (7.02)	5.20 (8.43)	3.95 (4.99)

TCS – total constant score, SPS – subjective pain score, ROM – range of motion

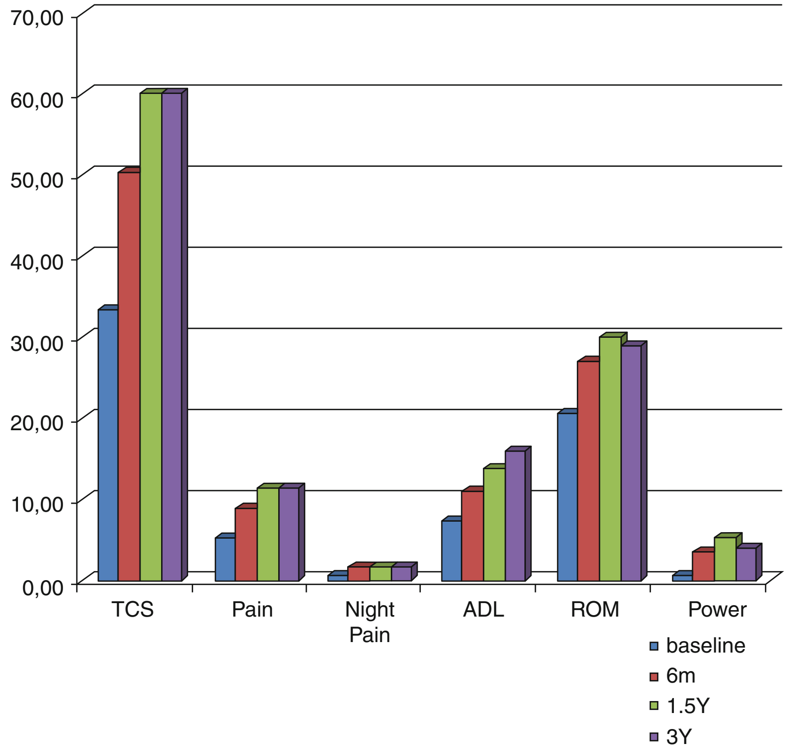


Fig. 8.14 Graphical representation of changes from baseline *during follow-up* in the constant variables following InSpace™ balloon insertion

dure-related adverse events were noted during the entire follow-up period.

Patients reported significant improvement in their activities of daily living beginning at the third week after surgery showing an average of 2.52 points of change (95 % CI 0.82–4.23; P = 0.004) which increased up to 8.76 points (95 % CI 6.91–10.61; P < 0.0001) at 3 years of follow-up. The range of motion also showed significant improvement beginning at 6 weeks postsurgery with a mean change of 3.96 points (95 % CI 0.454–7.48; P = 0.0272). This change progressively increased throughout the study period up to 7.27 points (95 % CI 3.87–11.49; P < 0.0001) at 3-year follow-up. Shoulder power was difficult to evaluate early on in the postimplantation period but showed significant improvement at 1.5 years (95 % CI 2.59–6.84; P < 0.0001) which was sustained at 3 years (95 % CI 1.24–5.5; P = 0.0022). In all measurable parameters, once an improvement reached significance, it was maintained throughout the follow-up period.

8.7.4 Conclusion

This preliminary prospective pilot study has shown clinical safety and efficacy of the InSpace™ device in a small group of patients with massive irreparable rotator cuff tears (RCTs). The insertion of the device was associated with significant early improvement in subjective pain scores and a decrease in reported night pain. The total Constant score showed statistically significant improvement as did scores of activities of daily living and range of motion, each of which was sustained at 3 years of follow-up. Further longitudinal randomized studies are required to determine its place in the management of irreparable massive rotator cuff injury.

8.8 Arthroscopic Assisted Latissimus Dorsi Transfer in Massive Rotator Cuff Tear

Viktoras Jermolajevas

8.8.1 Introduction

Irreparable rotator cuff teas are characterized by the inability to achieve direct repair to proximal humerus despite mobilization. Moreover, not all repaired tissue is able to heal. In 1988, Gerber describes the open technique of latissimus dorsi transfer (LDT) and, in 1992, showed that obtained results are long lasting [43]. First arthroscopic LDT technique was published in 2007 by Gervasi [44]. This technique was adopted to operate in beach-chair position with several improvements in harvesting and fixation.

8.8.2 Material and Technique

Since 2009, 31 patients were operated. Mean age was 62 years, range 41–78, 19 men, 12 women. The essential criteria for inclusion were good deltoid and at least reparable subscapular muscle, arthritis no more than stage II. Mean active elevation was 90, range 10–150. Belly press test was positive in 20 cases, but lift of test was negative in all cases; this suggested for partial subscap rupture. External rotation lag was gross in all cases. All patients were operated in beach-chair position. Portal used as for routine cuff surgery, with addition suprapectoral portal for LD release (Fig. 8.15a).

Definitive decision to perform LDT was made during surgery after tendon mobilization. Operation could be divided in six steps: (1) Posterior view: subs repair, biceps tenotomy (if needed); (2) Lateral view: anterior interval slide, SSc nerve release, circular capsulotomy, bursectomy, decision for LDT; (3) Lateral view: finding of interval between teres minor and deltoid, urinary catheter near long triceps tendon; (4) Anterior view: 1-cm release of Pec major, full LD release from humerus; (5) Posterior axillary incision (Fig. 8.15b), LD distal release from subcutaneous tissue, transfer subacromially; (6) Lateral view: partial cuff insertion (Fig. 8.16), LD insertion, acromioplasty.

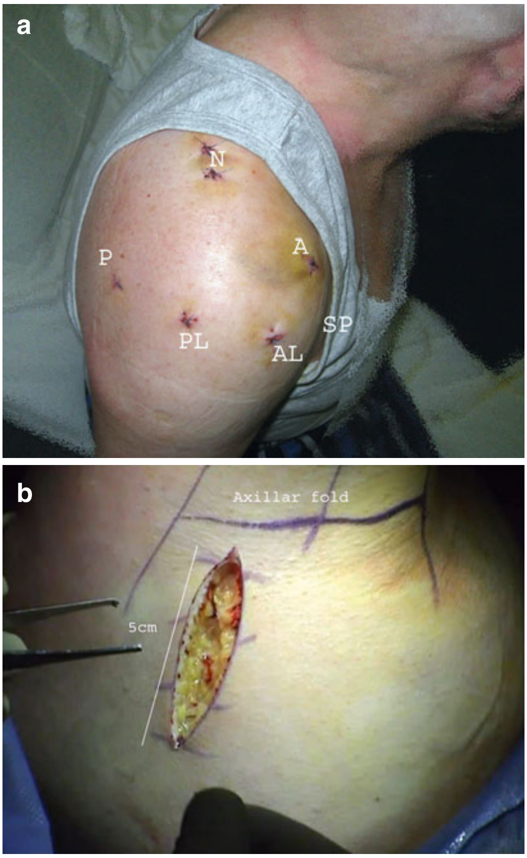


Fig. 8.15 Lateral view of right shoulder. (**a**) portals, (**b**) axillar incision (shoulder in ABD)

8.8.3 Results

Mean of follow-up after operation was 16 month, range 4–33 month. One patient had posterior transient humeral numbness. Twenty-eight patients improved in pain and motion and were happy with results. Mean gain in elevation was 40 °, in external rotation 30 °. Twenty-four patients remain with slight external rotation lag. Pain improvement was more noticeable than gain in motion. In remaining three patients, one patient developed deep infection 10 month after surgery, and two had LD tendon rupture about 4 months after surgery.

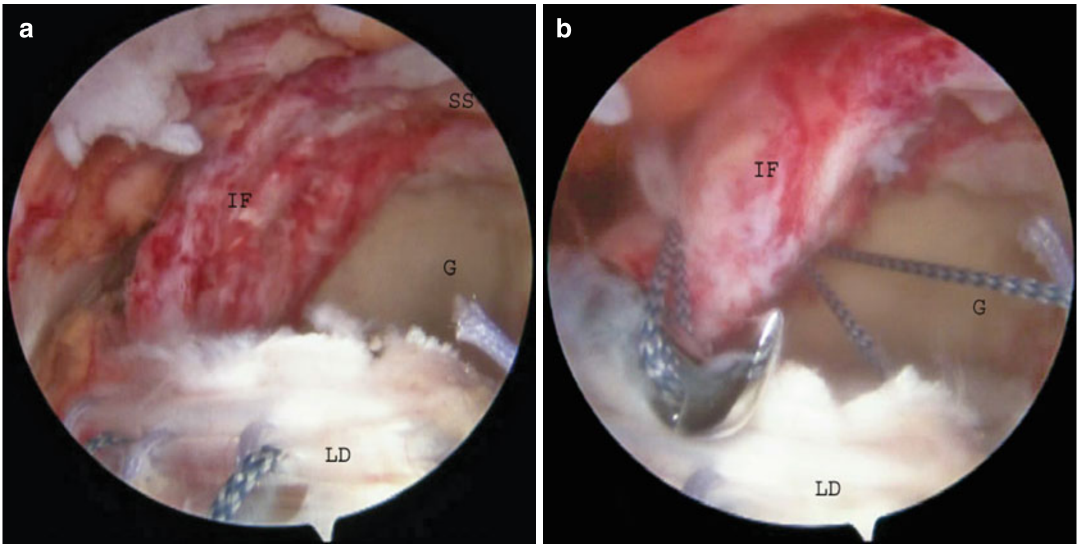


Fig. 8.16 (**a**, **b**) Lateral view of right shoulder. LDT – transferred latissimus dorsi, IF – infraspinatus muscle, SS – supraspinatus, G – glenoid

8.8.4 Discussion

The results of LDT are mostly dependant on deltoid and subscap muscle integrity. With damaged deltoid, age and gender adjusted Constant score reached only to 43 % [45]. In case of subscap insufficiency, CS increased to 49 % [43]. Arthroscopic technique for subs and remaining posterosuperior cuff repair maximally preserves deltoid. It also allows harvest LD with hand in ADD and slight flexion. In this position, axillary and radial nerves are in safest distance from harvest site from bone [46]. In recent study [47], LD harvesting with bone chips shoved better results due to lower rate of late LD tendon rupture. In our group, 2 of 31 develop late tendon rupture. This number should increase in time due to short follow-up, but we hope it will not reach 27 % due to improved fixation. In last few cases, harvesting was done with bone ships under direct arthroscopic visualization as proposed by Tauber et al. (2010).

8.9 The Anatomical Reconstruction of the Rotator Cuff

Ferdinando Battistella and Ettore Taverna

Theoretically, the repair of lesions of the rotator cuff should be able to reconstruct more anatomically possible the cuff. Various techniques have been described, and in recent years, attention has been focused particularly comparing single-row and double-row techniques. Studies with different levels of stresses, however, have shown that there are no differences in clinical outcomes but only in the rates of reruptures. Starting from the observation that the majority of complex lesions (medium and large) are multilayer and that the classifications used do not describe this type of injury is easy to see where is the weakness of these studies. According to recent anatomical studies, the importance of biomechanics component ascending infraspinatus tendon can explain why most of the supraspinatus and infraspinatus lesions are multilayer. Based on these and our own anatomical studies, we introduced a new technique called anatomical multilayer repair. With this technique, it is possible to make tendon-bone fixation without tension, biomechanically more stable and thus more potential with healing abilities.

8.9.1 Aim of This Work

The aim of this work is to evaluate the clinical results of repair of complex lesions (medium and large) of the rotator cuff with anatomical multilayer technique. Type of study: a prospective nonrandomized clinical study with a control group.

8.9.2 Materials and Methods

From 2006 to 2009, we treated with this technique 90 patients (52 men and 38 women), mean age of 56 years. Inclusion criteria were chronic injuries (more than 6 months), with acromion humeral distance greater than 6 mm, and medium cuff lesions (1–3 cm) and large (3–5 cm) evaluated arthroscopically, fatty degeneration less than grade 3 sec. Gouttalier. Exclusion criteria were the presence of rheumatic or autoimmune and metabolic diseases. Preoperative investigations included shoulder MRI, clinical and functional tests. The follow-up by ASES, UCLA, Constant was performed at 3, 6, 12, and 24 months by self-assessment test DASH.

The technique is called multilayer based on the recognition of different layers of the lesion and especially of the various components (horizontal and ascending) of the infraspinatus tendon and switching between infraspinatus and biceps pulley.

In most of the large lesions, the ascendant component of the infraspinatus tendon was involved and repaired first with the technique suture, and then the horizontal component was repaired with the technique anchor first, overlapped to the previous tendon repair in order to have a real anatomic repair. The same technique was performed in case of injury of the rotator cuff to the level of the supraspinatus and infraspinatus transition between. The control group consisted of 100 patients homogenous for the age and cuff lesions and treated with conventional arthroscopic suture system from 2003 to 2009 and valued at the same time follow-up. All operations were performed by the same surgeon. The data of both groups were compared using student's t tests for continuous variables, and the level of statistical significance was set <0.05.

8.9.3 Results

No complications were observed. Only six patients had to undergo reoperation for recurrence within 24 months or for poor results. All patients achieved the follow-up of 12 months, while nine patients were lost at the last follow-up of 24 months because they have not responded to the self-assessment test. Only at the 3-month follow-up, there were no statistical differences between the two groups in the treatment of medium lesions of rotator cuff. For all other follows-up, there were significant statistical differences between the two groups, with significantly better results for the group with anatomic reconstruction. With regard to the last follow-up with self-assessment test to DASH, there was statistical difference between the two groups, which also identifies a clinical difference, with better results for the anatomical reconstruction.

8.9.4 Conclusions

The anatomical reconstruction of the rotator cuff with multilayer technique gets better results than the standard technique of arthroscopic repair and can be considered a viable treatment option.

8.10 Methods of Conservative Treatment of Cuff Arthropathy and Limits of Acromioplasty

Andrey Korolev and Mansur Khasanshin

8.10.1 Introduction

Rotator cuff deficiency with degenerative shoulder joint is a treatment challenge. Most patients present primer complaint on shoulder pain. Shoulder function can be variable even with significant chronic rotator cuff deficiency. The arthritic condition of the shoulder due to a chronic rotator cuff tear has been named cuff arthropathy [48].

Theories explaining rotator cuff tear arthropathy of the shoulder joint include severe, localized rheumatoid arthritis [49, 50]; hemorrhagic arthritis [51]; microcrystalline-induced arthritis [52]; and arthritis due to chronic attrition, leading to a massive tear of the rotator cuff tendons [46, 48].

Rotator cuff arthropathy is defined as a combination of

- A massive rotator cuff tear
- Fixed upward migration of the humeral head
- Instability of the glenohumeral joint
- Severe glenohumeral arthritis

A massive tear causes the humeral head to be displaced upward, inducing subacromial impingement that in time erodes the anterior portion of the acromion and the acromioclavicular joint. Ultimately the soft, atrophic head collapses, producing the complete syndrome of cuff tear arthropathy. The incongruous head may eventually erode the glenoid so deeply that the coracoid becomes eroded as well.

8.10.2 Presentation

The symptoms in all of the patients are remarkably similar. They all have long-standing and progressively increasing pain that is worsen at night, exacerbated by physical activity, and compression of the humerus to the scapula. Also there are certain changes in XR and MRI.

8.10.3 Management

Treatment of patients with cuff arthropathy is extremely difficult because, at present, there are no perfect solutions to this complex and sometimes disabling problem. Treatment depends on the symptoms (pain and/or disability), age, and functional level. Other issues such as medical comorbidities, possible concomitant glenohumeral arthritis, the presence of an intact coracoacromial arch are also factors that must be considered in the treatment plan. The treatment options range from conservative (nonoperative) to surgical. Surgical treatment include debridement with acromioplasty, tendon transfer, muscle tendon slide procedures, the use of rotator cuff allografts and synthetic grafts, arthrodesis, and shoulder arthroplasty, including the use of reverse ball prostheses.

There is no best treatment. The surgeon has to select the type of treatment that will provide the best outcome as dictated by the specific patient's needs.

Unfortunately, there have been no evidence-based, prospective studies comparing the different nonoperative and surgical options [53].

8.10.4 Nonoperative Treatment

Many chronic irreparable rotator cuff tears can be treated successfully without surgery. A nonoperative approach to relieve pain and create "biomechanically compensated" function with use of the remaining rotator cuff, deltoid, and periscapular muscles is often the best method of initial treatment.

Nonoperative treatment includes nonsteroidal anti-inflammatory medications, steroid injections, and local therapeutic modalities to relieve pain.

Early restoration of the passive range of motion and activity are important initially. As soon as pain relief has been obtained and the range of motion has been restored, specific strengthening exercises for the remaining rotator cuff, deltoid, and scapular muscles can be started in to restore a stabile fulcrum for deltoid function. Strengthening exercises for the internal and external rotators of the shoulder should include resistive exercises below chest level initially. Deltoid strengthening exercises begin with the patient supine and are then progressed to antigravity positions such as sitting and standing. It may take more than 3 months for conservative treatment to be successful.

8.10.5 Operative Treatment

Arthroscopic irrigation for removing activated enzymes and crystals has been reported only recently and offers only limited, short-term relief. Arthroscopic acromioplasty and tendon debridement could also be used; however, the results were not stratified according to the location of the tear, and this technique should be viewed with caution.

The path of erosion caused by subacromial impingement clearly demonstrates that subacromial impingement occurs against the undersurface of the anterior one-third of the acromion and acromioclavicular joint. This provides further evidence that anterior acromioplasty is the correct treatment for impingement, rather than lateral acromionectomy.

If nonoperative management fails in these patients, a humeral hemiarthroplasty is the procedure of choice as it provides reliable relief of pain and improvement in function.

8.10.6 Conclusion

Chronic irreparable rotator cuff tears can cause shoulder pain and disability. As a result of the complex pathology in shoulders with irreparable rotator cuff tears, there are many different clinical scenarios and many available treatment options. For this reason, careful patient evaluation and treatment selection are critical to ensure a good result. Cuff tear arthroplasty is a disabling condition of the shoulder found in elderly patients. It is variable in its presentation with regard to the extent of degenerative osseous change in the glenoid, humeral head, and acromion. It is variable in its presentation with regard to preoperative active elevation ability and pain level.

Conservative management of cuff arthropathy is the method of treatment in cases of the patients with lesser manifestation of symptoms, contraindications for surgery, or refuse of operative treatment by patients.

Debridement and acromioplasty are best suited for lower-demand individuals, in case there are contraindications for more invasive surgery.

As shoulder arthroplasty, especially with reverse prosthesis, became more available, it may be considered a more preferred method.

8.11 Reverse Shoulder Arthroplasty: The Limits

Philippe Valenti

Reverse shoulder arthroplasty (RSA) is indicated in patients with pseudoparalytic shoulder secondary to irreparable rotator cuff tear. The concept of reversing the shoulder prosthesis reappeared in 1985 with Paul Grammont's biomechanical work [54] after the failures of the reversed constrained prostheses reported by Neer since 1974 [55]. Grammont demonstrated that medialization and distalization of the center of rotation on the glenoid bone increased the lever arm of the deltoid with a low rate of glenoid loosening. So the success of RSA to restore active anterior elevation and painless shoulder [56–60] since two decades has allowed to extend the indications but also to define the contraindications and the limits.

A meta-analysis of the literature performed by Zumstein et al. [61] reported a rate of complications and revisions after RSA of 24 % and 10 %, respectively. Complication rates differed among the different etiologies and were both twice as frequent in the revision of failure of hemi- or total arthroplasty patients as the primary arthroplasty group. Instability and infection were the two most frequent complications leading to revision.

There are two major contraindications to implant an RSA: a history of chronic infection and a nonfunctional deltoid muscle. The deltoid muscle can be paralyzed after an axillary nerve lesion secondary to a fracture dislocation in older patient. The deltoid muscle, after two or three previous surgeries, can be detached particularly, the middle part of the deltoid from the acromion.

Some situations represent a high potential of complications but are not a formal contraindications to implant an RSA:

After a breast cancer treated by radiotherapy, some patients develop an osteoarthritis with a cuff deficiency. The shoulder becomes painful with limited range of motion. The glenoid bone is osteoporotic with a low density, and the fixation of the baseplate is frequently not sufficient to resist to the shearing forces at the beginning of the abduction movement. Parkinson's disease with contracture muscle and involuntary movements can provoke a dislocation of the humerus or a glenoid component avulsion. RSA can be indicated if the Parkinson's disease is perfectly checked with a medical treatment. A high tension between the socket and the ball is recommended to avoid instability. A paraplegic patient who does alone a transfer from the bed to a chair or who used a wheelchair is not a good candidate for an RSA; the shearing forces between the glenoid bone and the back of the baseplate can pull out the glenoid component.

Some situations are not contraindications to implant an RSA, but the surgeon should have a good experience of this procedure with a considerable learning curve to avoid any complication.

A preoperative planning based on standard X-rays (AP view in neutral and external and internal rotation, axillary view) and a CT scan should be performed preoperatively to analyze the glenoid bone stock, the state of the cuff, and particularly the teres minor if the patient has a lack of active external rotation or a hornblower sign lack. In revision case after a failure of hemiarthroplasty for fracture, we have to analyze the size of bone loss at the metaphysis level and the thickness of the cortical bone particularly when the humeral prosthesis is cemented.

Proximal humeral bone loss secondary to a resection for tumor or a failure of hemiarthroplasty for complex fracture can result a high rate of instability and a failure of RSA secondary caused by an inadequate restoration of the length of the humerus. A bone allograft may restore proximal humeral bone stock, thereby helping to maintain the height of the prosthesis bone construct and to optimize the deltoid tension to prevent any instability [62]. Another option is a custom-made prosthesis or the use of spacer can restore the good length of the humerus with an optimal tension of the deltoid [63].

CTA and chronic glenohumeral dislocations often cause significant glenoid bone loss. Classically, severe glenoid bone loss is a contraindication of RSA, but it is often the only way to restore a shoulder function. Anomalies of the glenoid morphology represent a difficult challenge to implant the glenoid component and necessitate adjustments in surgical technique for RSA. A 3D CT reconstruction provides a reliable assessment of the bone loss [64]. A preoperative planning should be essential to define the direction of the center keel and the length of the screw.

A central erosion with a high medialization of the joint decreases the length of the glenoid bone stock; a special design of the baseplate with a long peg to fix into the native bone associated with an interpositional bone graft improves the press fit of the prosthesis and restores the lateral offset to increase the stability of the prosthesis [65]. (Figs. 8.17 and 8.18).

Superior erosion of the glenoid should be compensated with a bone graft to avoid a superior tilt of the baseplate with a high risk of glenoid loosening.

Anterior and posterior erosion of the glenoid can be corrected with an eccentric reaming in moderate glenoid bone loss. If it is not sufficient, a corticocancellous bone grafting (from humeral head or iliac crest) technique is helpful to provide adequate bone stock for glenoid component fixation. Macaulay et al. [66] reported three cases with an excellent result with a short-term FU (Figs. 8.19, 8.20, 8.21, and 8.22).

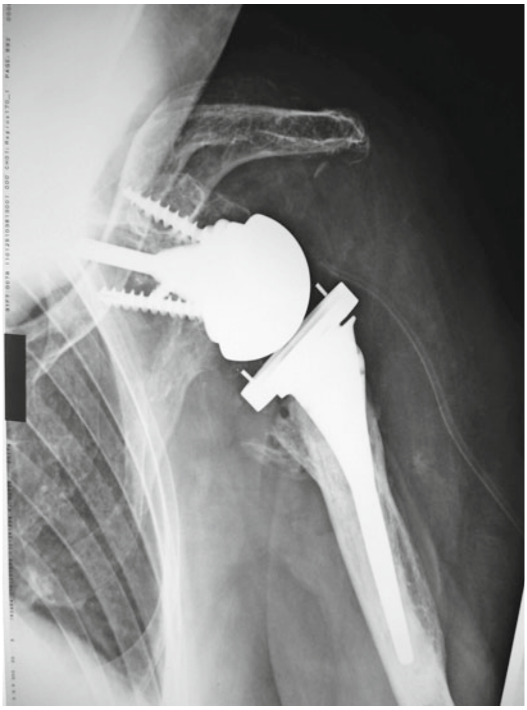


Fig. 8.18 Baseplate with a long stem and a bone graft to improve glenoid fixation in severe glenoid bone loss

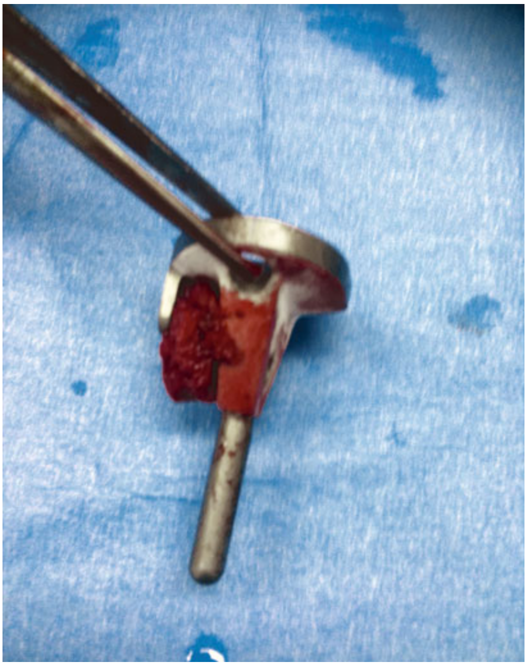


Fig. 8.17 Baseplate with a long stem and a bone graft to improve glenoid fixation in severe glenoid bone loss

Fig. 8.19 Chronic anterior dislocation with an anterior glenoid bone defect: fixation with two screws of an anterior bone graft and implantation of a baseplate with two frontal screws and one sagittal screw (Courtesy D Katz)

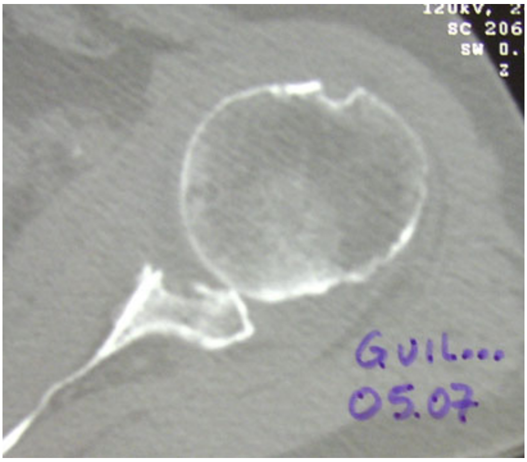


Fig. 8.20 Chronic anterior dislocation with an anterior glenoid bone defect: fixation with two screws of an anterior bone graft and implantation of a baseplate with two frontal screws and one sagittal screw (Courtesy D Katz)

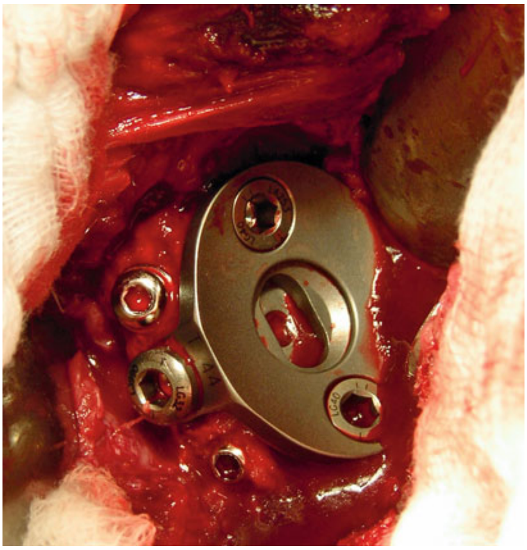


Fig. 8.21 Chronic anterior dislocation with an anterior glenoid bone defect: fixation with two screws of an anterior bone graft and implantation of a baseplate with two frontal screws and one sagittal screw (Courtesy D Katz)

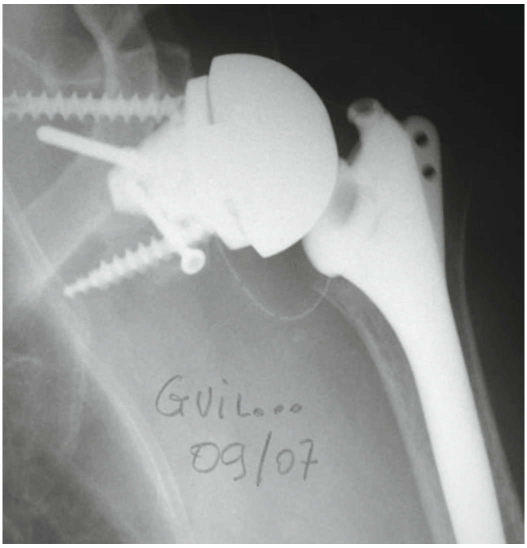


Fig. 8.22 Chronic anterior dislocation with an anterior glenoid bone defect: fixation with two screws of an anterior bone graft and implantation of a baseplate with two frontal screws and one sagittal screw (Courtesy D Katz)

8.11.1 Conclusion

Improvements of the prosthetic design combined with a greater experience of the surgeon can extend the limits of the classical indications of the RSA. In limit cases, the optimization of the fixation of the glenoid component is the key to decrease the rate of complication of RSA.

8.12 Instability of Reverse Total Shoulder Arthroplasty

Srinath Kamineni and Jonathan Chae

8.12.1 Introduction

The reverse total shoulder arthroplasty (RSTA) is an implant that has recently become more popular for the management of rotator cuff tear arthropathy, in addition to several other pathologies involving soft-tissue deficiency [17, 57, 67–73]. Originally the reverse arthroplasty was described by the French surgeon Paul Grammont in 1985 [68, 74] for the rotator cuff deficient shoulder with cranial migration of the humeral head and pseudoparalysis [68], with encouraging early results [41, 57, 59, 67, 69–72, 75–77]. In addition to cuff tear arthropathy, the spectrum of indications has rapidly increased over the past decade [74]. Most of the early reported results highlighted the significant improvements in pain and function. However, the initial enthusiasm has been muted by a growing awareness of complication rates ranging from 19 % to 50 % [28, 57, 68–71, 75, 76, 78, 79] and reoperation rates up to 33 % at 3 years [80]. The list of complications is extensive, but infection, component loosening, hematoma, and scapular notching are among the commonest [81]. Of all the complications, the two commonest that require revision operative intervention are infection and instability.

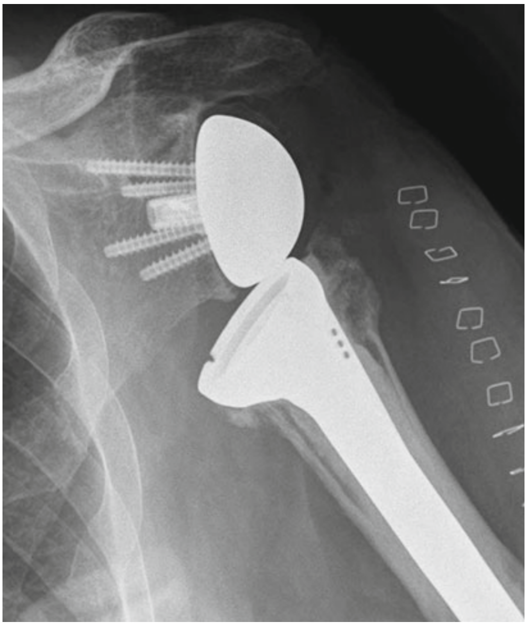


Fig. 8.23

Instability of the reverse shoulder arthroplasty is incompletely understood, almost certainly multifactorial, and ranges from subtle maltracking with impingement, inferior chronic subluxation, recurrent subluxation [81–84] to frank dislocations. Approximately 3–10 % of all reverse total shoulder arthroplasties have an episode of instability [82–84]. Most commonly, instability is evident immediately after surgery (Fig. 8.23) but can be also noticed at more prolonged intervals. The direction of instability is primarily anterior and anteroinferior, usually following an extension, adduction, and internal rotation of the arm. Instability has been widely reported in many series of reverse arthroplasties but in particular with series in which revision arthroplasty constitutes a significant proportion of the analyzed population [73, 85]. Revision arthroplasties frequently have issues of increased scarring from previous surgeries, poorer soft tissues (Fig. 8.24a–c), and fewer routine landmarks to guide the surgeon.

When dealing with such a complication as instability of a reverse shoulder replacement, the multifactorial nature can be better understood when all the factors are individually addressed. Once all the factors have been analyzed, they can individually be applied to one's own patients to better understand the individual circumstances of instability. The remainder of this chapter will try to conglomerate most of the important known factors involved in RTSA instability, without any particular order of importance.

8.12.2 Surgical Approach

The two commonest approaches utilized for the insertion of a reverse total shoulder arthroplasty are the superolateral (trans-deltoid) and deltopectoral approach. Ladermann et al. studied the functional influence between the two approaches and found no difference [86].

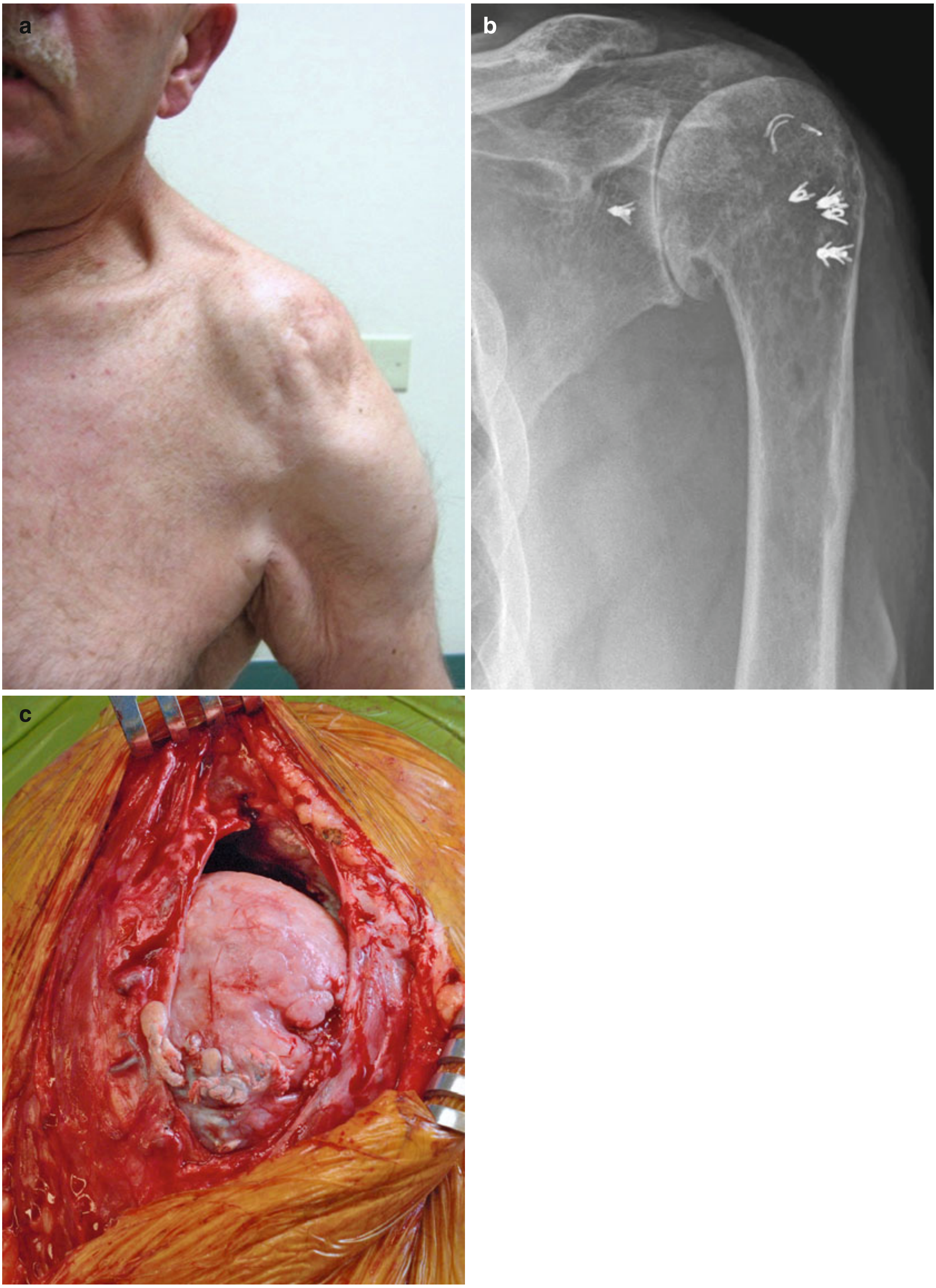


Fig. 8.24

The integrity of the subscapularis has been considered an important feature in the prevention of instability. Edwards et al. reported on a 138-patient prospective series of reverse arthroplasties, all performed by a single surgeon with the deltopectoral approach [82]. The subscapularis was irreparable in 76 patients, and seven dislocations were encountered in total, all in the irreparable group. Lack of subscapularis integrity was considered a significant risk for postoperative dislocation. A confounding feature of this study was that the group in which subscapularis was irreparable was a more complex preoperative group. But more recently, Clark et al. retrospectively reviewed 120 patients, all with deltopectoral approaches, 55 of whom did not have subscapularis repair with three dislocations, and 65 with subscapularis repair with two dislocations [87]. The authors concluded that subscapularis repair was noncontributory to dislocation risk. Hence, there is some conflicting data concerning the role of subscapularis repair, and where ever possible, it should be repaired, until more definitive data is available.

8.12.3 Humeral Component Version

Favre et al. assessed the effect of humeral and glenoid version on intrinsic stability of RTSA. Humeral version was found to be more critical for intrinsic stability than glenosphere version. Physiologic humeral version at 20 ° was found to have low intrinsic stability, and by increasing anteversion, one would be able to increase stability – more than 20 % increase for each 10 ° of anteversion. However, this resulted in limited external rotation and may hinder function [88]. Stephenson et al. demonstrated that humeral component version had a range of tolerances that allow good impingement-free motion [89]. Their cadaveric study demonstrated that in 20 ° anteversion, the external rotation in neutral abduction was almost −1 °. However, 30 ° of abduction considerably improved the ability to externally rotate without impinging. This study demonstrated the disadvantage of an anteverted humeral component, with much better overall motion in neutral or abducted arm positions with a neutral or mildly retroverted humeral component. Gulotta et al. concluded that retroverting the humeral component from 0 ° to 20 ° would allow maximum internal rotation with the arm by the side of the body without limiting the ability to externally rotate when the arm is abducted [90].

8.12.4 Glenoid Component Position

Metaglenes can be positioned according to the native glenoid and are commonly positioned to cover the native glenoid (Fig. 8.25). However, with the interrelated issues of component impingement, scapular notching, and instability, more attention has been focused on positioning the metaglene to minimize such complications.

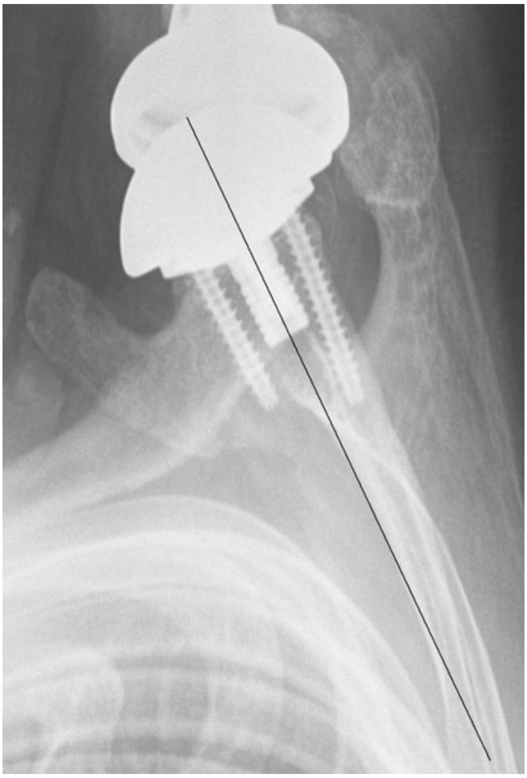


Fig. 8.25

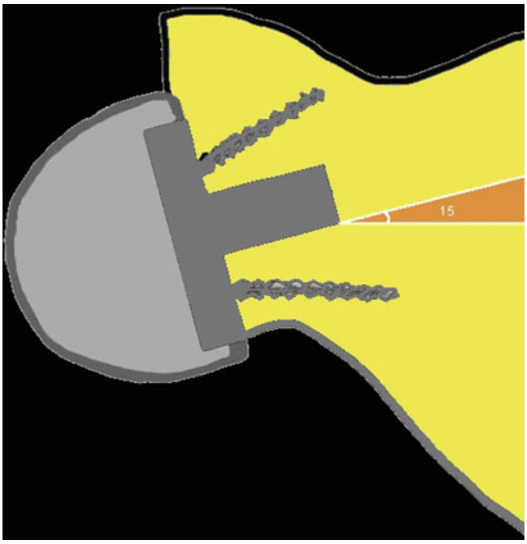


Fig. 8.26

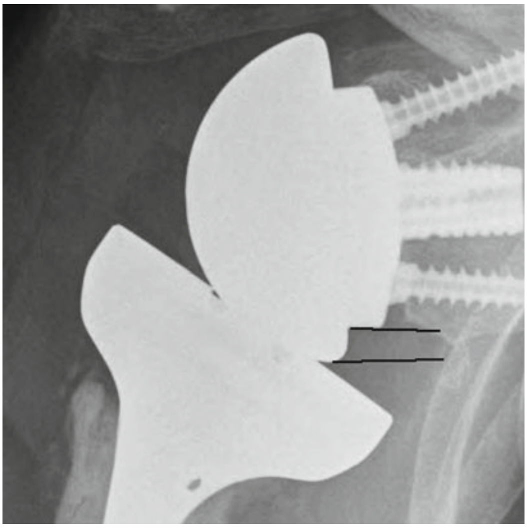


Fig. 8.27

Gutierrez et al. examined glenoid component stability with regard to angle of implantation. Implantation with an inferior tilt of 15 ° reduced the incidence of mechanical failure of the glenoid component, which increased implant stability [91] (Fig. 8.26). Nyffeler et al. performed an in vitro cadaveric study with the delta III reverse implant to compare metaglene position that relates to motion. They found that placement of the baseplate overhanging the inferior glenoid rim significantly improved adduction and abduction, when compared to other positions (centered on the glenoid, flush with the inferior rim, inferiorly tiled) [92] (Fig. 8.27). As is predictable from these two latter studies, every effort should be made to avoid superior metaglene tilt (Fig. 8.28).

8.12.5 Humeral Length

The length of the humerus is essentially an indicator of the length of the deltoid and indirectly a measure of the deltoid tension. The judgment of humeral length can be made using several bony (acromion/tip of greater tuberosity/base of coracoid) or soft-tissue landmarks (insertion of pectoralis major/deltoid muscles). However, this judgment is more difficult in cases of bone and soft-tissue loss, a common scenario in revision surgery (Fig. 8.29). In cases in which the humeral length is shortened, this can lead to instability as was noted by Melis et al. [93]. In their multicenter retrospective review of 37 reverse arthroplasty for aseptically loosened anatomical shoulder arthroplasties, they observed three instabilities, two of which were due to humeral shortening. Both successfully resolved after the addition of a metallic spacer, which effectively lengthened the humerus. The third case of instability was reduced and immobilized, resulting in a stable joint, without further intervention. Ladermann et al. assessed the effect of humeral lengthening and tensioning of the deltoid on its effects on intrinsic stability. He found a strong correlation between

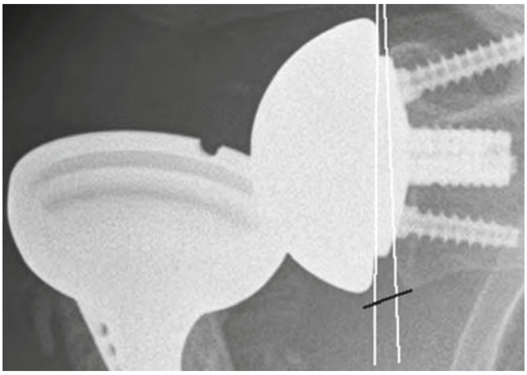


Fig. 8.28

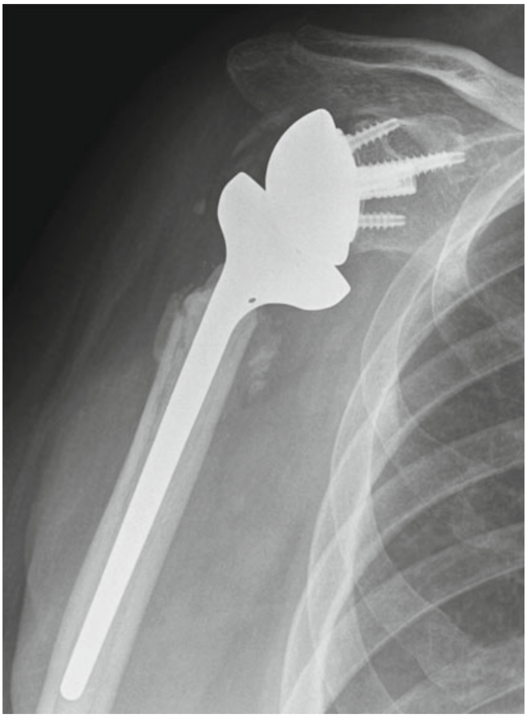


Fig. 8.29

preoperative length compared with contralateral humerus and apparition of dislocation. Shortening of the humerus postoperatively, as compared to preoperatively contralateral humeral lengths, was observed to have a high correlation with dislocation [63, 94]. Failure to restore sufficient tension in the deltoid can be responsible for prosthetic instability.

When inserting the humeral component, several factors influence the final length outcome. The first is obviously the judgment of the surgeon, who uses the bony and soft-tissue landmarks to aid correct implant insertion, when they are available. A third factor is the ability to judge the instability of the inserted components as a function of constraint, to be addressed later, and soft-tissue tension, acting across the joint. Soft-tissue tension, as a function of humeral length, requires surgical judgment. An often quoted method of judging tension is that thumb pressure of the reduced components should not be able to translate the humerus more than 50 % of its articular diameter. However, a confounding feature of this aspect is the increasingly common practice of regional anesthesia and muscle relaxation. No studies are available to help understand the true effect of these interventions and how they influence the intraoperative judgment of soft-tissue tension acting across the implants.

Humeral length, and hence soft-tissue tension, can decrease due to component subsidence [93]. The humeral component can subside for several reasons. With uncemented implants, the initial intraoperative press fit may be inadequate, leading to early component motion, and “settling” leading to loss of humeral length and soft-tissue envelops tension. In cemented and uncemented components, a cortical breach, as is more common in revision surgery with cement removal or with periprosthetic fractures, can allow subsidence into the cortical deficiency. In cemented implants, aseptic loosening can allow distal migration of the humeral component.

8.12.6 Intrinsic Component Stability

Gutierrez et al. examined intrinsic stability in terms of the force required to dislocate the humeral socket from the glenosphere. Joint compressive force was determined to be the most important more so than socket depth and glenosphere size [95]. Increasing tension of the soft tissues may lead to increased stability. Ratio between depth of socket and diameter of the metaglene – higher ratios result in more stable implants [96], although higher ratios are more likely to result in scapular notching [97]. Although scapular notching is one of the commonest observed complications after reverse shoulder arthroplasty, its association with reoperation rates has not been firmly validated. However, the polyethylene wear of the humeral socket can be responsible for aseptic loosening, leading to component migration and implant instability. Such scapular notching related medial polyethylene wear has been corroborated by Nam et al. in a retrieval study [98]. Such notching has been shown to decrease when the metaglene is positioned in an eccentrically inferior position on the glenoid [99].

Compared to conventional shoulder replacements, which utilize relative roll-spin-translation kinematics, reverse shoulder arthroplasties function without roll and translation between the components. The design is inherently more constrained and stable, and Matsen et al. defined the "balance stability angle" [100], the maximum angle that the joint reaction force can form within the concavity of the humeral socket, prior to dislocation. For the reverse geometry implant, this 45°arc of stable motion is greater than for conventional, anatomically designed shoulder arthroplasty (30 °).

Roche et al. examined the jump distance of the glenosphere in relation to instability. Jump distance was defined as lateral distance necessary for the glenosphere to escape from the humeral liner at varying degrees of abduction. Increasing the glenosphere size reduced the jump distance and created more stability in RTSA [101].

8.12.7 Axillary Nerve Dysfunction

Axillary nerve function is critically important for the outcome of reverse shoulder replacements, and any dysfunction can lead to instability of such implants. Dysfunction can be transient or permanent and, when permanent, serves as a contraindication to reverse arthroplasty. Most nerve palsies are temporary neurapraxias resulting from a variety of causes, including nerve traction due to fracture dislocations, shoulder manipulations, retractor malplacement, or overstuffing of the joint. The axillary nerve is prone to a traction neurapraxia during surgical exposure since the humerus is externally rotated, posteriorly retracted, and abducted [80]. Interscalene regional local anesthetic anesthesia can also produce temporary axillary nerve palsy, which can lead to a joint subluxation immediately postoperation.

8.12.8 Acromial Fracture

In the pursuit of stability and optimal reverse shoulder arthroplasty function, a poorly understood parameter is the amount of optimal deltoid tension. Since there are few objective methods available, surgical experience is paramount, with the inherent miscalculation always a possibility. When calculating the intraoperative tension required, the parameters to be borne in mind are the acromial strength (thickness being a surrogate) and deltoid integrity (previous surgical scarring, atrophic thinning, etc.). During the intraoperative tensioning of components, there is a natural tendency to over tension with the insertion of thicker implants, with the belief to gaining greater stability. Whereas short-term stability may indeed be afforded by such a strategy, this may also predispose to fatigue fractures of the acromion, which in turn can result in loss of deltoid tension and consequent implant instability. However, acromial fractures are not universally associated with a loss of active elevation and instability but do represent a complication that is associated with these adverse results [102–104].

8.12.9 Conclusion

Overall, instability is a leading cause of revision operative intervention in RTSA [97]. Achieving a stable and well-functioning reverse total shoulder arthroplasty requires a multifactorial understanding and approach. Basic principles of soft-tissue release and balancing, correct deltoid tensioning, component positioning that allows functional motion without impingement, subscapularis repair, and cautious rehabilitation appear to be the key to avoid this complication. Several factors that have emerged as playing an important role remain incompletely understood, but some basic parameters are now defined, including the importance of adequate deltoid tension.

Treatment guidelines for an unstable RSTA are not well defined, but early joint reduction and a trial of immobilization, correction of a malverted humeral/glenoid component, insertion of a thicker humeral lining when humeral length is inadequate, and ruling out infection as a source of early component loosening are some well-established basics. Revision of components should be considered when a trial of reduction immobilization fails to resolve the instability, although it is challenging to determine if one or all components need to be revised.

Revision requires focusing on increasing soft-tissue tension. Increasing the compressive forces should be considered a priority [95]. This can be achieved by increasing humeral length, therefore increase deltoid function and converting more torque to compressive forces, with caution on over-tensioning and acromial fractures. Soft-tissue tensioning can also be increased through lateralization of the glenosphere, adjusting the humeral neck-shaft angle, and increasing the thickness of the humeral component and/or the size of the glenosphere [105]. If possible, subscapularis should be repaired which can improve stability as well [82].

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Multiple Ligament Injury Management

9

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Contents

9.1 Overview of Multiligament Knee Injuries

Daniel Whelan, M.D.

9.1.1 Background

Knee dislocations were previously thought to be relatively uncommon injuries. However, the prevalence of multiligament knee injuries appears to be increasing. These numbers may be a factor of increased participation by the public in "extreme sports," improved trauma assessment and care, or changes to air bags and auto design. They may also be due to an increased awareness of doctors

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to this diagnosis. Previously, the definition of knee dislocation was rather ambiguous. Combined with physical presentation of spontaneous reduction and a guarded clinical exam, knee dislocations are challenging to detect. MRI has improved our ability to diagnose these injuries.

Currently, the term "knee dislocation" is used to describe a multiligament knee injury in which at least two of the four major ligaments are injured. It often presents along with knee instability. A "central pivot" or bicruciate injury is a common example.

9.1.2 Controversies in the Literature

The literature indicates that knee dislocations are rare and have a poor prognosis. There is ongoing debate over whether it is preferable to treat these injuries with a brace to promote knee stiffness or whether it is better to perform reconstruction to promote knee motion and therefore function. Controversy also surrounds the issue of whether acute or delayed surgical reconstruction is more beneficial.

9.1.3 Quality of the Evidence

No Level 1 or 2 studies of knee dislocation treatment have as of yet been performed. A few comparative cohorts and 2 systematic reviews have been conducted.

In a 2009 *Arthroscopy* systematic review by Levy et al., 413 studies were identified that addressed treatment of multiligament-injured knees [1]. Eleven of these were comparative studies. Four compared surgical versus nonsurgical treatment, two compared repair with reconstruction, and five compared early and late surgery [1]. The review suggested that early operative treatment of the multiligament-injured knee yields improved functional and clinical outcomes as compared with late surgery. However, several studies not meeting the inclusion criteria were shown to favor delayed multiligamentous surgery, and due to the difficulty of conducting prospective, comparative studies of these injuries, many questions still remain.

Level 1 studies may not be possible or practical because multiligament knee injuries are relatively rare, extremely heterogeneous, and occur in a very heterogeneous patient population. The definitions of this injury remain inconsistent, and the surgical techniques used for treating these injuries vary greatly and have a high surgical learning curve. Knee dislocations are further complicated by commonly associated injuries that tend to dominate clinical outcomes.

9.1.3.1 Brace Versus Reconstruction

In 1971, Meyers and Harvey published a study of patients with traumatic dislocations of the knee joint seen at the Los Angeles County-University of Southern California Medical Center [2]. Of 16 patients treated operatively, 13 had good/excellent outcome and 3 had fair/poor outcome. Thirteen patients were treated conservatively, and of those, one patient had good/excellent outcome and the rest were classified as fair/poor. A 2002 study conducted by Richter et al. analyzed 63 surgical repair patients and 26 nonsurgical patients with an average follow-up of 8.2 years [3]. The outcome of the surgical group in this study was better than the nonsurgical group's. Positive prognostic indicators were found to be age younger than 40, sports injury rather than motor vehicle accident, and functional rehabilitation over immobilization. Surgical treatment was also shown to lead to better function (as demonstrated by IKDC scores) and better objective and subjective stability in a 2004 study by Wong et al. [4].

9.1.3.2 Acute Versus Delayed Reconstruction

In 2003, Liow et al. published a study of 21 patients with 22 dislocations of the knee by either repair or reconstruction. Although the differences were small, patients whose knees had been reconstructed within 2 weeks of injury had better function and activity than those who were treated after 6 months. After mean follow-up of 32 months, patients in the acute group had a mean Lysholm score of 87 and patients in the delayed group had a mean score of 75 [5]. Similar beneficial results for acute treatment were found in a 2004 study by Harner et al. [6].

9.1.4 Literature Review

From the literature, we can make the following generalizations: (1) stiff knees lead to poor outcomes, (2) mobile knees (despite some laxity) perform well, and (3) it is easier to reduce and maintain the joint with early surgery.

9.1.5 Assessment of Multiligament Knee Injuries

Acute assessment of the patient is important as there is often significant associated trauma to the patient's head, chest, and abdomen. Patients can be assessed based on the Advanced Trauma Life Support program while making sure to monitor their airway, breathing, and circulation and vascular and neurological status. At the knee joint itself, it is important to assess whether there is an open wound or associated fracture and to determine the ligamentous injury pattern and presence of concurrent cartilage injury.

9.1.6 Initial Management

The initial management steps for knee dislocation include the following: maintaining a high index of suspicion for vascular injury, performing a gentle closed reduction if needed, examining the joint under anesthetic if possible, performing a serial neurovascular assessment, performing a compartmental monitoring, and immobilizing the joint in extension.

An external fixator is not preferentially used but can be indicated in a joint that is unstable in extension after vascular repair for large soft tissue defects.

Acute surgery (within hours) is indicated if there is a vascular injury, open injury, or occurrence of compartment syndrome. It is also indicated for an irreducible joint, which is usually a result of a posterolateral dislocation, exhibiting medial “dimple sign” and a subluxed medial joint on x-ray.

9.1.7 Associated Neurovascular Injury

Vascular injuries are associated with knee dislocations in 20% of cases with 10–64% of these injuries to the popliteal artery. Nerve injuries occur in conjunction in about 30% of the time. There is no recovery in over 50% of cases, which is why aggressive passive foot and ankle range of motion should be encouraged as soon as possible. Other common associated injuries include injuries to the extensor mechanism, fractures to the femoral condyles and tibial plateau/spines, and venous injury, which should be addressed by aggressive DVT prophylaxis.

If results of vascular assessment are normal, then patient should continue to be observed as intimal injuries are still possible. However, if exam is abnormal at any stage, for example, patient shows signs of ischemia, ABI<0.8, or pulse asymmetry, arteriogram should be performed. If the leg is ischemic, vascular repair must be done and arteriography will delay surgery.

9.2 Managing Medial Collateral Ligament Injuries

Iftach Hetsroni, M.D.

9.2.1 MCL Function

The medial collateral ligament (MCL) is the primary restraint to valgus stability of the knee. At 20–30° flexion, it provides approximately 80% of the restraining force, whereas at full extension, it provides approximately 60% of the restraining force with the posteromedial capsule, posterior oblique ligament (POL), and ACL providing the remaining restraint [7]. Failure in recognizing dysfunction of this ligament in the setting of concomitant ligament reconstruction surgery (ACL or PCL) can result in excessive valgus stresses applied to the reconstructed ligaments, subsequently leading to graft stretch-out and failure.

9.2.2 MCL Anatomy

The MCL has three major components:

1. The superficial MCL which is the largest component, originating 3.2 mm proximal and 4.8 mm posterior to the medial epicondyle and inserting on the proximal tibia, just anterior to the posteromedial crest of the tibia and posterior to the pes anserinus insertion [8].
2. The deep MCL which is a thickened part of the medial joint capsule, lying deep to the superficial part of the MCL, and has meniscotibial and meniscofemoral components. The femoral attachment is 12.6 mm distal and deep to the femoral attachment of the superficial MCL, and the tibial attachment lies just distal to the edge of the articular cartilage of the medial tibial plateau, 3.2 mm distal to the medial joint line [8].
3. The POL, functioning as an additional medial knee restraint when the knee is extended. This is a fibrous extension of the distal aspect of the semimembranosus that blends with the posteromedial joint capsule. Its major and central portion attaches on the femur 7.7 mm distal and 2.9 mm anterior to the gastrocnemius tubercle. This is just proximal and posterior to the femoral insertion of the superficial MCL [8].

9.2.3 Assessment of MCL Dysfunction

9.2.3.1 Physical Examination

Physical examination should begin with assessing alignment and gait. When excessive valgus is identified in the injured limb and confirmed with AP hip-to-ankle axis view, varus-directed osteotomy to correct the alignment should be thought of as a first step before ligament reconstruction is considered [9]. This may result in decreasing valgus moments and consequently may lead to the resolution of the sense of instability. Following assessment of alignment and gait, the knee is thoroughly examined, including laxity assessment of all ligaments. The uninjured contralateral knee is used as a baseline for comparison. MCL laxity should be tested and graded with valgus stress applied at 0° and at 20–30° knee flexion. MCL laxity grade 0 corresponds to 0–2-mm side-to-side medial opening difference, grade 1+ corresponds to 3–5-mm difference, grade 2+ corresponds to 6–10-mm difference, and grade 3+ corresponds to more than 10-mm difference [10–12].

9.2.3.2 Imaging

Stress x-rays can also be used to provide further quantification of medial laxity. However, the amount of medial opening on stress x-rays that correlates with a specific grade of MCL laxity has not been well documented in vivo. Recently, reference values were provided, but this was tested in an old-age population cadaveric model which may not apply to young or middle-age living humans [13].

9.2.3.3 Examination Under Anesthesia

The operated knee should be examined under anesthesia and compared with the nonoperated side for range of motion and ligament laxity prior to surgery. While in the awakened patient physical examination of MCL laxity relies both on the patient's ability to relax and the clinician's skill to detect the amount of medial opening and existence or absence of an endpoint, in the anesthetized patient, the former is avoided, allowing the clinician a more objective evaluation of ligament laxity without muscle guarding.

9.2.3.4 Arthroscopic Evaluation

Following an orderly arthroscopic examination of the knee, emphasis is applied to the medial compartment in cases where increased medial constraints laxity is suspected. Quantitative assessment of medial compartment opening can then be performed using the tip of the arthroscopic probe as a scale after its length is measured and confirmed outside the knee. Medial compartment opening of above 5 mm is suggestive of grade 2+ MCL laxity [14], whereas 10 mm or more medial opening is suggestive of grade 3+ MCL laxity [15].

9.2.4 Surgical Approaches to Address MCL Dysfunction

9.2.4.1 Direct Repair

An absolute indication for direct repair of the MCL is bony avulsion with displacement of the femoral insertion of the ligament.

9.2.4.2 Medial and Posteromedial Plication/Reefing

In cases where residual medial laxity at the end of a cruciate reconstruction remains and arthroscopic assessment reveals grade 2+ medial laxity (medial opening > 5 mm), reefing of the medial constraints should be considered, unless chronic distal lesions with poor-quality scarring excludes this alternative [14].

9.2.4.3 MCL Reconstruction

In cases where grade 3+ medial laxity is observed (medial opening > 10 mm), reconstruction of the MCL should be considered. Surgical techniques which have been described to reconstruct the MCL include semitendinosus autograft with preservation of the tibial insertion [16–19], allograft tissues [20, 21], and double-bundle reconstructions [12, 18, 20–22]. Drawbacks related to these techniques include a long incision across the medial aspect of the knee with up to 20° loss of knee flexion or extension in 20% of the operations [19], keeping the semitendinosus insertion distally and using it as an MCL graft [16–19], resulting in a too anterior tibial attachment (i.e., the tibial insertion of the MCL should be posterior to the pes anserinus [8, 23]), harvesting a dynamic medial stabilizer that applies adduction moment during gait (i.e., semitendinosus) in a knee with an already medial instability, and the relative complexity of double-bundle reconstructions, compared to single-bundle reconstructions, corresponding to their need for multiple attachment sites on the femur as well as on the tibia, more graft tissue, and number of fixation devices (i.e., screws, washers, staples, etc.) required [12, 18, 20–22]. Recently, a new technique to reconstruct the MCL has been described that uses Achilles tendon allograft [15]. Benefits include avoiding donor site morbidity, secure fixation with bone-to-bone healing on the femur, small skin incisions that do not cross the knee, and isometric reconstruction.

9.2.4.4 Surgical Technique [15]

With the patient under anesthesia, after confirming MCL laxity that requires reconstruction as indicated previously by physical examination and arthroscopic examination, the following steps are carried out (after fixing the cruciate graft on the femur): (1) The Achilles allograft is prepared creating a 9-mm diameter by 18-mm length bone plug. (2) A 3-cm longitudinal skin incision is made over the medial femoral epicondyle. (3) A guide pin is inserted 3–5 mm proximal and posterior to the medial femoral epicondyle, parallel to the joint line, and in a 15° anterior direction to avoid the intercondylar notch. Location of the pin is confirmed with fluoroscopy. (4) The skin is undermined from the femoral guide pin to the anatomic MCL insertion on the tibia, creating a tunnel for the graft under the subcutaneous fat. (5) A nonabsorbable suture loop is placed around the guide pin and brought distally under the skin through the tunnel just created. (6) The distal suture is held against the tibia at the estimated anatomic insertion, just posterior to the pes anserinus insertion. Isometricity is tested through knee motion from 0° to 90°. The tibial insertion point is modified, if needed, until the loop is isometric. (7) The isometric point is marked on the tibia with a Bovey. (8) Soft tissue around the guide pin is debrided to allow for insertion of the Achilles bone plug into a socket created around this pin later. (9) A 9-mm-diameter reaming is performed over the guide pin to a depth of 20 mm. (10) The Achilles bone plug is inserted into the femoral socket and fixed with a 7-mm diameter by 20-mm length metal interference screw. (11) The Achilles tendon tissue is passed under the skin and distally. (12) The cruciate graft is now tensioned and fixed on the tibia. (13) The MCL graft is tensioned with the knee at 20° flexion under varus stress and fixed at the isometric point on the tibia with a 4.5-mm cortical screw and a 17-mm spiked washer. (14) Subcutaneous tissue and skin are closed. Tunnels position and hardware placement are confirmed postoperatively with radiographs.

9.2.4.5 Outcomes After MCL Reconstruction

In the literature, except for this recent description of an MCL reconstruction technique using Achilles allograft [15], there are only two studies reporting ROM and function in patients that had MCL reconstruction with one similar graft tissue in all patients and a similar specifically described MCL reconstruction technique in a combined MCL and another cruciate reconstruction [18, 19]. Both described a technique that uses the semitendinosus tendon with preservation of the insertion site at the pes anserinus on the tibia, creating anterior and posterior limbs to reconstruct the MCL. However, in both studies, the group of patients was heterogeneous and included isolated MCL reconstructions as well as concomitant cruciate reconstructions, but ROM was reported for all patients as one group, not differentiating the combined reconstructions from the isolated MCL reconstructions. In one of these, which included six cases of isolated MCL reconstruction and 18 cases of MCL with another cruciate reconstruction, the investigators found motion limitation between 5° and 10° in extension or in flexion in five patients (21% of the patients) [18], whereas in the other study, which included 11 cases of isolated MCL reconstruction and 39 cases of MCL with another one or both cruciate ligament reconstructions or posterolateral corner reconstruction, the investigators noticed motion loss of between 5° and 20° in extension or in flexion in 10 patients (20% of the patients) [19]. Both studies did not report ROM specifically for the combined reconstructions, and therefore the comparison to the technique described here, using the Achilles allograft, is limited. The fact all MCL grafts, using the Achilles allograft technique [15], demonstrated grade 0–1+ valgus laxity on physical examination is comparable to previous reports after double-bundle MCL reconstruction in a combined ligament reconstruction scenario that described grade 0 to 1+ valgus laxity in more than 90% of their cases [18, 19]. The fact mean IKDC-subjective and Lysholm knee scores demonstrated excellent (i.e., above 90 points) [24–26] function in patients with MCL reconstruction and primary ACL reconstruction, using the Achilles allograft technique [15], is comparable to the mean Lysholm score reported by others when creating a double-bundle MCL reconstruction with the semitendinosus, preserving its tibial insertion [18]. Mean KOOS subscores in the Achilles allograft technique were between 77 and 96 for the five categories of the score in cases with primary ACL reconstruction, which is comparable to another study that created a double-bundle MCL reconstruction and reported mean KOOS subscores between 75 and 89 for MCL reconstruction in a multiligament reconstruction scenario, the vast majority of which were MCL with ACL reconstructions [19]. In patients with the Achilles allograft MCL reconstruction with revision ACL reconstruction, IKDC-subjective, Lysholm, and KOOS subscores demonstrated inferior outcome [15]. Tegner and Marx activity level scores demonstrated patients with concomitant primary ACL reconstruction were able to return to preinjury activity levels, which were at means of between 6 and 7 points, indicating that cutting and pivoting sports on a recreational level may be a realistic goal after this type of Achilles allograft MCL reconstruction, but when this technique is performed in the setting of revision ACL reconstruction, return to preinjury activity levels may not be achieved despite regaining normal knee laxity.

9.3 Managing Posterior Cruciate Ligament Injuries

Lars Engebretsen, M.D., Ph.D.

9.3.1 PCL Function

The posterior cruciate ligament (PCL), which sits near the center of the knee, is responsible for the knee's basic stability. It serves as the knee's primary restraint to resist posterior tibial translation relative to the femur. It prevents hyperextension and limits internal and varus/valgus rotation. The PCL appears more vertical in extension and more horizontal in flexion. It has been reported that 5% to 20% of all ligamentous knee injuries involve the PCL. However, these injuries are often thought to go undiagnosed. Injuries to the PCL may be obvious when combined with other capsuloligamentous injuries in the knee, but may not be so apparent when isolated, as knee instability in isolated PCL injury can be subtle or even asymptomatic.

9.3.2 PCL Anatomy

The PCL is made up of a larger anterolateral bundle and a smaller posteromedial bundle. It is an extrasynovial structure, found behind the intra-articular area of the knee. It originates from the intercondylar notch of the femur and inserts central on the posterior aspect of the tibial plateau, on a depression between the plateaus.

9.3.3 PCL Injuries

9.3.3.1 Pathoanatomy

PCL injury is often due to a direct blow to the proximal aspect of the tibia. For instance, an athlete may fall onto the flexed knee while flexing the foot plantar. This results in a posterior force on the tibia, which can rupture the PCL.

PCL injuries often occur along with injury to other capsuloligamentous structures in the knee. When three or more ligamentous structures are injured, the injury is known as a dislocated knee. These combined injuries are especially common after a high-energy trauma, such as a motor vehicle accident. It is believed that certain PCL injuries, especially when combined with other knee injuries, can lead to knee instability, pain, and osteoarthritis.

9.3.4 Evaluation of PCL Injuries

9.3.4.1 History

Assessment of the PCL should consist of a history to determine whether the trauma was high or low energy. Dislocation, neurologic injury, and additional injuries may also contribute to the evaluation. A chronic PCL tear may manifest as discomfort with a semiflexed position, particularly when ascending and descending stairs and inclines, starting a run, lifting a load, and walking long distances.

9.3.4.2 Physical

Physical examination for PCL injury relies mainly on the posterior drawer test. Other tests, such as the Lachman test for ACL injury, testing for varus and valgus, and testing for external and internal rotation, may also be important for determining whether PCL injury is isolated or combined. Individuals with PCL injury commonly have minimal to no pain, minimal hemarthrosis, full or functional range of motion, contusion over the anterior tibia, and posterior tibial sag.

An isolated PCL injury will exhibit a positive posterior drawer test at 90°, translating as >10–12 mm in neutral rotation and 6–8 mm of posterior translation in internal rotation. However, if the PCL is injured along with other structures, such as the ACL, posterolateral corner, or medial side, a positive posterior drawer test at 90° will be >15 mm in neutral rotation and >10 mm in internal rotation.

9.3.4.3 Imaging

Plain radiographs are important for determining whether or not the knee is dislocated. MRI can also be used to provide information about the site of injury and continuity of the PCL and can influence treatment course.

9.3.5 Treatment Approaches

Surgical approaches for addressing PCL dysfunction include repairs (avulsions), augmentations, and reconstructions. Reconstruction can be performed using a femoral tunnel technique with a tibial inlay or a tibial/femoral tunnel technique. Single-bundle or double-bundle femoral tunnel techniques are also used. No studies as of yet have been able to conclusively prove a better clinical outcome of one technique over the others.

Debate also exists over the best tissue to use for reconstruction. Allograft tissue is usually used, most commonly, Achilles tendon. However, bone-patellar tendon-bone, hamstring tendons, semitendinosus tendon, gracilis tendon, and anterior tibialis tendons may also be used. Graft choice is usually not made based on outcome studies from the literature but instead is based on previous surgeon training and availability. Allograft is preferred for multiligament reconstructions to avoid multiple harvests.

9.3.6 Postoperative Rehabilitation

Rehabilitation after surgery is focused on increasing quadriceps strength and reducing patellar pain. The patient is also told to focus on maintaining patellar mobility through practice of self-mobilization exercises for the patella, scar, and soft tissues surrounding the kneecap. The goal of the recovery phase is to advance weight bearing and return the patient to a normal gait pattern with normal range of motion. Cold therapy, compression, and evaluation are important for controlling pain and swelling after surgery.

9.4 Managing Lateral Collateral Ligament and Posterolateral Corner Injuries

Robert G. Marx, M.D., M.Sc. FRCSC

9.4.1 LCL and Posterolateral Compartment Function

The lateral collateral ligament (LCL) is the primary restraint to varus stress in the knee. At 5° of knee flexion, it provides 55% of restraint and at 25° it provides 69%. The popliteus structure limits posterior tibial translation, external tibial rotation, and varus rotation.

Injuries to the LCL and posterolateral compartment result when a force is directed at the medial side of the knee or leg. These injuries occur in about 7–16% of all knee ligament injuries. They are reported less commonly than injuries to the medial collateral ligament as they are less frequently recognized and are usually prevented by the presence of the opposite leg which can block direct blows to the knee's medial side.

9.4.2 LCL and Posterolateral Corner Anatomy

The lateral compartment of the knee contains both dynamic and static stabilizers. The dynamic stabilizers include the biceps femoris, the iliotibial band, the popliteus muscle, and the lateral head of the gastrocnemius muscle. The lateral collateral ligament, popliteofibular ligament, and the arcuate ligament make up the static ligamentous complex.

The lateral capsular complex of the lateral aspect is further divided into three parts. The anterior third is attached to the lateral meniscus anterior to the LCL. The middle third is attached proximally at the femoral epicondyle and distally at the proximal tibia, while the posterior third is found posterior to the LCL.

9.4.3 Evaluation of Lateral Compartment Injuries

9.4.3.1 History

A direct force applied to the weight-bearing knee which causes excessive varus stress, external tibial rotation, and/or hyperextension can cause lateral ligament injury. This force commonly demonstrates as a posterolaterally directed force to the medial tibia while the knee is in an extended position. This frequently occurs during motor vehicle accidents and athletic injuries. Injury to the lateral and posterolateral structures often occurs in conjunction with cruciate injury rather than as isolated injuries. Patients with this injury present with instability of the knee near full extension. They may have difficulty ascending and descending stairs and performing cutting or pivoting movements. They may also complain of lateral joint-line pain.

9.4.3.2 Physical

The injured extremity should be examined by performing adduction stress at both 0° and 30° of knee flexion. Signs of posterolateral injury include footdrop, peroneal nerve injury, posterolateral corner tenderness, and pain with posterior-internal rotation of the tibia. If the knee demonstrates isolated laxity at 30°, injury to the LCL is likely. Laxity at both 0° and 30°, however, is indicative of combined injury to the LCL and ACL, PCL, or arcuate complex.

In chronic injuries, it is also important to evaluate their gait. This can help determine whether there is a varus or hyperextension thrust. Neurovascular injuries must also be assessed, as peroneal nerve deficits have been reported along with acute posterolateral corner injuries in up to 29% of cases.

9.4.3.3 Imaging

Plain radiographs should be taken for all patients suspected to have injuries to their LCL and posterolateral corner. These images are used to rule out associated osteochondral fracture, fibular head avulsion, Gerdy tubercle avulsion, and fracture of the tibial plateau. MRI is the preferred imaging tool to assess the integrity of the LCL, popliteus tendon, and cruciate ligaments. MRI can be used to determine the severity and location of the knee injury.

9.4.3.4 Classification

Isolated injury to the LCL rarely results in coronal plane laxity. Rotatory instability demonstrating as multiplanar laxity can be seen with combined injury to the LCL and other structures such as the ACL and mid-third capsular ligament or arcuate ligament, popliteus tendon, and fabellofibular ligament. Chronic isolated injury to the LCL rarely occurs. Most patients with this type of injury will eventually develop injury patterns of the other posterolateral corner structures.

Grading of posterolateral corner injuries (grade I, II, or III) is determined based on the degree of ligament disruption – minimal, partial, or complete. However, a more precise method exists which relies on quantification of lateral joint opening with varus stress.

9.4.4 Treatment Approaches

9.4.4.1 Nonsurgical

Nonsurgical treatment is indicated by grade I and II (partial) isolated injuries of the LCL. Such patients have little functional instability. Nonsurgical treatment consists of limited immobilization with protected weight bearing during the first 2 weeks after injury. As the patient improves, progressive ROM, quadriceps strengthening, and functional rehabilitation are encouraged. The patient may return to sports in about 6–8 weeks. If associated injuries to the posterolateral structures fail to be identified, nonsurgical treatment can, however, lead to progressive varus/hyperextension laxity.

9.4.4.2 Surgical

Surgical treatment is indicated by complete injuries or avulsions of the LCL; rotatory instabilities of the LCL and arcuate ligament, popliteus tendon, and fabellofibular ligament; and combined instability patterns of the LCL/posterolateral corner and ACL or PCL.

Acute injuries can be treated surgically by primary repair of torn or avulsed structures or reconstruction of the tissue. Direct repair can be hindered by the formation of scar tissue and distortion of the tissue planes, so it must be done within 2 weeks if performed. Reconstruction has been shown to have a lower failure rate than isolate repair in two comparative studies.

Surgical treatment of chronic LCL and posterolateral corner dysfunction can be done using allograft tissue to form a single-stranded graft. Some authors advocate a separate graft to reconstruct the popliteofibular ligament from the femur to the tibia, but no comparative studies have been done.

Full-length upright radiographs of both lower extremities of patients with chronic instability should be taken to determine whether or not varus mechanical axis is present. If so, a high tibial osteotomy may be indicated.

9.4.5 Complications

Chronic injuries can result in persistent varus or hyperextension laxity due to advancement of attenuated lateral and posterolateral structures. Surgical treatment may cause peroneal nerve injury as a result of exposure of the fibular neck or during drilling or graft passage. Hardware irritation at the lateral femoral condyle may also occur, and knee range of motion may be lost, as can occur after the reconstruction of multiple knee ligaments.

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Osteotomy: The Basics

10

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Contents

10.1 Deformity Analysis and Planning

Deformities around the knee can occur in all three anatomical planes of reference. There are frontal plane deformities (i.e. genu varum and genu valgum), sagittal plane deformities (i.e. genu procurvatum and genu recurvatum) and transverse plane deformities (translation and torsion). Deformities can even occur in the so-called oblique plane (i.e. in between the frontal and sagittal planes). Furthermore, deformities can be either uniplanar or multiplanar. Since the most frequent and relevant deformities around the knee occur in the frontal plane, the primary focus is on these deformities.

Deformity in the frontal plane will increase the distance from the centre of the knee to the mechanical axis and thus create a moment arm at the knee joint. In a dynamic experimental loading study, it was demonstrated that the position of the loading axis in the frontal plane has a strong effect on the tibiofemoral cartilage pressure distribution of the knee. The medial compartment is predominantly loaded in a varus knee; a neutral mechanical axis loads the medial slightly more than the lateral compartment, and in valgus alignment, the main load runs through the lateral compartment. It has been shown that frontal plane malalignment around the knee is associated not only with progression of knee osteoarthritis but also with the development of knee osteoarthritis. Therefore, axis deformities around the knee are regarded as

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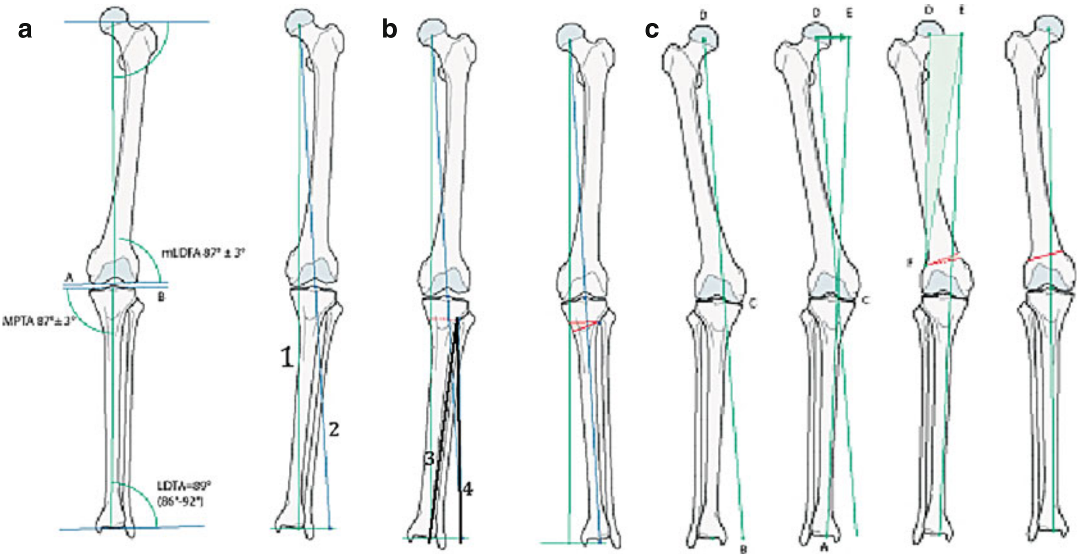


Fig. 10.1 (**a**) Deformity analysis: mechanical leg axis with the joint orientation angles of the distal femur (mLDFA) and proximal tibia (MPTA) and distal tibia (LDTA). (**b**) Planning for valgization open-wedge HTO correction (line numbers – see text). (**c**) Planning for varization closing wedge DFO correction: line *D-B* connecting old hip centre to planned weight-bearing line position at the knee joint (*C*), line *A-E* connecting old ankle centre through planned weight-bearing line position at the knee joint (*C*) to new hip centre (*E*), angle between line *D-F* (hinge point DFO) and line *E-F* is correction angle which is projected on medial cortex, leg alignment after medial closing wedge DFO

pre-arthritic deformities. The goal of correctional osteotomies around the knee is the transfer of mechanical load from the overloaded areas of the joint to the healthy compartment of the knee, e.g. unloading of the medial compartment can be achieved with a high tibial osteotomy aimed at slight valgus overcorrection. The success of correctional osteotomies around the knee highly depends on an accurate preoperative analysis of the deformity as well as accurate planning of the deformity correction. This requires detailed knowledge of normal limb alignment.

To understand the true nature of the deformity, a thorough radiographic examination is indispensable. Preoperative evaluation for frontal plane corrections around the knee includes AP weight-bearing views in full extension, 45° flexion PA weight-bearing view (Rosenberg view), lateral views and skyline views of the patella. These allow an assessment of the extent and localization of knee osteoarthritis including the patellofemoral joint. The AP whole leg standing radiograph is considered the gold standard for measuring alignment and joint orientation and serves as the basis for the planning of osteotomies in the frontal plane. Standardized calibrated radiographs with the knee in full extension and in neutral rotation (patella forward on the AP projection) are necessary for such measurements. Varus and valgus stress views are not absolutely necessary but may be helpful to assess abnormal laxity of the collateral knee ligaments or to define the degree of involvement of the less affected tibiofemoral compartment. Other imaging modalities, i.e. MRI to assess the condition of cartilage, menisci and ligaments, are not obligatory, but may be of use under certain circumstances. If a rotational deformity is suspected, a CT scan may be of additional value.

To determine if a frontal plane deformity is present, the mechanical axis of the entire leg is drawn first (Fig. 10.1a). This is the line connecting the centre of the femoral head and the centre of the ankle joint, and it normally passes slightly medial to the centre of the knee joint. The distance between the mechanical axis line and the centre of the knee is the mechanical axis deviation (MAD) expressed in millimetres. The normal MAD is 8 ± 7 mm medial to the centre of the knee joint. Malalignment is present if the MAD exceeds its normal range. A MAD that lies more medial than the normal range indicates a varus deformity and a MAD lateral to the normal range a valgus deformity. Secondly, the mechanical and anatomic tibiofemoral axes are evaluated to assess the magnitude of the deformity. The mechanical femoral axis in the frontal plane runs from the centre of the femoral head to the centre of the knee joint. The tibial mechanical axis is a line connecting the centre of the ankle to the centre of the knee joint. The anatomic femoral and tibial axes can be determined by drawing mid-diaphyseal lines. Physiologically, the angle between the mechanical axis of the femur and tibia is 1.2 ± 2.2° of varus. The anatomic tibiofemoral angle is physiologically 5–7° valgus. Thirdly, the source of the malalignment is determined by measuring the joint orientation angles of the distal femur (mLDFA) and proximal tibia (MPTA). These angles are the angles between the joint orientation lines of the distal femur and proximal tibia and the mechanical axes of the femur and the tibia, respectively. Paley has standardized the nomenclature of these joint orientation angles and also reported on the normal reference values relative to the mechanical and anatomic axes in the frontal plane. Values less than 85° and more than 90° are abnormal for both the mechanical lateral distal femoral angle (mLDFA) and the medial proximal tibial angle (MPTA) and indicate that the source of the deformity is respectively in the femur or the tibia. The angle between femoral and tibial joint orientation lines is called the joint line convergence angle (JLCA). Abnormal values of the JLCA indicate ligamentous laxity or cartilage loss as causes of malalignment. Using the same principles, malorientation of the hip and ankle joint relative to the mechanical and anatomic axes can be identified.

With the fourth step of the deformity analysis, the level of the deformity within a particular bone is identified. For this, the anatomical axes for both femur and tibia are used. In a deformed bone, the proximal and distal anatomic and mechanical axes intersect. This point is known as the centre of rotation of angulation (CORA). This method is relatively straightforward for diaphyseal localized deformities. For deformities localized at/near the bone ends, it is not. In these cases, the joint centre and a reference joint orientation angle (of the opposite normal limb or alternatively the normal population averages) is used to draw the axis of the juxta-articular segment.

Each axis deformity around the knee should be described in terms of its magnitude, level (the apex of the deformity, i.e. the CORA), plane (frontal, sagittal, transverse) and direction (valgus, procurvatum, recurvatum, etc.). Deformity correction should be performed at its source (femur, tibia or both) and if possible at the CORA. If angular deformities are corrected by an osteotomy that passes through CORA, realignment occurs without translation. When the osteotomy is performed at another level than at the CORA, the axis will not only realign by angulation, but translation will occur as well. In that case, correction of the mechanical axis may be achieved, but a pathological joint line orientation may be the secondary adverse result. The goal of correction is different for different conditions. Neutral alignment is the goal for posttraumatic conditions without knee osteoarthritis. In varus alignment associated with medial compartment osteoarthritis of the knee, some degree of overcorrection to unload the affected compartment is desired. In lateral compartment osteoarthritis associated with valgus alignment correction to neutral often sufficiently unloads the diseased compartment.

Several planning methods to achieve optimal correction have been described. Our preferred method is the one described by Miniaci. Planning a valgus high tibial osteotomy for medial compartment osteoarthritis is started with drawing the weight-bearing line, i.e. the mechanical leg axis of the deformed leg (line 1) (Fig. 10.1b). Then the desired weight-bearing mechanical axis (line 2) is drawn from the centre of the femoral head through a point that is located on 62.5%of the tibial width (medial being 0%, lateral 100%) ending at the new ankle centre given by the equal distance between femur head and ankle centres of line 1. This point is equal to a 3–5° of mechanical valgus leg alignment. Then a third line is drawn from the hinge point of the planned osteotomy to the centre of the ankle. A fourth line is drawn from the osteotomy hinge point to the new ankle centre. The angle between lines 3 and 4 is the planned correction angle. The planned correction angle forming a triangle is now projected in the tibial head originating from the osteotomy hinge point. The length of the base of this triangle located at the cortex opposite to the hinge point corresponds to the size of the wedge to be opened (or closed) intraoperatively. For femoral deformities, the same strategy is used in a retrograde fashion drawing the planned weight-bearing axis from the centre of the ankle joint through a desired point in the knee to the hip centre (Fig. 10.1c). In varus producing distal femoral osteotomy for lateral compartment osteoarthritis, the postoperative weight-bearing mechanical axis should cross the knee at a point just medial to the medial tibial spine. It should be noted that soft-tissue laxity, and cartilage and intra-articular bone loss contribute to the overall varus or valgus deformity sometimes found in an abnormal JLCA. This portion of the deformity does not require bony correction and should be accounted for when planning the osteotomy to avoid overcorrection.

Besides proper patient selection criteria, the achievement of the optimal amount of correction is key for the success of osteotomies around the knee. Both under- and overcorrection lead to failure of the osteotomy and poor results. Systematic deformity analysis helps to recognize the magnitude, level, plane and direction of the deformity. Once the nature of the deformity is understood, the correctional goal has to be defined. Finally, a careful and precise planning will help to achieve the desired correction.

10.2 Indications and Surgical Technique: High Tibial Osteotomy

Objective criteria in which patients' high tibial osteotomy (HTO) should be performed are not defined to full extend. Concerning age, there is no definite cut-off; nevertheless, some authors prefer HTO in patients younger than 65 years. This seems to be justified also against the background of a higher activity level. Even progressed osteoarthritis of the medial compartment seems tolerable, and non-symptomatic cartilage defects of the patellofemoral joint do not significantly influence clinical outcome. Smoking seems to delay consolidation of the osteotomy gap and is therefore considered an exclusion criteria by some authors.

Concerning the type of varus deformity, the tibial bone varus angle (TBVA), which describes the amount of extra-articular metaphyseal varus of the proximal tibia, has been described as a reliable prognostic factor, which is associated with good clinical outcome. The question of the minimal amount of varus deformity that requires realignment still remains unclear. Recent studies demonstrate additional positive effects of HTO when performed in combination with cartilage repair even in mild varus deformities in patients suffering of isolated cartilage defects of the medial femoral condyle.

Since the introduction of HTO, the surgical technique has evolved. Recently, the open-wedge technique (OW-HTO) has become more popular since it provides some potential benefits including less risk of intraoperative damage of the peroneal nerve, less soft-tissue damage and the ability of continuously variable correction. Concerning the surgical technique, biplanar, intraligamentous OW-HTO has been recommended. Using this technique, rotational stability is provided by the biplanar osteotomy approach. Furthermore, the tibial tuberosity is preserved and remains attached to the distal main fragment. In patients with pre-existing patella baja, the biplanar technique can also be modified in terms that the osteotomy is performed distally of the tibial tuberosity. Further advantage of the biplanar technique is that osseous consolidation starts in the anterior part of the osteotomy since the direct bone-to-bone contact is preserved between the two main fragments. Concerning collateral ligaments, a controlled release of the medial collateral ligament is essential in order to achieve unloading of the medial compartment.

For OW-HTO, specific implants are needed in order to stabilize the osteotomy. Among those implants, internal plate fixators have been proven superior concerning biomechanical properties, which seems to be of clinical relevance. This seems especially important in those cases in which a controlled fracture of the lateral cortex is observed intraoperatively and might help to explain the fact that higher complication rates have been reported in some studies using smaller and less stable implants.

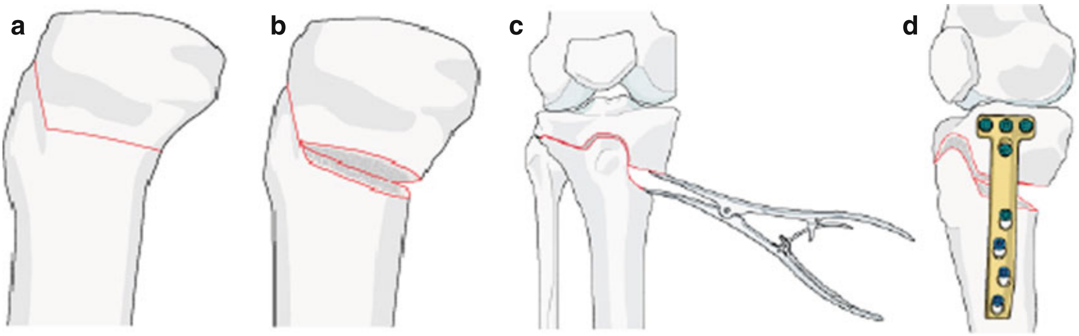


Fig. 10.2 (**a**) Sagittal plane view of open-wedge HTO biplane cuts. (**b**) Sagittal plane view after opening of the wedge. (**c**) Frontal plane view of open-wedge HTO with bone spreader. (**d**) Oblique plane view of open-wedge HTO with internal fixator plate fixation

In conclusion, HTO today seems a well-established, safe and effective surgical treatment for unicompartmental gonarthrosis in patients with varus-malalignment. Biplanar open-wedge osteotomy (OW-HTO) using an internal plate fixator in combination with a controlled release of the medial collateral ligament is the method preferred with additional advantage that early full weight-bearing is possible (Fig. 10.2).

10.3 Indications and Surgical Technique: Supracondylar Femur Osteotomy

The objective of a varization supracondylar femur osteotomy (SFO) is a shifting of the mechanical axis from the lateral towards the medial compartment in patients with lateral osteoarthritis in combination with valgus deformity. Besides patients with osteoarthritis of the lateral compartment in combination with valgus deformity of the (distal) femur indications for this procedure consist of patients with posttraumatic and congenital valgus deformities of the (distal) femur. Contraindications for SFO consist of patients with osteoarthritis of the medial compartment (≥ grade 3 on Outerbridge scale) and patients that have a total loss of the medial meniscus after previous surgery. Furthermore, acute or chronic infections around the knee as well as rheumatoid arthritis are reasons to exclude patients. Finally, patients with knee extension or flexion deficit >20° and poor soft-tissue conditions on the site of surgery as well as heavy smokers should preferably not be indicated for SFO. Traditionally the medial closing wedge SFO has been performed as a uniplanar technique. The saw cuts need to be made proximal to the trochlea where bone healing of the osteotomy is slower. In the last years, the preferred surgical technique of the SFO has evolved to a biplanar medial closing wedge technique which enables positioning the saw cuts lower into the better healing metaphysial bone. In this technique, a medially based wedge is removed using two incomplete saw cuts ending at a hinge point within the lateral cortex from the posterior ¾ of the bone (Fig. 10.3). After that, a third saw cut is made proximally in the anterior ¼ of the bone parallel to the posterior femur cortex. After wedge removal and closure of the wedge, fixation is performed with an internal fixator implant. Biomechanical testing has shown that the biplanar SFO with internal fixator plate fixation shows superior fixation strength as compared to previously performed single plane SFO's and lateral opening wedge SFO techniques. Whereas the new technique reduces rehabilitation time after SFO already due to decreased

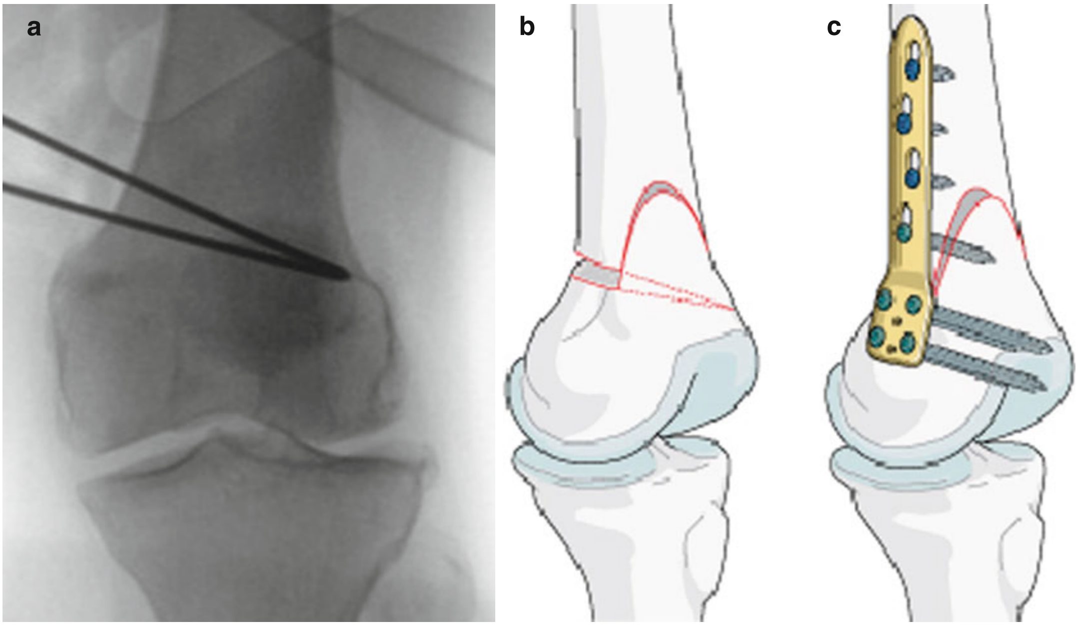


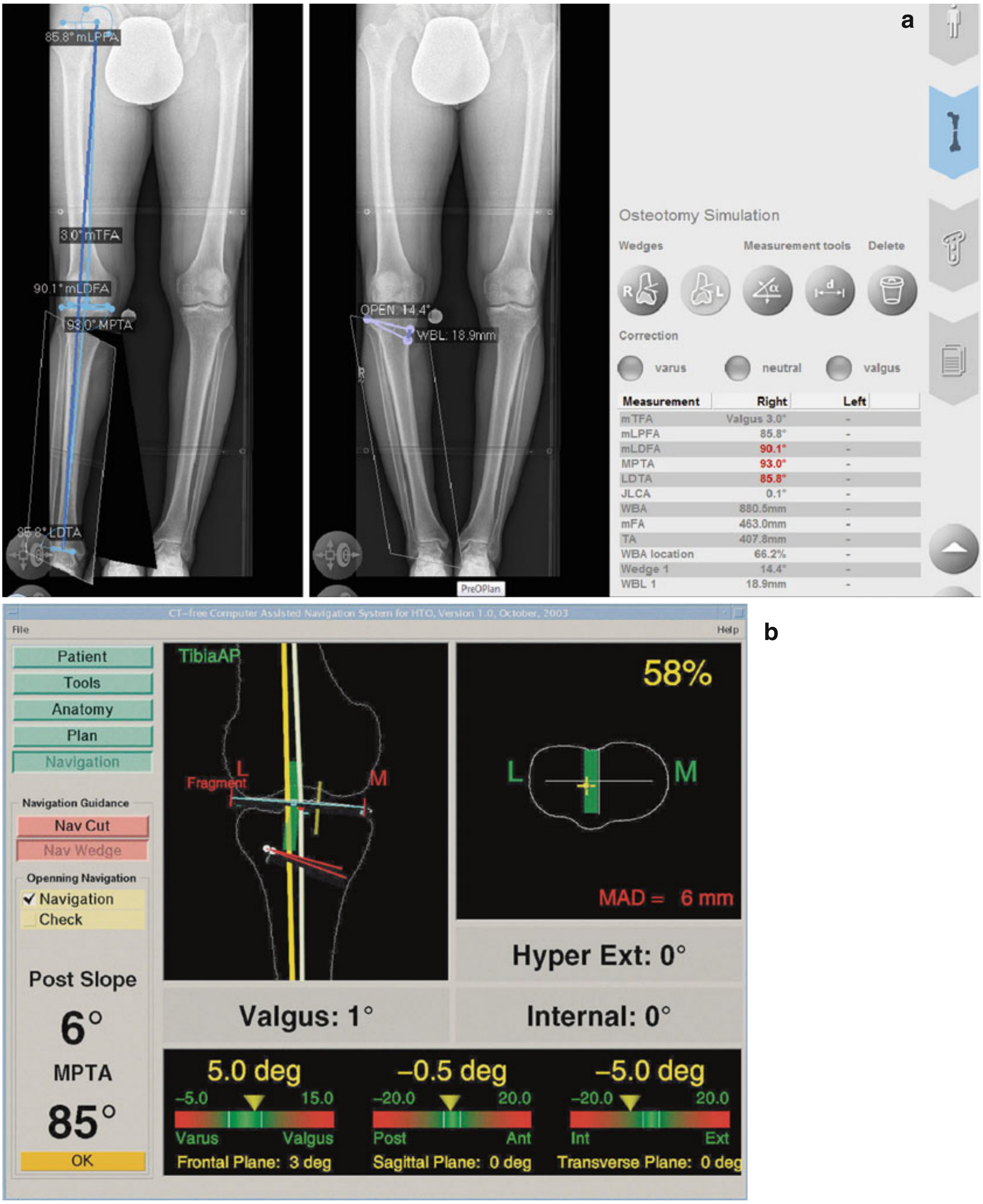
Fig. 10.3 (**a**) Radiograph with K-wires inserted to guide the saw cuts towards the hinge point in medial closing wedge SFO. (**b**) Biplane SFO after wedge removal. (**c**) Biplane SFO after wedge closure and fixation with internal plate fixator

time for partial weight-bearing until 4–6 weeks after surgery, the safety of brace-protected immediate full weight-bearing after biplane SFO is yet under investigation.

In conclusion, SFO today seems a well-established, safe and effective surgical treatment for patients suffering from femoral valgus-malalignment with and without unicompartmental gonarthrosis. Biplanar medial closed-wedge osteotomy using an internal plate fixator is the method preferred with additional advantage that decrease of time to full weight-bearing is possible.

10.4 Digital Planning and Navigation

In recent years, picture archiving and communication systems (PACS) for medical imaging are routinely used in many trauma and orthopaedic departments. Different planning programmes are available to measure angles and plan deformity correction of the lower extremity. The advantage and success of digital planning software depends



Measurement	Right	Left
mTFA	Valgus 3.0°	-
mLPFA	85.8°	-
mLDFA	90.1°	-
MPTA	93.0°	-
LDTA	85.8°	-
JLCA	0.1°	-
WBA	880.5mm	-
mFA	463.0mm	-
TA	407.8mm	-
WBA location	66.2%	-
Wedge 1	14.4°	-
WBL 1	18.9mm	-

☑ Navigation
☐ Check

Post Slope 6°

MPTA 85°

58%

MAD = 6 mm

Hyper Ext: 0°

Valgus: 1°

Internal: 0°

5.0 deg (−5.0 to 15.0) Frontal Plane: 3 deg

−0.5 deg (−20.0 to 20.0) Sagittal Plane: 0 deg

−5.0 deg (−20.0 to 20.0) Transverse Plane: 0 deg

Fig. 10.4 (**a**) Screenshot of digital planning program. (**b**) Screenshot of navigated HTO on ease of learning and use for experienced as well as inexperienced surgeons. For digital 2D planning, a full weight-bearing long leg standing radiograph, including a reference ball or a ruler as calibration, is required. Commonly used digital planning software is landmark-based medical planning software, i.e. mediCAD® (Hectec, Germany) or PreOPlan® (Siemens, Germany). The measurement of the joint angles is according to the principles of deformity correction. Calculated from the marked landmarks, the digital planning software displays all relevant angles. After this, the osteotomy technique (open wedge or closed wedge) and the level of the osteotomy (tibial or femoral, double level or one level) can be simulated. Subsequently, the planned osteotomy is positioned in the X-ray, and the angle of correction can be adjusted to the target angle during osteotomy simulation. A high reliability of alignment measurements and planning of correction with the height of a wedge base as a result of the digital planning process has been described.

To implement the high precision of the digital planning result in the operating theatre, a verification of the calculated angles intraoperatively is desirable. Different methods are available to check the alignment after a correction in the frontal plane. An alignment rod and grid plate are tools to visualize the mechanical leg axis during fluoroscopy; however, the mechanical tibiofemoral angle cannot be measured. Meanwhile, different navigation systems for high tibial osteotomy are available and have been introduced as an intraoperative aid. Underlying principles are the real-time acquisition of the rotation centre of the hip, knee and ankle and of the anatomical landmarks at the level of the knee joint line and ankle. Navigation systems allow for a dynamic visualization of the mechanical leg axis and the mechanical tibiofemoral angle of the lower extremity on the computer screen. Screenshots of the preoperative and postoperative measurements are displayed and saved on the computer terminal. Different authors reported a high precision of open-wedge HTO using a navigation system. Comparing conventional open-wedge HTO to a navigation group of open-wedge HTO, no significant statistical differences of the postoperative mTFA could be found. The risk of undercorrection, however, is reduced by navigation.

Although navigation is a good tool to check the precision of correction intraoperatively and reduce undercorrection, it cannot replace preoperative planning. An exact preoperative deformity analysis before planning is the indispensable key to the success of osteotomies (Fig. 10.4).

All figures (except Fig. 3a and Fig. 4a) are taken from: Lobenhoffer et al. with permission.

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11

Study Design and Research Methodology in Sports Medicine

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Contents

11.1 Introduction

Sports injuries occur often at young ages at all levels of sports activity. These injuries may cause lifelong disability or problems for future sport or work participation. Currently, the treatment of these injuries is of major importance to the individual and to the society both seen from the quality of life perspective but also from the economical point of view. Decisions about treatment must be evidence based. Knowledge about study design and methodology is crucial in order to detect misleading studies or reviews that unfortunately

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sometimes are published in this field [1]. Knowledge of study designs and the potential weaknesses of study designs are necessary to obtain the best treatment to people with sports injuries. In this chapter, we present knowledge about how to plan, perform, and evaluate studies in sports medicine.

11.2 Sports Medicine Studies in High Impact Journals

11.2.1 Impact Factor

Impact factor (IF) is a measure reflecting the average number of citations to articles published in scientific journals. For example, the impact factor 2010 for a journal would be calculated as follows: A = the number of times articles published in 2008–2009 were cited in indexed journals during 2010. B = the number of articles, reviews, proceedings, or notes published in 2008–2009. IF 2010 = A/B

Many controversies are related to "impact factor." A journal will, for example, increase its impact factor by publishing many review articles and by publishing editorials with references from the same journal. Journal ranking lists based on the impact factor only moderately correlate with journal ranking lists based on the results of an expert survey [2]. The highest ranked journals in medicine (The "Big Five" – all IF > 13) are Lancet, New England Journal of Medicine (NEJM), British Medical Journal (BMJ), Journal of American Medical Association (JAMA), and Annals of Internal Medicine. For comparison, the highest ranked orthopedic/sports medicine journal is Osteoarthritis and Cartilage with IF 3.9

11.2.2 Sports Medicine in High Impact Journals

Sports medicine publications are not common in high impact journals. The reasons may be that they are seldom of high enough quality, and if they are, they are often too specialized or study topic might not arouse general medical interest. There may also be reasons not to publish in these high impact journals: Maybe the readers you want for your research do not read the high impact journal and that a more specialized journal is a better choice – even if the study is of high enough quality. To decide where to publish your article, you must decide who you are aiming at: sports orthopedic surgeon, general orthopedic surgeons, sports medicine doctor, physiotherapists, general practitioners, or the general public.

Example: Guidelines for publication in British Medical Journal (IF 13.5)

BMJ will publish original, robust research studies that can improve decision making in medical practice, policy, education, or future research and that are important to general medical readers internationally.

If studies in the field of sports medicine should be published in these highly ranked general medical journals, they need to be of high quality but also of great importance and of general interest. Examples of research topics that could be of interest are:

- Prevention of important injuries in common sports
- Effect of a new treatment (surgical or nonsurgical) of a common disorder or injury
- A major step forward in the treatment of a common injury:
  - Make a torn ACL to heal to normal morphology and function
  - Restore normal hyaline cartilage (injection, surgery)

In conclusion, it can be summarized that sports medicine studies can be published in high impact journals if they are of high quality, give new original knowledge, and are of sufficient general interest.

11.3 Prestudy Power Analysis for Calculation of Sample Size

In clinical research, observations are performed on a limited amount of individuals (e.g., a group of patients with habitual patellar dislocations or a group of patients with ACL ruptures). This group of individuals constitutes a sample from a target population. The target population is the population of interest about which the researcher wants to acquire new knowledge. The researcher uses the observations from the sample to draw conclusions about the target population. With larger samples, the uncertainty of the conclusions is reduced. Therefore, ideally, one should use as large samples as possible. For several reasons, such as limitations of time and money, it is necessary to use as small sample as possible. Statistical methods are used to quantify the uncertainty of the conclusions drawn on basis of observations in the sample but can also be used in advance to calculate the sample size needed to have acceptable chance to detect a meaningful difference between two groups (e.g., patients with patellar dislocations or ACL ruptures that are given two different types of treatment).

11.3.1 Hypothesis Testing

The calculation of sample size is closely related to another statistical method, hypothesis testing. In a research project, it is often a goal to detect clinically meaningful differences between two groups in the target population. This is performed by making inferences from observations made in a sample from this population. Let us consider the following example: In a research project, one group receives treatment A and the other group does not receive treatment A. The null hypothesis, H0, is that there is no difference between the groups, which means that there is zero effect of treatment A. The alternative hypothesis, H1, is that treatment A has an effect. The conclusion drawn from the observations in the sample could be that the H0 is rejected, which in principle means that it is unlikely that one should observe the given results in the sample if H0 were true. The conclusion could also be the opposite; H0 is not rejected, which means that it is likely (or rather not unlikely enough) that the observations in the sample could be acquired when H0 is true. On the basis of the observations in the sample, it is thus possible to reach two conclusions, H0 is rejected or H0 is not rejected and the decisions could be right or wrong.

	H0 is true, zero effect of treatment A	H1 is true, treatment A has an effect
H0 is not rejected	Right decision	Wrong decision Type II error
H0 is rejected	Wrong decision Type I error	Right decision

Statistical significance testing is the method that is used to reach a conclusion regarding the H0.

Let us consider two artificial examples:

In a group of patients with habitual patellar dislocation, a high proportion is expected to experience a new dislocation over the course of one year. One group of the patients is given a new type of operative treatment, whereas the other group receives standard treatment. H0 is that there is no difference in the proportion of new dislocations. One determines the threshold probability in advance, i.e., the significance level. This is the probability to observe the data, or more extreme data, when the H0 is true. Usually, the threshold is 0.05. One can use the chi-square test to test for statistical significance, and when the result is $P < 0.05$, H0 is rejected. This could be a right decision, when the new treatment has an effect, or it could be a type I error. The rate of type I error equals the significance level.

In a group of patients with ACL ruptures, two different operative treatments are given. The results are measured with a functional, self-reported outcome score, KOOS. H0 is that there is no difference in the mean KOOS values between the groups. One can use the student's *t* test to test for statistical differences between the two groups. The considerations regarding rejection of the H0 or failure to do so are equivalent to the previous example. However, when comparing continuous variables in groups, other statistical tests are needed, than when comparing proportions.

11.3.2 Statistical Power

The statistical power of a statistical test is the probability of not committing a type II error, i.e., failure to reject the H0, when this is false. The statistical power is dependent on several factors, of which the following are the most obvious: the size of the sample, the chosen significance level, and the size of the effect. In a practical setting, the researcher wants to know the size of the sample needed in order to achieve an acceptable power. Often the target power is defined as 0.8 or 0.9, i.e., 80% or 90% chance of not committing a type II error.

Let us again consider the previous artificial examples:

In the first example, the researcher wanted to detect differences in proportions between groups of patients with habitual patellar dislocations that received different types of treatment. The researcher needs to decide the following parameters: the significance level which often is 0.05, the statistical power, which in this case will be 0.8, and the expected proportion of new dislocations in the group that receives standard treatment. This should be known from previous studies or clinical experience. In this example, we say that it is 0.3. And the last parameter is the most difficult one to determine: What proportion in the treatment group would be interesting to detect? The difference in proportions can be defined as the effect of the treatment. It is reasonable to decide that a size of an effect that will lead to a new treatment practice is clinically significant. For this example, we define this as 0.1. It is possible and convenient to use a statistical program, a web service, or even a smart phone app to calculate the sample size. In this example, I have used the free software R to do the calculations, and the result for this example is 62 patients in each group. It is noteworthy that fairly large samples are needed to achieve acceptable power when the proportions in the groups and the differences between them are small. If the two different proportions were 0.03 and 0.005, for example, 431 patients in each group are needed.

In the second example, the researcher wanted to detect differences in mean values of KOOS in patients with ACL ruptures that received different types of treatment. Let us say that the same parameters for statistical significance and statistical power are chosen: 0.05 and 0.8. The researcher then needs to decide size of the effect that is clinically relevant. For KOOS, this could be 10, which means that a difference of means between the two groups of 10 is the minimum difference of interest. Clinical experience, rather than statistical experience, is important when deciding this value. For some symptom scores, there exist guidelines. IKDC has, for instance, 11. When calculating the sample size using power analysis for a test for difference of means in KOOS, yet another value needs to be known: the standard deviation of the KOOS values. The common sense explanation to this is the following: When the variation of the values in the group is high, the estimate of the mean in the target population is more uncertain. This means that high standard deviations lead to low power, which can be corrected for by increasing the sample size. Obtaining a correct estimate for the standard deviations can be difficult. With a validated outcome score, like KOOS, one can use previously published data. It is also possible to conduct a pilot study and use the data from this study to estimate the standard deviation. Using the previously given parameters, and a standard deviation of 18, the result from the power analysis is that 52 patients are needed in both groups.

11.4 Pitfalls and Strengths in Registry Studies

Swiontkowski [3] once wrote that “in order to continue to serve our patients in the best way possible, we need to understand the results of our treatment so that, as new treatments and approaches are developed, we may continually offer our patients the best treatment options possible. This requires detailed knowledge of the end results or outcomes of our care. It is our responsibility and is an important component of our efforts to maintain our competence in caring for patients.”

There is a common argument that this goal is best achieved through conducting randomized controlled trials (RCTs), since they provide the highest level of evidence for the comparison of different clinical interventions. But these trials often take a long time to complete, are expensive, and most often include highly selected patient populations (in most cases a low risk subgroup) and clinicians. In general, their external validity (generalizability) is often too low. But sometimes RCTs are not feasible due to practical, ethical, or financial constraints.

On the other hand, I will argue that this goal, most often, is best achieved through establishing (national) clinical-quality registries. These registries are an essential tool in monitoring and benchmarking quality of clinical care. Registries systematically and uniformly collect information from people who undergo a procedure, are diagnosed with a disease, or use a health-care resource. They are particularly appropriate for monitoring and benchmarking processes and outcomes of care where there is known variation and where poor performance results in high additional cost or poor quality of life. In addition to providing information on safety and efficacy of treatment, data from registries can also be used to determine whether patients have timely access to care, and whether care is delivered in line with best practice and evidence-based guidelines.

Regarding therapeutic questions, the real-life data contained in registries allow researchers and clinicians to evaluate whether an intervention found to be efficacious in the setting of a controlled trial becomes effective when placed into general clinical use. The validity of analysis of registry data are threatened by the same pitfalls that are of concern for any observational study, namely, selection bias (if patients included in specific registry analysis are not representative of patients as a whole), information bias (especially if measurements are systematically different for one group compared with another), and confounding (when the apparent relationship between an exposure and an outcome is distorted by the relationship of both to a third factor). A final hazard in the interpretation of observational data is that even though associations between registry variables might be unassailable, and causality might appear obvious, causality is not provable using the techniques of registry analyses.

Registry studies might suffer from both selection and information bias in several respects: most commonly due to the voluntary nature of the registry; participation only of enthusiastic, and thus more dedicated, surgical teams; incomplete reporting; and lack of representatives control group to allow direct comparisons. As opposed to RCTs, there is no inherent quality control of data capturing in observational studies. Thus, the reliability of the registries' scientific work depends on the registry employee's dedication and motivation. Therefore, standardized data collection methods for various orthopedic traumas need to be developed, and PROs (patient-reported outcomes) for several minor and major traumas need to be validated. This will remedy much of the problem regarding information bias. In addition, both surgeons' and patients' reporting rate is expected to increase as the level of details reported decreases. But it is important that this is not done at the expense of the minimum and necessary data set. Thus, the validity of the registry results relies on near-complete inclusion of all eligible patients. This is exemplified in the high compliance rate in the National Norwegian ACL Registry [4] and as such minimizes selection bias.

The third shortcoming for registry studies is confounding. Confounding by missing variables is particularly problematic when investigating a research question that was not previously anticipated, because pertinent variables might not have been considered for inclusion at the initiation of the registry.

Nevertheless, registry data have proved to be valid and more likely to truly reflect the "real-world" situation (while RCTs are more likely to underestimate). Information derived from registries is therefore invaluable for the surgeon, the resident, the patient, the researcher, the industry, as well as the health-care administrators. It is, therefore, imperative that the registries be conducted either by national authorities or at least under the guidance of well-respected (and independent) scientific bodies.

The resultant conclusions in registry studies will only be as good as the quality of the data collected. Thus, "whether a registry becomes of lasting value depends on it being embedded in the routine process of clinical care, and this in turn depends on a careful decision as to the purpose, together with a design that allows for operational data capture and easy utilization by clinicians with the aim of informing and improving patient care" [5].

11.5 Systematic Reviews and Meta-analyses in Sports Medicine

11.5.1 Systematic Review

Systematic reviews and meta-analysis are placed on the top of the hierarchy of study designs. A systematic review differs from a narrative review in that it is systematically done after a protocol that can be replicated by others. In a systematic review, the authors strive to include all literature there is on the particular topic of interest. Inclusion and exclusion criteria for the study, a search protocol, and criteria for methodological quality assessment of the studies must be predefined [6].

11.5.2 Meta-analysis

A meta-analysis involves statistical analyses on extracted data in systematic reviews. An assumption for doing a meta-analysis is that the data is based on a systematic review. Meta-analysis was first used on randomized controlled trials (RCTs) as they represent the most consistent study design, but meta-analyses are now used on observational studies as well – both cohort and case-control studies, screening studies, diagnostic studies, and economic evaluations [7]. Observational studies are weaker than RCTs because it is harder to account for confounding factors – and they may be vulnerable for observational bias. Using individual-based data for meta-analysis may deal with such challenges.

There is a difference between meta-analysis that is based on the results of each included study and a meta-analysis based on individual data from each study. The latter gives one data set. Using results of each study is easier than using individual-based data, but individual-based data gives more opportunities to deal with limitations and biases.

Steps in a systematic review from Elwood [6] are as follows:

1. Define the objective and the question.
2. Define the criteria for inclusion of the studies.
3. Find all eligible studies.
4. Review the methods and results of each study.
5. Summarize the results of each study in a standard format.
6. Apply statistical methods (meta-analysis) to produce a summary result.
7. Assess variation between studies (heterogeneity).
8. Review and interpret findings, and report them.
9. Set up plan for monitoring new evidence and revising the review.

11.5.3 Assessment of Methodological Quality

Assessment of the study quality is important to filter out those studies that lack adequate methodology. Methodological quality in orthopedic studies has become better over time [7], but there are still studies of low quality being published. Several sets of quality criteria exist, mostly for RCTs, but there is no gold standard for assessing methodological quality in observational studies including most orthopedic studies. The Coleman Methodology Score [8] has been used in some orthopedic studies to assess study quality. This score includes both clinical and methodological aspects of a study. After assessment of methodological quality, the results from the studies with highest methodological quality should be emphasized. However, there are no clear cutoffs in the literature for what should be considered a high-quality study or a low-quality study. The quality criteria are often not validated for observational studies or for the purpose of defining study quality.

11.5.4 Extraction of Data

The research question of the study decides extraction of data from the included studies. Data from all studies should be extracted, but heterogeneity of the studies and study quality should decide whether a meta-analysis could be performed. Unfortunately, positive and statistically significant results are generally more likely to be published and presented. Journals are interested in research that are new, interesting, and research that makes a difference. Systematic reviews including meta-analyses that evaluate all literature on a topic may be a good opportunity to detect heterogeneity, publication bias, and methodological weaknesses in existing literature.

To test whether the overall summary estimate is adequate representation of the set of data, sensitivity tests are used. Comparing the result of each study with the summary estimate does this. This method can detect outlier studies, and reasons for the heterogeneity can be identified such as differences in the intervention, the exposure, the study design, or the population studied. Stratification of studies into subgroups can be used to account for heterogeneity. Methodological issues in studies may give heterogeneity; thus, stratification on methodology may show similarities in heterogeneity (EBM December 2009, vol 14 No 6).

11.5.5 Examples of One Systematic Review and One Meta-analysis in Sports Medicine

Within the literature of anterior cruciate ligament (ACL) injuries, there are more than 11,000 search results on PubMed. Systematic reviews help to sort out the best studies and to sum up results. For new researchers, it may be impossible to get an overview of the literature on ACL topics, without systematic reviews. Systematic reviews and meta-analyses may be the best alternative for clinicians to be updated. In the following, two studies on important issues in sports medicine will be used to exemplify a systematic review and a meta-analysis in sports medicine.

The first review on development of osteoarthritis following ACL and meniscus injuries was written by Guillquist and Messner [9]. This review was a so-called narrative review. Øiestad et al. [10] published a systematic review on the prevalence of knee osteoarthritis after ACL injury. No meta-analysis could be performed on the published studies because the existing observational studies were too heterogenic to be completely compared. On the basis of this review, it was detected few prospective studies with high methodological quality (rated after the Coleman Methodology Score), and there exist several ways to define radiographic knee OA. The authors of this review emphasized results from the prospective studies that had the highest score on the quality rating.

Return to sport after an ACL injury or reconstruction is a topic that is debated in most research and clinical groups treating sports active patients. Ardern et al. [11] published a systematic review and meta-analysis on the rate of return to sport after ACL reconstruction. They merged data from 48 studies including 5,770 participants that matched their inclusion criteria, and they found an average return rate on average 41 months after the reconstruction. Quality assessment was performed using a six-item checklist developed for the study, but all studies were considered for meta-analyses independent of the results on the quality rating.

11.6 RCT: A Subgroup of Patients in Certain Areas of Sports Medicine

The highest level of evidence is systematic meta-analyses, which are pooling systematically data from several RCTs in order to achieve a consensus in the field. However, this requires that the inclusion and exclusion criteria used in the RCTs selected confirm a representative group for the whole patient group. Otherwise, the validated information used to make treatment decision for the whole group subjected to a specific injury or disease might only be useful for minor selection of patients and in worst case wrong for the majority of the patients seen in the clinical practice. However, unfortunately, the numbers of excluded patients are often not reported in important studies in the field, and this makes it difficult to generalize the finding. This has been highlighted in a recent study on cartilage repair studies in which a high variation in the selection of patients compared to the general referral of cartilage defect patients was found [12]. In one of the most debated studies in the field of ACL surgery, many of the patients evaluated as candidates for the study were not included due to various reasons [13, 14]. Of 560 patients screened, only 162 patients could be included, due to the inclusion criteria and of these 25% declined inclusion in the study. Reasons not to participate and be included in the study of Frobell and coauthors [13] were reported to be self-employment without insurance cover for an extended sick leave or participation in a sport that required an ACL reconstruction for an early return to sport. However, the authors of the study deserve credit for reporting on this important problem in a separate publication. Even though the ruptured ACL is one of the most published topics in sports medicine journals, flowcharts illustrating the recruitment, exclusion, and selection of patients are seldom found but should be included in all studies in the future. The CONSORT flowchart [15] is an important tool in order to provide information to readers of a study and is now a required for clinical trials to be published in high impact journals (JAMA). Also important is that studies with significant findings are more likely to be published [16]. This might be even more likely for industry-supported studies in favor of the drug or device study. The establishment of clinical trials.gov is essential to ensure that also RCTs with nonsignificant or negative findings will be made available to the public. Registry studies may reduce the risk of concluding based on information from one subgroup of patients and as such help clinicians to make the right decisions for their patients.

11.7 Conclusion and Future Directions in Sports Medicine Studies

Sports medicine is the frontier in exploring new treatment options. However, the progress in the treatment requires proper study design and research methodology. An increasing number of people take part in sports activities. The AOSSM is part of initiative in the USA named "Stop injuries," and the program is a response to the increasing number of sports injuries (http://www.stopsportsinjuries.org/). The adolescents involved in sports today are those who will break the world records and become the Olympic champions in the future. They deserve that the science also makes the improvements needed to provide them with the best medical support available and to avoid that undocumented treatment options are being introduced. This will also benefit all the patients seen in the clinic every day, rapidly adapting the new treatment options available. Further progress requires improvement in prevention studies, statistics applied, meta-analyses, registry studies, as well as RCTs in order to achieve the goals set by the ESSKA organization. Although we do not have all the answers, we hope that the issues highlighted here may contribute to better future studies.

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Wrist Arthroscopy in Traumatic and Post-Traumatic Injuries

12

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12.1 Introduction

The development of wrist arthroscopy was the natural evolution of the successful application of arthroscopy to the other joints of the human body.

In the recent years there has been considerable growth since pioneers such as Terry L. Whiplle, Gary Poehling, and Lee Osterman reported their original description of the technique.

Although wrist arthroscopy was first introduced in 1979, it did not become an accepted method of diagnosis until the mid-1980s. As the surgical technique and technology improved, wrist arthroscopy became a therapeutic modality as well as a diagnostic one.

The complex anatomy of the carpus made of eight carpal bones with their cartilaginous facets tightly connected by intrinsic and extrinsic ligaments is being revealed day by day by the different arthroscopic views. At first dorsal portals were described, then volar, which are more rarely used.

Wrist arthroscopy has greatly improved our knowledge and understanding of these complex joints, and has allowed treating a variety of wrist pathologies with a minimally invasive approach, such as TFCC lesions, ganglia, loose bodies, arthritis of the wrist and trapeziometacarpal joint, scapholunate and other ligament lesions, and instability. More recently, it has been used in the treatment of fractures, such as scaphoid fractures, articular fractures of the hand, and distal radius fractures.

As we will see, this technique is still developing, and an increasing number of wrist problems are now being solved by the arthroscopic approach alone or to assist with an open approach.

12.2 Clinical Results of Wrist Arthroscopic Assistance Intra-articular Distal Radius Fractures

Ferdinando Battistella

12.2.1 Background

Recent advances in wrist arthroscopic surgical techniques and instrumentation have enabled the surgeon to improve the treatment of intraarticular distal radius fractures, but no clinical studies have been published yet that provide clear evidence of advantages of the arthroscopic technique over more traditional techniques.

12.2.2 The Arthroscopic-Assisted Technique Offers Several Theoretical Advantages

1. It allows for the evaluation of the articular reduction under a bright light and magnification. Particularly, rotation of the fracture fragments, which is difficult to judge under fluoroscopy, can be detected arthroscopically and corrected.
2. Washing out fracture hematoma and debris potentially allows for an improved range of motion.
3. It allows for detection and management of associated soft tissue and chondral lesions.
4. It is a minimally invasive technique causing less tissue damage, and fewer fracture fragments will be devitalized.
5. The fracture reduction is carried out with a traction tower, so it is possible to control the amount of radial shortening.

12.2.3 Purpose

The purpose was to determine the clinical results and usefulness of arthroscopic assistance in articular distal radius fractures. The study design was a double-blind clinical study in a prospective case series (group A) with a control group (group B).

12.2.4 Methods

From 2005 to 2009, we treated 40 patients with intra-articular fractures with arthroscopic assistance: 18 fractures had two fragments (Figs. 12.1 and 12.2), 12 fractures had three fragments (Fig. 12.3), and 10 had four fragments (Figs. 12.3 and 12.4). The fractures were classified according to the Doi classification into two-, three- and

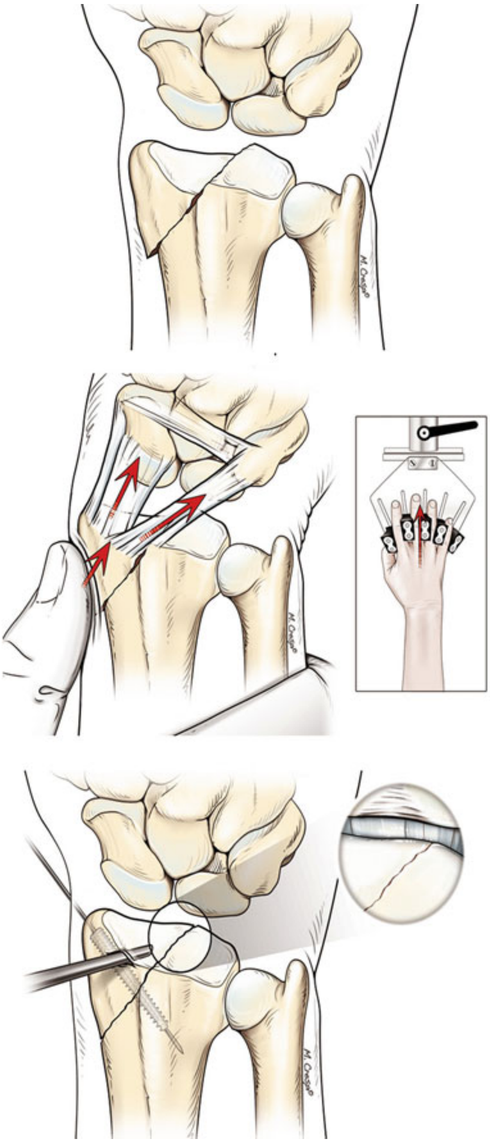

Fig. 12.1 Reduction of two-part fracture by ligamentotaxis, internal fixation with K-wire or cannulated screw

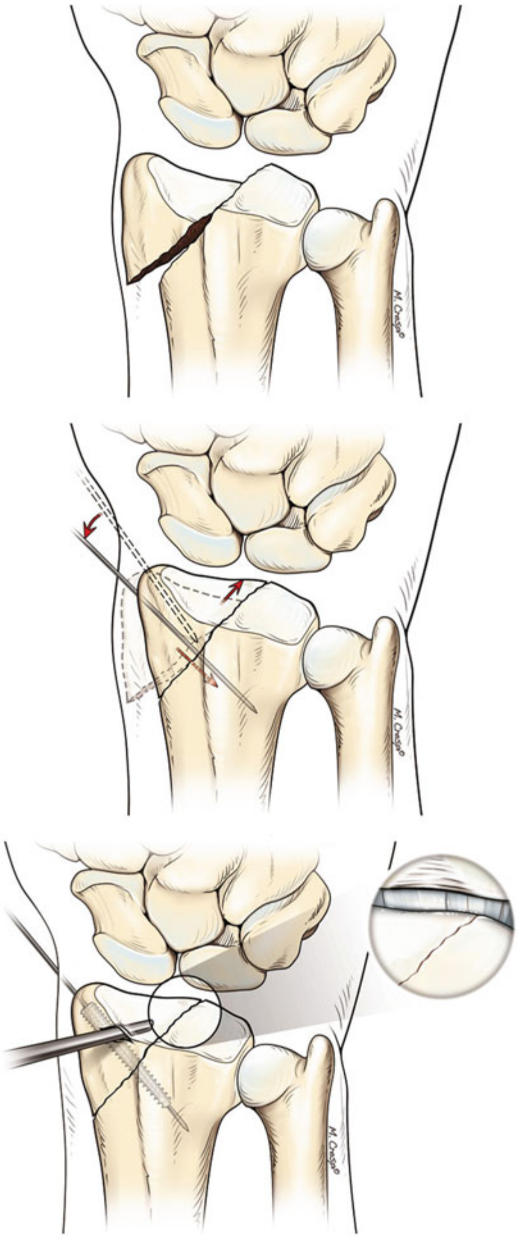

Fig. 12.2 Reduction with percutaneous k-wire used as Joy-stick of a two part fracture with vertical rim. In this case reduction by ligamentotaxis was not successful

four-part types, according to the number of main fracture fragments in the distal radial aspect on the basis of preoperative 3D CT scanning. Patient inclusion criteria were: articular step-off or gap formation greater than 2 mm after closed reduction, age less than 60 years old, and an associated evident lesion of the intercarpal ligament or distal radioulnar joint (DRUJ). Patient exclusion criteria were: open fractures, initial carpal tunnel syndrome, or compartment syndrome. The control group comprised 40 patients with the same fracture type treated without arthroscopic assistance.

12.2.5 Technique

Reduction of articular congruity was initiated by arthroscopic elevation of the die-punched fragments and depression of the articular surface. Then the fracture was reduced using a five-step algorithm: (1) traction and closed manipulation; (2) percutaneous K-wire manipulation; (3) arthroscopic manipulation; (4) limited open techniques (Figs. 12.1, 12.2, 12.3 and 12.4). These are required if the above procedures are unsuccessful or are potentially unsafe for elevation of the die-punched fragments and depression of the bulging surface. (5) The last step is open procedures. If all of the above techniques have not succeeded, then an open reduction is required. At the end of the procedure, the associated lesions of the intercarpal ligaments or triangular fibrocartilage complex (TFCC) were treated.

The fractures were pinned in 25 cases, and in 6 cases external fixation was used; in 9 cases open reduction and internal fixation were performed, and 18 patients were treated for associated lesions [scapholunate ligament (SL), TFCC].

Range of motion, grip strength, VAS, Mayo modified wrist score, DASH questionnaire and standard radiographs were registered at 1, 3, 6 and 12 month after the treatment. All patients were matched to control group B of 40 patients for fracture pattern, age and gender treated with conventional procedures. For the statistical methods, data from both groups were compared using Student's t test for continuous variables, and the level of significance was set to $p < 0.05$.

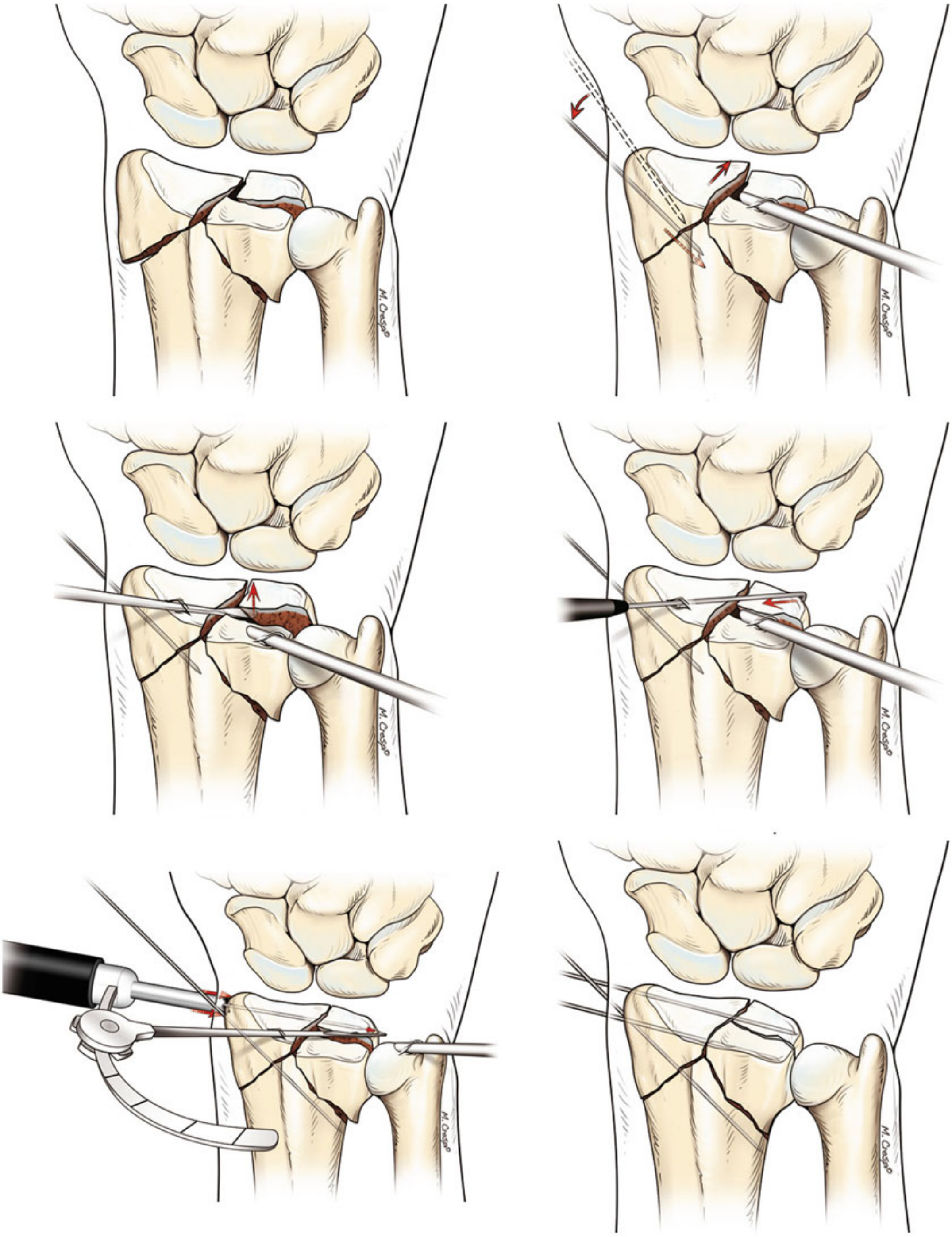

Fig. 12.3 Reduction of a three part fracture with k-wires used as joy-stick or with the use of a compass

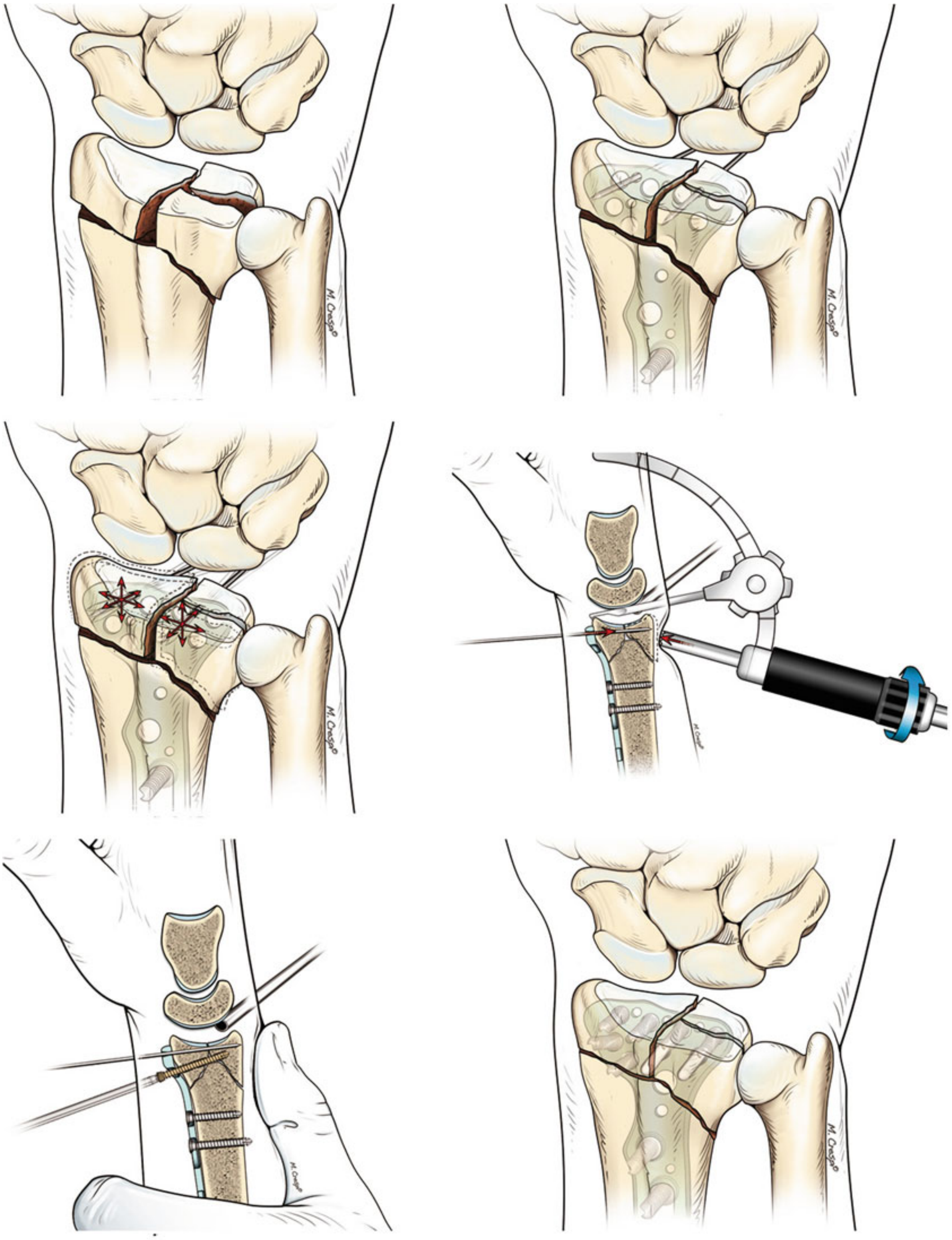

Fig. 12.4 In multifragmentary fractures, reduction is performed under arthroscopy, then internal fixation with plate and screws may be necessary to stabilize the fragments

12.2.6 Results

No perioperative complications occurred. The scores for overall outcome demonstrated that group A had better outcomes and better ranges of motion and grip strength ($p < 0.05$) than group B. The radiographic results showed that the group A patients had better reduction of volar tilt, ulnar variance, and articular displacement than group B patients.

12.2.7 Conclusion

On the basis of our prospective comparative study, we found that the arthroscopically guided procedure was superior to the conventional open procedure.

12.3 Wrist Arthroscopy in Distal Radius Fractures with Associated Lesions

Grzegorz Adamczyk and Maciej Miszczak

12.3.1 Introduction

Distal radius fracture takes first place on the epidemiological lists of fractures, in some classifications comprising 17.5% of all fractures.

Long-term results of distal radius fractures are a matter of discussion, but at 32-year follow-up, fully symptomatic osteoarthritis had developed in 40.5% of patients. Open reduction brings much better short- and better long-term results than splinting, and great initial displacement predisposes to a greater remaining displacement – most patients lose the reduction at 2 weeks, which becomes unacceptable.

Poor reduction is connected with pain and decreased grip strength.

The average age of distal radius fracture patients is slightly connected with the mechanism of injury: among patients over 64 years, it is a simple fall; in those between 48 and 64 years, frequently a fall from height; in those younger than 32 years, usually a sport.

Active young people always demand faster and better help, so short- and long-term results are their point of interest. Having a remaining step-off of 2 mm after reduction, among young patients, may lead to painful arthrosis [1]. The problem is how to measure the step-off. One third of patients with poor intraarticular reduction are evaluated by fluoroscopy as perfectly reduced [2].

One of the most useful tools seems to be arthroscopy.

The confusing elements when the technique was developed were fluid effusion, technical problems, nerve compression syndromes, compression syndromes, problems with visualization and edema, as well as problems with skin closure.

The solution seems to be the “dry arthroscopy” technique [3].

12.3.2 The Role of Arthroscopy in Distal Radius Intraarticular Fractures

Indications are:

- Articular fractures of the distal radius, enhancement of open surgery
- Removal of loose bodies
- Reduction of the articular surface
- Evaluation of the TFCC and scapholunate (SL)
- Radial and ulnar styloid fracture
- Fracture of the medial column of radius
- Three- and four-part fractures
- Extraarticular fractures with signs of instability (DRUJ, PLI).

In more than 80% of cases of complex intraarticular fractures of the radius, other lesions that are invisible on X-ray, but manageable, are visualized: TFCC lesions (>50%), SLs, lunotriquetral (LTs) (ca. 30%), dorsal ligaments, chondral lesions, styloid fractures and loose bodies.

Contraindications:

- Large hand edema, forearm compartment syndrome
- Severe soft tissue injury with contamination
- Open fractures and infection (relative)

12.3.3 Technique

Surgery can be performed immediately after injury, optimally 2–4 days after injury (up to 7–10 days). After 3 weeks the fragments have consolidated, and an osteotome is needed to displace them. The operation is done under regional or general anesthesia, with i.v. antibiotics, vertical traction of 2–4 kg and rarely horizontal traction. Low-weight long-term traction makes closed reduction easier.

In my opinion, computer tomography is mandatory in all cases of intraarticular fractures with scans of less than 1 mm; 3D reconstruction might be helpful, but is often misleading.

The open question is whether to start from arthroscopy or start with the open technique?

I start from the incision, in the majority of cases volar, and install a volar plate with LCP screws, provisionally locked to the shaft of the radius. Often if a large fragment is visible on the volar side, I also reduce and stabilize it. Sometimes at the beginning I use shorter screws so as not to interfere with later reduction. In some cases I also make a limited dorsal incision and stabilize the volar bony defect with a frozen bone graft (I never use artificial substances).

Then, the patient's arm is positioned as is typical for arthroscopy, and standard portals are made.

The fluid (10–20 ml) is given by syringe, just to keep the tissue moist. The scope's valve is kept open to let the suction work. The tips are perfectly described by del Pinal [4].

We start with the elevation of large fragments, temporary stabilization, sometimes with K-wires, and bone loss grafting. Reduction is performed with the hook, and often the K-wire serves as a "joystick" in transcutaneous reduction. The needle is introduced into the joint parallel to the expected final position of the fragment, then an assistant introduces the K-wire 8 mm below, elevates the fragment, and fixes it with wire.

For SL, LT and TFCC lesions, when there are indications, always try to stabilize them. One of the advantages of arthroscopy is verification of the DRUJ. Arthroscopic stabilization of the scapholunate interosseous ligament (SLIOL) might be ARASL as described by Hausman [5]. Early versus delayed carpal ligament treatment shows better results according to Geissler [6].

After the reduction of fragments, fluoroscopic control is performed with a 23° tilt of the distal radius for better visualizations of the screws.

At the end, the arm is again positioned on a table, fixation of the plate is completed, and sometimes some K wires are left. The forearm is then put in a cast for a minimum of 4 weeks.

12.3.4 Results and Conclusions

- This is a technically demanding procedure and should be used in well-selected cases of articular fractures.
- A very good assisting surgeon is needed (this is not a "one man show").
- One should expect the procedure to last 2 h.

The reported results are good when we take into consideration that we are dealing with complex lesions.

This procedure allows a better range of motion (ROM) (flexion and extension ca. 60°), recovery in 95%, and full grip strength with a 23% decrease. A quick return to work (2 months) is possible according to Osterman [7].

Luchetti and Atzei reported the results of 22 cases (20–104 months follow-up), with 21 excellent and 1 good result [8].

I have changed my technique. From January 2009 until December 2010, I performed 12 fixations under dry arthroscopy. My preliminary results were satisfactory. We did not observe any loss of reduction, once we had to remove the metal work, and no tendon lesions occurred. In all the cases bone union was obtained between 6 and 8 weeks postoperatively. Twice we had to perform arthrolysis to obtain a better ROM. The average ROM was 63°–40°.

12.4 Outcome of Arthroscopically Assisted Percutaneous Fixation of Scaphoid Fractures

Christophe Rizzo and Christophe Mathoulin

12.4.1 Introduction

Classically, it was considered that consolidation of scaphoid fractures could be achieved without surgery. However, for many years, open reduction and internal fixation have been the recommended and well-accepted treatment for displaced and unstable intraarticular fractures. This trend has also influenced the therapy of scaphoid fractures. Furthermore, the inconvenience of conservative treatment, with its unpredictable economic consequences due to the long duration of immobilization, and increasing demands of patients have been reasons for surgery. The complex morphology and small size of the scaphoid bone have resulted in the development of numerous sophisticated techniques to achieve an anatomic and stable fixation. In 1984, Herbert [9] reported his experience using a cannulated screw, which originally was not developed for fixation of scaphoid fractures. In the early 1990s, the first article was published [10] reporting the insertion of cannulated screws with a minimally invasive technique. The main principle was to preserve the surrounding ligaments of the carpal bones in order to avoid a destabilization of the reduction and to protect the fragile vascularization of the scaphoid bone [11].

Whipple [12, 13] was the first who presented a method with percutaneous screw fixation using a modified Herbert screw combined with image intensifier control and arthroscopic examination of the wrist. This technique allows controlling the exact fracture reduction, maintaining the fixation under compression, avoiding an intraarticular penetration of the screw and assessing potential associated lesions.

Furthermore, this makes an early return to activities of daily living possible.

The purpose of this study was to report our experience and results of scaphoid fractures treated with an arthroscopically assisted percutaneous screw fixation technique using a cannulated Herbert type screw in a consecutive series of patients (Table 12.1).

12.4.2 Materials and Methods

Between April 2001 and December 2004, 24 consecutive patients with scaphoid fractures underwent arthroscopically assisted percutaneous screw fixation at a mean age of 35 years (range, 17–55 years). Two patients could not be reviewed with a follow-up of at least 24 months (follow-up of 10 months and 16 months, respectively) and were excluded from the study. The remaining 22 patients comprise the study population. In the 17 men and 5 women, the dominant side was involved in 16 cases. There were only acute fractures (type B according to the classification of Herbert [9]) and mainly corpus fractures (type III in 13 patients and type IV in 7 patients according to the classification of Schernberg [14]). Fractures of the proximal pole were not included. In 16 cases the fracture was non-displaced; in six cases the fracture was minimally displaced (articular step of 1 mm or less). The mean delay from trauma to surgery was 10 days (range, 1–21 days).

12.4.3 Operative Technique

Under ambulatory conditions the operation is performed under locoregional anesthesia. The patient is placed in the supine position on a special arm table with a tourniquet on the arm applied as proximally as possible. During the critical parts of the operation the forearm can be

Table 12.1 Classification of scaphoid fractures according to Schernberg [14]

Displacement	Type I	Type II	Type III	Type IV	Type V	Type VI
None	0	2	11	3	0	0
< 2mm	0	0	2	4	0	0
> 2mm	0	0	0	0	0	0

Fig. 12.5 Percutaneous retrograde pinning of the scaphoid through a small approach centered on the distal tubeosity

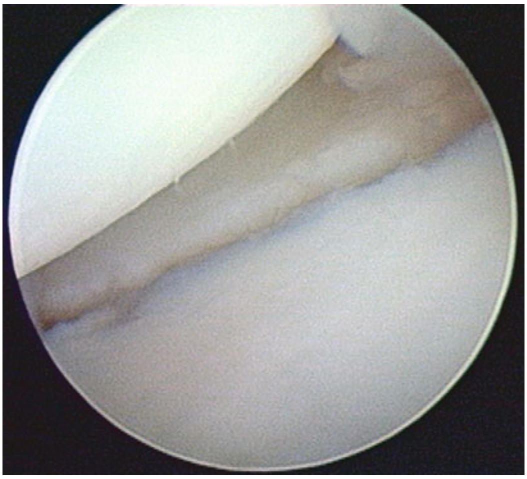

Fig. 12.6 Medio-carpal arthroscopic view of a displaced scaphoid fracture

relatively extended using a pad underneath the wrist. Another possibility is to put the wrist under traction with a traction device, which is placed outside the arm table, still allowing positioning of the image intensifier. A retrograde (from distal to proximal) screw fixation is the aim. At the beginning, the fracture is visualized under arthroscopy using standard portals, leaving the forearm free on the table. Then, a 1-mm pin is placed through a small (5-mm) incision to the distal tuberosity of the scaphoid in a retrograde fashion (Fig. 12.5). The wrist is put under traction, allowing arthroscopic control to verify the exact reduction of the scaphoid. The arthroscope is then introduced through a radial mediocarpal portal through which the fracture can be assessed very easily. If necessary, a debridement of the articulation can be done with the shaver while cleaning the medial surface of the scaphoid. If the fracture is displaced, reduction of the fragments is possible with a small retractor introduced through a 1–2 mediocarpal portal. Under arthroscopic control, the fracture fixation pin is pulled back slightly beyond the fracture line; then the fracture is reduced and the pin replaced into the proximal fragment (Figs. 12.6 and 12.7). As soon as a satisfying reduction has been achieved, the hand is removed from the traction device, and the wrist is positioned on a pad on the arm table. Under fluoroscopic control, the hole for the screw is then tapped (Fig. 12.8). The screw is then inserted over the guide wire (Fig. 12.9). Again under arthroscopic control the radiocarpal compartment is visualized through a 3–4 radiocarpal portal. This allows verifying the absence of an intraarticular penetration of the screw head at the level of the proximal pole. Then the entire radio-carpal compartment is inspected to assess potential associated lesions. Mediocarpal exploration allows the inspection of the fracture line to the medial articular surface of the

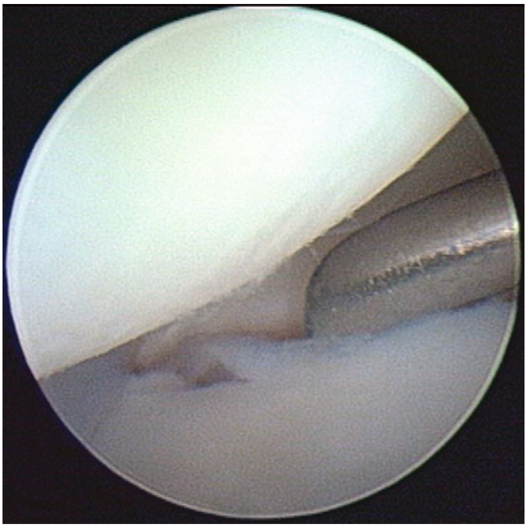

Fig. 12.7 Medio-carpal arthroscopic view of the same fracture during reduction

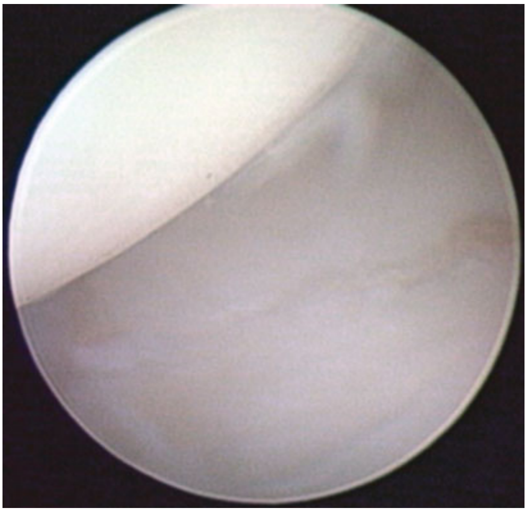

Fig. 12.8 Medio-carpal arthroscopic view of the same fracture after reduction and stabilization

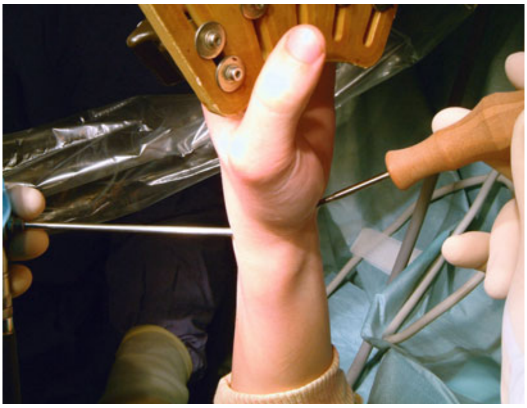

Fig. 12.9 Screw fixation under arthroscopic control

scaphoid and the assessment of the reduction quality. In case of insufficient compression, the screw can be redrilled while visualizing the compressive effect. The scapho-trapezo-trapezoid articulation remains untouched. The incisions are then closed using steristrips.

12.4.3.1 Postoperative Protocol

Postoperatively, the wrist is left unprotected; a simple anterior splint can be applied after the first dressing just for analgesic reasons.

12.4.4 Results

12.4.4.1 Intra- and Peroperative Results

The duration of surgery averaged 30 min (range, 15–45 min). The last case had the shortest duration, documenting the learning curve of this technique.

In displaced fractures the reduction could be held with intraarticular arthroscopic maneuvers. All 22 Herbert screws were inserted retrogradely from distal to proximal. Arthroscopic control was used systematically, independent of the perioperative fluoroscopic control. Although there was a satisfying intraoperative fluoroscopic result, wrist arthroscopy revealed an overlength of the screw tip due to an intraarticular break out at the proximal pole of the scaphoid in three cases. The screws had to be changed to shorter ones.

In our series we found only a few associated lesions. In one patient a central perforation of the TFCC was debrided with the shaver. In another case a lesion of the anterior part of the scapholunate ligament without dynamic instability was observed, which did not have any therapeutic consequences. In a third case the associated lesion was a distal comminuted t-shaped radius fracture, which was treated with ORIF (palmar plating) during the same surgery.

12.4.4.2 Complications

There were no postoperative complications, especially no infections and no nerve lesions.

12.4.4.3 Clinical Results

The mean follow-up was 35 months (range, 24–53 months). All patients were very satisfied or satisfied with the results. None of the patients regretted choosing this method. The main reason for this high satisfaction rate was the fast functional recovery and the absence of postoperative immobilization. Furthermore, patients appreciated the small scars, an observation regularly made after most of the endoscopic and arthroscopic procedures.

According to the Mayo Modified Wrist score, 13 patients had excellent, 6 patients good and 3 patients fair functional results. Two of the three patients with a fair result had an associated lesion.

The mean Mayo Modified Wrist score was 91.5 points (range, 65–100 points).

At final follow-up, 30 of the 34 wrists reached 90% and more of the mobility compared to the contralateral side. Average wrist flexion was 67° (range, 35°–85°), extension was 69° (range, 40°–90°), radial abduction was 22° (range, 0°–40°), and ulnar abduction was 37° (range, 20°–50°).

Average grip strength measured with the Jamar® dynamometer was 40.7 kg (range, 20–60 kg) and reached 91% of the healthy contralateral side.

Patients returned to work after a mean duration of 23 days (range, 1–93 days). Twelve patients could return to work immediately after surgery. Only the patient with the associated radial fracture returned to work after 3 months. Most patients either had an independent occupation or were professional high-level athletes.

12.4.4.4 Radiographic Results

All 22 fractures healed primarily; non-union or malunion was not observed. The mean duration of consolidation was 6 weeks (range, 4–8 weeks). Whereas the mean duration in originally displaced fractures was 64 days, it was 45 days in originally non-displaced fractures.

12.4.5 Discussion

Numerous recent studies have shown the capability of a percutaneous fixation of scaphoid fractures using cannulated screws [10, 15–17], which competes with the classical conservative method of forearm immobilization for 3 months. Several studies confirm the increased rate of fracture consolidation with percutaneous screw fixation [15–18]. Especially in non-displaced fractures consolidation seems to be shorter. Bond and Shin reported (percutaneous screw fixations vs. conservative treatment) a consolidation time of 4–5 weeks after percutaneous screw fixation in their randomized study [18]. In our study the average radiological consolidation period was less than 2 months for non-displaced fractures, which confirms this statement.

In various series return to professional activities were earlier after screw fixation [16, 18, 19]. In our study the functional recovery was also exceptionally fast. This might be also due to a patient selection bias because many of our patients chosen this method with regard to their professional and personnel duties. We are very well aware of the fact that this is a special patient collective: It seems to be more logical to propose the percutaneous screw fixation for a motivated and well-informed patient, especially when conservative treatment has the risk of failure, e.g., in unstable fractures. The failure rate in terms of consolidation can reach up to 15% after cast immobilization of 3 months [20, 21]. In our series there were no non-unions.

Wrist arthroscopy combined with percutaneous screw fixation allows avoiding certain complications that are relatively frequent in fracture fixation of the scaphoid. Filan and Herbert [21] found 14 intraarticular (Herbert) screw penetrations in their series of 431 patients. In our series, after final arthroscopic control of the radiocarpal joint, we had to change three screws because of break out of the screw tip out of the scaphoid. Arthroscopic mediocarpal examination also allows assessing the quality of fracture reduction after screw fixation. In our series there were no problems in terms of reduction, and all the displaced scaphoid fractures could be reduced and maintained under arthroscopic control (Fig. 12.9).

We only performed screw removal in the case of persistent anterior wrist pain. A longer follow-up is necessary to evaluate the potential development of secondary osteoarthritis.

12.5 Wrist Arthroscopy in Acute TFCC Tears

Eva-Maria Baur

Arthroscopy has gained increasing importance for treating traumatic lesions of the TFCC in the last 15 years. Now it seems the most powerful tool for the diagnosis and treatment of TFCC lesions.

In 1989 Palmer introduced a classification of acute (traumatic) and degenerative lesions [22] (Fig. 12.10).

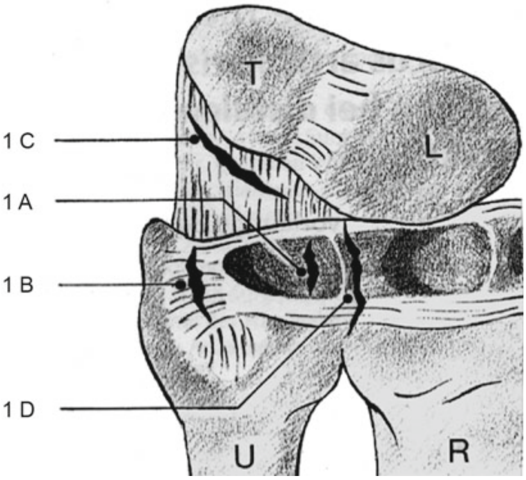

Fig. 12.10 Palmer Classification of class I (traumatic) injuries of TFCC

12.5.1 Palmer Class I: Traumatic (Acute)

A Central perforation
B Ulnar avulsion
  With styloid fracture
  Without styloid fracture
C Distal avulsion (from the carpus)
D Radial avulsion
With sigmoid notch fracture
Without sigmoid notch fracture

12.5.2 Treatment of Acute TFCC Tears

12.5.2.1 Class IA Tears

Arthroscopic debridement is sometimes combined with a wafer or ulnar shortening procedure (Fig. 12.11).

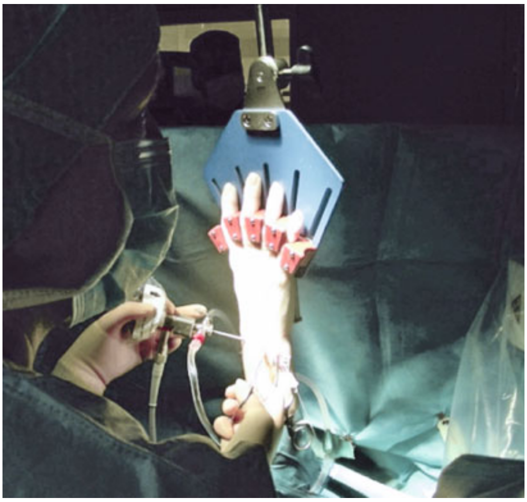

Fig. 12.11 Arthroscopy of the wrist: TFCC repair

12.5.2.2 Class IB Tears

There is a discrepancy between the anatomical description of Palmer class IB and the clinical finding of a variety of IB lesions, with different treatment requirements. Therefore, A. Atzei described a subclassification of class IB [23, 24]. Sometimes, proximal unstable TFCC lesions in the fovea are not easy to detect.

According to the literature the foveal reconstruction of TFCC lesions has gained increasing importance over the last 10 years [23–28]. The most common reconstruction is still suturing the TFCC to the floor of the sixth extensor tendon compartment, but this is not the place where the detachment took place. Thus, the attachment back to the bone is the crucial element of the reconstruction.

In addition to arthroscopic refixation of the TFCC to the fovea using an anchor technique, other techniques are described – arthroscopically assisted or only arthroscopically (Figs.12.12 and 12.13).

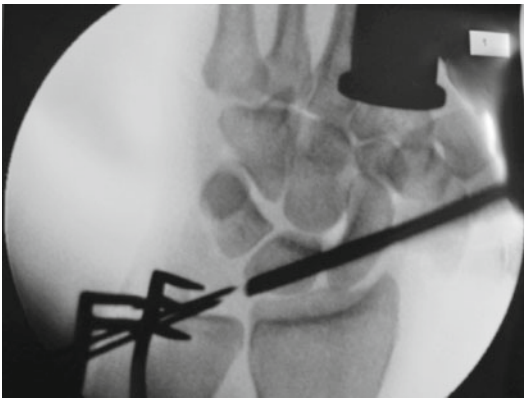

Fig. 12.12 Foveal refixation of TFCC: fluoroscopic view

Also the completely open technique of suturing or anchoring the TFCC is very common.

In any case, refixation of the TFCC back to the fovea is most important for DRUJ stability.

To reach the diagnosis the MRI scan or arthro-CT scan can be helpful (provided they are of good quality). However, the most important tool is wrist arthroscopy, which provides the opportunity to diagnose and treat the patient in the same procedure.

Nakamura describes the necessity and also a technique to fix the foveal insertion of the TFCC back to the ulna arthroscopically. But he only uses and recommends this technique for acute and subacute lesions [23]. G. Tuennerhoff reported good results in chronic lesions as well, using a slightly different technique.

Fig. 12.13 Intra-articular aspects of refixation of TFCC

12.5.2.3 Class IC Tears

These tears consist of a rupture along the volar attachment of the TFCC and ulnocarpal ligaments. Culp and colleagues described an arthroscopic refixation [27].

12.5.2.4 Class ID Tears

Osterman presented his results on a retrospective study of 19 patients with Palmer class ID TFCC lesions without DRUJ instability that compared the clinical outcomes after TFCC reattachment versus debridement, obtaining the same results for both. But lesions with instability require a refixation to the radius, open or arthroscopic [28].

12.6 Arthroscopy in the Treatment of Acute Scapholunate Ligament Lesions

Nicolas Dauphin

12.6.1 Introduction

Scapholunate ligament lesions are mostly seen in wrist trauma with the wrist in extension and supination. The lesion can also be associated with a distal radius fracture. Scapholunate tears lead to chronic instability and secondary carpal arthritis. Arthroscopy is the most valuable tool in the early diagnosis of acute lesions. Treatment can also been done arthroscopically or with arthroscopic assistance.

The scapholunate ligament is composed of three parts: the dorsal part is actually the strongest part and is firmly attached to the dorsal wrist capsula near the dorsal scaphotrapezial ligament and the dorsal intracarpal ligament. The intermediate part is fibro-cartilaginous and not vascularized, and can therefore not be repaired. The palmar part is in relationship with the palmar capsule. The dorsal and the palmar part are components of the extra-articular system and thus are vascularized. The scapholunate ligament is the main joint stabilizer, especially the strong dorsal part.

The scapholunate joint has flat joint surfaces and is particularly sensitive to metallic fixation through the joint. This leads to important secondary arthrofibrosis that can stabilize the proximal pole of the scaphoid. This is the principle of the K-wire fixation of the scapholunate joint as described by T. Whipple [29].

12.6.2 Patients and Technique

We present a series with 42 patients presenting an acute SL lesion (<2 months) (Fig. 12.14). Thirty-five men and 7 women with a mean age of 34 years underwent operations. Mean follow-up was 37 months. Ninety-two percent of the patients achieved good to excellent results according to the Mayo wrist score [30].

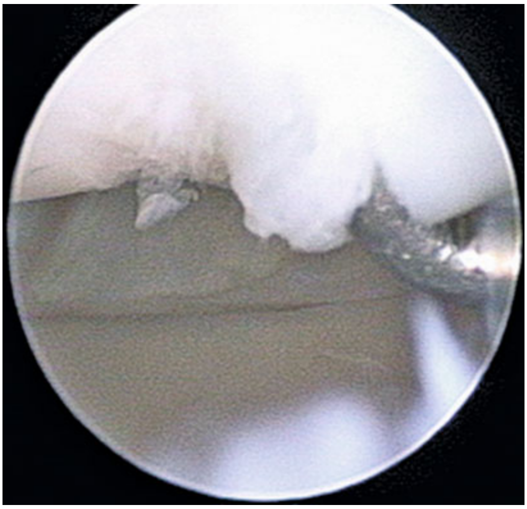

Fig. 12.14 Under arthroscopy, from radiocarpal portals, scaphlolunate tear with protrusion of proximal part of SLIOL

Arthroscopy is performed as outpatient surgery under axillary bloc and a tourniquet. Distraction is achieved by traction of 3–5 kg with a wrist arthroscopy tower. Standard arthroscopic portals are used for exploration of the radiocarpal joint (3–4, 6R) and the midcarpal joint (MCR, MCU). The radiocarpal joint is explored first, and the SL ligament inspected and palpated.

The lesion is refreshed by shaving the remnants of the ligament. The scaphoid is then reduced by external and internal maneuvers under arthroscopic control in the mid-carpal joint. Two 1 to 1.2-mm K-wires are used under fluoroscopic and arthroscopic control (Fig. 12.15).

12.6.3 Discussion

The staging is done according to Garcia-Elias in six stages [31]. Stage 1 is an acute or chronic partial lesion with the dorsal part being intact. We prefer conservative treatment with an 8-week

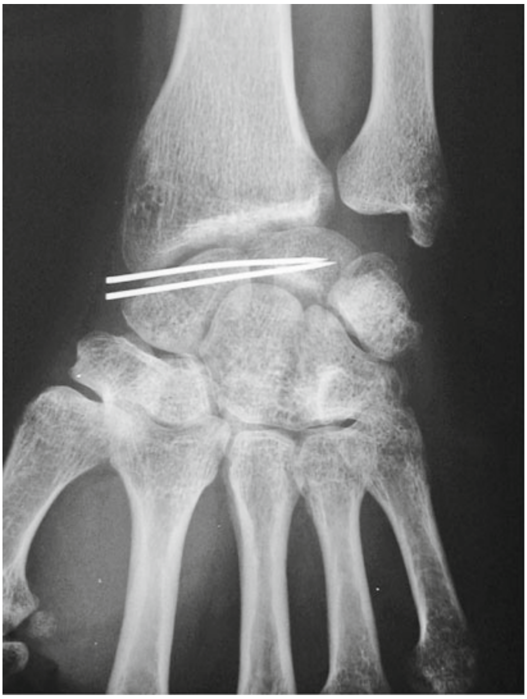

Fig. 12.15 Pinning of SL space under arthroscopy

cast. In certain stages, we now associate an arthroscopic dorsal wrist capsuloplasty with the K-wire treatment in order to recreate a relationship between the dorsal wrist capsule and the dorsal remnants of the ruptured scapholunate ligament [32]. The new arthroscopic dorsal wrist capsuloplasty attaches the two remnants of the SL ligament to the overlying dorsal wrist capsule. This is done by arthroscopy as described in our technique. Stage 2 according to Garcia-Elias' suggestion is a complete lesion with the ligament being repairable. In this stage we recommend K-wires through the SL interval or arthroscopic dorsal capsuloplasty without K-wires. In stage 3, the ligament cannot be repaired, and dorsal capsuloplasty is used. In stage 4, the carpal bones are malaligned, and they have to be reduced. In this case, we recommend K-wires combined with dorsal capsuloplasty [32].

12.7 Arthroscopic Management of Bennett's Fractures

Didier Fontès and Riccardo Luchetti

12.7.1 Introduction

This type of fracture dislocation of the base of the first metacarpal was first described in the British Medical Journal in 1885 by Edward H. Bennett. It is an avulsion fracture of the volar and ulnar portion of the first metacarpal base. Figure 12.1 shows the Gedda classification (Fig. 12.16).

The surgical management remains controversial (percutaneous screw or wire fixation) and is sometimes difficult. The accuracy of fluoroscopic reduction control is doubtful. There can be problems of associated ligamentous lesions and late arthritis changes. Basal joint articulation is not plane or flat but complex (saddle), so in comparison with distal articular radius fractures, only arthroscopic control makes it possible to evaluate the reduction accurately. Peroperative fluoroscopy is insufficient, and the basal joint saddle is more complex than the radial epiphysis.

The displacement mechanism of these fractures is a trauma with axial compression with bone crushing. The abductor pollicis longus has a subluxation function, and associated ligamentous lesions are possible.

12.7.2 History of the arthroscopy of small joint

Historically, small joint arthroscopy was first developed by Masaki Watanabe (1970–1972) and Terry Whipple (1985). CMC basal joint-specific endoscopic exploration was developed by several authors [33–39]:

- J MENON [33]
- RA BERGER [34]
- MA ORELLANA, J CHOW [35]
- D. FONTÈS [36, 37]
- EF WALSH et al. [38]
- A BADIA [39]

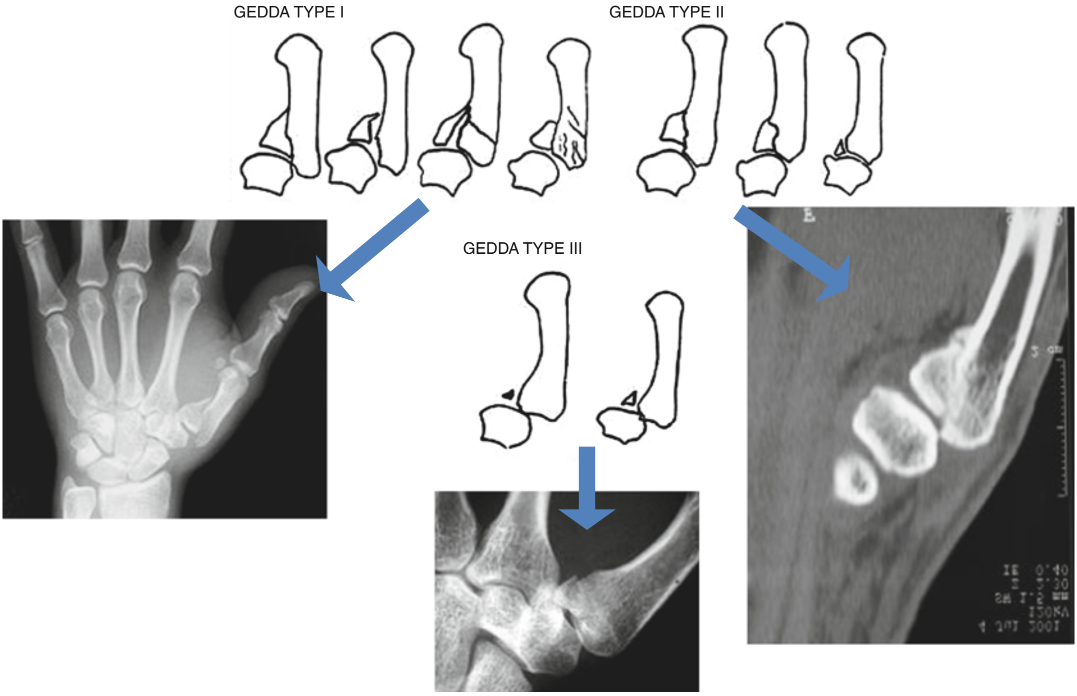

Fig. 12.16 Gedda classification of Bennett's fractures

Fig. 12.17 Installation of the patient for basal joint arthroscopy with a singler finger trap and a Whipple traction tower

12.7.3 Instrumentation for First CMC Arthroscopy

First of all we need a traction tower (Whipple) or shoulder holder, then an assistant is needed to stabilization the forearm (Fig. 12.17). Single thumb finger traps are required (5-8-lb traction).

Mini-fluoroscopy is used for X-ray control, using a short-barrel optical and smooth trocar, diameter: 1.9 mm.

Specific miniaturized instruments are necessary as probes, dissectors, graspers, baskets, power shavers and burs. Cautery or radiofrequency ablation probes (mini VAPR) are available.

The 1R, 1U and/or thenar portals are used (Fig. 12.18). Caution should be used concerning the superficial nerves, radial artery and tendons. The extrinsic ligaments have a controversial physiology. The cartilage and bones form a double saddle-shaped joint.

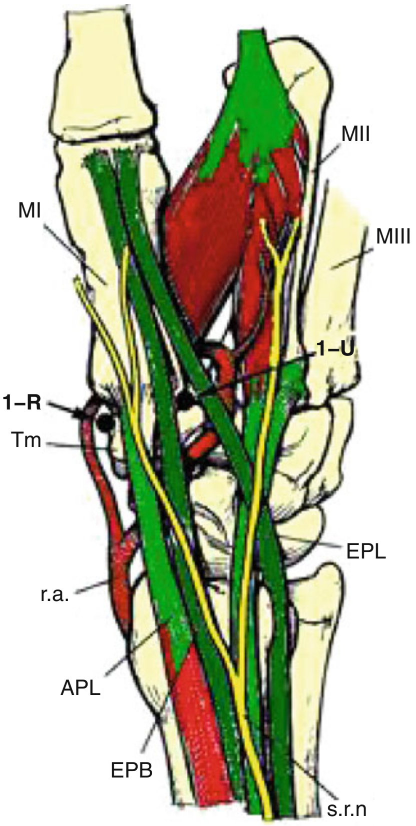

Fig. 12.18 Description of 1R and 1U portal close to superficial nerves and radial artery

12.7.4 Materials and Methods

This was a multicentric study, with simultaneous evaluation of different strategies examining a few cases per center.

There were two cases of malunion and 16 fractures. All patients had preoperative plain X-rays (A. Kapandji incidences) and 3D CT scans.

12.7.5 Technique

Under horizontal arthroscopy (Fig. 12.19), debridement of bloody tissues and articular free fragments was obtained. Reduction of articular fragments was obtained, and inter-metacarpal pinning was performed under fluoroscopic check. Osteosynthesis was performed by

- *Direct or extra-articular pinning*
- *Headless screwing*

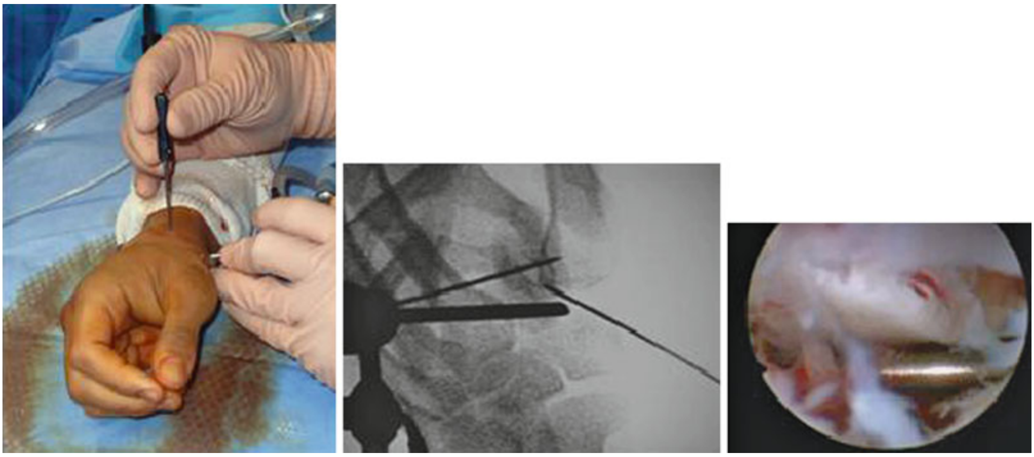

Fig. 12.19 Our preferred method = horizontal arthroscopy after intermetacarpal pinning

Arthroscopy allowed the management of associated lesions.

12.7.6 Results

This was a small, multicentric series with no uniformity of fracture management. It was possible to treat associated lesions. No specific complications were recorded.

We obtained good cosmetic appearances, good anatomical reductions, and excellent function and return to activities. All patients recovered key pinch and grasp strength. There was an early return to sport competition at the same level as preoperatively.

12.7.7 Conclusions

Our procedure for Bennett's fractures is arthroscopic assisted reduction and fixation, which means a minimally invasive procedure. No specific complications were recorded in trained hands. Accurate articular reduction for the Gedda type of fracture was obtained, with testing of the stability and management of the frequently associated lesions. Nevertheless, we need larger prospective series for definitive results.

12.8 Treatment of Scaphoid Fractures Associated with Scapholunate Ligament Lesions

Jane C. Messina and Riccardo Luchetti

12.8.1 Introduction

The simultaneous occurrence of a scaphoid fracture and scapholunate ligament (SL) lesion has been described for many years. Although rare, it usually occurs in high-energy trauma with a transscaphoid palmar perilunate fracture dislocation [40–43]. An undisplaced fracture of the scaphoid would traditionally exclude the occurrence of an associated ligamentous lesions in the wrist and so be treated alone. The diagnosis of associated scapholunate (SL) lesions relied on radiographic investigations (Fig. 12.20) and on surgical findings during open surgical procedures using the dorsal approach. With the development of wrist arthroscopy several previously unknown associations of lesions have been described [44, 45] (Fig. 12.21). In particular, the use of arthroscopic assistance in scaphoid internal fixation has allowed finding the association between scaphoid fractures and SL lesions in a high percentage of cases, ranging from 10 to 75% [46–52]. Among these, we nevertheless have to distinguish the rate of occurrence of clinically relevant scapholunate ligament tears (especially Geissler stages III-IV), which need to be repaired effectively. The recently described EWAS (European Wrist Arthroscopy Society) Classification seems to be more accurate in distinguishing the severity of SL lesions, as partial lesions are better identified and distinguished in partial anterior, partial posterior and complete SLIOL lesions (Table 12.2) [53, 54].

Current treatment of scaphoid fractures associated with SL tears involves internal fixation of the

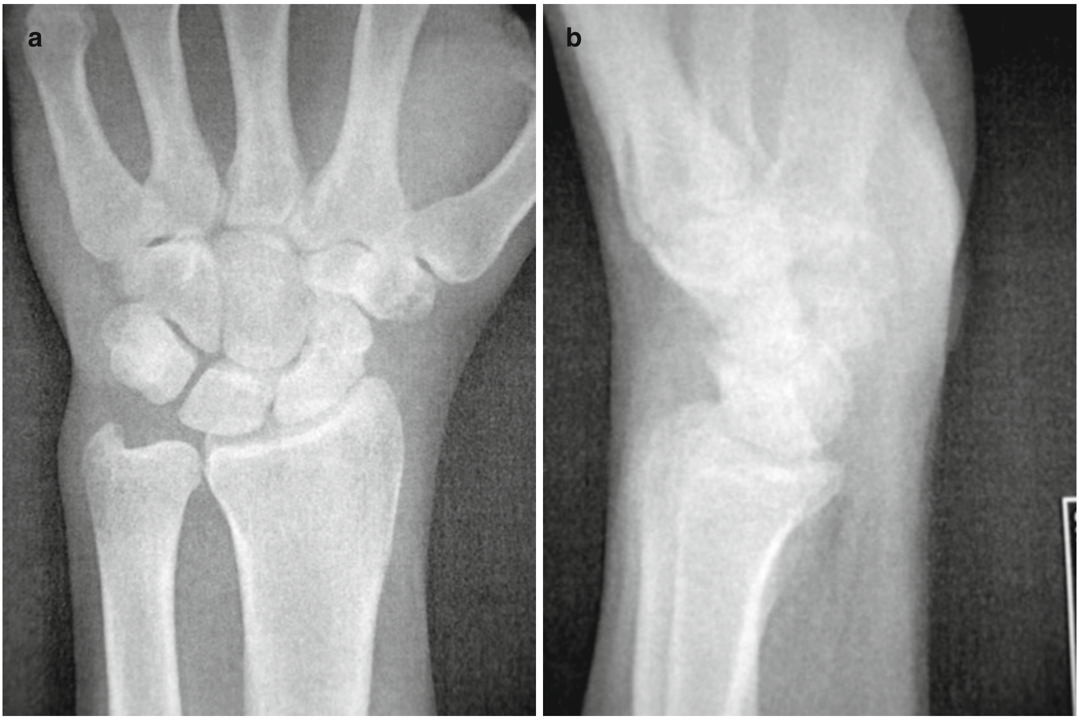

Fig. 12.20 (**a**, **b**) Patient of 28 years old, preoperative XRay of a fracture of the waist of scaphoid associated to scapholunate lesion

scaphoid and reconstruction of the SL ligament. According to some authors, the presence of an SL lesion may interfere with the scaphoid union [55, 56]. In acute lesions a simultaneous treatment of the two lesions, possibly under arthroscopy, is advisable with a screw fixation of the scaphoid (open or arthroscopic) and a pin fixation of the SL interval [30, 48, 50]. If the SL lesion is severe (Geissler/EWAS stage IV), a simultaneous open treatment of the SL lesion is suggested (SL ligament repair with dorsal capsulodesis) [57–59]. In chronic lesions a two-stage procedure with scaphoid screw fixation (with a bone graft) and subsequent capsulodesis or another reconstruction technique to repair the scapholunate ligament is preferable [57–59].

Fig. 12.21 Same patient pre-operative MRI image which shows the waist fracture and SL lesion

12.8.2 Materals and Methods

Seven patients affected by scaphoid fracture and SL ligament lesions have been treated since 2008 (Figs. 12.20, 12.21, and 12.22). All were males, and the mean age was 29 years old [21–39]. There were four chronic injuries and three acute (operated within 3 weeks from trauma). All patients had standard X-rays with oblique scaphoid views. X-rays documented the scaphoid fracture in all cases: a waist fracture was shown in five cases, a proximal pole fracture in one case and a distal pole fracture in one case. MRI scans performed in all cases confirmed the scapholunate-associated lesion (Fig. 12.21). All patients were examined under arthroscopy. The treatment of acute injuries was arthroscopic examination of the wrist, screwing of the scaphoid fracture associated to pinning of the SL joint or dorsal capsulodesis [19]. In the chronic cases arthroscopy was used to

Table 12.2 Arthroscopic classifications of scapho-lunate ligament tears (simplified).

STAGE	GEISSLER (1995)	EWAS (2009)
		Acute (A) and Chronic (C) SL lesions
I	RC Attenuation/haemorrage of SL MC normal	RC: Attenuation/haemorrage of SL lig MC normal
II	RC: Attenuation/haemorrage of SL lig MC: Incongruency SL, tip of the probe can go through SL space	RC:Attenuation/haemorrage of SL lig MC: Incongruency SL, tip of the probe can go through SL space The instability test is negative
III	RC: protrusion of SL ligament MC: Incongruency/step-off Probe can be twisted in SL space	RC: protrusion of SL ligament MC: Incongruency/step off IIIA instability test pos at anterior part IIIB instability test pos at posterior part IIIC complete instability of SL
IV	RC and MC : obvious gap, instability, step-off Passage of arthroscope though SL space	RC and MC: obvious gap, instability, step-off Passage of arthroscope through SL space

confirm and stage the SL lesion, and classify it according to the Geissler and EWAS classifications (Fig. 12.22). The chronic patients underwent open surgery, screwing of the scaphoid (through a small volar approach or dorsal approach) and reconstruction of the SL ligament by capsulodesis according to Berger using the dorsal approach (Figs. 12.23 and 12.24). Capsulodeses were performed in the same intervention or secondarily in a second operation.

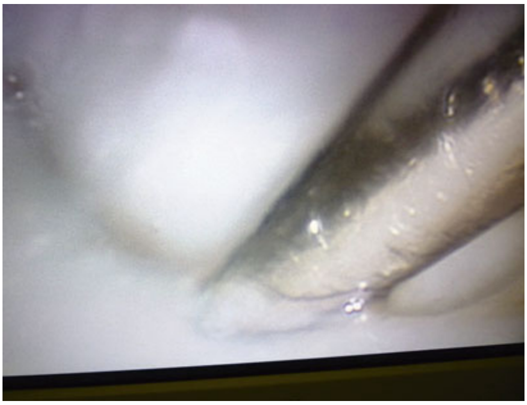

Fig. 12.22 Under arthroscopy from radiocarpal joint we can observe the protrusion of the scapholunte ligament in the same patient

All patients were evaluated at a mean follow-up of 18 months (range 10–30 months). The Mayo wrist score was used to evaluate the patients at follow-up.

12.8.3 Results

Arthroscopy documented Geissler stage III in six patients and stage II in one patient (EWAS stages IIIC in six cases and EWAS IIIB in one case).

At follow-up X-rays documented healing of the fracture in all cases. The results were excellent in five and good in two cases according to the Mayo Wrist Score. Grip strength was comparable to the contralateral side in these patients, and the patients returned to their previous work. One

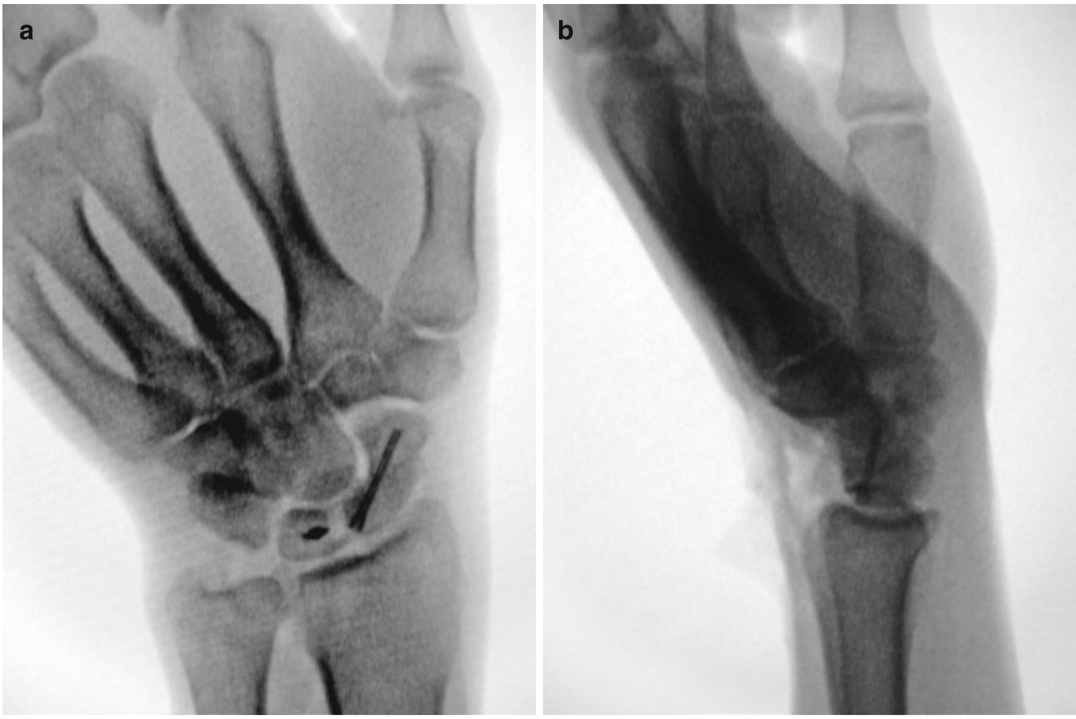

Fig. 12.23 (**a**, **b**) Intraoperative check of the internal fixation of scaphoid fracture by dorsal approach (proximo-distal) associated to a Berger open dorsal capsulodesis to reconstruct the scapho-lunate ligament rupture, stabilized with an ankor, in the same operating time

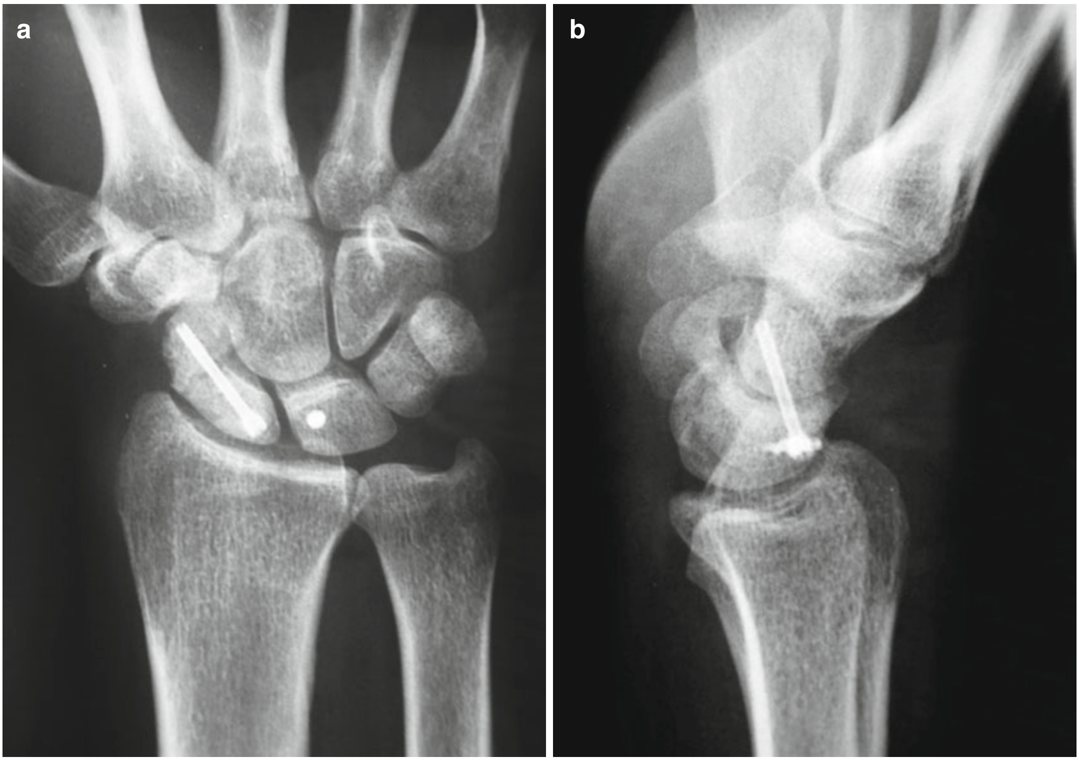

Fig. 12.24 (**a**, **b**) Check XRays at 2 years post-operatively

patient reported occasional pain under load-bearing at follow-up. Two patients treated with dorsal capsulodesis had a slight reduction of flexion of the wrist. No complications were documented in the treated patients.

12.8.4 Discussion and Conclusions

The diagnosis of a ligamentous lesions in the wrist associated with scaphoid fracture has been evolving in the last years with the diffusion of wrist arthroscopy, which allows the identification of associated lesions. The association of scaphoid fracture and evident carpal instability has been described in the past, and traditionally these lesions were thought to be part of a perilunate dislocation type injury due to a high-energy trauma. Nowadays, we know that a spectrum of different ligament lesions can occur, and they can be associated in different ways, which are still being defined. Some authors have identified up to 75% of scapholunate tears associated with scaphoid fracture, in 25% of cases referred as complete ruptures [49]. Nevertheless, the lesions were not staged according to Geissler or other arthroscopic classifications, so it is difficult to evaluate the real percentage of cases that really needed surgical treatment of the scapholunate injury (at least 25%).

The routine use of wrist arthroscopy allows the detection of a variety of different lesions (bone fractures, ligament tears, cartilage damage, TFCC lesions). Wrist arthroscopy can also be performed with the dry technique, which has the advantage of avoiding fluid extravasation during the procedure. It is advisable to describe all the lesions in the operative report of each patient and if possible to treat them at the same time. Some are more severe or chronic, or require too much time to be treated at the same time, and may require a subsequent surgical treatment. However, sometimes there are minor lesions (i.e., SL lesions, Geissler/EWAS stage I, II) that the surgeon can choose to leave alone or to select the best treatment option for the patient.

Our experience with the treated cases demonstrated that both lesions can be treated at the same time. A single dorsal approach or a double approach can be used depending on the type of scaphoid lesion. In acute cases without fragment displacement, the scaphoid fracture fixation can be performed percutaneously (under arthroscopic assistance) or through a short volar approach. Pinning of the SL space can be added to this procedure (Geissler stages II - III). The traditional volar approach is mainly used when the scaphoid fracture is displaced and needs to be reduced. The dorsal approach can also be used to fix the scaphoid in association with the treatment of the SL lesion. Chronic SL lesions, or acute ones in severe cases (Geissler/EWAS stage IV), are generally treated by a traditional dorsal approach: the SL ligament is identified and sutured with a bone anchor, and a capsulodesis is added as an augmentation technique using a radially based dorsal intercarpal ligament flap [57–59]. In chronic cases the choice of surgical approach to treat the scaphoid fracture depends on the condition of the scaphoid itself. If the scaphoid nonunion has a humpback deformity, and a DISI is present, a cortical bone graft will be needed, and the volar approach will be mandatory; the dorsal approach can be adopted if there is no scaphoid deformity or carpal malalignment. The SL lesion can be treated at the same time by the dorsal approach, as previously described. With the development of new arthroscopic techniques, such as arthroscopic dorsal capsulo-ligamentodesis, it should now be possible to treat the fresh fracture and the scapholunate tear arthroscopically at the same time, which should simplify the technique [32, 58].

Our preliminary results are excellent and good; a longer follow-up is needed to evaluate the results correctly in the long term. According to our experience, lesions needing treatment do not occur frequently, but we cannot exclude that they are still underdiagnosed in clinical practice. We have to remind that in perspective a residual carpal instability can lead to degenerative arthritis and an SLAC wrist, emphasizing the importance of early treatment of the SL lesions, especially in the young patient. The lack of identification of these lesions could also explain some of the not completely satisfactory results, even when the scaphoid fracture has been correctly treated and healed [50].

12.9 Innovative Procedures in Wrist Arthroscopy

Andrea Atzei, Federica Braidotti,
and Riccardo Luchetti

12.9.1 Background

The introduction of the arthroscopic approach has provided tremendous improvement in the management of wrist disorders.

Both diagnosis and surgical repair have improved in terms of accuracy and specificity, so that many surgeons use "all-arthroscopic" treatment, which allows results comparable or even superior to traditional surgical techniques.

As a mini-invasive procedure, arthroscopy has the advantage of reduced capsular damage and scarring; thus, joint mechanoceptors are potentially preserved, and wrist proprioception can be subjected to the least alteration after the surgical procedure [60].

For this reason, a number of procedures have been proposed for the treatment of wrist ligamentous disorders, especially of the ulnar compartment and distal radioulnar joint (DRUJ), since this area is very narrow and difficult to reach by the open approach, and there are many important structures to protect.

Many repair techniques have been described for all-inside suturing of peripheral TFCC tears [61] or for TFCC foveal refixation when the DRUJ is unstable [24, 62]; these have shown very rewarding results.

12.9.2 Complete Arthroscopic Reconstruction of the TFCC

Recently, an arthroscopic reconstruction technique using a tendon graft has been introduced for non-repairable TFCC tears.

This technique is a modification of the open procedure originally described by Mansat (1983), then popularized by Adams (2001), which uses a palmaris longus graft through a transosseous tunnel into the radius and ulna [63, 64]. It takes advantage of the magnified visualization and easy access to intra-articular structures of the ulnar wrist in order to improve the accuracy of the surgical reconstruction.

Although the arthroscopic approach requires three 2.5/3-cm skin incisions for tunnel preparation, it produces very little capsular damage, which is limited to the standard radiocarpal portals (3–4; 4–5; 6R/6U) and to a small piercing of the ulnocarpal ligament interval. This piercing between the interval between the ulnolunate and the ulnotriquetral ligaments, just distal to the remnants of the palmar DRUJ ligament, improves stabilization of the ulnar carpus and allows a real anatomic reconstruction of the radio-ulno-carpal ligamentous complex (Fig. 12.25). Because of the limited field of view, this passage is much more demanding with the open technique than with arthroscopy. The procedure is further improved from the original version with the use of a 4-mm absorbable interference screw to secure graft fixation into the ulnar tunnel. The wrist is immobilized in neutral rotation or slight supination in a long-arm cast for 3 weeks, followed by a further 4 weeks in a Münster-type splint, to regain elbow flexion/extension. Then the wrist is protected by a short splint for 2 more weeks, and rotation is recovered. Afterwards, progressive resisted wrist and hand strengthening exercises are started. My personal experience with this technique started in 2005, and I have operated on 13 patients since then. I had only one intraoperative complication because of an undisplaced fracture of the ulnar tunnel that healed uneventfully, and at early follow-up DRUJ stability had been restored in all patients. At follow-up longer than 3 years, DRUJ stability had been maintained in all seven patients. The range of motion increased from 85% to 95% on the contralateral side, and the grip strength increased from 65% to 87%. Pain decreased from 8.7 to 1.7 on a 10-point visual analogue scale. The patients were very happy, especially with the reduced early postoperative pain, which eased the early postoperative rehabilitation phases. The modified Mayo Wrist Score was excellent in five patients and good in two. All patients were satisfied with the results of the procedure and resumed their previous manual activities; only one changed work for unrelated reasons.

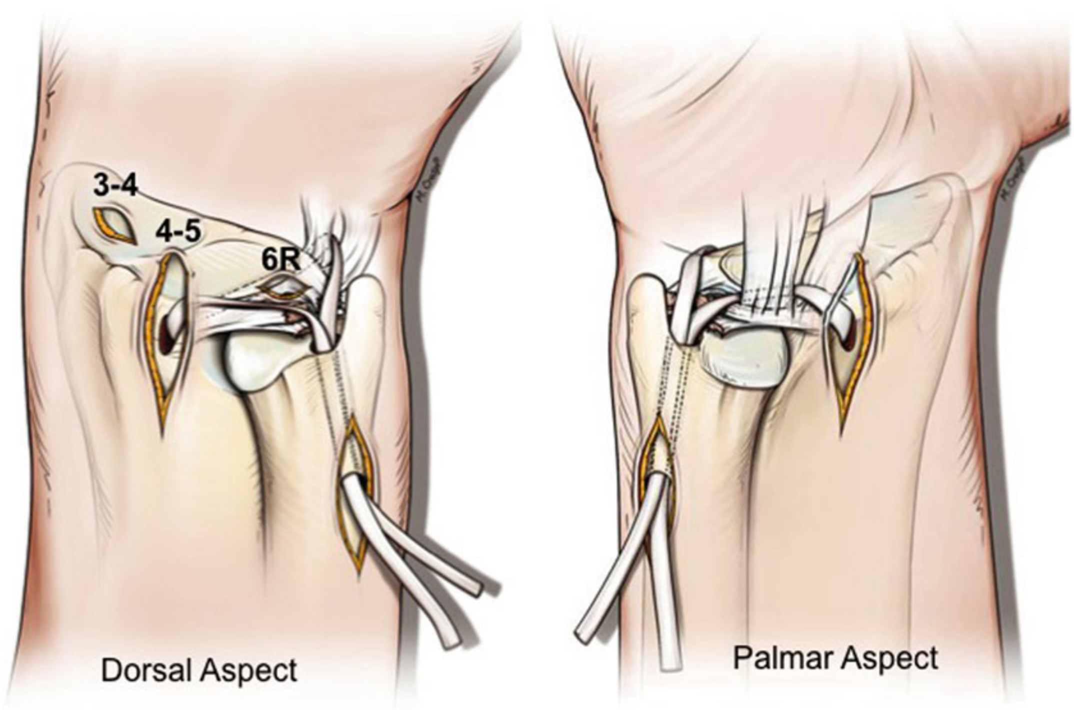

Fig. 12.25 Complete reconstruction of TFCC

12.9.3 Arthroscopic Treatment of Midcarpal Instability

An arthroscopic approach may be of benefit also in the treatment of some forms of midcarpal instability (MCI). MCI is still a poorly understood condition that is common in patients with congenital or acquired ligamentous laxity. It is characterized by an abnormal motion of the carpus, with sudden VISI subluxation of the proximal carpal row, which causes the typical "clunk." Although treatment of the most severe clinical forms (with very frequent and painful spontaneous clunks) requires partial carpal arthrodesis, milder forms respond to conservative treatment of tendon strengthening. The reconstructive problem is for those intermediate forms with transient wrist dysfunction for which partial fusion may be an over-treatment, but physiotherapy is not enough to reduce symptoms. In 2007 Mason and Hargreaves suggested application of capsular thermal shrinkage in order to reproduce the open technique of dorsal capsular reefing described by Lichtman in 2003. A cautious approach to ligament thermal shrinkage should be recommended because of the high risk of thermal injuries to intra-capsular (mechanoceptors) and capsular-adjacent structures (tendons and nerves), due to the reduced thickness of the wrist ligaments, and because of the usual high rate of recurrence of laxity following this procedure even in larger joints. As an alternative, capsular reefing may be achieved with the use of strong non-resorbable sutures (Fig. 12.26). Two sutures are introduced through the 6U portal in a sewing-machine fashion, retrieved and secured with an intra-articular sliding knot through the MCU and MCR portal, respectively, after catching the dorsal radiotriquetral ligament and dorsal intercarpal ligament. Tightening of the dorsal ligaments produces a reduction of the VISI subluxation via a direct mechanical effect. We can also suppose the occurrence of a dynamic effect that is produced by the enhancement of the tone of the stabilizing periarticular muscles caused by the stimulation of the ligamentous mechanoceptors, due to ligament

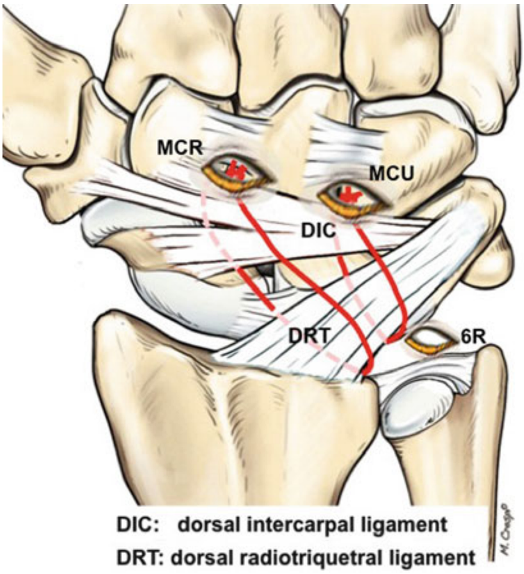

Fig. 12.26 Arthroscopic capsular refixing for midcarpal instability

stretching. Patients should wear a short arm splint for 3 weeks, then use a specifically designed hinged splint restricting radio-carpal motion for a further 3 weeks. Rehabilitation along the arc of the DTM is facilitated, and recovery of the complete arc of motion along other patterns is discouraged. Isometric co-contraction of the ECU and FUC and progressive proprioception exercises are started at 4 weeks. Forearm strengthening is not allowed before 3 months postoperatively. Return to work is allowed after recovery of adequate muscular strength, and patients are instructed how to maintain good ECU and FUC muscular tone. In my experience with four patients reviewed at an average follow-up of 1.7 years, this technique is very effective in preventing wrist clunking. All patients improved and returned to heavy work. The modified Mayo wrist score was excellent in two cases, good in one and fair in one, mainly because of the loss of range of motion.

Conclusions

Wrist arthroscopy is a very useful tool to correctly evaluate traumatic and post-traumatic radiocarpal, midcarpal and hand injuries. Intracarpal lesions of the ligaments and TFCC can be directly visualized and repaired. Articular joint surfaces can be visualized and anatomically reduced. Nevertheless, the technique is demanding, and accurate training on cadaver specimens is necessary to learn the technical skills and to minimize the operating time.

The increased use of arthroscopic examination of the wrist is advisable in wrist trauma in order to establish a correct diagnosis, prognosis and treatment of all the patient's lesions, possibly preventing the future development of degenerative arthritis.

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Lateral Compartment Injury of the Knee

13

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Contents

13.1 Introduction

Injuries to the lateral structures of the knee are often combined with cruciate ligament injuries and can result in significant morbidity [1, 2]. In the last two decades, significant advancements have been made with respect to understanding the anatomy and biomechanics of the lateral knee. This has led to an improved ability to diagnose these injuries and to the development of biomechanically validated, anatomically based surgical reconstruction techniques. Ideally, these injuries are treated acutely within the first few weeks after injury; however, misdiagnosis and delays in presentation may result in a chronic injury.

13.2 Anatomy

Recent reports have provided quantitative descriptions of the gross and radiographic anatomy of the lateral compartment of the knee. Important regional structures include the fibular collateral ligament (FCL), popliteus tendon, popliteofibular ligament (PFL), mid-third lateral capsular ligament, iliotibial band, and biceps femoris ([2, 3]).

The principal proximal attachment of the FCL is slightly proximal and posterior to the lateral epicondyle of the femur (average 1.4 mm and 3.1 mm, respectively), with an average cross-sectional area of 0.48 cm^2 [3]. As the FCL courses distally, it passes superficially over the popliteus

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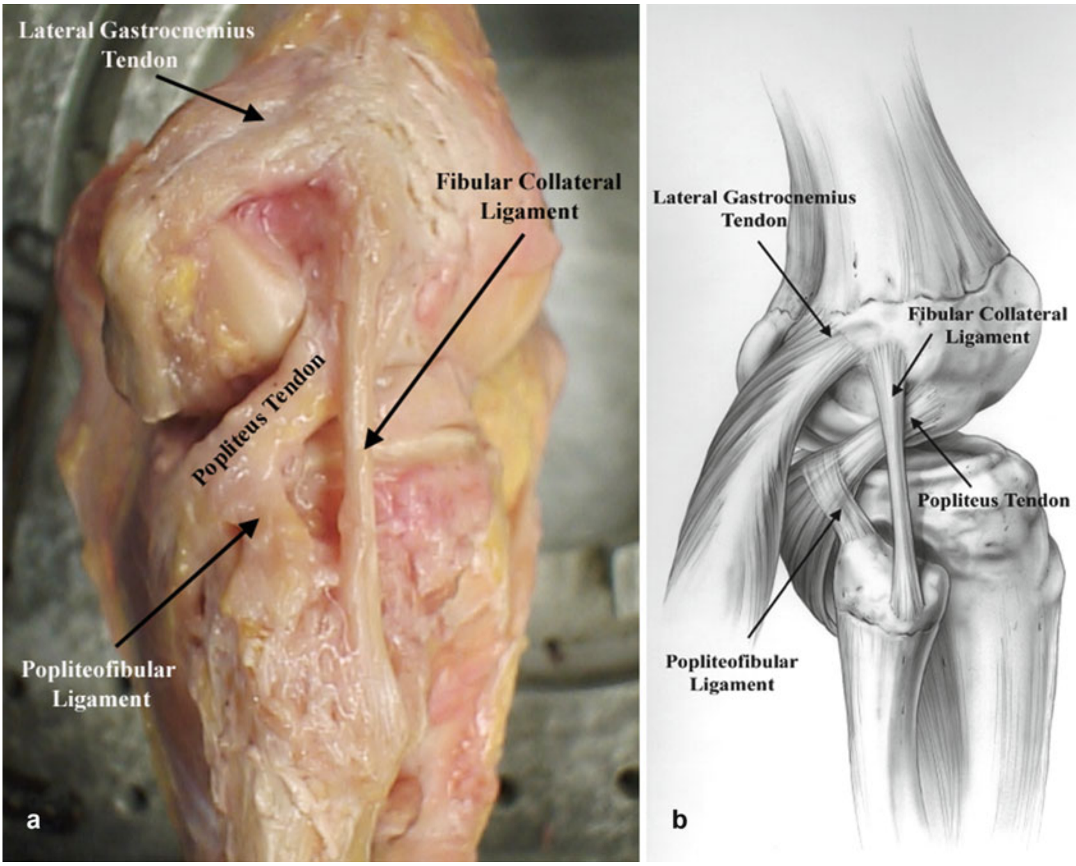

Fig. 13.1 Photograph (**a**) and illustration (**b**) depicting the fibular collateral ligament, popliteus tendon, popliteofibular ligament, and lateral gastrocnemius tendon (lateral view, right knee) (Reprinted with permission from LaPrade et al. [3], Fig. 13.1)

tendon. It attaches to the lateral aspect of the fibular head, at an average of approximately 8.2 mm posterior to the anterior margin of the fibular head and 28.4 mm distal to the tip of the fibular styloid (Fig. 13.1). The average length of the FCL is approximately 70 mm [3, 4].

The popliteus muscle-tendon complex is a dynamic stabilizer of the posterolateral. The muscle belly arises from the posteromedial tibia and courses anterolaterally; the tendon becomes intra-articular and attaches to the femur at the anterior one-fifth of the popliteal sulcus [3]. This is located anterior and distal to the FCL attachment at an average distance of 18.5 mm. The average cross-sectional area at this attachment site is approximately 0.59 cm^2, and the average length from the myotendinous junction to the femoral attachment is 54.5 mm. In full knee extension, the popliteus tendon is subluxed anteriorly from the popliteal sulcus and is relocated at approximately 112° of knee flexion. The proximal attachment of the PFL is at the myotendinous junction of the popliteus muscle-tendon complex; distally, the PFL attaches to the posteromedial aspect of the fibular styloid [3].

The mid-third lateral capsular ligament is a thickening of the lateral capsule of the knee. The meniscofemoral portion attaches to the femur in the region of the lateral epicondyle [5]. The meniscotibial portion attaches to the lateral meniscus and inserts on the tibia slightly distal to the lateral articular cartilage margin between the anterior edge of the popliteal hiatus and the posterior border of Gerdy's tubercle. A bony avulsion of this structure from the tibia is known as a Segond fracture.

The iliotibial band has a superficial and deep layer [6]. The superficial layer is the main tendinous component and inserts distally at Gerdy's tubercle; it covers a significant portion of the lateral aspect of the knee and is the first structure encountered deep to the subcutaneous tissue. The deep layer attaches to the lateral intermuscular septum at the distal femur. Infrequently, the iliotibial band is injured in patients with posterolateral corner injuries.

The biceps femoris is composed of a long head and short head, both with complicated tendinous (direct and anterior arms) and fascial attachments at the knee [5, 6]. The direct arm of the long head inserts onto the middle of the posterolateral aspect of the fibular styloid; the anterior arm attaches to the far lateral edge of the fibular head and styloid, is separated from the FCL by a bursa [4], and terminates distally as an aponeurosis over the anterior compartment of the leg. The direct arm of the short head inserts slightly lateral to the tip of the fibular styloid process and medial to the attachment of the long head direct arm. The anterior arm of the short head passes medial to the FCL and attaches at the same site as the meniscotibial portion of the mid-third lateral capsular ligament.

13.3 Clinically Relevant Biomechanics

The structures of the lateral and posterolateral corner of the knee serve as the primary restraints to external rotation and varus stress. In addition, they also serve as secondary restraints to anterior and posterior tibial translation. The FCL is the primary restraint to varus stress of the knee [7–9, 26]. The popliteus tendon and PFL have been shown to restrain external rotation of the knee at increasing angles of flexion. The FCL has been found to share a role in stability against external rotation with the popliteus tendon, especially near 30° of knee flexion ([9]; LaPrade et al. 2004).

The anterior cruciate ligament (ACL) is the primary restraint to anterior tibial translation; however, in the ACL deficient knee, the posterolateral corner structures serve as an important secondary restraint [10]. While the posterior cruciate ligament (PCL) is the primary restraint to posterior tibial translation, the PLC structures also act as a secondary restraint to posterior tibial translation [8, 9, 11, 12].

13.4 Clinical Presentation and Diagnosis

Injuries to the lateral and posterolateral aspect of the knee commonly are the result of contact or noncontact hyperextension injuries, valgus contact force to a flexed knee, or a contact force to the anteromedial aspect of the knee with the knee near full extension. A patient with an isolated or combined injury to the lateral structures of the knee commonly reports a history of such an injury, combined with swelling, mechanical symptoms, and a sense of instability. The patient may report instability as a sense of "giving-way" or a sense of side-to-side instability. Furthermore, the patient may report a foot drop as a concomitant injury to the common peroneal nerve can occur in 12–17% of patients [1, 2, 13, 14]. The majority of these injuries are associated with a cruciate ligament injury [1, 5, 36].

Along with the patient's injury and treatment history, the physical examination has a crucial role in the diagnosis and ultimate operative planning. Patients that present with acute injuries must be evaluated for fracture, common peroneal nerve injury, vascular injury, and other injuries that threaten life or limb [15]. In all patients, a physical examination (which may be limited by pain and swelling in the acutely injured patient) with comparison to the uninjured knee should include varus opening at 20° (Fig. 13.2), posterolateral drawer test, external rotation at 30° and 90° (dial test), and the reverse pivot shift and external rotation recurvatum tests. In addition, valgus opening at 20° should be assessed along with Lachman, pivot shift, and posterior drawer tests for anteroposterior instability [37].

Imaging studies are recommended to supplement the physical exam and to allow for advanced operative planning. Standard radiography including anteroposterior and lateral views of the knee

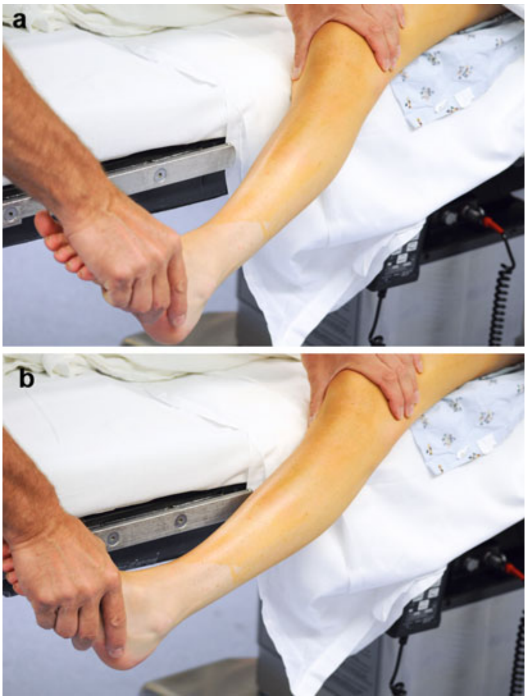

Fig. 13.2 Photographs showing varus stress testing at 20°: neutral (**a**) and with stress applied (**b**)

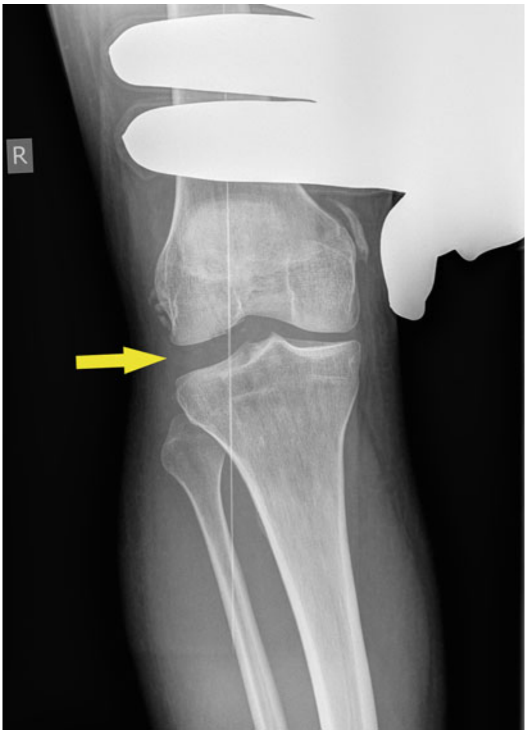

Fig. 13.3 Varus stress radiograph of a right knee showing increased lateral side gapping (*yellow arrow*)

should be obtained. Magnetic resonance imaging (MRI) will not only allow assessment of PLC structures [5] but will also allow for assessment of the cruciate ligaments and medial collateral ligament, articular cartilage, articular surfaces for bone bruises [1], and associated meniscal injuries. Varus stress radiographs (Fig. 13.3) should be obtained for both acute and chronic injuries; it has been reported that an average increase in side-to-side lateral compartment gapping of 2.7 mm is present for isolated FCL tears and 4.0 mm for grade III PLC injuries, when compared with the intact knee [16]. Standing long-leg radiographs should be obtained for patients with chronic injuries to assess for varus malalignment.

13.5 Treatment

In general, grade I and II injuries to the FCL can be treated nonoperatively [17, 18]. However, assessment and surgical treatment for concomitant cruciate ligament injuries should occur. For low-grade FCL injuries, knee bracing and physical therapy are the main components of treatment; athletes may return to competition once pain is absent and varus stress testing, strength, and range of motion are equal to the uninjured side.

In contrast, grade III injuries are best treated operatively as it has been demonstrated in human [17] and animal studies [19, 34] that these injuries do not heal. Furthermore, it has been reported that ACL [10] and PCL [20, 21] graft integrity depends on the recognition and surgical treatment of concomitant PLC injuries.

13.5.1 Acute PLC Injuries

An important distinction for treatment of acute grade III PLC injuries is whether a structure can be repaired or if reconstruction is required. The first reported results of acute repair were good or fair in 88% to 100% of patients [13, 14, 22], and this was the accepted treatment for several years. This trend changed when recent comparison studies reported failure rates of 37–40% for primary repairs of the main PLC structures versus successful outcomes in 94% of patients treated with acute reconstructions [23, 24].

We recently reported a series of patients treated for acute PLC injuries by repair of avulsions of the main PLC structures combined with reconstruction of midsubstance tears [36]. Ten patients were treated with an anatomic PLC reconstruction, and the remaining sixteen knees were treated with a posterolateral corner repair or repair/reconstruction hybrid technique. All patients in the repair cohort received grade A (normal) results on the IKDC objective stability subscores (lateral joint opening at 20°, dial test at 30° and 90°, and reverse pivot shift test); one patient in the PLC reconstruction group failed his initial surgery and required a high tibial osteotomy for severe varus malalignment and revision PLC reconstruction.

It is our preference to perform the open dissection prior to the arthroscopic portion of the surgery in order to allow optimal identification of injured extra-articular structures by minimizing arthroscopic fluid extravasation. A 6-cm skin bridge is designed between the posterolateral incision and the anterior knee for patients with a planned autogenous patellar tendon graft harvest for concurrent ACL reconstruction. A standard lateral hockey-stick-shaped incision is made over the posterolateral knee [26, 36] and continued down to the superficial layer of the iliotibial band.

A step-by-step search is performed to identify injuries to structures attached to the fibula, femur, tibia, and lateral meniscus. The long and short heads of the biceps femoris are identified, and a retraction stitch is placed in the distal aspect of the common biceps tendon if avulsed from the fibular head; a common peroneal nerve neurolysis is performed. Next, the distal FCL is identified via a biceps bursa splitting incision [4], and blunt dissection in the region in the interval between the lateral gastrocnemius and soleus muscles and anterior to the common peroneal nerve allows for assessment of the PFL at its attachment on the posteromedial aspect of the fibular styloid.

Centered over the lateral epicondyle, a splitting incision is then made through the superficial layer of the iliotibial band in line with its fibers, from approximately 6 cm proximal to the lateral epicondyle and distally to Gerdy's tubercle. This allows for identification of the proximal attachment of the FCL as well as the femoral attachment of the popliteus tendon [3]. A reconstruction of the FCL (Fig. 13.4) is planned for midsubstance tears or substantial intrasubstance stretch injuries [26]. If the popliteus tendon is avulsed without an apparent intrasubstance stretch injury and can be re-approximated to its anatomic femoral attachment in full knee extension, a recess procedure is planned [25, 36]). Popliteus tendon injuries including midsubstance tears and musculotendinous avulsions require reconstruction (Fig. 13.5) [26]. The mid-third lateral capsular ligament is assessed for soft tissue or bony (Segond) avulsions off the tibia, and a direct repair is planned if indicated.

The arthroscopic portion of the procedure is performed following identification of all extra-articular injuries. A standard arthroscopic examination is performed in order to identify cruciate ligament tears, meniscal tears, and chondral damage. Reconstruction of cruciate ligament tears is performed as indicated, and the grafts are secured in their respective femoral tunnels; fixation of grafts in the tibial tunnels is delayed until later in the operation. If repairable, meniscal tears are treated with an inside-out technique; a partial meniscectomy is performed for nonrepairable tears. Chondral flaps are debrided and microfracture is performed if indicated.

Following identification of PLC injuries and treatment of intra-articular injuries, the next step in the procedure is the repair and/or reconstruction of the PLC injuries. A stepwise approach is utilized for structures with attachments to the femur, lateral meniscus, tibia, and lastly the fibula. An important assessment is made earlier in the procedure when it is determined whether a structure is amenable for a repair or if it requires a reconstruction. Structures avulsed directly from the bone with no obvious midsubstance stretch

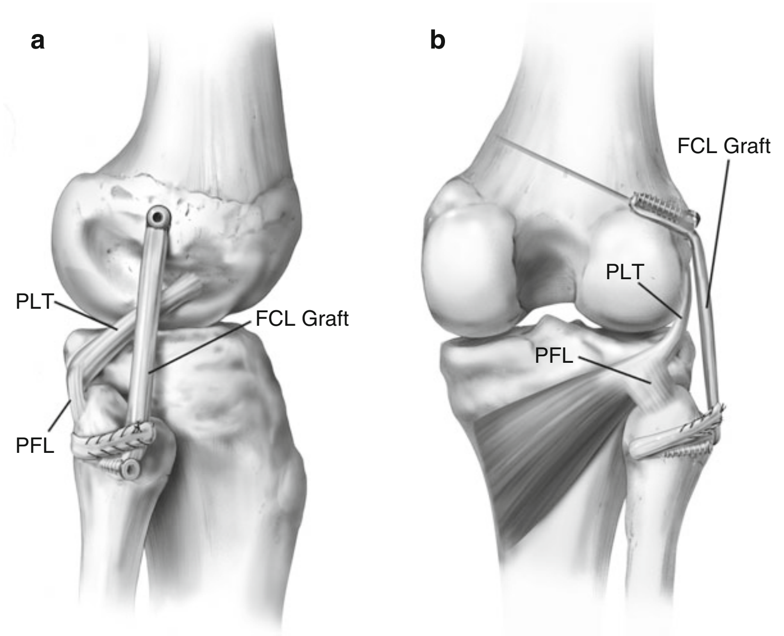

Fig. 13.4 Illustration of a FCL reconstruction using a semitendinosus graft showing an intact popliteus tendon and popliteofibular ligament. Lateral view (**a**) and posterior view (**b**) of a right knee. *FCL* fibular collateral ligament, *PLT* popliteus tendon, *PFL* popliteofibular ligament (Reprinted with permission from Coobs et al. [7], Fig. 13.2)

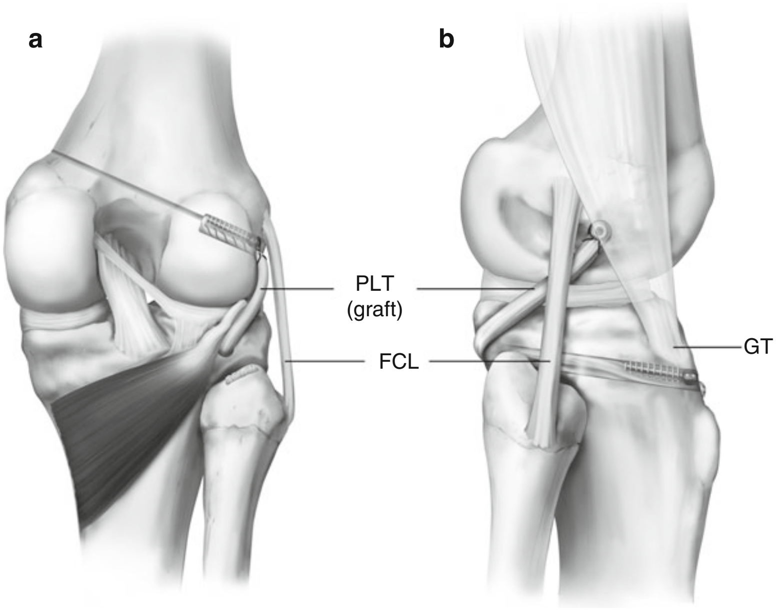

Fig. 13.5 Posterior (**a**) and lateral (**b**) view illustrations of an isolated anatomic popliteus tendon reconstruction using a semitendinosus graft. *FCL* fibular collateral ligament, *PLT* popliteus tendon, *GT* Gerdy's tubercle (Reprinted with permission from LaPrade et al. [26], Fig. 13.1)

injury and that are able to be reduced back to their anatomic attachment with the knee in full extension are considered for repair. Structures considered for reconstruction are the FCL, popliteus tendon, and PFL; reconstruction is required for structures with an intrasubstance stretch injury, midsubstance tear, and inadequate tissue length.

The femoral attachments of the FCL and popliteus tendon are addressed first. Repair of an FCL avulsion off the femur via a recess procedure is performed for patients with open physes. Popliteus tendon avulsions are also repaired with a recess procedure [25, 27, 37]. If a repair is not indicated, isolated tears of the FCL or the popliteus tendon are treated with an anatomic reconstruction of the individual structure with an autogenous semitendinosus graft [7]; if both structures are torn, an anatomic PLC reconstruction is performed with the use of an Achilles tendon allograft [26, 34, 36, 37]. This technique for an anatomic PLC reconstruction (i.e., the FCL, popliteus tendon, and PFL) in acute injuries is the same technique used for chronic injuries and will be described in detail, along with fixation of concurrent cruciate ligament reconstruction grafts, in the following section on Chronic PLC Injuries.

Structures attached to the lateral meniscus are addressed next. Mattress sutures under direct vision are used for tears of the coronary ligament (posterior horn of the lateral meniscus) and tears of the popliteomeniscal fascicles [28]. An avulsion of the tibial attachment of the mid-third lateral capsular ligament [5, 29] is repaired with suture anchors [36].

Next, injuries to fibular-based structures are addressed. An avulsion of the biceps femoris is repaired with the knee in full extension and requires suture anchors. It is important to avoid excessive tension on the repair; therefore, a proximal release of the long head of the biceps from adhesions to the lateral aspect of thigh is performed bluntly until sufficient length is achieved allowing anatomic reduction. Repair of the PFL is considered for patients with an intact popliteus tendon and if the PFL is avulsed directly from the fibular head with sufficient tissue present to allow re-approximation by suturing. If the PFL is not amenable for a repair and a concurrent FCL reconstruction is indicated, a combined FCL-PFL reconstruction is performed [36]. The fibular limb of the FCL graft is passed out of the posteromedial aspect of the reconstruction tunnel in the fibular head and looped around the intact popliteus tendon at the musculotendinous junction, passed laterally, and sutured to itself to reconstruct the PFL. Rarely, the FCL is avulsed directly from the fibular head, has adequate length, and demonstrates no signs of an intrasubstance stretch injury. In these instances, a suture anchor repair is considered.

Fibular head avulsion (arcuate) fractures [30] occasionally occur in patients with severe posterolateral corner injuries. These are repaired primarily; a nonabsorbable number 5 cerclage suture is placed through the proximal fracture fragment and into the common biceps tendon. Drill holes are placed 1 cm distal to the fracture edge on the lateral aspect of the fibula, and the sutures are passed through and tied in full knee extension [36].

During repair of injured structures, careful attention must be paid to tissue tension and surgical release of retracted injured tissues to ensure that all structures could be anatomically repaired with the knee in full extension. Prior to skin closure, the “safe zone” knee range of motion is determined intraoperatively; the minimal goal for range of motion on postoperative day one is 0–90°.

13.5.2 Chronic PLC Injuries

It is not infrequent that patients present with chronic PLC injuries – this may be due to the difficulty in diagnosing these injuries or prior failed treatment. Unlike patients with acute PLC injuries, those with chronic PLC injuries cannot be treated with a primary repair of avulsed structures and a reconstruction of torn PLC structures is necessary. As discussed, it is important to evaluate bilateral standing long-leg radiographs to assess their weight-bearing axis. Patients in varus malalignment must be treated with an osteotomy in order to restore normal alignment prior to any soft tissue procedure or their grafts are likely to fail. It has been demonstrated that approximately 40% of patients treated with a first-stage osteotomy may not require a second-stage ligament reconstruction [26, 31].

Patient positioning, surgical approach, peroneal neurolysis, identification of anatomic landmarks, arthroscopic evaluation, and treatment of intra-articular injuries are the same for acute and chronic injuries. Isolated injuries to the FCL or popliteus tendon can be treated with a reconstruction as described previously [7, 26].

Reconstruction tunnel creation and graft preparation are the next steps in the procedure once the exposure of the posterolateral corner is complete. All tunnels are prepared initially. The fibular reconstruction tunnel is reamed first. A K-wire is drilled through the fibular head between the FCL and PFL attachment sites using a cannulated cruciate ligament tunnel aiming device and is overreamed by a 7-mm reamer. Next, the guide is positioned 1 cm distal to the articular cartilage margin on the posterior popliteal tibial sulcus, and while protecting the neurovascular bundle, a K-wire is drilled to this location originating from the flat spot slightly distal and medial to Gerdy's tubercle [26, 32, 33]. The tibial tunnel is reamed to 9 mm and a rasp is used to smooth the tunnel aperture edges.

The two femoral tunnels are created next. The proximal FCL attachment and the insertion of the popliteus tendon are identified; the distance between the centers of these two sites has been reported to average 18.5 mm [3]. Using the aiming guide, an eyelet pin is drilled through each site in an anteromedial vector to exit the distal femur and overreamed to a diameter of 9 mm diameter and depth of 20–25 mm (Fig. 13.6a, b).

In order to minimize operative time, graft preparation should be performed concurrently with tunnel creation. An Achilles tendon allograft with length ≥ 23 cm is split lengthwise to prepare two tendon grafts. The two bone plugs are designed to fit the femoral tunnel dimensions, and number 5 suture is used to tubularize the ends of the tendons. The graft bone plugs are pulled into their femoral tunnels and secured with 7 × 20-mm-cannulated interference screws. The popliteus graft is passed along the anatomic path of the popliteus tendon, through the popliteal hiatus. The FCL-PFL graft is passed through the interval deep to the superficial iliotibial band and the biceps femoris long head anterior arm and then from lateral to posterior through the fibular tunnel (Fig. 13.6c, d).

Once the posterolateral corner grafts are secured in the femoral tunnels and passed into the respective tunnels, the distal fixation of the PCL reconstruction grafts is performed according to previously described techniques [21, 26]. The grafts are held tightly while the knee is cycled; the PCL graft is secured first in order to restore the central pivot of the knee, then the posterolateral corner grafts are secured in their distal tunnels, and the ACL graft is secured last [21, 26]. A 7-mm-cannulated bioabsorbable interference screw is used to fix the graft in the fibular tunnel while the knee is held in neutral rotation, 20° flexion, and a slight valgus reduction stress. The same graft is then passed through the tibial tunnel, along with the popliteus tendon reconstruction graft and secured with a 9-mm-cannulated bioabsorbable interference screw with the knee in neutral rotation, 60° of flexion, and while anterior traction is placed on the grafts. If desired, a staple may be placed distal and medial to Gerdy's tubercle for supplemental graft fixation.

13.5.3 Postoperative Management

The patient's postoperative rehabilitation is a critical component of treatment for a PLC injury. Additionally, rehabilitation in advance of the surgical procedure, also known as "pre-hab," has been advocated to improve range of motion, increase quadriceps control, and to prepare patients for their postoperative care [35].

A full discussion of rehabilitation is beyond the scope of this chapter, and modification of these guidelines may be indicated for patients with combined cruciate ligament and/or meniscus injuries. As such, a patient's specific protocol may require individualization. General principles are described below; a comprehensive review of rehabilitation for repairs/reconstructions of the PLC is provided by Lunden et al. [35].

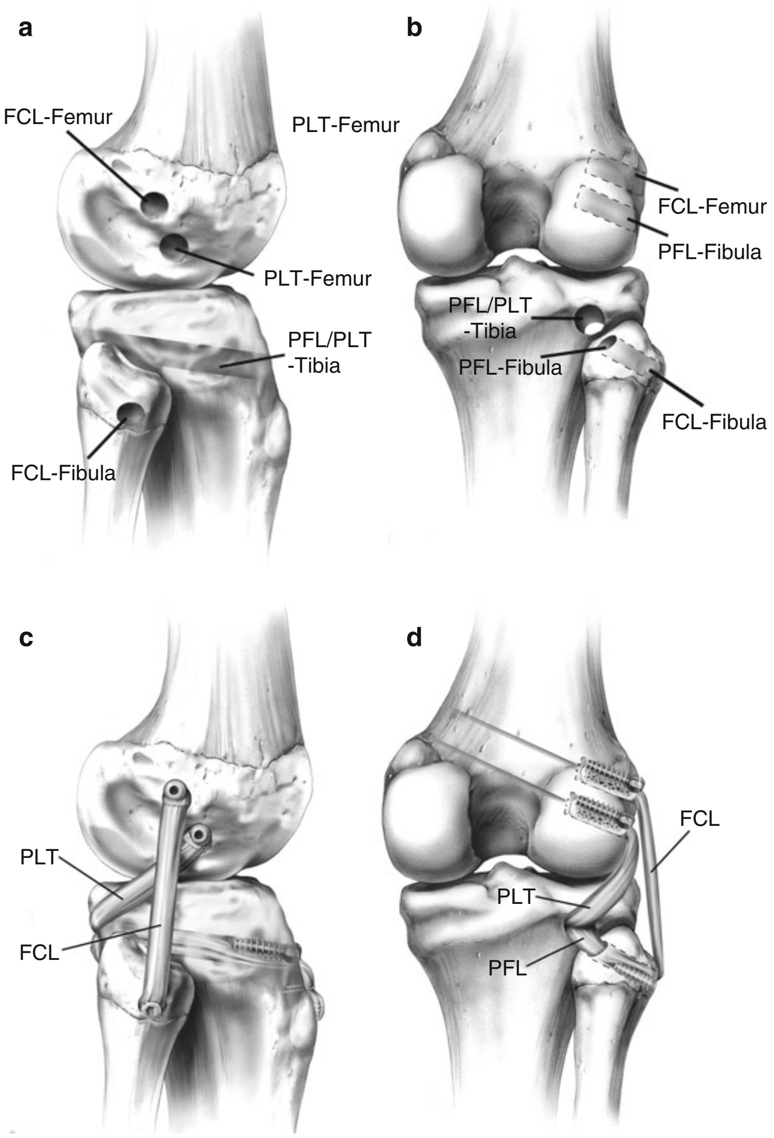

Fig. 13.6 The femoral, tibial, and fibular posterolateral knee reconstruction tunnel placement in a right knee: lateral view (**a**) and posterior view (**b**). Final reconstruction with grafts secured in place: lateral view (**c**) and posterior view (**d**). *FCL* fibular collateral ligament, *PLT* popliteus tendon, *PFL* popliteofibular ligament (Reprinted with permission from LaPrade et al. [34], Fig. 13.2)

Postoperatively, patients are placed in a knee immobilizer for 2 weeks and locked in extension except when working on their “safe zone” range of motion. At 6 weeks, patients are allowed to initiate weight bearing as tolerated. Further progression is then allowed including low-intensity stationary bike exercises and leg presses to a maximum of 70° of knee flexion. Strength, core stability, proprioception, and endurance are emphasized between postoperative months 2 and 4. If there is pain-free range of motion, adequate balance and strength are demonstrated, and healing is felt to be adequate based on physical exam and stress radiographs, progression to light jogging at 4 months postoperatively is allowed. A full return to activities is allowed once adequate strength, endurance, and agility are demonstrated on functional testing and varus stress radiographs confirm adequate graft healing.

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Cartilage Committee Seminar: Algorithms and Flowcharts for the Treatment of Cartilage Pathology

14

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14.1 Classification of Chondral and Osteochondral Lesions of the Knee

Mats Brittberg

There are many published reports on the outcomes of total joint replacement based on clinical scores and radiographic evaluations.

However, it has been difficult to interpret the reported results of the repair of focal cartilage defects as there has not been a universally well-accepted system to describe the lesions, the repair tissue or the clinical symptoms for this category of patients. The most commonly used system for traumatic and osteoarthritic cartilage lesions has been the Outerbridge system [1]. However, the Outerbridge classification system was originally used to describe patellar chondromalacic lesions [1].

Brismar et al. [2] studied 19 videotaped knee arthroscopies in 19 patients with mild to moderate osteoarthritis (OA) of the knee in order to compare the intraobserver and interobserver reliability and the patterns of disagreement between four orthopaedic surgeons. Three different classifications of OA were used; Collins, Outerbridge and the French Society of Arthroscopy scoring were used. Intraobserver and interobserver agreements using kappa measures were 0.42–0.66 and 0.43–0.49, respectively [2]. Only 6–8 % of paired intraobserver classifications differed by more than one category. Observer-specific disagreement was evident both within and between observers. The authors concluded that even if reliability could improve by an analysis of disagreement, it appeared that the arthroscopic grading of early osteoarthritic lesions was inexact [2]. However, osteoarthritic lesions are diffuse and more difficult to classify compared to localized traumatic defects.

Cameron et al. [3] looked upon six cadaveric knees that were examined by diagnostic arthroscopy, which was videotaped. The arthroscopy was followed by an arthrotomy, and the arthroscopically identified lesions were measured with callipers. Nine orthopaedic surgeons reviewed each video and graded each chondral lesion two separate times. Accuracy of observations was calculated based on the percentage of agreement between the grades determined during arthroscopy and arthrotomy. The overall accuracy was 68 % but varied by location. The mean interobserver kappa between the two physicians in practice 5 years or more was 0.72, compared with 0.50 for physicians in practice less than 5 years [3].Those authors concluded that the Outerbridge classification was moderately accurate when used to grade chondral lesions arthroscopically [3].

A working group of the ICRS was established in 1997 with the aim of developing a common, easy system for clinical and arthroscopic evaluation. Shortly thereafter, the Articular Cartilage Imaging Committee of the ICRS was created to assess the existing clinical imaging techniques, to recommend specific magnetic resonance imaging techniques for the assessment of articular cartilage and to develop a standardized magnetic resonance imaging evaluation system for native and repaired cartilage

Spahn et al. [4] made an investigation to evaluate the use of different evaluation scoring systems. In the grading of the cartilage lesions, the Outerbridge classification was most frequently used ($n = 87$), followed by the ICRS protocol ($n = 8$) and the Insall score ($n = 3$). The majority (61 %) of the arthroscopic surgeons felt that differentiation between healthy cartilage and low-grade cartilage lesions was simple [4]. For differentiation between grade I and grade II lesions, and for differentiation between grade II and grade III lesions, 41.9 % and 51.4 %, respectively, thought that there was a ‘need for improvement’. In the case of grade IV lesions, 70.5 % of the surgeons thought that the diagnosis was valid [4].

In another cartilage lesion study [5], a high correlation was found between arthroscopic and open evaluation of the cartilage defect size, but there was a significant overestimation of the cartilage defect size during arthroscopy. This observation was independent of defect location. Smaller defects and inexperienced surgeons were factors that made an overestimation of defect size more likely [5]. However, the authors found that the arthroscopic detection and estimation of the full-thickness cartilage defects according to the ICRS classification seemed reliable [5].

This chapter will describe the use of the ICRS classification [6].

At the start of arthroscopy, the surgeon needs to decide the aetiology of the lesions and if it is an acute or chronic defect. Do not use if possible the word osteoarthritis but describe the appearance of the lesion. Use a probe to examine the surface. The probe is also useful when to decide the depth of the lesion.

It is the debrided lesion that is to be repaired. Subsequently, the true size of the defect is the debrided lesion which should be described in cm^2.

Furthermore, the examiner should decide the level of containment or not and the localization of the lesion. A lesion can be monofocal or exist with other lesions as bifocal or monofocal. The localization can be described using the ICRS mapping system for cartilage lesions.

The examiner should also evaluate the joint stability, meniscal status and what has been done prior to the actual surgery.

If there exists a repair tissue from earlier cartilage lesion surgery, the repair tissue should be described using the ICRS cartilage repair assessment [6].

As mentioned above, the best known arthroscopic cartilage lesion classification system was developed by Outerbridge [1]. This system divides lesions into four grades (grades I through IV) and is easy to understand and to use [1].

However, Outerbridge grades II and III do not include a description of the lesion depth, and degree of depth is important when to decide which type of surgery that may be used to treat a cartilage defect.

When the surgeon is looking at a cartilage lesion, loose destroyed parts of cartilage is removed. A debrided, stabilized lesion could then first be defined as:

Superficial
Partial thickness
Full-thickness cartilage defect

To use this type of division of the destroyed cartilage, the ICRS classification system focuses on the lesion:

Depth (graded from 0 to 4)
Area of damage (graded from normal to severely abnormal with use of the IKDC system)

14.1.1 ICRS Grade O

Macroscopically normal cartilage without notable defects is classified as ICRS 0 (normal).

14.1.2 ICRS Grade Ia–b

If the cartilage has an intact surface but fibrillation and/or slight softening is present, it is classified as ICRS 1a, and if additional superficial lacerations and fissures are found, it is classified as ICRS 1b (nearly normal) (Fig. 14.1).

14.1.3 ICRS Grade II

Defects that extend deeper but involve <50 % of the cartilage thickness are classified as ICRS 2 (abnormal).

These lesions are often unstable, with partly detached fragments that need to be debrided to form stable lesions.

The prognosis for ICRS II partial-thickness lesions seems good [7] with diminished mechanical symptoms following a simple debridement that involves excision of the unstable cartilage fragments back to smooth edges and leaves the base intact (Fig. 14.2).

14.1.4 ICRS Grade IIIa–d

There are four subgroups of this grade:

ICRS Grade IIIa

Deep defects that extend through >50 % of the cartilage depth but not to the calcified layer are classified as ICRS 3a.

ICRS Grade IIIb

Deep defects that extend through >50 % of the cartilage depth to the calcified layer are classified as ICRS 3b.

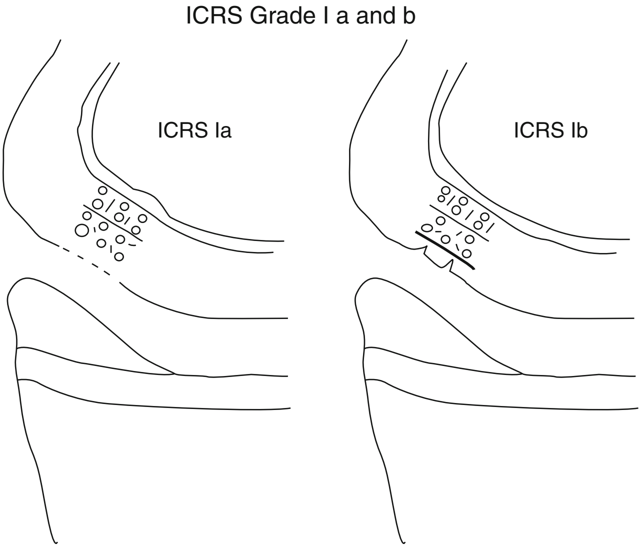


Fig. 14.1 ICRS Grade I a–b: If the cartilage has an intact surface but fibrillation and/or slight softening is present, it is classified as ICRS 1a. If additional superficial lacerations and fissures are found, it is classified as ICRS 1b (nearly normal) (Brittberg 2011)

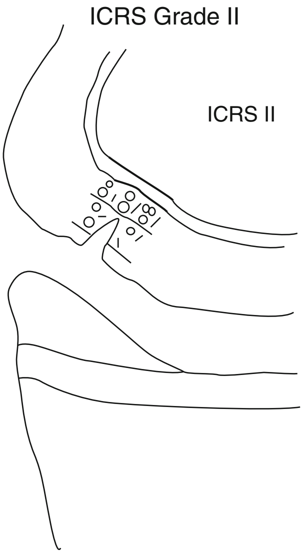


Fig. 14.2 Defects that extend deeper but involve <50 % of the cartilage thickness are classified as ICRS 2 (abnormal) (Brittberg 2011)

ICRS Grade IIIc

Defects that extend down to but not through the subchondral bone plate are classified as ICRS 3c finally.

ICRS Grade IIId

Blisters are classified as ICRS 3d. They may look innocent, but if one takes a probe and tests the surface, the probe will easily go through the top layer and one will notice that the area is empty below the blister.

All of the lesions in category ICRS 3 are simply defined as defects that extend through >50 % of the cartilage thickness, through the cartilage but not through subchondral bone plate (Fig. 14.3).

While debridement of unstable edges (as is suggested for ICRS II lesions) is suitable for ICRS III lesions, further treatment is recommended for these more extensive lesions.

14.1.5 ICRS Grade IVa–b

Joint trauma may create cartilage defects that extend into the subchondral bone. These full-thickness osteochondral injuries are classified as ICRS IV (severely abnormal).

Grade IVa are defects just through the subchondral plate, while grade IVb are defects extending deep into the bone (Fig. 14.4).

Excluded from this grade are defects that are classified as osteochondritis dissecans (OCD), which have a classification system of their own.

ICRS IV lesions can be treated in the same manner as described for ICRS III lesions, but a lesion with extensive cavitation into the bone may require bone grafting.

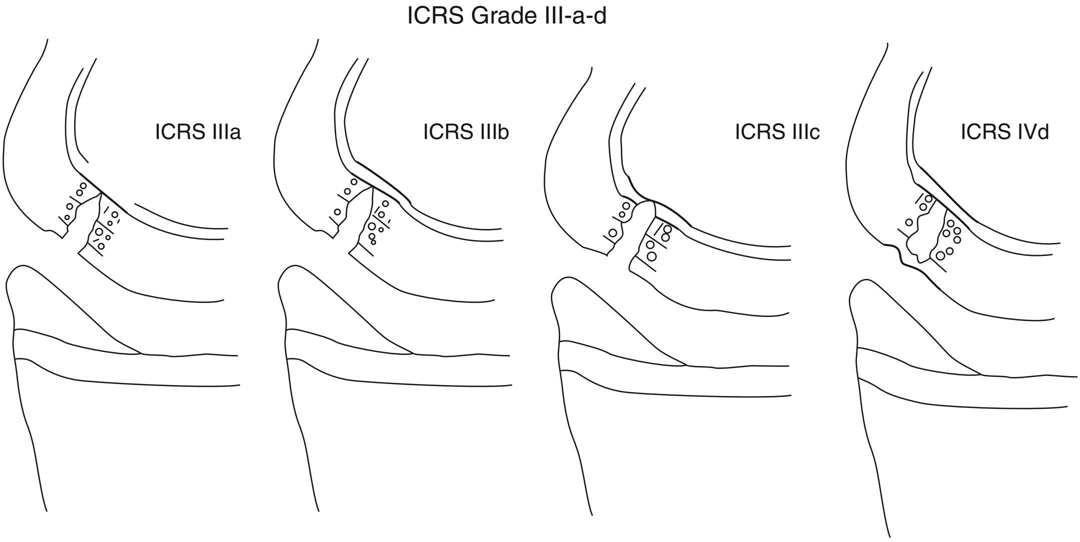


Fig. 14.3 There are four subgroups of this grade. Deep defects that extend through >50 % of the cartilage depth but not to the calcified layer are classified as ICRS 3a. Deep defects that extend through >50 % of the cartilage depth to the calcified layer are classified as ICRS 3b. Defects that extend down to but not through the subchondral bone plate are classified as ICRS 3c. Blisters are classified as ICRS 3d (Brittberg 2011)

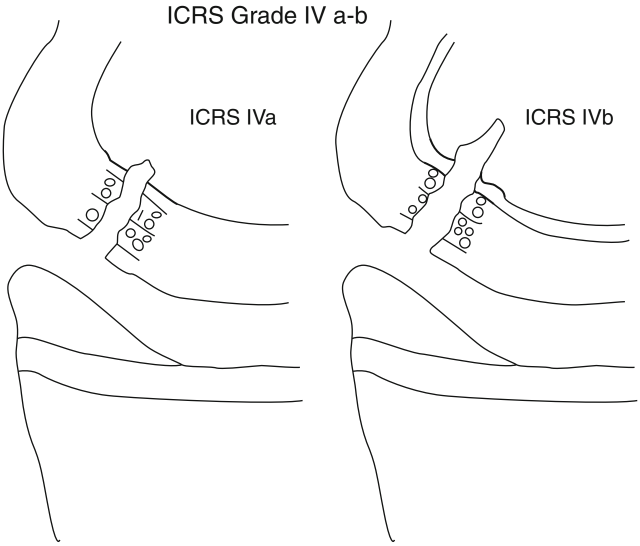


Fig. 14.4 Grade IVa are defects just through the subchondral plate while grade IVb are defects extending deep into the bone (Brittberg 2011)

14.1.6 Osteochondritis Dissecans (OCD)

There exist several different classification systems for OCD. The most well-known is the arthroscopic classification according to Guhl [8]:

Stage 1: Stable lesion

Stage 2: Lesions showing signs of early separation

Stage 3: Partially detached lesions

Stage 4: Craters with loose bodies

ICRS has developed also a system for OCD evaluations [6]. The *ICRS OCD classification,* which is a modified Guhl classification to adjust cartilage evaluation of OCD lesions to the common ICRS evaluation system:

ICRS OCD 0: Stable, normal intact overlying cartilage

ICRS OCD I: Stable with continuous but softened area with intact cartilage

ICRS OCD II: Stable with partial discontinuity

ICRS OCD III: In situ lesion with complete discontinuity

ICRS OCD IV: Empty defect with dislocated or loose fragments

Even though, unenhanced MRI using a 1.5-Tesla magnet (and even stronger machines) with conventional sequences (proton-density-weighted, T1-weighted, and T2-weighted) is most accurate at revealing deeper lesions and defects at the patellae, Figueroa et al. [9] could show that a considerable number of lesions will remain undetected until arthroscopy is used, which remains the gold standard [9]. Von Engelhardt and coworkers [10] found that when 3-T MRI suggests a cartilage defect, the probability that the arthroscopic finding corresponds exactly to the MRI result is between 39 and 74 %. Therefore, the value of arthroscopy for a detailed assessment and grading of a cartilage disorder with regard to definitive planning of a therapeutic procedure cannot be replaced by 3-T MRI.

However, the imaging technique is becoming better and better. However, recently, Krampla and coworkers [11] looked upon the interobserver reliability in the interpretation of meniscal lesions, degree of chondropathy and integrity of the ACL while taking the radiologist's experience and field strength into account. The authors found that the interobserver correlation was low, although the diagnostic criteria were defined [7]. They strongly stated that the use of the classification scheme should be standardized by uniform training. Radiologist experience seemed to be more important than field strength.

The same statement accounts for the arthroscopic surgeons evaluating cartilage lesions. For all involved in articular joint evaluations, the knowledge of how to describe cartilage lesions is of great importance. Depth of lesions and the size of the lesions are parameters that decide the operative activity, choice of treatment and the prognosis. With an increasing amount of treatment alternatives, the use of systems/scores that everyone can easily understand and practice will increase our knowledge of both the natural history of cartilage lesions as well as the results after cartilage surgery.

14.2 Treatment Algorithms of Chondral Lesions <4 cm²

Alberto Gobbi and Anup Kumar

14.2.1 In Adolescents

The lesions on weight-bearing surfaces and that are greater than 1 cm in size have shown to have an unsuccessful outcome with non-operative treatment [12, 13]. Reduction and stabilization of the OCD fragment less than 2 cm can be done with a multitude of devices such as K-wires, variable pitch screws, cannulated screws, bio-absorbable pins, tacks nails and screws. Anderson et al. reported that long-term results for large lesions are poor [14].

We usually do not recommend operative intervention for chondral lesions in adolescent patients, as we believe that any operative intervention might interfere with their growth potential and also they have a good potential for cartilage regeneration. In such patients, we prefer to adopt the wait and watch policy and follow them at regular intervals with watchful neglect.

14.2.2 Age <45 Years

A. Low-demand patients:

1. With contained lesions

We recommend microfracture as a primary treatment option for full-thickness-contained chondral lesions in patients less than 45 years of age and involved in low-demand activities. By systematic penetration of the subchondral bone plate, microfracture leads to formation of a blood clot that contains pluripotent, marrow-derived mesenchymal stem cells, which develops into a fibrocartilage repair tissue with varying amounts of type II collagen content [15–17]. The patient's age significantly affects the outcome after microfracture, with better results with patients younger than 40 years 17, 19. Younger age results in better clinical outcome scores and better repair cartilage fill on MRI. The reported age threshold varies between 30 and 40 years [18–21].

Studies showed that repair cartilage fill on MRI is better with age less than 40 years and smaller defect size [21–24].

Multiple studies have evaluated the utility and efficacy of various approaches such as scaffold enhancement, hyaluronic acid visco-supplementation, growth factor augmentation and cytokine modulation techniques [25].

2. With non-contained lesions

OATS using a single plug as a primary treatment option for full-thickness non-contained chondral lesions in patients less than 45 years of age and involved in low-demand activities. The results of OATS are satisfactory at medium- to long-term follow-up in relatively small (not more than 2.5 cm^2) grade III or IV lesions of femoral condyles in young- and middle-aged patients.

B. High-demand patients

1. With contained lesions

High-impact joint loading, as is characteristic of high-intensity exercise, has been shown to decrease cartilage proteoglycan content, increase levels of degradative enzymes and cause chondrocyte apoptosis [26]. These facts demonstrate the need for an effective and durable joint surface restoration in high-impact athletes that can withstand the significant joint stresses generated during athletic participation.

Recent studies showed that patients in the BMSC group had similar improvement in clinical outcomes as the ACI group. Bone marrow biopsy is less invasive than knee arthroscopy, normal articular cartilage is not damaged and 1 less surgery is required; consequently, the cost is less [27].

Recent studies and systematic review showed that 65 % of athletes younger than 40 years of age returned to sports after microfracture compared to 20 % of older patients [28]. Relative thinning of the overlying repair cartilage tissue by subchondral bone overgrowth after microfracture chondroplasty may be another potential factor involved in the observed functional deterioration in high-impact athletes [28]. Compared with characterized chondrocyte implantation, microfracture produced significantly lower histological scores for type II collagen and matrix proteoglycan content [29, 30]. The recent observation that primary marrow stimulation, including microfracture, can increase combined failure rate from secondary autologous chondrocyte transplantation from 17 to 50 % suggests that primary microfracture may have detrimental effects on subsequent cartilage repair attempts with other techniques. The reasons for this effect are not clear and require further investigation.

These findings emphasize the importance of clearly defining the indications for microfracture and the development of validated treatment algorithms for cartilage repair [31]. Incomplete peripheral integration with the surrounding native articular cartilage was seen in the majority of the patients (92–96 %) who underwent microfracture and was worst with poor-fill grade. Limited peripheral integration is important because it increases the susceptibility to shear forces seen especially in high-demand physical activities and raises the potential for repair cartilage deterioration and functional decline [28]. Implantation using a characterized cell therapy product resulted in significantly better structural regenerate tissue, based on cartilage biopsy, when compared with MF. Better repair tissue quality can be considered predictive of improved long-term durability [32].

Mithofer et al. [33] reported high return rates to sports after ACI in professional soccer players. Horas et al. [34] compared ACI with transplantation of an osteochondral cylinder and noted a similar improvement in activity levels (Tegner) over 24 months in both groups. When compared with pre-injury activity levels, MF-treated patients showed a significant reduction in activity levels compared to ACI at 1 and 2 years after surgery. In 2005, Gudas et al. reported superiority of mosaicplasty over microfracture in the treatment of small articular cartilage defects in young, active athletes [18, 19]. In this prospective, randomized study with an average follow-up of 37.1 months, only 52 % of microfracture athletes could return to sports at pre-injury level compared to 93 % of the mosaicplasty athletes. A recent study showed that despite similar success in returning to competitive sport, microfracture allows a faster recovery but presents a clinical deterioration over time, whereas arthroscopic second-generation autologous chondrocyte implantation delays the return of high-level male soccer players to competition but can offer more durable clinical results [35].

2. With non-contained lesions

The results of OATS are satisfactory at medium-to long-term follow-up in relatively small (not more than 2.5 cm^2) grade III or IV lesions of femoral condyles in young- and middle-aged patients. It is not indicated for the treatment of large chondral lesions because of technical difficulty and increased donor site morbidity [36]. Studies have shown that OATS gives encouraging clinical results after a mean period of 37 months, although MF appeared to deteriorate with time. OAT was found to be superior to MF at 37 months after surgery [18, 19] (Table 14.1).

14.2.3 In Patients >45 Years

1. Contained

Microfracture is a primary treatment option for full-thickness chondral lesions in patients more than 45 years of age.

2. Not Contained

In patients older than 40 years, outcome after microfracture is poor. Age-dependent qualitative and quantitative differences in metabolic activity and repair cartilage synthesis offer a biologic explanation for this effect, but other factors such as a slower overall recovery and increasing socioeconomic demands in older patients have also been suggested [37, 38].

Various studies have shown that microfracture and ACI are best suited for young patients 19. Therefore, in an attempt to improve the quality of the cartilage, investigators devised methods to replace rather than repair a cartilage defect. This involves allografts or autografts that fill the defect through a variety of techniques.

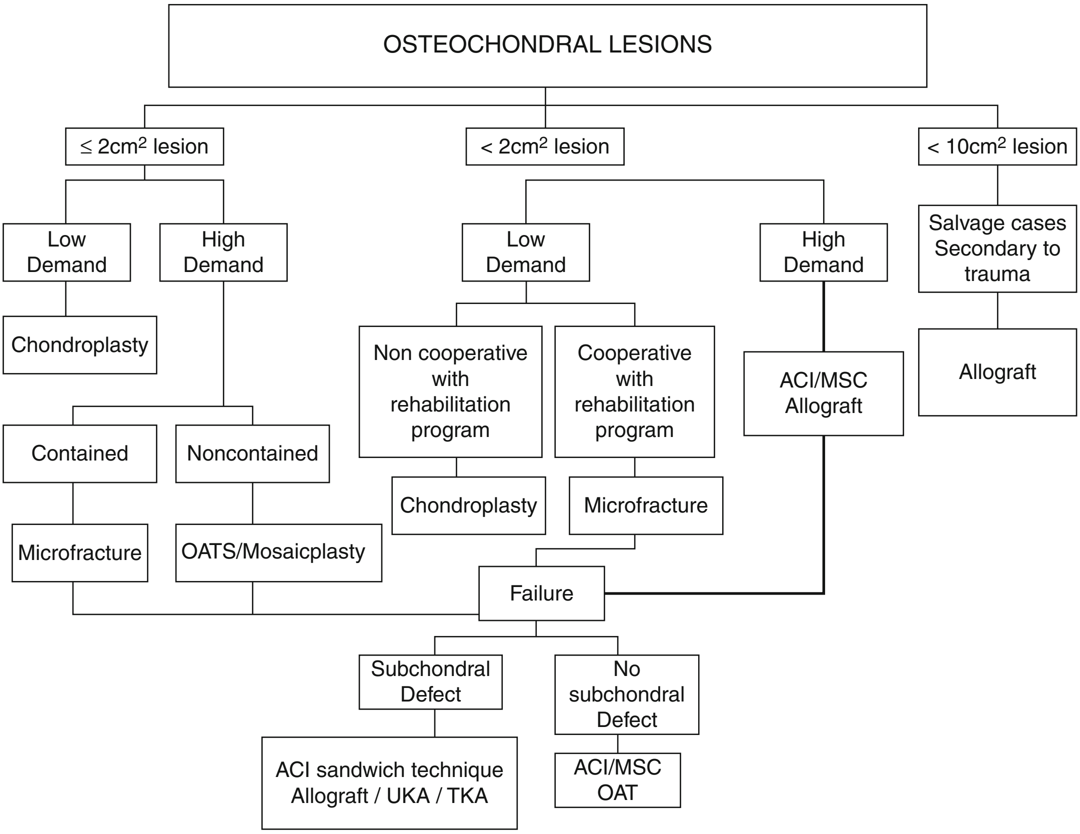
Osteochondral autograft transplantation is a viable source of hyaline tissue for articular cartilage defects. It is best suited for smaller lesions due to limited donor tissue availability.

Moreover, patients older than 45 years in the BMSC group had the same results as younger

Table 14.1 Age-based management of cartilage lesions less than 4 cm^2

Age-based management of small (<4-cm^2 cartilage lesions)							
Age	Adolescents	<45 Years				>45 Years	
Activities		Low demand		High demand		Low/high demand	
Containment		Contained	Not contained	Contained	Not contained	Contained	Not contained
Primary treatment	OCD: fix the fragment Other lesions: wait and watch	Microfracture	OATS, MSCs	MSCs	MSCs	Microfracture	OATS/Microfracture/or MSCs
Secondary treatment option		MSCs (or) Second-generation ACI		Second- and third-generation ACI		MSCs	Second- and third-generation ACI-allograft

Table 14.2 Treatment algorithm for patients with osteochondral injuries



Osteochondral lesions:
I. Adolescents
II. Age <45 years
    A. Low-demand patients:
        (i). Contained lesion
        (ii). Non-contained lesion
    B. High-demand patients:
        (i). Contained lesion
        (ii). Non-contained lesion
        III. Age >45 years:
    A. Low-demand patients:
        (i). Contained lesion
        (ii). Non-contained lesion
    B. High-demand patients:
        (i). Contained lesion
        (ii). Non-contained lesion

patients. This study demonstrated that the use of BMSCs was as effective as chondrocytes for articular cartilage repair. The use of BMSCs in cartilage repair undoubtedly offers advantages. Bone marrow biopsy is less invasive than knee arthroscopy, normal articular cartilage is not damaged and 1 less surgery is required; consequently, the cost is less [27] (Table 14.2).

14.3 Treatment of Cartilage Lesions >4 cm²

Henning Madry

14.3.1 Patients Younger than 20 Years

The main pathologies in children and young adults that result in defects larger than 4 cm^2 are trauma and osteochondritis dissecans [83]. Chondral defects can be treated by marrow stimulation such as microfracturing or abrasion arthroplasty, both of which usually show very good results based on the high endogenous repair activity in this patient population (Fig. 14.5) [84]. Refixation of an intact and large chondral or osteochondral fragment in <20-year-old patients is another important therapeutic option that restores the original articular surface [85]. In chronic cases, such as osteochondritis dissecans, extensive curettage of fibrous tissue and sclerotic subchondral bone followed by bone grafting at the lesion base is necessary. When the osteochondral fragment is destroyed, subchondral bone reconstruction followed by coverage of the defect with a membrane or performing an articular chondrocyte implantation (ACI) is possible; however, physeal closure is recommended for ACI [86].

14.3.2 Patients 20–60 Years

Traumatic defects and osteochondritis dissecans (young adults) are the key problems [83]. Here, ACI is the method of choice to treat large defects in patients above 20 years of age [87] (Fig. 14.6). Classically, ACI has been performed by injecting a chondrocyte suspension under a periosteal flap that covers the defect in a water-tight fashion [88]. Currently, biodegradable membranes (e.g. based on type I/III collagen), in which the chondrocytes are seeded prior to implantation, are used [87, 89]. Maximal defect sizes are 10–12 cm^2; however, there are also reports where defects of 15 cm^2 were treated [87, 89]. If the lesion extends into the subchondral bone, the ‘sandwich technique’ can be applied [32]. Here, the subchondral lesion is filled with autologous bone graft. Two major level 1 studies reported similar clinical results of ACI when compared with microfracture after 5 years ([20], [90]). Younger patients with a short duration of symptoms and no previous surgery show best results [91]. ACI is clinically superior to microfracture when defects are treated within the first 3 years since onset of the symptoms [90]. Besides mosaicplasty, autologous transfer of the posterior femoral condyle (mega-OATS) is an additional option [92].

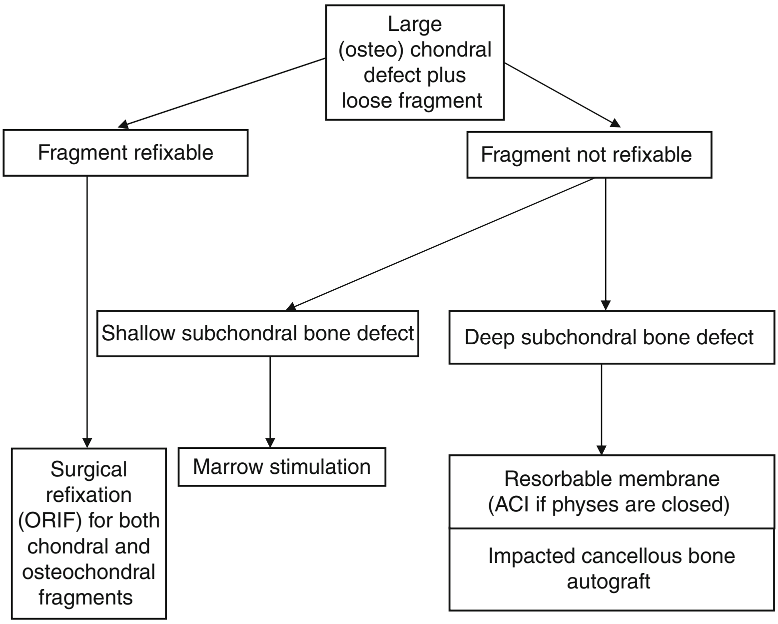


Fig. 14.5 Treatment algorithm, patients younger than 20 years and large defects

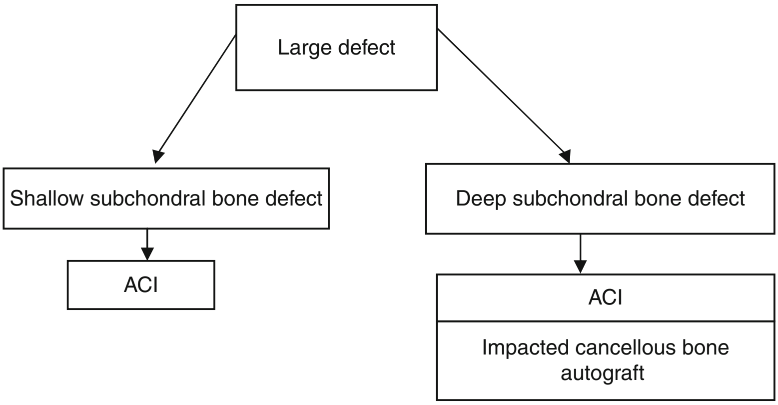


Fig. 14.6 Treatment algorithm, patients 20–60 years and large defects

High tibial osteotomy is the classical option for symptomatic early medial femorotibial osteoarthritis (elderly patients) in the knee with an intact lateral femorotibial joint in a patient with a genu varus deformity [91]. The ideal candidate is <50 years of age with stable ligaments without a higher degree of axial malalignment, a good range of motion and optimal BMI [93, 94].

14.3.3 Patients Older than 60 Years

Since patients above the age of 60 mainly suffer from osteoarthritis or from cartilage defects secondary to osteonecrosis (M. Ahlbäck), unicompartmental knee arthroplasty (UKA) and total knee arthroplasty (TKA) are indicated for large defects. Because of the lesser repair capacity in this patient population, marrow stimulation or ACI is not indicated. Since there is a considerable overlap in indications for UKA and HTO, HTO is another option [95].

14.4 How to Treat Cartilage Lesions in Patients with Osteoarthritis?

Andreas H. Gomoll

14.4.1 Introduction

Osteoarthritis is a very common disease affecting close to half the population at some point during their life and causing significant morbidity [39–52]. Unfortunately, treatment options for young arthritics remain limited: conservative measures provide symptomatic relief but do not stop or delay disease progression. Arthroscopic debridement has demonstrated disappointing results for the treatment of degenerative changes in the knee [53]. And while the outcomes of primary total knee replacement are generally excellent in older populations, it remains controversial for the treatment of young patients, since only approximately half of patients younger than 40 years report good or excellent functional outcomes after total knee replacement [54]. Cartilage repair techniques have demonstrated promising outcomes for the treatment of focal chondral defect [55]; however, more advanced stages of degenerative disease usually present as a constellation of articular comorbidities of which the cartilage is only one factor. Chondral damage in young osteoarthritic patients frequently is the result of chronic malalignment or maltracking, or due to prior injury to the menisci or ligaments. Unless corrected, these comorbidities will likely compromise the outcomes of cartilage repair. Therefore, even more so than for focal defects, the treatment of osteoarthritic lesions requires careful assessment of the entire joint with correction of all abnormalities. Lastly, we now better appreciate osteoarthritis as an osteochondral disease, rather than one just affecting the joint surface alone. Therefore, careful consideration has to be given to the underlying subchondral bone, which should be treated if abnormal.

14.4.2 Indications and Contraindications for Cartilage Repair in Degenerative Lesions

The decision to proceed with biologic, rather than prosthetic treatment in patients with osteoarthritis presents the first and most difficult step. Little data exist to guide surgeons as to what level of degenerative disease is still amenable to cartilage repair; hence, recommendations are based on expert opinion rather than rigorous controlled trials. One difficulty is the definition of osteoarthritis, which in our opinion is present when a joint demonstrates more than 50 % joint space narrowing due to bipolar defects without good circumferential containment. Likely, the most critical aspect of cartilage repair is the condition of the cartilage surrounding and opposing the defect. Defects contained by thick shoulders of surrounding cartilage are more easily treated with cell-based therapy than those defects where the surrounding cartilage is thin or nonexistent. Bipolar defects are frequently regarded as a sign of osteoarthritis, rather than focal cartilage damage, and are mostly considered a contraindication to cartilage repair in the tibiofemoral compartment. Conversely, bipolar defects in the patellofemoral compartment (where they are particularly common) that have good shoulders of surrounding cartilage with normal or near-normal-appearing radiographs are not a contraindication for cartilage repair.

14.4.3 Conclusion

Cartilage repair in patients with osteoarthritis remains a challenging and controversial subject. Its application should be reserved for the physiologically young patient who is not a candidate for alternative treatment options such as arthroplasty. The correction of comorbidities such as malalignment, meniscal and ligamentous insufficiency appears critical to improve outcomes.

14.5 Consideration of Religion/Food Habits While Selecting a Cartilage Product

Deepak Goyal

14.5.1 Introduction

Implantation of cultured chondrocytes along with various synthetic and biological scaffolds is getting increasingly popular [56, 57]. Some of the single-stage techniques do not use cultured cells but use biomaterials as scaffolds and glues to seal the defect. Apart from various biological, structural and mechanical properties that a scaffold must qualify, certain religious and cultural issues must also be taken into account. Some dietary or religious customs forbid the use of these substances from certain animal sources, and such issues may limit or prevent its consumption by certain people. While treating an ailment, such issues are of least importance to many, but still, for some, these issues are of utmost importance and can affect their religious sentiments. It is always better for a clinician to know what the source of the products he is using is. Sometimes, it will be on a safer side to cross-check the use of a particular product with a patient.

14.5.2 Different Religions and Restrictions

Muslims and Jewish: Muslim customs (*halal*) and Jewish customs (*kosher*[1]) may require materials from sources other than pigs, like cows and/or fish. Muslims may require to consume products coming only form animals slaughtered in the *Islamic* ritual manner. However, there are many different views to this, as some Muslims do not follow *halal*, yet do not eat pork [66]. Alcohol and blood products are also forbidden for Muslims.

Buddhists: There is no such clear distinction between permitted and forbidden foods in *Buddhism*, as against Muslims and Jewish customs. Meat and fish are not eaten by many people in the *Theravada* and *Mahayana* schools of Buddhism. Some believers in both *Theravada* and *Mahayana* are vegans, and some particularly from China and Vietnam do not eat onion, garlic or leek either – referring to these as the 'five pungent spices' [74].

Hindus: *Hindu* customs may require substance coming from sources other than animals. Many *Hindus* are strict vegetarians that mean they do not eat fish, meat, beef, poultry, eggs, pork or any animal product, except milk. Some Hindus are not vegetarian and do not mind product coming from various sources except cow, which is considered sacred.

Romani: *Romani* people are cautious of any products that may have been made from horses, as consuming horses is culturally forbidden to them.

14.5.3 Vegetarians/Vegans/Nondairy Vegetarians

Veganism is the practice of eliminating the use of animal products. *Ethical vegans* reject the commodity status of animals and the use of animal products for any purpose, while *dietary vegans* or *strict vegetarians* eliminate them from their diet only [67].

Another form, *environmental veganism*, rejects the use of animal products on the premise that the industrial practice is environmentally damaging and unsustainable. Vegans were defined as a vegetarian who eats no butter, eggs, cheese or milk [58]. However, there are 'nondairy vegetarians' also vegetarians who eat dairy products like milk, butter, etc. Some 'nondairy vegetarians' do not eat eggs also.

There are many companies that specifically indicate the source of the product used and let the consumers know this via various means. Same practice can also be followed by various cartilage product manufacturer companies.

Religious restrictions (*based on source of product*)

- Bovine: Not for vegetarian Hindus as well as non-vegetarian Hindus
- Porcine: Not for Muslims and Jews
- Any animal product: Not for vegetarian Hindus

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[1] Food in accord with *Halacha* (Jewish law) is termed *kosher* in English.

14.5.4 Source of Various Commonly Used Cartilage Products

Gelatin is derived from the collagen inside animals' skin and bones. Gelatin is an irreversibly hydrolyzed form of collagen and is classified as a foodstuff and therefore carries no E number [64]. Shells of pharmaceutical capsules are also made up of gelatin. Hypromellose is vegan-acceptable alternative to gelatin, but is more expensive to produce.

Acid form of *hyaluronan* is known as hyaluronic acid, and the salts as sodium hyaluronate. Hyaluronan is synthesized by a class of integral membrane proteins called hyaluronan synthases, of which vertebrates have three types: HAS1, HAS2 and HAS3. These enzymes lengthen hyaluronan by repeatedly adding glucuronic acid and N-acetylglucosamine to the nascent polysaccharide as it is extruded via ABC transporter through the cell membrane into the extracellular space. Bacillus subtilis recently has been genetically modified (GMO) to culture a proprietary formula to yield hyaluronans, in a patented process producing human-grade product [65].

Collagen [62] is a group of naturally occurring proteins found in animals, especially in the flesh and connective tissues of mammals. Porcine collagen and bovine collagen are commonly used sources.

Alginic acid [60], also called *algin* or *alginate*, is an anionic polysaccharide distributed widely in the cell walls of brown algae, where it, through binding water, forms a viscous gum. In extracted form, it absorbs water quickly; it is capable of absorbing 200–300 times its own weight in water. Its colour ranges from white to yellowish brown. It is sold in filamentous, granular or powdered forms. Sodium alginate is the sodium salt of alginic acid. Sodium alginate is a gum, extracted from the cell walls of brown algae. Potassium alginate is a potassium salt of alginic acid. It is an extract of seaweed. *Alginate hydrogel* used in some of the cartilage products comes from alginate.

Agar [59] or *agar-agar* is a gelatinous substance derived from a polysaccharide that accumulates in the cell walls of agarophyte red algae. Agar-agar is a natural vegetable gelatin counterpart.

Fibrin glue [63] (also called *fibrin sealant*) is a formulation used to create a fibrin clot. It is made up of fibrinogen and thrombin that are injected through one head into the site of a fibrin tear. Thrombin is an enzyme and converts the fibrinogen into fibrin between 10 and 60 s and acts as a tissue adhesive. Some of the fibrin sealants use bovine apoprotein that may not be acceptable to Hindus.

Chitosan [61] is produced commercially by deacetylation of chitin, which is the structural element in the exoskeleton of crustaceans (such as crabs and shrimp) and cell walls of fungi.

14.5.5 Disclaimer

1. Utmost care has been taken to ascertain the source of each product. But still, above table is for reference purpose only. There may be a case where modification of the source has been done by a particular company.
2. In no way it is intended to harm or disrespect any product.
3. The chapter is written with a purpose of informing clinicians and industry about various religious sentiments and possible restrictions.
4. This information may help clinicians and industry to avoid any complication arising after use of a particular product in a strict religious patient.
5. Information provided about various religions is also not complete. Basic guidelines have been drawn from various sources, so as to educate industry and clinicians about sentiments of various religions.
6. Clinicians and industry are advised to study each case individually and use best practice (Table 14.3).

Table 14.3 Various products, its contents and possible restrictions[a]

	Trade name	Constituents	Company	Used for	Possible religious restrictions
Cells	Carticel [72, 77]	Cells and DME medium	Genzyme Biosurgery, USA	ACI	None
Membranes	Chondro-Gide® [80]	Collagen membrane [21] made up of porcine collagen types I and III	Geistlich Pharma AG, Wolhusen, Switzerland	AMIC Techniques	Muslims, Jews, vegetarian Hindus
	Maix® [76]	Collagen membrane made up of porcine collagen types I and III	Matricel, Herzogenrath, Germany	ACI	Muslims, Jews, vegetarian Hindus
	Chondrotissue® [71]	Made of hyaluronan and polyglycolic acid (PGA) scaffold [13]	BioTissue Technologies, Freiburg, Germany	AMIC Techniques	None
Scaffolds	Cartipatch [81]	Ultrapurified agarose-alginate suspension	GelForCel; Tissue Bank of France	3-D Scaffold for ACI	None
	MACI® [76]	Cells seeded on membrane made of porcine collagen types I and III [18]	Verizon, Genzyme	ACI	Muslims, Jews, vegetarian Hindus
	ChondroCelect® [73]	Bovine serum [15]	TiGenix NV, Haasrode, Belgium		All Hindus
	Hyalograft-C® [75]	Hyaluronic acid	Fidia Advanced Biopolymers Laboratories, Abano Terme, Italy	ACI on Hyaff-11® Scaffold	None
	Hyaff-11® [75]	Hyaff® is a benzyl ester of hyaluronic acid [17]	Fidia Advanced Biopolymers Laboratories, Abano Terme, Italy	Scaffold-containing hyaluronan	
	Atelocollagen® [20]	Collagen type 1 gel, bovine dermis	Kouken Co., Ltd, Tokyo, Japan	Culturing medium for chondrocytes	All Hindus
	BioSeed®-C [70]	Cells embedded in a resorbable fleece together with a biological ‘glue’[12].Glue is either Tissucol Duo or Tisseel [11]	BioTissue Technologies, Freiburg, Germany	ACI	All Hindus if glue contains bovine material
	BST-CarGel® [82]	Chitosan [23]	Piramal Healthcare Canada Ltd	Chondroinduction	Vegetarian Hindus
Glues	Tissucol® [68]	Human fibrinogen, human thrombin, bovine apoprotein as stabilizing agent [10]	Tissucol, Baxter, Warsaw, Poland	AMIC Techniques	All Hindus

[a] While some of the products are restricted for dietary usage, they may not be restricted for surgical use. Religious restrictions described here are based on dietary restrictions

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Total Knee Arthroplasty: The Basics, Surgical Technique to Get Your Total Knee Arthroplasty Right

15

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15.1 Pearls for a Consistent and Reliable Exposure

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Total knee arthroplasty (TKA) is a successful procedure that is performed increasingly due to more present painful knee osteoarthritis. After a correct indication for a TKA, a good exposure during this procedure will assure a good clinical and radiological result.

A systematic approach to expose the knee joint will allow for a rapid and safe exposure even in severe deformities and complex cases.

The most performed approach to the knee joint in TKA is the *anteromedial incision* [26]. This approach starts 5 cm above the patella and ends at the medial part of the anterior tibial tubercle. In order not to compromise the vascularity of the soft tissue, no subcutaneous dissection should be performed before opening the superficial aponeurosis. This aponeurosis is a thin structure but easily distinguished from the subcutaneous fatty tissue. Once this aponeurotic plane has been reached, further dissection can be performed without any risk. The anterior plane of the patella is visualized up to the lateral part of the knee cap. The quadriceps tendon is seen superior to the patella, and below the knee cap, the medial part of the patella tendon is visualized (Fig. 15.1).

The anteromedial arthrotomy is then realized, beginning with a longitudinal opening medial to the quadriceps tendon (a midvastus, subvastus, or quad-sparing approach could also be considered) with a thin layer of the tendon left at the medial vastus muscle assuring and facilitating a firm closure at the end of the procedure. The incision is pursued on the medial part of the patella, and the arthrotomy continues at the medial border of the patella tendon ending at the superomedial part of its insertion on the anterior tibial tubercle. The medial meniscus is further on resected, and the medial capsule is released to the bone from its anteromedial part of the tibial plateau. This is the triangle detachment of the anteromedial capsulomeniscal tissue. The deep fibers of the medial collateral ligament are released on the superior part of the tibia plateau, and, consequently, the complete resection of the medial meniscus completes the visualization of the medial compartment of the knee joint.

The knee is then extended, and the patella is everted or luxated followed by flexion of the knee without any damage to the insertion of the patella tendon. The synovial tissue present anterior to the femur is extensively resected to visualize the supratrochlear region. The Hoffa fat pad could also be resected, and the lateral meniscus is then removed. To optimize the exposure, all the osteophytes are removed and the intercondylar notch is carefully cleaned up with removal of the anterior cruciate ligament (posterior cruciate ligament). The tibia could then be luxated anteriorly to give a full exposure of the tibia plateau, once again taking care of the insertion of the patella tendon.

Proper retractor placement will facilitate the procedure. A blunt Homann retractor at the medial femoral condyle will reduce the risk of any damage or transection of the medial collateral ligament. The same is true for protecting the popliteal tendon when performing the posterolateral femoral cuts.

The *lateral approach or Keblish approach* could be performed in a contracted valgus deformity and in the valgus knee combined to patellofemoral osteoarthritis with subluxation. This approach differs substantially from the standard medial parapatellar approach. The arthrotomy is performed lateral to the patella tendon, the patella, and the quadriceps tendon [28]. In cases where the luxation of the patella is difficult or when the visualization of the tibia plateau is insufficient, a tibial tubercle osteotomy could be performed [27]. When the valgus deformity is partially reducible, an inside-out lateral release with the piecrusting technique can be safely performed. If the deformity is contracted, a lateral epicondylar sliding osteotomy is a reliable technique to balance the replaced joint in flexion and extension. Care should be taken not to damage the popliteal tendon as this potentially will increase the flexion laxity.

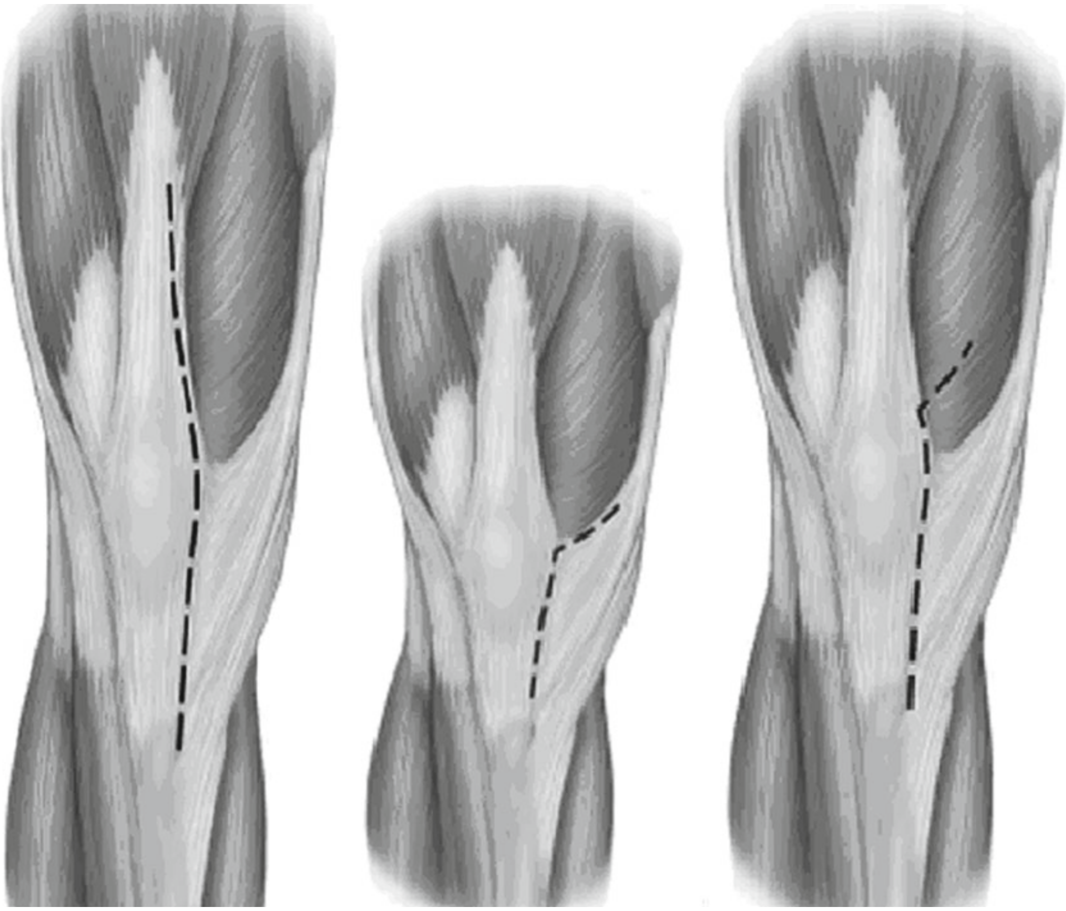

Fig. 15.1 Three different anteromedial approaches to the knee joint – parapatellar, subvastus, and midvastus

15.2 Joint Line Preservation in the Deformed Primary Knee

Paolo Adravanti

15.2.1 Introduction

The main issues of total knee arthroplasty (TKA) are (1) restoration of femorotibial alignment, (2) reproduction of similar flexion and extension space configurations, (3) soft tissue balancing, (4) optimization of the patellofemoral biomechanics, and (5) restoration of the joint line.

Joint line position is an important factor in overall functioning of the knee and therefore must be taken into account when performing total knee arthroplasty (TKA) [1]. Changes in joint line position are likely to have multiple effects involving the femoral-tibial articulation and the patellofemoral extensor complex. Indeed, a decrease in the Insall-Salvati ratio is associated with a reduction in knee joint function and in the ability to climb stairs [2, 3].

The preservation of the correct joint line strictly depends on the bone cuts and on the ligament balancing. Evaluation of the patellofemoral compartment is the key point to correctly perform the bone cuts. Moreover, the inextensibility of the patellar tendon is an essential parameter to choose the correct femoral size in order to obtain an ideal patellar height.

15.2.2 Surgical Approach

15.2.2.1 Joint Line Preservation in Extension

Starting from the distal femoral cut, it is important to remove the bone according to the thickness of the distal femoral prosthesis, but especially in the deformed knee, the loss of the cartilage needs to be taken in count. Indeed, when the jig gets in contact with the subchondral bone, surgeon should reduce the distal femoral resection in order to avoid elevation of the joint line. On the contrary, the thickness of the tibial cut does not affect the joint line since it is substituted by the tibial metal-backed component and by the insert.

The conservative distal femoral and the proximal tibial cuts have to be performed so as to use the minimum tibial PE insert; then, it is fundamental to obtain the balancing in extension avoiding over-release, in particular in deformed knees where over-release causes the elevation of the joint line.

15.2.2.2 Joint Line Preservation in Flexion

The main objective of this step is to reestablish the posterior condylar offset (PCO) (Fig. 15.2) since it allows a greater degree of flexion [4] and a correct positioning of the joint line. For this reason, bone cuts have to guarantee the same A/P size of the femur, considering the cartilage loss of the posterior femoral condyles. Therefore, surgeon should be able to predict the space in flexion before

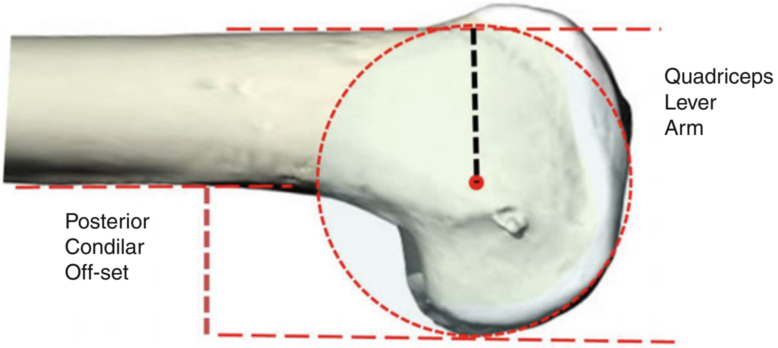

Fig. 15.2 The posterior condylar off-set and the quadriceps lever arm

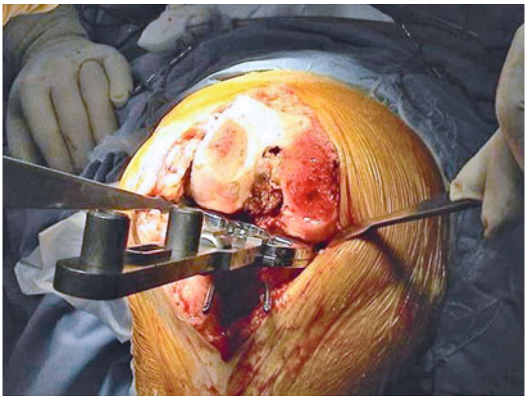

Fig. 15.3 Spacer used to analyse the amount of space in flexion

cutting the posterior femoral condyles. Moreover, the volume in flexion is strictly dependent from the type of implant (CR-PS) [5, 6]. This new volumetric concept is totally independent both from anterior and posterior reference instrument sets. Spacers that allow analyzing the amount of the space in flexion could be therefore very useful (Fig. 15.3). Another important issue concerns the reestablishment of the quadriceps lever arm (QLA) (Fig. 15.2), avoiding notching of the anterior femoral cortex and overstuffing of the patellofemoral joint [7].

Extra rotation can also affect joint line in flexion; indeed, many instrument sets used to calculate the extra rotation pivot centrally, increasing the resection of the posterior condyle medially and decreasing it in the same way laterally. Especially in the deformed knee, it would be useful to have jigs able to determine extra rotation pivoting on the medial femoral condyle, with reference just to joint line medially due to the patient-specific anatomic laxity of the lateral compartment in flexion.

To achieve an adequate joint line position, it is possible only with modular femoral components that differ minimally in size, which then allow to posteriorize as far as possible the component, while maintaining a correct anterior cut and particularly without compromising flexion and extension spaces.

15.3 Dealing with Fixed Flexion Deformity

Peter C.M. Verdonk, M.D., Ph.D.,
K. Fredrik Almqvist, M.D., Ph.D., and
Jan Victor, M.D., Ph.D.

15.3.1 Introduction

Flexion contracture (FC) is a common finding in the degenerative knee. The incidence is estimated to be approximately 30% of patients who are candidates for primary total knee arthroplasty. Most commonly, this deformity is caused by pain and effusion in combination with posterior femoral and tibial osteophytes. The posterior capsule is tented around these osteophytes, resulting in a functional shortening of the posterior capsule (Fig. 15.4). Often, flexion contracture is combined with angular deformities of the lower limb, most commonly varus malalignment. In a small number of patients, isolated bone deformities can explain the phenomenon.

In a large database, the mean flexion contracture was 5° in osteoarthritic joints, 10.5° in rheumatoid arthritis, and 14.1° in posttraumatic cases. Flexion contracture is also notorious in hemophilic arthropathy.

The importance of FC is illustrated by the effect it has on the outcome of primary TKA procedure: persistent FC after TKA results in a significant poorer clinical outcome and lower patient satisfaction. During normal gait, the knee is in full extension at heel strike and then gradually flexes during stance and swing phase. Inability to fully extend the knee will result in increased quadriceps contractions to prevent the knee from buckling. In addition, lack of full extension will shorten the leg, resulting in limping and potential pain in the hip and lower back. Flexion contracture should therefore be addressed during TKA and full extension should be obtained.

In this chapter, we will provide an overview of the known risk factors for persistent FC after TKA and provide a surgical algorithm to address FC during primary TKA.

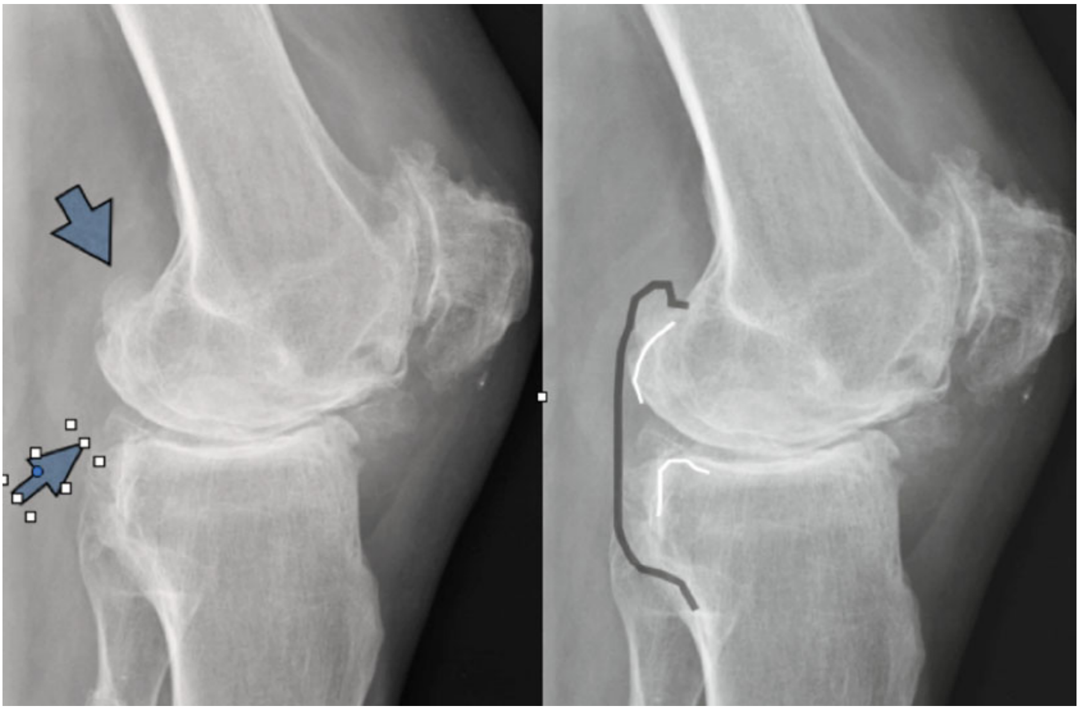

Fig. 15.4 Radiographs showing posterior osteophytes and the position of the posterior capsule

15.3.2 Patient-Related Risk Factors for Persistent Flexion Contracture After Primary TKA

Several patient-related risk factors have been identified for persistent FC after primary TKA. The incidence of FC after primary TKA was 3.6% at 2 years in a recent study. Men were 2.6 times more likely than women to have FC. Preoperative FC resulted in a 2.3 times increased risk for postoperative FC. Increased age was also associated with an increased risk. There was no significant difference in patients treated with navigated vs. conventional surgery nor did obesity influence the occurrence or persistence of FC after TKA.

15.3.3 Surgical Algorithm for Treating Flexion Contracture at Time of TKA

Flexion contracture is most commonly caused by a functional shortening of the posterior capsule. The functional shortening is a direct consequence of the tenting of this capsule around posterior osteophytes (Fig. 15.4). Most surgeons therefore proposed to meticulously remove all osteophytes especially in the back of the knee (step 1). If full extension is not yet achieved at this point, a progressive release of the posterior capsule and head of gastrocnemius is performed (step 2). Over-resection of the distal femoral cut by up to 4 mm can be deemed necessary if extension is not reached (step 3). A tenotomy of the medial hamstrings is only rarely necessary (step 4). In a recent study by Bellemans et al., full extension could be achieved in 98.6% of cases after steps 1 and 2. Even in flexion contractures greater than 30°, steps 3 and 4 had to be performed in only 29% and 23% of cases, respectively.

15.3.3.1 Tips and Tricks

Access to the posterior compartment of the knee can be challenging. Complete removal of all osteophytes is essential prior to any ligament release in extension and flexion.

To open up the posterior compartment in order to reach the femoral posterior osteophytes, a laminar spreader can be used in flexion (Fig. 15.5). Careful resection using a chisel or bone resector is advised (Fig. 15.6).

The posterior femoral capsular release can be performed using a rugine while always staying in

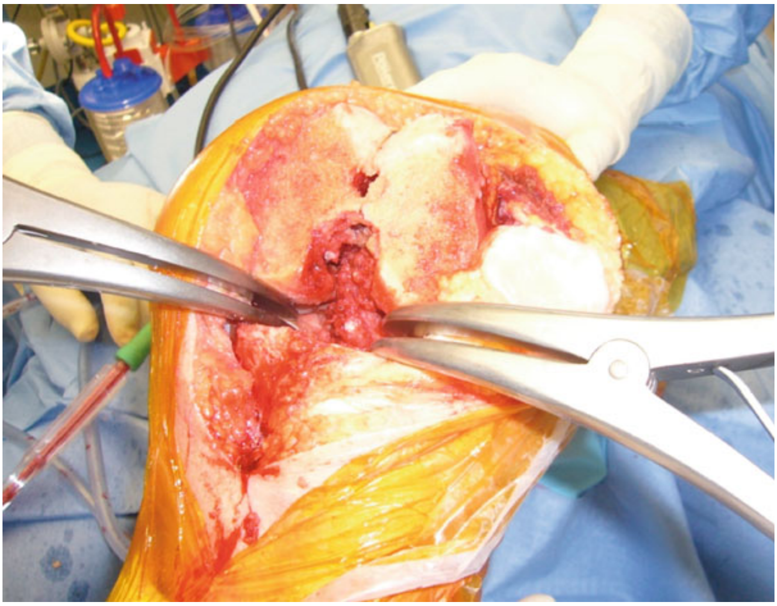

Fig. 15.5 Laminar spreaders are used to expose the posterior compartment in flexion

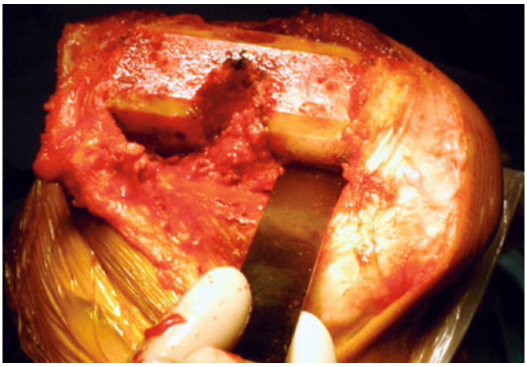

Fig. 15.6 Resection of posterior ostephytes

contact with the bone. A powerful trick is the use of swaps in addition to the rugine. This “volume” distraction results in a safe and soft release of the posterior capsule. On the tibial side, the posterior capsule can be released in flexion. To do so, the tibia is forced into external rotation and pushed forward of the femur. The attachment of the musculus semimembranosus is sharply dissected from the posteromedial corner of the tibia (Fig. 15.7). The capsule can then be further released from the posterior edge of the tibia onto the insertion site of the PCL.

The PCL does not contribute to flexion contracture as its release affects the flexion gap more than the extension gap.

15.3.3.2 Surgical Errors

Surgical errors and component malpositioning can also account for the occurrence of a flexion contracture postoperatively. A tight extension gap resulting from an insufficient resection of the tibia or distal femur often results in a flexion contracture. The surgeon should also be knowledgeable of the configuration of the prosthetic design. Excessive flexion of the femoral component can result in a post-cam conflict limiting full extension. Excessive tibial slope in combination with a tibial component with a high anterior buildup (ultracongruent) can result in anterior impingement and extension loss. In posterior-stabilized TKA, the cam has to consider the extra volume in between the condyles and can create an additional conflict with the posterior capsule in extension (Fig. 15.8). This may result in a FC. Therefore, the authors pay specific attention to the release of the femoral capsular attachments in the posterior notch area.

15.3.4 Postoperative Treatment

Postoperatively, an FC can develop based on intra-articular swelling and hematoma. Frequently, the patient will use a pillow or other bolster under the knee. If this occurs on a repeated basis in the first weeks, FC can develop.

Of interest is a recent study looking into the natural history of FC after TKA in patients with limited FC preoperatively (preoperative FC less than 15°). In that series, 10.5% of patients presented initial FC after TKA. The vast majority were diagnosed with a limited FC of less than 15°. 8.8% presented an initial post-op FC of more than

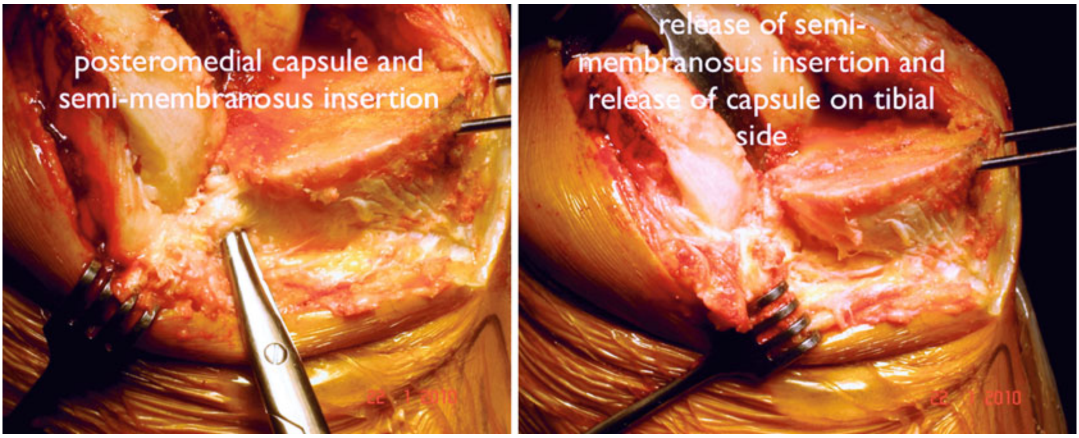

Fig. 15.7 Posterior capsule release on the tibia

Fig. 15.8 The cam of the femoral component of a posterior stabilized TKA (*center* and *right* pictures) creates an extra volume between the condyles, as compared to the femoral component of a PCL-preserving TKA (*left picture*)

15°. FC gradually improved in over half to normalize at 12 months. FC persisted in only 5.9% of patients. In another study, FC greater than 15° at 3 months had a tendency to persist at 2 years.

In the postoperative stage, physical therapy with focus on quad strengthening exercises and serial casting or splinting can be beneficial. However, correction can be slow and partial.

15.4 Rotational Alignment of the Tibial and Femoral Component

Victoria B. Duthon and Philippe Neyret

15.4.1 Introduction

Correct rotational alignment of the femoral and tibial component is an important factor for successful TKA. Rotational malalignment may lead to patellar maltracking, anterior knee pain, femorotibial flexion instability, and premature wear of the polyethylene inlay, leading to higher revision rates and less favorable clinical results.

15.4.2 Rotational Alignment of the Femoral Component

Femoral component rotation affects the kinematics of both tibiofemoral and patellofemoral joints after TKA. For example, a biomechanical study has shown that internal rotation of 5° causes tibial abduction at 90° of flexion, and external rotation of 5° causes tibial adduction at 90° of flexion [8].

Rotational alignment of the femoral component can be determined by two methods: a *technique based on bony landmarks* (also called "measured resection technique") and a *technique based on ligament balancing* (also called "gap balancing technique") described by Insall [9].

Several anatomical axes have been described to evaluate femoral component rotation (Fig. 15.9):

- *The transepicondylar axis* (TEA) defined as the line connecting the lateral epicondylar prominence and the medial sulcus of the medial epicondyle [10]. However, the epicondyles may be difficult to find during surgery because of the soft tissues. Then Yoshino et al. [11] defined a "clinical" and a "surgical" TEA. A recent anatomic study showed that using this axis as the only landmark to position the femoral component during a first intention TKA is not recommended [12].
- *The posterior condylar axis* (PCA) defined as a line connecting the posterior condylar surfaces of the femur; the mean angle between the PCA and the TEA is called "condylar twist angle" and is 4.7° for men and 5.2° for women.

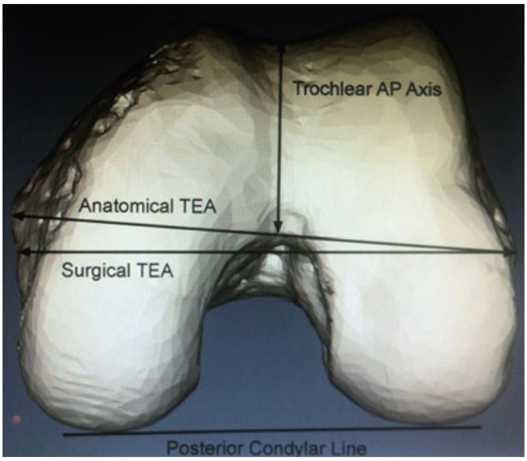

Fig. 15.9 Common axes used to evaluate femoral component rotation

- *The anteroposterior axis* (Whiteside's line) defined as the line connecting the deepest part of the patellar groove anteriorly and the center of the intercondylar notch posteriorly [13]; the mean external rotation of the anteroposterior axis relative to the PCA is 4°.

Based on those anatomic angles, surgeons commonly place the femoral component of a TKA in different ways:

- With a fixed external rotation of 3° relative to the posterior condylar axis, as proposed by many instrumentation systems, the idea is to compensate for the angular discrepancy that results from the proximal tibial cut because the tibial articular surface is in 3° varus in normal knees [14]; Akagi et al. ([15]) confirmed that setting the femoral component with an external rotation of 3°–6° relative to the PCA is appropriate in a knee with common varus or neutral alignment but is not recommended in cases of severe valgus deformity with abnormally small lateral condyle.
- Aligned with the PCA and then without any rotation.
- Aligned with the TEA or 4° externally rotated from the PCA, the anterior femoral cut then has a bimodal shape with the lateral peak twice the height as the medial peak: this is called the "grand-piano sign" [16].
- The technique of "condylar asymmetry report" (based on the TEA). In this technique, the

rotation depends on the asymmetry of the distal femoral cut. If the jig touches only the medial condyle, the distal cut will be bigger on the medial condyle than on the lateral one. This asymmetric cut is reported in flexion by turning the jig in order to cut less on the posterior lateral condyle than on the posterior medial condyle. This posterior cut will induce an external rotation of the femoral component equivalent to the asymmetry of the distal cut. This is even more important in severe valgus knees with hypoplastic external femoral condyle. However, in case of femoral varus (femoral mechanical angle < 90°), the asymmetric distal cut is not reproduced to prevent internal rotation of the femoral component. The cut is done with no rotation, and we accept some amount of residual femoral varus. Nevertheless in case of very severe femoral varus, one may consider a more constrained prosthesis or a correction of the femoral extra-articular deformity.

We apply the method of measured resection with condylar asymmetry report and subsequent ligament balancing according to the differential nature of the collateral structures between flexion and extension. Once correct bony alignment is achieved, any ligament imbalance can be corrected.

A preoperative computed tomography (CT) is recommended to evaluate individual morphology and to do a correct preoperative planning [17]. Indeed the optimal adjustment of femoral component rotation is individual and depends on the type of deformity and femoropatellar joint pathology. The results of radiographic measurement analysis will allow the surgeon to plan the operative strategy and select a suitable type of instrumentation system and implant.

15.4.3 Rotational Alignment of the Tibial Component

There is little consensus in the literature over the ideal rotational alignment of the tibial component. Internal rotation of the tibial component leads to subluxation of the patella and to stiff TKA [18].

Described landmarks are anterior tibial tubercle (ATT), PCL insertion, posterior tibial margin (PTM), and the widest dimension of the tibial surface.

Another option is the “self-seeking method” which aligns the tibial component according to the rotational alignment of the femoral component during trial reduction. This technique positions the tibial plateau parallel to the femoral component and prevents rotational discrepancy between femoral and tibial components [19]. However, the risk is to transfer a femoral malrotation to the tibia.

Most surgeons use the ATT as reference point. A recent study states that the medial third seems to be better than medial border of tibial tuberosity [20]. However, Bonnin et al. [21] recently showed that ATT is not a reliable landmark for rotation of the tibial component. Knee prosthesis is still essentially symmetrical, and design of the tibial component restricts the choice of rotational alignment because the goal is to optimize simultaneously prosthetic cut coverage and alignment with the extensor mechanism. He concludes that it is important to keep the centers of the prosthetic compartments on the centers of the osseous compartment. That often means no parallelism with the posterior tibial margin, which however has been described to be the least variable local landmark for tibial component positioning at deep resection levels (during TKA revision) [22].

To compensate for tibial malrotation, mobile bearing tibial plates can be used. They allow decoupling of bone coverage and rotational alignment either with fixed bearings, which allow rotation at the femur/insert interface, or with rotating platforms, which allow rotation at the insert/baseplate interface.

15.4.4 Evaluation of Rotational Alignment of the Tibial and Femoral Component

The postoperative radiological measurement of tibial and femoral component rotation is necessary when patients present knee stiffness, altered knee kinematics, or abnormal femoropatellar tracking. CT with a software lowering metallic artifacts is necessary in order to see bony landmarks important for measures [23]. The condylar

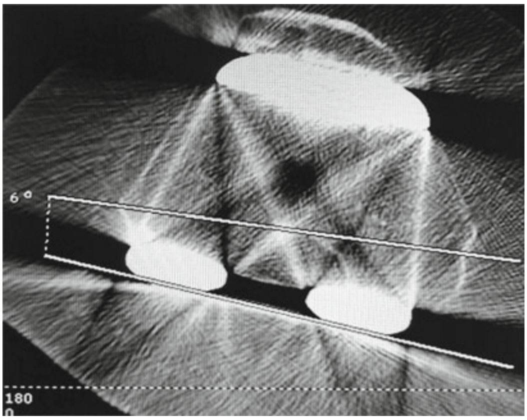

Fig. 15.10 Condylar twist angle measured on CT

twist angle should be measured for the femoral component (Fig. 15.10). The tibial component position is evaluated relative to the ATT or to the posterior border of the tibial condyles. Femoral component rotation alone can be measured on standard radiographs as described by Eckhoff [24] and Kanekasu [25], but it is less accurate than scanographic measures.

No "normal values" are described in the literature, but it is well known that internal rotation leads to poor outcome and that the condylar twist angle ranges between 0° and 7° in the majority of patients preoperatively. Considering that TKA aims at reproducing normal knee kinematics, this angle should approximate these values postoperatively.

15.4.5 Conclusion

Correct rotational alignment of femoral and tibial component of a TKA is crucial to obtain ideal femorotibial and femoropatellar kinematics and should be evaluated by CT in case of poor clinical outcome.

15.5 How to Achieve Tibiofemoral Stability

Jean-Louis Briard

Until today, surgeons are trying to approach "neutral" tibiofemoral alignment with bone cuts insisting that we should never overcorrect. As already addressed, they tend to preserve the joint line level by making the distal femoral cut with reference to the most prominent condyle [36, 39].

Next step is to achieve good ligament balance through the whole range of motion (ROM).

Stability is achieved by the design of the prosthesis (+ weight bearing) and the guiding of the capsule and ligaments which trigger muscular response.

When operating a deformed knee, the deformity must be analyzed:

1. Is there extra-articular (EA) deformity? The surgeons must know how to correct it: with an extra-articular osteotomy or with intra-articular release anticipating the consequences.
2. Is there flexion deformity?
3. What is the status of the collateral ligament frame in the concavity (retraction?) and in the convexity (elongation?)?

Stability in extension is provided by the posterior capsule and the posterior corners. But as soon as the knee bends, the collateral structures come into action and provide the medial and lateral stability through the whole ROM [37].

When the posterior cruciate ligament (PCL) is excised, this creates some tibiofemoral distraction or laxity between 3 and 7 mm at 90° flexion, which must be taken in account. This is one reason why PS surgeons use spacer block to decide of flexion and extension gaps.

If the surgeon wants to correct EA deformity inside the joint, he will have to create some coronal laxity in extension with a release of the concave posterior capsule, corner and collateral structures. If the deformity is femoral, this will also influence the balance of the flexion gap and the rotation of the femoral implant.

Next, the posterior capsule may need to be addressed after excision of the posterior osteophytes and release of adhesions. Retraction of the posterior capsule is responsible of coronal deformity. For example, retraction of the posterior medial capsule after long-standing inflammation is responsible by itself of fixed varus deformity near to extension. This will require release of the posterior capsule with the expansions of the semimembranosus including the posterior medial corner [41].

Then the real condition of the collateral ligament frame can be appreciated. In practice, for varus knee (after the excisions of all the osteophytes), a valgus stress is applied at 30° flexion:

1. If the knee is in neutral (provided that there is no convex laxity) and the collateral ligament frame is balanced, then the knee is brought in extension:
   - It is in neutral, the posterior capsule is fine.
   - It is still in varus, there is still retraction of the posterior structures which need to be released.
2. If the knee is in varus at 30° flexion, there is either EA deformity or the medial structures are contracted. A posterior and medial release should be performed until reaching neutral alignment at 30° and then at 0°.

The technique of release of the soft tissues must be progressive with sequential controls to avoid over-release and instability. Medial and lateral structures are quite different, but we should proceed from posterior to anterior. The release can be achieved with piecrusting technique or with a sleeve technique elevating the soft tissue from the tibia as in genu varum, a sleeve keeping all the structures together so that they remain strong and continuous.

Laterally, the soft tissues are more complex [40] and consist of posterior capsule (mostly the arcuate complex which is behind the popliteofibular ligament at the level of the tibial cut). Then the fascia lata may need piecrusting. If the knee is still too tight laterally, further piecrusting of the posterolateral structures will involve lateral collateral ligament, but the popliteus tendon must be preserved as a good secondary stabilizer. In case of significant femur valgum, a sliding lateral condylar osteotomy is a safe mean to open the space laterally and gives good access for safe release of the posterior capsule.

If after such releases, the medial lateral stability is not achieved, more constrained (VVC) designs may be necessary.

Excellent stability near to extension is essential for good gait with full extension. The fine tuning of the tension between collateral structures and posterior capsule is quite important and should avoid midflexion instability [38]. Instability after 30° and at 90° is still too frequent and leads to insufficient results which may require revisions (25% of early revisions are due to instability).

15.6 How to Achieve Correct Patellar Tracking

Andrea Baldini, M.D.

Total knee arthroplasty has been a successful procedure for various decades. Complications originating from the patellofemoral side compromised the results of TKA for several years. Actually, this aspect of the replaced knee does not represent anymore the most frequent source of problems, but it is often involved in postoperative residual pain or suboptimal results.

Functional result after TKA is now being emphasized, including maximal range of motion recover. Extensor mechanism management has a crucial role in this new challenge. Optimization of the technique for patella resurfacing can eliminate postoperative complications from this source and guarantee an excellent extensor mechanism function even in the presence of high demand.

Based on the literature review, we believe that patella resurfacing can achieve the best results with the following guidelines:

- Have a low threshold to resurface the patella.
- Consider to leave the patella unresurfaced (with a proper patient's consensus) if intraoperative PF tracking is good, mostly in male patients or in relatively young (<65 years) patients.
- Resect the same amount of bone you replace (final composite thickness should be equal or 1–2 mm less than the initial one).
- Double check the symmetry of the patellar bone remnant in all quadrants (refer to the anterior patellar surface).
- Resurface the patella with a cemented all-polyethylene three-pegged dome component.

Tibiofemoral design features to patellofemoral complications	
Short trochlea	Cannot guide patellar tracking adequately
	May facilitate clunks (particularly in PS knees)
Shallow trochlea	Does not capture the patella enough throughout ROM leading to patellar instability
Femoral flange with high lateral ridge	May increase tension on lateral patellar retinaculum, increasing patellar tilting and shear forces
Prominent shoulder (femoral "boxy" profile)	Increases PF joint force in flexion
	Facilitates synovial entrapments (clunks/crepitus)
Thick anterior femoral flange	Contributes to overstuff the anterior compartment in flexion
Prominent anterior wall of polyethylene insert	Patellar tendon impingement in flexion (particularly in deep dishes)
Highly constrained tibiofemoral joint	Does not accommodate for knee rotation leading to patellar instability (particularely in fixed hinges)
Tibiofemoral factors related to patellofemoral complications	
Anteriorized femoral component	Overstuff anterior compartment thereby increasing patellar strain
Flexed femoral component	Same as before (only in early flexion) if femoral flange is proximally elevated
Medialized femoral component	Increases the Q angle
Internally rotated femoral component	Increases PF joint shear forces leading to maltracking with tilt and subluxation
Excessively externally rotated femoral component	May add tension to the medial patellar retinaculum causing patellar maltracking
Excessive valgus femoral component	Medializes the trochlea leading to maltracking
Overall excessive valgus alignment	Increases the Q angle leading to maltracking
Anteriorized tibial component	May overstuff the anterior compartment impinging the patellar tendon
Internally rotated tibial component	Increases the Q angle leading to maltracking
Raised joint line	Causes patella baja with abnormal PF kinematics
Absent femorotibial rollback	Increases PF strain in flexion

- Medialize the component and chamfer the excessive uncovered lateral bone to avoid bone-implant impingement.
- If maltracking is evident with trial components, recheck component rotation, cement the final components, deflate the tourniquet, and check it again, pulling the slack of the quadriceps tendon superomedially.
- If a lateral release is required, perform a lateral subperiosteal peel of the retinaculum. If it is not enough, perform a release with multiple punctures into the tight retinaculum avoiding the SLGA.
- Check patellar alignment and tracking at follow-up with a standing patellar axial view.

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Elbow Arthroscopy

16

W. Jaap Willems, Luigi Pederzini, Paolo Arrigoni,
François Kelberine, and Marc R. Safran

Contents

16.1 Introduction

Arthroscopy of the elbow is not performed as commonly as many of the other joints of the body. There are several reasons for this: first is the relative unfamiliarity of elbow arthroscopy techniques, second is the concern about neurovascular risk when performing elbow arthroscopy, third is the limited maneuverability in the joint that makes the procedure somewhat more difficult than some other joints and fourth is the relatively limited number of indications for elbow arthroscopy.

This chapter (and ICL) will demonstrate that elbow arthroscopy is not that difficult and that complications can be minimized by adhering to basic principles and paying attention to detail. We will also demonstrate that there are many indications where elbow arthroscopy is not only indicated but the favorable approach to manage problems about the elbow.

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16.2 Portals and Anatomy

W. Jaap Willems, M.D., Ph.D.

16.2.1 Positioning

Three positions of the patient can be utilized in elbow arthroscopy: supine, lateral decubitus, and prone.

In daily practice, the approach with the patient in lateral decubitus and supine position is more convenient for the anesthetist. In the supine position, the arm should be suspended to achieve distraction. A counterweight hanging on the upper arm will help to increase the distraction. In the lateral decubitus and prone position, the upper arm rests on a support with the lower arm hanging in about 90° of flexion. The gravity will assist in distraction of the joint. The support for the upper arm should be high enough to enable more flexion of the elbow during the procedure. The advantage of the latter positions is the free mobility of the elbow compared to a fixed position in the supine position.

Generally, a patient is operated under general anesthesia, although regional anesthesia (plexus block) can be used. A tourniquet is preferred to enable a bloodless and thus safer and more efficient procedure. Standard equipment, like a 4.5-mm arthroscope and standard shaver can be used in general, although it is advisable to use a 2.7-mm scope in younger patients (Figs. 16.1, 16.2, and 16.3).

16.2.2 Portals and Anatomy

The anatomic structures most at risk are the *ulnar nerve* dorsally and the deep branch of the *radial nerve* ventrally. The median nerve and brachial artery are at less risk while they are separated from the joint by the brachial muscle.

After inflating the tourniquet, disinfection of the skin and draping it is advisable to mark the portals and even more the ulnar nerve. An important trick for the beginner, especially when one is confused by the prone position, is the rule of thumb that the radial head is always at the side of the head of the patient.

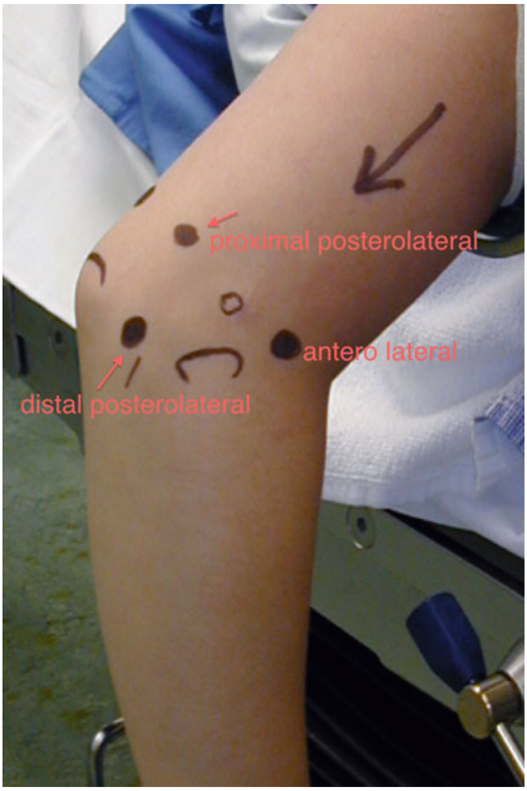

Fig. 16.1 Lateral view of the right elbow, patient in prone position

The joint is inflated with physiological saline through the distal posterolateral portal in the soft spot between capitellum and radial head posteriorly. The proof of an adequate insufflation is the extension of the elbow once enough intra-articular pressure is reached.

The safest entry for the arthroscope is through the proximal medial portal: about 5 cm proximal of the medial epicondyle, a small skin incision is made; with the trocar and sheath, the intermuscular septum is palpated, and staying ventral to this structure, the sheath and trocar are directed to the center of the ventral part of the joint to penetrate the distended capsule.

An alternative portal to start the procedure is the anterolateral portal, about 1 cm distal and 1 cm ventral from the lateral epicondyle. Care

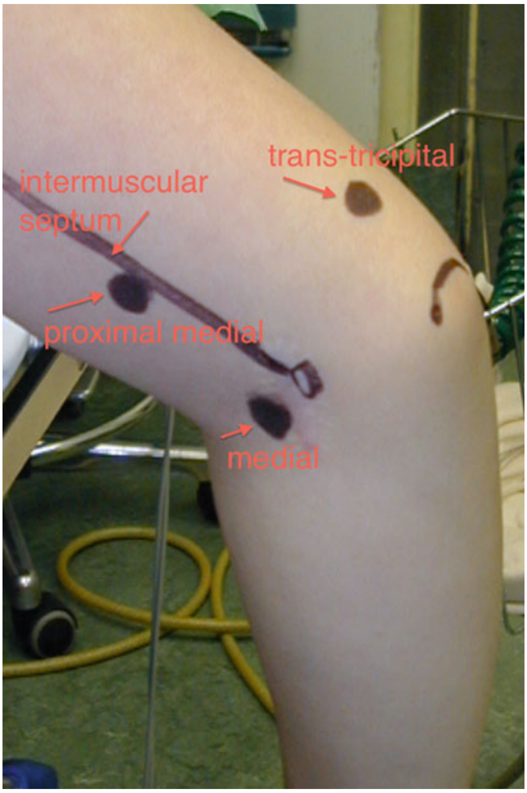

Fig. 16.2 Medial view of the right elbow

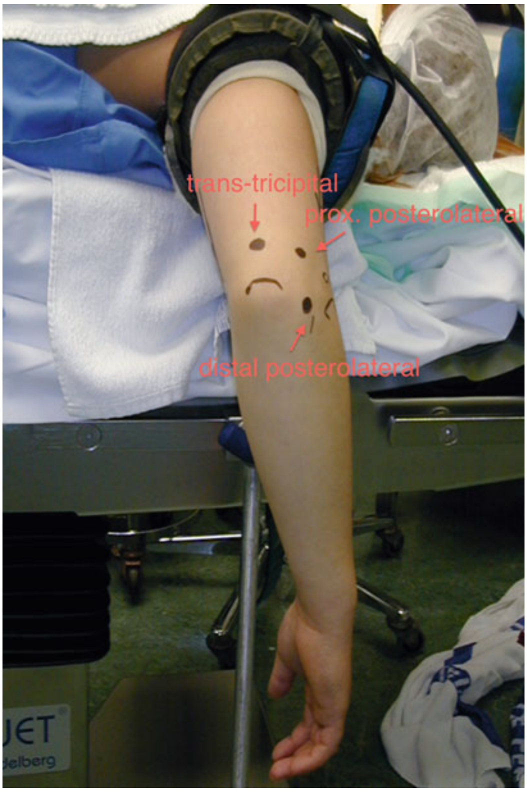

Fig. 16.3 Dorsal view of the right elbow

should be taken to aim the scope in the direction of the joint to prevent damage to the deep branch of the radial nerve, which passes outside the capsule, just ventral to the radial head and lateral to the brachial muscle.

When viewing from the proximal medial portal, the anterolateral portal is made by first introducing a needle from outside in at the proper level, preferably at the level of the joint line, to facilitate surgical procedures.

For surgical procedures in the ventral part of the joint, the medial portal can also be utilized: it is located just in front of the joint and is a safe portal while no neurovascular structures are nearby, as long as the trocar is directed toward the joint line. A switching stick from the anterolateral portal can be used to create the medial portal.

Through these two or three portals, a complete inspection as well as surgical procedures can be performed in the ventral part of the elbow, like removal of loose bodies and ventral osteophytes, synovectomy, tennis elbow release, and arthrolysis.

The distal posterolateral, which was used to inflate the joint, can be used to inspect the posterior part of the radiocapitellar joint, radial head, and dorsal capitellum, the preferred place for OCD lesions. Medially, the trochlea of the ulna and the proximal radioulnar joint can be inspected.

When using a 2.7-mm scope, an adjacent portal in this soft spot can be used for the shaver or instruments to treat OCD lesions.

The proximal posterior compartment of the elbow joint can be inspected through the transtricipital portal, aiming at the center of the olecranon fossa. A portal lateral to this portal is the proximal posterolateral portal, running through the triceps muscle as well. With these two portals, a complete overview of the dorsal part of the elbow joint can be achieved, both at the ulnar side and lateral side, where one can see the posterior capitellum and radial head.

If necessary, extra portals can be used, taking into consideration not to jeopardize the ulnar nerve. All procedures in the posterior compartment can be performed, like tennis elbow release, arthrolysis, removal of loose bodies and osteophytes, treatment of OCD lesions, and synovectomy.

16.3 Arthroscopic Treatment of the Stiff Elbow

Luigi Pederzini, M.D.

Stiff elbows can be classified in intrinsic, extrinsic, or mixed causes. Posttraumatic or degenerative causes can also result in an arthrofibrotic or arthritic elbow. A possible posttraumatic initial cause can produce a degenerative stiff elbow. The ideal situation for arthroscopic management of the stiff elbow is when bone congruency is maintained. In cases of bony ossifications in the capsule, when there is combined retraction of medial and lateral collateral ligaments and/or there has been previous surgery with transposition of the nerves, open surgical treatment is preferred.

The arthroscopic technique of the stiff elbow mainly consists of (a) prone positioning or lateral decubitus, (b) general and brachial plexus anesthesia, (c) ulnar nerve isolation (open), and (d) three posterior portals and two anterior portals (associated portals for retractors can be used posteriorly or anteriorly). The approach is posterior and anterior debridement, followed by posterior and anterior capsulectomy, then removal of hypertrophic olecranon and coronoid tissues, and then removal of osteophytes.

We have studied 220 cases of stiff elbow treated arthroscopically with an average follow-up of 24 months. There were 126 degenerative and 94 posttraumatic cases of stiff elbow. Patients were evaluated by an independent/external observer using the Mayo Elbow Performance Index (MEPI), a visual analogue scale (VAS) as well as measurement of elbow range of motion (ROM).

Results: ROM extension average increased 28°, while elbow flexion increased an average of 25°, with an average increase in flexion/extension arc of 53°. In 60%, the pain disappeared, while 30% of patients had mild residual pain, and 10% had residual pain. The MEPI demonstrated excellent results with males scoring 89 points and females 90 points.

There were some complications in these difficult cases. There were 4 superficial portal infections, 18 synovial fistula, 1 neurapraxia of the posterior interosseous nerve, and 3 recurrences of heterotopic ossification.

This technique allows a perfect view of all different intra-articular areas. Particular care must be taken in respecting nerves: ulnar nerve can be isolated before we start arthroscopy in order to allow a better rehabilitative flexion program. During the arthroscopic procedure, a retractor can be positioned under the triceps recess to protect the nerve in performing posterior fossa debridement or removing osteophytes from the cubital canal. The radial nerve is extracapsular just anterior to the radial head after anterior capsulectomy can be thoroughly arthroscopically isolated. Median nerve is extracapsular anterior to the coronoid and the brachialis muscle. We have to remember that in stiff elbow, the muscle can be very thin and the nerve not so far.

Managing the stiff elbow requires some experience in elbow arthroscopy before being undertaken. After developing experience, we can affirm that elbow arthroscopy for the stiff elbow is a high demanding technique that can permit optimal results following guidelines regarding anatomical portals, intra-articular technique, and indications.

Taking in consideration elbow arthroscopy in treating elbow stiffness and thoroughly examining our results, we can conclude:

(a) A large number of cases are due to previous incomplete surgical technique. Reconstruction of ligaments and fixing fractures are mandatory in order to decrease late complications and late stiffness.
(b) On the other hand, some very difficult cases can expose to the risk of stiffness, and we can accept this risk due to immobilization and slow rehabilitation.
(c) Some very well-defined fractures (radial head particularly) must be treated anatomically. The higher percentage of stiffness in our registry is due to incomplete treatment of radial head fractures.

16.4 Osteochondritis Dissecans (OCD)

Paolo Arrigoni, M.D.

Osteochondritis dissecans was first described in 1887 as an inflammation of the bone–cartilage interface. Many other conditions were once confused with OCD when attempting to describe how the disease affected the joint. Some authors have used the terms osteochondrosis dissecans and osteochondral fragments as synonyms for OCD.

OCD is a joint disorder of the articular cartilage and the underlying subchondral bone caused by blood deprivation in the subchondral bone. This loss of blood flow causes the subchondral bone to die in a process called avascular necrosis. The bone is then reabsorbed by the body, leaving the articular cartilage prone to damage. In osteochondritis dissecans, fragments of cartilage or bone become loose within a joint, leading to pain and inflammation.

Despite much research, the causes remain unclear but include repetitive trauma, which leads to microfractures and sometimes an interruption of blood supply to the subchondral bone determining restriction of blood flow [1]. Interestingly, there is a lack of inflammatory cells in histology that suggests to exclude an inflammatory cause. Some recent studies support that some people may be genetically predisposed to OCD [2].

Four minor stages of OCD have been identified after trauma. These include revascularization and formation of granulation (scar) tissue, absorption of necrotic fragments, intertrabecular osteoid deposition, and remodeling of new bone. With delay in the revascularization stage, an OCD lesion develops.

OCD usually causes pain and swelling of the affected joint which catches and locks during movement. Physical examination typically reveals an effusion, tenderness, and crepitus. People with OCD report activity-related pain that develops gradually. OCD can be difficult to diagnose because symptoms are in common with other disease.

The disease can be confirmed by X-rays, computed tomography (CT), or magnetic resonance imaging (MRI) scans. OCD is classified by MRI or by arthroscopy of the joint and represented in stages I, II, III, and IV of disease progression [3]. Stages I and II are stable lesions. Stages III and IV describe unstable lesions in which a lesion of the cartilage has allowed synovial fluid between the fragment and bone. Symptoms typically present within the initial weeks of stage I; however, the onset of stage II occurs within months and offers little time for diagnosis. The disease progresses rapidly beyond stage II as OCD lesions quickly move from stable cysts or fissures to unstable fragments. If left untreated, OCD can lead to the development of degenerative arthritis secondary to joint incongruity and abnormal wear patterns [1, 4].

16.4.1 Elbow OCD

Osteochondritis dissecans of the elbow is a pathology of cartilage and subchondral bone with a high incidence between 10 and 15 years involving generally capitulum humeri [5, 6]. It begins after the complete ossification of capitulum humeri and must be distinguished from Panner's disease. This is an osteochondrosis of the capitulum in patients between 7 and 12 years of age during the ossification phase [7]. The initial symptoms are moderate pain with an extension deficit of 5–20°. Pain can be greater at the lateral side of the elbow. Symptoms can resolve spontaneously without sequelae. OCD symptoms include unlocalized pain and muscular contraction. Initially, X-ray may be negative, then intra-articular fragments may appear, and modifications of the shape of capitulum humeri are often present.

Nonsurgical treatment including modified activity immobilization is rarely an option as the capacity for articular cartilage to heal is limited. Surgical treatment varies widely and includes arthroscopic drilling of intact lesions, securing of cartilage flap lesions with pins or screws, drilling, mosaicplasty, and osteoarticular transfer system (OATS) [3, 8, 9].

Generally, if there is no evidence of healing, and the articular cartilage is intact, drilling is often recommended to stimulate a healing response. Arthroscopic drilling may be performed by using an antegrade (from the front) approach from the joint space through the articular cartilage or by using a retrograde (from behind) approach through the bone outside of the joint to avoid penetration of the articular cartilage [3, 8, 9].

If the articular cartilage is violated, then the options are to remove the fragment or to refix the fragment in its native bed either with pins or screws. If the fragment is not reparable or absent, then the options are to debride, microfracture, or fill the defect. A method used to promote normal articular cartilage replacement in the setting of an empty defect is autologous osteochondral plugs. OATS plugs can be taken from the lateral facet of the patella or lateral trochlea with the patient positioned in lateral decubitus position harvesting the cylinder from the ipsilateral knee.

16.5 Arthroscopic Treatment of Epicondylitis

François Kelberine, M.D.

“Lawn tennis elbow” was described by Morris in 1882. Nirschl used the term of “angiofibroblastic tendinosis” due to the absence of inflammatory cells. The common extensor tendon experiences high stresses leading to microtears and partial degeneration of the tendon attachment [10]. A recent study showed a hypovascular zone at the lateral epicondyle and another 2 cm more distal to the insertion [11]. The normal tissue of the extensor carpi radialis brevis (ECRB) and the extensor digitorum communis (EDC) tendons is invaded by immature fibroblasts with mucopolysaccharide infiltration, bone formation, and vascular proliferation [12, 13]. The lack of efficacy of the multiple nonoperative and surgical treatments is evidence of our misunderstanding of the disease.

Population at risk for this problem is between 35 and 50 years old, with an equal sex ratio [14, 15]. The pain at the lateral elbow radiates to the forearm with tenderness at the epicondyle and pain with dorsal wrist flexion and resisted elbow extension. The grip is weakened [16]. The examination should rule out other causes of elbow and forearm pain as entrapment of the posterior interosseous nerve sometimes combined with epicondylitis [17], referred pain from cervical or OCD of the capitellum.

On X-rays, 19% had a calcification along the lateral epicondyle [18]. Common findings with ultrasound include calcification of the EDC tendon, focal hypoechoic area, partial discrete cleavage tear, and some heterogeneity [19, 20]. MRI shows microtears in T1 signal with a thickening and edema in T2 within the common extensor origin [21–23].

Ultrasound sensitivity is 64–82% compared with MRI one from 90% to 100% [24].

16.5.1 Conservative Treatment

Cyriax in 1936 reported that “spontaneous cure is probable from 8 to 12 months” [25].This is supported by various studies that include a “wait-and-see” attitude [26]. Proximal forearm splints place a compressive force on the muscle bellies so decrease the stress at the extensor origin and limit the muscle excursion.

Different types of injection are also used. The most common is a combination of anesthetic and corticosteroid. The literature shows early pain relief but with high recurrence rates [27–29]. However, at 1 year, there is no significant difference compared with other treatments [30].

Other injections include autologous blood, botulinum toxin, or glycosaminoglycans.

Rehabilitation includes deep friction massage, strengthening, and stretching protocols. Recent studies compared rehabilitation to other treatments without difference in long-term outcomes [26, 31, 32]. Physiotherapy (as ultrasound) is often combined with rehabilitation. For some authors, it improves effectively function and pain in two-thirds of patients [33]; however, in other randomized controlled trials, this has not been supported [34–37]. Low electrical current (like phoresis) drives topical medications (as cortisone or nonsteroidal anti-inflammatories) to the deeper soft tissues [38, 39]. A recent meta-analysis about extracorporeal shock wave therapy (ESWT) versus placebo with more than 1,000 patients concluded that there was no benefit [40] even though one randomized prospective study reported significant improvement versus control group [41]. Laser therapy and acupuncture have also been proposed.

The vast majority of cases respond to conservative therapy. Little data supports one method over others Anyway, a prospective study reported that these treatments get a similar onset than simple observation, and it may take up to 18 months to full recovery [42]. Surgery is recommended after failed conservative treatment.

16.5.2 Operative Treatments

Multiple techniques have been described to treat epicondylitis, including the release of the common extensor origin ECRB and EDC (open, arthroscopic, or percutaneously with or without repair), debriding the pathologic tissue, and sometimes releasing the posterior interosseous nerve.

Open release or lengthening of ECRB and EDC tendons is performed from their attachment on the lateral epicondyle [18, 43–47] with a high rate of good results (73%) and return to work (97%) [48, 49].

Another open technique described is microtenotomy using a radiofrequency probe with a significant decrease in pain and disability at 2-year follow-up [50].

The debridement of granulation tissue was part of the first described treatment with removal of necrotic tendon, inspection of the radiocapitellar joint, and decortication of the epicondyle [51]. Drilling is an alternative to decortication [52]. Reattachment of the tendon has also been suggested with good results [53, 54].

All these surgical techniques could be effective because they denervate the area [55, 56]. Overall detachment seems the main prognostic factor of success [44, 49].

As posterior interosseous nerve entrapment can be a predominant cause of lateral elbow pain in up to 30% of patients [57], it can coexist with epicondylitis. However, the results of decompression of the arcade of Frohse give no difference with the lengthening the ECRB tendon [18, 58].

Percutaneous technique is done after lidocaine infiltration. An incision with a number 11 blade straight to the bone results in a release with a palpable defect in the extensor origin. Good results have been reported up to 90% at a 3-year follow-up [59–61]. In this technique, patients return to work significantly earlier (2 vs. 5 weeks) with a better subjective satisfaction rate [62, 63].

The first arthroscopic attempt was made through extra-articular endoscopy [64].

The real arthroscopic approach is excellent alternative to the treatment of lateral epicondylitis, allowing an intra-articular assessment and a reliable release of the tendons involved. Baker described an arthroscopic classification of capsular tears associated with lateral epicondylitis: type I with an intact capsule, type II with a linear tear, and type III with a complete tear [65]. Additional arthroscopic findings include degenerative fringe of tissue and radiocapitellar chondropathy [65, 66].

The feasibility and reproducibility of release of the affected tendons have been confirmed [67, 68]. Technically, to avoid harm to the LCL, the release must stay in front of the lateral crest of the epicondyle and the equator of the radial head. The landmarks are the cartilage of the capitellum at the upper part and the joint line level [68, 69]. The arthroscopic release reported significant improvement in this symptoms with a quicker return to work [65, 70–74].

16.6 The Role of Arthroscopy in Elbow Instability

Marc R. Safran, M.D.

The role of arthroscopy in the setting of elbow instability is continuing to evolve. Recurrent elbow instability is uncommon and may be valgus laxity and/or varus laxity of posterolateral rotatory laxity/instability.

Posterolateral instability (PLRI) is the result of injury to the lateral ulnar collateral ligament (LUCL) where the radial head subluxates posteriorly to the capitellum while the proximal radioulnar relationship remains normal. Essentially, the ulna hinges open within the trochlea. This injury usually is associated with the residuals of elbow dislocation, though may be the result of varus stress or may be iatrogenic – such as after tennis elbow surgery or radial head surgery.

The role for arthroscopy for PLRI is to help confirm the diagnosis. With the elbow in the posterior or posterolateral portals, one can see posterior radial head subluxation with supination of the forearm. Recently, Savoie has reported his results of an arthroscopic plication of posterolateral capsule for the treatment of PLRI with excellent results [75].

Medial Instability is usually the result of injury to the ulnar collateral ligament (UCL). UCL injury may be the result of an acute rupture (valgus overload or dislocation), chronic attenuation, or what is seen most commonly in overhead athletes, an acute rupture of a chronically attenuated ligament. In the overhead athletes, it is usually the anterior oblique ligament of the UCL that is injured in throwing athletes.

It may be difficult to make the diagnosis of an UCL injury, as the amount of laxity is subtle, MRIs may show damage in "normal" UCLs of asymptomatic athletes. As a result, arthroscopy may play a larger role in the diagnosis of UCL injury than PLRI. It is important to note that one cannot see the whole UCL arthroscopically (Andrews) [76]. Andrews showed that one can only see approximately 20% of anterior oblique portion of the UCL and only 30–50% of the posterior oblique ligament. Importantly, the amount of laxity seen during stress testing is not large. In 1996, Field and Altchek studied UCL injury in cadavers [77]. They performed valgus stress tests in cadaveric elbows, with the elbow in 60–75° of elbow flexion and the forearm in pronation. With an isolated anterior bundle UCL injury, there was only 1–2 mm of gapping between the coronoid and trochlea and only 4–10 mm of opening with a complete UCL injury. Timmerman and Andrews also showed that the best position to evaluate UCL injury via arthroscopic stress testing was with the forearm in pronation and the elbow in 70° of elbow flexion [76]. They showed that any medial joint opening was consistent with UCL injury in throwing athletes. Arthroscopically, one can also see secondary signs of chronic UCL laxity, such as radiocapitellar degeneration and posteromedial olecranon osteophytes.

There may be a role for arthroscopy in acute, simple dislocations; however, the literature is sparse on this topic. However, the role of arthroscopy in the evaluation or treatment of acute elbow dislocation may be forthcoming. Associated articular cartilage damage may be managed arthroscopically. Further, Eygenndall has shown that persistent valgus laxity after elbow dislocation results in a poorer outcome than those with no laxity [78]. Thus, we may be able to predict who will do better and who will not and thus intervene early to prevent poorer outcomes. However, there are potential limitations to using arthroscopy in an acute elbow dislocation – especially due to capsular injury preventing joint distention and resulting in extravasation.

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Navigation in Orthopaedic Sports Medicine

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17.1 Computer-Assisted Anterior Cruciate Ligament Reconstruction: Four Generations of Development and Usage

Tiburtius V.S. Klos and Stefano Zaffagnini

17.1.1 Introduction

In the last 15 years, computer-assisted surgery (CAS) has been used for many purposes during ACL reconstruction. This paper is an evidence-based literature review of the contribution of such technology to ACL surgery.

17.1.2 Methods

PubMed and Medline research was performed. Papers have been classified according to the study design and to the research topic: anatomy, laxity, kinematics, and comparison of surgical techniques. Evidence-based approach was used to verify the clinical usefulness of CAS to ACL surgery. The use of CAS for research purposes was also evaluated.

17.1.3 Results

CAS showed to improve femoral tunnel positioning, even if clinical outcomes showed no differences with manual techniques. CAS technology resulted useful in research for a better comprehension of the effect of different ACL reconstruction and of the different bundles to joint laxity and to describe tunnel positioning in relation to native ACL insertion.

17.1.4 Conclusion

CAS in ACL surgery can improve results at time zero and can improve knowledge in this field. Its application remains limited mostly for research purposes due to the invasiveness of the system and to the absence of improved clinical results at follow-up.

17.1.5 Introduction

Computer-assisted surgery (CAS), in anterior cruciate ligament (ACL) reconstruction, has now reached 15 years of research. First publications started during the 1990s [1]. The main goal of the navigated procedures was to improve the correct position of the graft, considering anatomical references and graft isometry during the range of motion. Research in this field was conducted considering that 70–80 % of the complications were due to malpositioned tunnels [2].

The purpose of these first systems was to augment the information given to the surgeon in order to better identify the anatomical landmarks that could be difficult to be recognized in an arthroscopic setup. The efficacy of this enhanced information given by computer-based ACL reconstruction was evaluated in the clinical use. Desenne et al. [1] and Bernsmann et al. [3] demonstrated the feasibility of image-less navigation in routine clinical setup.

These studies however have not increased the interest of the orthopedic community on this field for several years. The reason for this scarce interest in navigation was probably due to the unclear goal in tunnel placement and orientation during the ACL reconstruction, and the correct positioning of graft insertions is still a matter of debate [4].

In addition, the costs and the time-consuming problems related to the use of these devices are still the major obstacles to the wide spreading in clinical practice.

Thanks to more surgeon-friendly systems and to the evolution of software for computer-based ACL surgery; recently, there has been an increased interest in this field. This development permits to perform stability testing, including rotational and translational measurements or decomposition of complex clinical test such as pivot-shift [5], allowing to better evaluate the effect of different surgical procedures to the stability of the knee and to better describe patients' specific laxity.

The augmented performance of navigation systems allowed using this methodology to assess the performance of new reconstructive surgical techniques like double bundle. In fact, starting from 2005, there has been a big number of articles on navigated ACL as well as on anatomical double-bundle reconstruction techniques.

The purpose of this chapter is to give an evidence-based literature overview of current states in computer-assisted techniques for ACL reconstruction, highlighting the current concept of navigation and the future perspectives in this field.

17.1.6 Materials and Methods

PubMed and Medline research on May 2009 with query "anterior cruciate ligament" and ("computer-assisted" or "navigation") showed 213 papers. Of these, 84 papers were related to the topic. Exclusion included the use of medical imaging to study joint kinematics in laboratory setup, bone or graft structural properties studies, studies on animals, study of ACL ligament in total or unicondylar knee arthroplasty (TKA and UKA), and reviews on ACL surgical techniques where navigation was cited but not described.

Most of the papers present case series in vivo or controlled laboratory studies; more recently, comparative and review studies were published. Of 84 papers, 4 had a level of evidence of I, 41 had a level of significance of II, 34 had a level of significance of III, and 5 had a level of significance of IV.

In vivo studies were more than in vitro; this may be related to the fact that navigation, with respect to other technologies like robotics, has been specifically designed for surgery, which means an easier setup despite a lower accuracy; therefore, the possibility of in vivo evaluation was exploited by researchers.

Main topic of papers was uniformly distributed, anatomical studies (including ligament insertions, tunnel positioning, and graft isometry), similar to kinematic studies. Comparison (different CAS surgical techniques or conventional surgery) and descriptive papers had also similar number of publications. Only three papers presented clinical follow-up. It is interesting to note how a number of in vivo, kinematic, and comparison between surgical techniques studies have been increased in the last years, while in vitro, validation, and anatomy studies have been decreased.

Literature about CAS in ACL reconstruction presents a variety of topics and methodologies. All the aspects of the surgery have been covered in the studies, from anatomical considerations to kinematic and from technical to clinical aspects. Between the late 1990s and beginning of 2000, the navigation was used to find the most appropriate graft attachments for a single-bundle reconstruction considering isometry [1, 6–9] or according to tibia and femur anatomy [1, 3, 6–16]. Mauch et al. [17], Buckart et al. [18], and Schep et al. [19] found no significant differences between CAS surgery and manual placement by an experienced surgeon. In contrast, Klos et al. [20] and Degenhart et al. [21] found improved accuracy with a computer-assisted system based on radiographs and computer simulation.

The use of navigation for kinematic evaluation of translational and rotational uniplanar joint laxities under stress has been evaluated since the 2000 [22–24]. Zaffagnini et al. [25] and Martelli et al. [26, 27] validated an in vivo setup demonstrating high intersurgeon and intrasurgeon repeatability of the maneuvers [26]. Pearle et al., in vitro, demonstrated the reliability of the measurements compared to a robotic manipulator [22].

In conclusion, navigation resulted reliable in the clinical setup, and for femoral placement, most of the papers show improved positioning in navigated ACL compared to manual technique, but the clinical efficacy of CAS compared to conventional techniques has not been proved [8, 28, 29].

17.1.7 Navigation in Research

Due to intrinsic precision of the systems and to the possibility to evaluate joint laxity and anatomy intraoperatively, navigation has been extensively used for research. A more structured analysis of the literature may help to understand the trends of research. Literature can be divided into four different categories:

1. *Drill hole placement*: studies that evaluate the usefulness of CAS in performing tunnel drilling or studying native ligament insertions.
2. *Laxity measurement*: studies that evaluate the usability of CAS in measuring anteroposterior knee laxity, comparing with conventional arthrometers.
3. *Kinematics*: studies that evaluate joint kinematics under different clinical stress test such as pivot-shift or primary rotations.
4. *Individualized surgery*: studies that evaluate the effect of different surgical strategies on joint laxity.

17.1.8 Drill Hole Placement

One of the most critical factors for successful clinical outcome of anterior cruciate ligament (ACL) reconstruction is proper intra-articular positioning of the graft. There is general agreement that long-term results are significantly influenced by correct tunnel placement [30]. CAS systems for ACL reconstruction have focused on isometry and graft elongation [7–10, 16, 23] or on impingement-free placement [1, 8, 10, 17, 19, 31, 32]. Most of the papers highlighted the versatility of the systems for different surgical techniques, indicating the CAS as useful tool in reducing surgical errors [7, 10, 21].

17.1.9 Tibial Placement

In tibial placement, the mean position of tunnels is not altered by the use of navigated systems but the deviation is significantly decreased [10, 19, 20]. Graft orientation was not correlated clinically to a better result [29]. Burkart et al. [18] showed with the use of a robotic system that the drill hole placement of even experienced surgeons is not consistent. Systems are using different tools for helping surgeons to navigate tibia insertion. These can be notch contour-related or anteroposterior measurement.

Studies partly failed to show advantages of navigated over non-navigated ACL reconstructions [28]. The necessity of finding the correct graft positioning according to the surgical technique still remains a matter of debate. Guidelines for anatomical placement in double-bundle reconstruction with the use of navigation systems are still under construction [13, 33].

17.1.10 Femoral Placement

In femoral placement, most studies [10, 11, 20] show improved positioning in navigated ACL reconstruction using radiographic data. Because many studies are still defining position of ACL at the femoral site, there is no clear optimal aiming point. The position in the femur is nevertheless related to kinematic outcome in the laboratory setting [34–37]. The recent interest in double-bundle reconstruction has again opened the discussion on where to anatomically position the drill holes [16, 38, 39] and the second step would be to relate this position with radiographic and navigating aiming point.

In conclusion, most of studies on tunnel placement suggest that, for tibial placement, an experienced surgeon can achieve comparable results with or without navigation [10, 17–19, 29, 40], only few authors have shown to improve tibial drill hole placement with navigation [8, 20]. While for femoral placement, most of the papers [10, 11, 20] show improved positioning in navigated ACL compared to manual technique.

17.1.11 Laxity

One of the most important goals in ACL reconstruction is restoring the normal anterior/posterior laxity of the knee. For this reason, joint laxity measuring devices, like the KT-1000/2000 and the Rolimeter, have been developed and used pre- and postoperatively to assess joint laxity and are now also available for intraoperative use [41–43]. A number of studies have been conducted to assess the accuracy and reliability of the main devices. Zaffagnini et al. [25] and Valentin et al. [29] compared intraoperative kinematic data with laxity data reported in literature acquired with instrumented testing devices, such as KT-1000 or the Rolimeter. The results obtained were in accordance with previous results and showed that navigation can reliably measure a significant reduction of all knee laxities after ACL reconstruction. More recently, Monaco et al. [44] and Lopomo et al. [45] used a navigation system to evaluate reliability of Rolimeter used intraoperatively.

Several other methods for instrumented measurements are introduced over the years. Antero/posterior laxity was evaluated in the 1990s with stress radiography in scientific papers [30, 46], using the posterior aspects of the proximal tibia and of the femoral condyles as landmarks for determining relative translations. However, the use of this measurement tools seems to be complicated for routine use, and the reproducibility of this method has not been reported. The introduction of computer-assisted techniques for stress radiography made the identification of anatomical landmarks easier. Klos et al. [47, 48], with condylar contour technique, found superior reproducibility in aligning the measurement with a full AP position on the proximal tibia; other alignment lines [49] have been used for the tibia, but recently, Doi et al. [50] suggested once again to use the AP tibia line.

17.1.12 Kinematics

Since the beginning of CAS ACL reconstruction, the possibility of evaluating knee laxity at time zero has been utilized by surgeons. This technology allows evaluating not only the anterior posterior translation during Lachman or drawer test but also internal-external and varus-valgus rotations of tibia under different stress test at fixed flexion angle. Several studies have been published, in particular after 2000, reporting the quantification of the effect of ACL reconstruction in controlling knee laxity.

The possibility to explore different laxities was widely used in DB ACL reconstruction in order to quantify the effect of each bundle in controlling knee rotational instabilities, but studies reported contradictory results.

Ishibashi et al. [52] evaluated in 32 patients the effect in controlling knee laxity of the AM and PL bundles in DB ACL reconstruction. He noted that the PL bundle has an important role near extension, whereas the AM bundle throughout the flexion range in controlling AP laxity. But he found no effect in controlling tibial rotation for both bundles.

Steckel et al. [53] evaluated on cadavers the double-bundle ACL reconstruction; anteroposterior translation data showed that the double-bundle technique and anteromedial bundle technique could restore anteroposterior stability comparable to the intact state. For internal-external laxity, the double-bundle technique demonstrated overcorrection. The anterior drawer and manual Lachman knee laxity tests showed improved stability for the double-bundle compared to the anteromedial bundle technique. Similar results were found also in vivo by Zaffagnini et al. [54] and Ferretti et al. [55] at 30 ° of flexion.

17.1.13 Pivot Shift

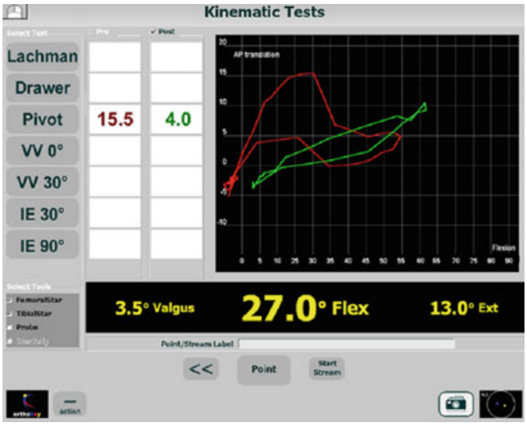
While the primary control of the native ACL and of the reconstructed graft, in the AP laxity of the knee, has been demonstrated to be effective, the controversial results obtained with IE rotation may be related to the fact that the ACL has a secondary control for this laxity or that other structures of the knee joint may be involved in the definition of the constitutional laxity of the patient. Results shown by Steckel et al. in [56] on the contribution of AM and PL bundles in vitro, of native ACL in controlling tibial translation and rotation, highlighted that current clinical knee laxity measurements may not be suited for detecting subtle changes such as PL bundle deficiency in the ACL anatomy.

Recently, Bull et al. [57] reported that these specific clinical procedures allow to assess two different types of joint instability: (1) static and (2) dynamic instability. The static measurement is in general associated to uniplanar laxity tests. On the other hand, the dynamic instability of the knee is commonly presented as symptoms, thus clinical tests try to mimic these symptoms by controlling loads/movements of the joint. For this reason, several authors have recently focused on the analysis of the pivot-shift test trying to quantify and describe the dynamic laxity of the joint.

Amis et al. [5], Colombet et al. [38], and Ishibashi et al. [58] described the envelope of passive motion of the tibia during a pivot-shift test before and after anterior cruciate ligament reconstruction founding consistent reductions during the pivot shift as a combination of external tibial rotation and posterior tibial translation.

Hoshino et al. [59], in office setup, and Lane et al. [60], intraoperatively, found that the increase of tibial anterior translation and acceleration of subsequent posterior translation could be detected in knees with a positive pivot-shift result, and this increase was correlated to clinical grading. Similar experiences with the electromagnetic tracking system were reported by Kubo et al. [61].

In conclusion, the CAS evaluation of knee kinematics has highlighted how primary uniplanar laxity evaluation may not be sufficient to describe the effect of ACL reconstruction in controlling secondary laxities [56]. This fact leads to the evaluation of more complex test, such as the pivot shift, which seems to be more related to patient's subjective status and to the clinical outcome [60]. ACL insufficiency can be documented clinically with the pivot-shift maneuver, with navigation (Fig. 17.1).


Kinematic Tests

Select Test	Pre	✓ Post
Lachman		
Drawer		
Pivot	15.5	4.0
VV 0°		
VV 30°		
IE 30°		
IE 90°		

3.5° Valgus 27.0° Flex 13.0° Ext

Fig. 17.1

17.1.14 Individualized Surgery

Some studies have compared, recently, the effect of different surgical techniques in controlling knee laxity. These studies are important to comprehend the effect of different surgical strategies on knee laxity and to help surgeons to improve the surgical outcome, considering the patient-specific laxity.

Monaco et al. [62] evaluated the effect of a lateral extra-articular reconstruction in addition to a standard single bundle with hamstrings tendons graft ACL reconstruction as compared with an anatomic double-bundle ACL reconstruction. He found that the addition of a lateral plasty is more effective in reducing the internal rotation of the tibia at 30 degrees of knee flexion. Similar results were found by Bignozzi et al. [63] studying a lateral plasty added to a single bundle over the top graft.

Ishibashi et al. [64] compared hamstring DB and patellar tendon graft techniques [65]. Results showed that both techniques similarly improved knee laxity. In the DB reconstruction, the two grafts showed contrasting behavior. The posterolateral bundle restrained tibial displacement mainly in knee extension, whereas the anteromedial bundle restrained it more in the knee flexion position. The posterolateral bundle has a more important role in controlling rotation of the tibia than the anteromedial bundle.

Kanaya et al. [66] evaluated knee laxity on 26 patients, with a custom device, for under regular loads before and after ACL reconstruction, comparing double bundle and single with lower femoral tunnel reconstructions. No significant differences were found between the two groups and affirmed that that a lower femoral tunnel placed single-bundle reconstruction reproduced AP and rotational stability, as well as double-bundle reconstruction. Similar results were found by Ho et al. [67] and Seon et al. [68] in two cohorts of patients operated with central anatomic single bundle and anatomic double bundle. Zaffagnini et al. [69] evaluated the effect of an over-the-top DB technique, in reducing joint laxity, in patients with isolated ACL rupture compared to patients with associated grade II MCL strain. They found different preoperative AP and VV laxities at 30 ° and 90 ° of flexion and that the reconstruction was not able to fully restore laxity in flexion, raising the question for addressing the MCL when a grade II strain is found.

In conclusion, quantification of joint laxity may be also helpful to start to define a translational quantification of different surgical techniques and of different associated pathologies. These data can be useful to define what has been recently called as "on demand" surgery [16, 35]. With this improvement, the possibility of address patient's pathology according to its specific kinematic and anatomical features, choosing the most appropriate surgical technique, is achieved.

17.1.15 Conclusions

As Lord Kelvin stated in the nineteenth century, "If it can be measured, it can be improved." This philosophy fully adapts to the concept of navigation. With the help of less invasive and image-free systems in the last 15 years, the knowledge about anatomy and kinematics of the ACL has improved dramatically. However, the use of surgical navigation for tunnel placement remained limited because the targets and tolerances for this optimal graft positioning are still poorly understood. With the introduction kinematic evaluation, however, it became possible to quantify at time zero the effect of the surgery in controlling knee laxity.

The biggest challenge however of navigation remains the tracking technology: accurate tracking of knee motion is predicated with use of rigid osseous fixation of trackers. Navigation still remains an invasive technique; therefore, it adds potential risks to surgery, and comparative examinations of the contralateral limb or at follow-up are difficult. Furthermore, application of standardized loads during stability testing in vivo remains a challenge.

These data begin to establish requisite translational values for various types of ACL reconstructions. With this information available to the surgeon during surgery, it is now possible to think at the "on demand" individualized surgery, where quantitative data can help refine tracking of surgical outcome.

At present, generation one of system allows a complete intraoperative evaluation of the intervention, but with the evolution of technology, with noninvasive CAS systems, we will be able to increase knowledge about knee kinematics also outside the operating room. That will allow researcher to compare kinematic data also with contralateral limb or in postoperative rehabilitation without the use of radiological techniques. Further improvement will be the possibility of standardize kinematic tests and therefore to start the collection of a global dataset that may be used on navigation systems, where a real-time feedback, together with a intraoperative decision-making software, will provide an effective help to the surgeon.

17.2 Navigated Intra-articular ACL Reconstruction with Additional Extra-articular Tenodesis Using the Same Hamstring Graft

Philippe D. Colombet, M.D.

17.2.1 Introduction

Anterior cruciate ligament reconstruction (ACLR) is nowadays a safe and effective surgery. However, the functional results are not always perfect, the current techniques secure good to excellent results in 70–80 % of cases [71, 82, 85], and the most common reason for failure is a recurrent instability [81]. In cases without any technical error, early and late failures have been reported with many different reasons such as posterolateral instability and graft damage caused surgically, biologically, or traumatically [76]. In revision surgery, the same isolated intra-articular reconstruction should lead to the same failure. Revision surgery with an additional extra-articular reconstruction remains an option [79], and we agree with Draganich et al. [77], who believed that the extra-articular reconstruction can protect the graft from excessive, undesired stresses during the early postoperative period, and thus, it would be useful in revision anterior cruciate ligament surgery. In majority of cases, the iliotibial band is used to perform these lateral tenodesis in an open procedure [80, 87]. However, these lateral structures, especially iliotibial band and Kaplan's fibers, are significant secondary restraints in resisting the anterior translation and rotational laxity. Many authors [73, 78, 88] have reported disadvantage to harvest the iliotibial band for lateral tenodesis. Hamstring tendon graft has been used for both the lateral tenodesis and ACL reconstruction; Bignozzi et al. [72] uses an open surgery and passes the graft over the top that is not isometric graft placement. In order to preserve the lateral structures and to place the graft in better isometric position, we perfected of a navigated surgical procedure using hamstring tendon graft in continuity to the intra-articular reconstruction to perform a percutaneous extra-articular tenodesis.

17.2.2 Technical Note

17.2.2.1 Patient Setup and Operative Approach

The patient is placed in supine position on the operating room table. A pneumatic tourniquet is placed in highest position on the thigh. We secure a lateral thigh post which allows full extension and flexion of the knee and ensure that the foot is supported (Fig. 17.2). We identify and mark the anterior tibial tubercle (ATT), the tibiofemoral joint lines, the Gerdy's tubercle, the hamstring tendon position, and borders of the patellar tendon. The operative approach consists in arthroscopic anterolateral portal on lateral part of the patellar tendon and anteromedial portal for arthroscopic instrumentation. A 3-cm incision is placed 2.5 cm medially to the ATT and 4 cm from the medial joint line to harvest the gracilis and semitendinosus (SemiT) tendons (Fig. 17.3). On the lateral site of the knee, two short skin incisions (1 cm) are performed, one on the Gerdy's tubercle and one proximally to the lateral condyle tubercle (Fig. 17.4).

Fig. 17.2 Patient setup. Complete free knee motion is required

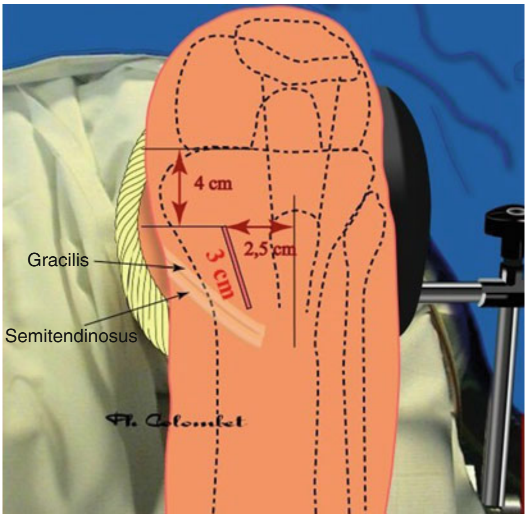


Fig. 17.3 Skin incision to harvest hamstring tendons

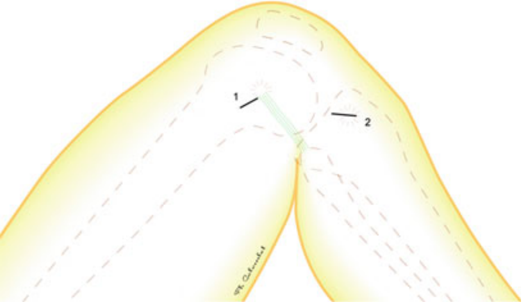


Fig. 17.4 Skin incision for the percutaneous lateral tenodesis

17.2.2.2 Graft Preparation

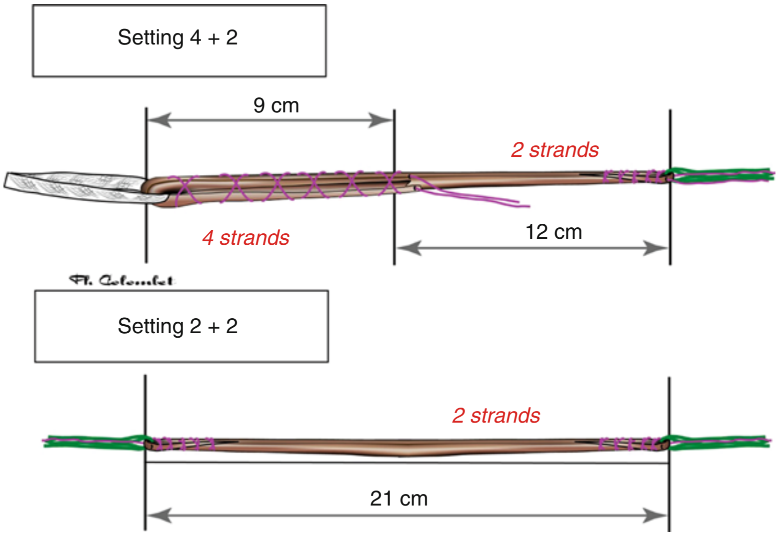
The two tendons are dissected and harvested with a Linvatec tendon harvester in order to get the whole tendons. The muscle fibers are cleaned out from the tendons, and all the expansions are removed from the tendon in order to get a homogenous and regular graft. The tendons are calibrated, then two kinds of settings are possible depending on the graft length available:

The setting "4+2" or "2+2." The "4+2" setting is the best setting for a standard patient (ranged from 1.75 to 1.85 m and 70 to 90 kg); the perfect lengths for each part of the graft are 9 cm length for the 4 strands part and 12 cm for the 2 strands part. If it is not possible to get these correct graft dimensions, the "2+2" setting must be preferred.

Setting "4+2": The joint part of the graft is composed of 4 strands, two from the gracilis and two from the SemiT; they are passed through a 5-mm Mersilene loop. The extra-articular part has got only two strands. All the four strands part is sutured with Polysorb™1, and the two strands extremity is sutured through a Ti-cron 2 loop (Fig. 17.5).

Setting "2+2": The intra-articular part of the graft consists of two strands, one from the gracilis, one from the SemiT, and the same for the extra-articular part of the graft. The two tendons should be detached from the tibia in case the graft length is not enough to return to the tibia. A better option is to let the tendons attached on the tibia to improve their fixation. In both cases, the extremities of the

Fig. 17.5 Graft setting "4+2": Distal part of Gracilis and Semitendinosus are passed over a Mersilene loop and compose the 4 strands part. The other extremity is sutured through a Ti-cron 2 loop and composes the 2 strand part of the graft. Ideal lengths are: 9 cm length for the 4 strands part and 12 cm for the 2 strands part. Graft setting "2+2": The two tendons are simply sutured through two Ti-cron 2 loops at each extremity



graft are sutured with Polysorb™1 suture to increase the interference screw fixation (Fig. 17.5).

17.2.2.3 Tunnel Preparation

Two tunnels are drilled in the tibia and one in the femur. The ACL Logics® bone-morphing navigation system (Praxim-Medivision, La Tronche, France) is used to optimize tunnels positions [74]. First of all, a meticulous preparation of the notch under arthroscopic control is performed. After a short step of calibration, the knee is placed at 90° of flexion, a bone morphing of ACL footprint on the femur and on the tibia is performed, as well as the extra-articular part of the lateral condyle. Then we select two points on the tibia: one on the Gerdy's tubercle for the outside joint part of the reconstruction and one in the center of the antero-medial bundle of the ACL tibial footprint. The system provides two different isometric maps [75] (Fig. 17.6). One is located on the lateral part of the intercondylar notch and one outside the lateral condyle. Optimal points are selected on these two maps constituting two targets. Computer guide drill is used to perform the femoral tunnel outside – in a manner from the outside target to the inside target (Fig. 17.6b). The two tibial tunnels are drilled using the same system. These tibial tunnels are drilled from the initial navigation selected points.

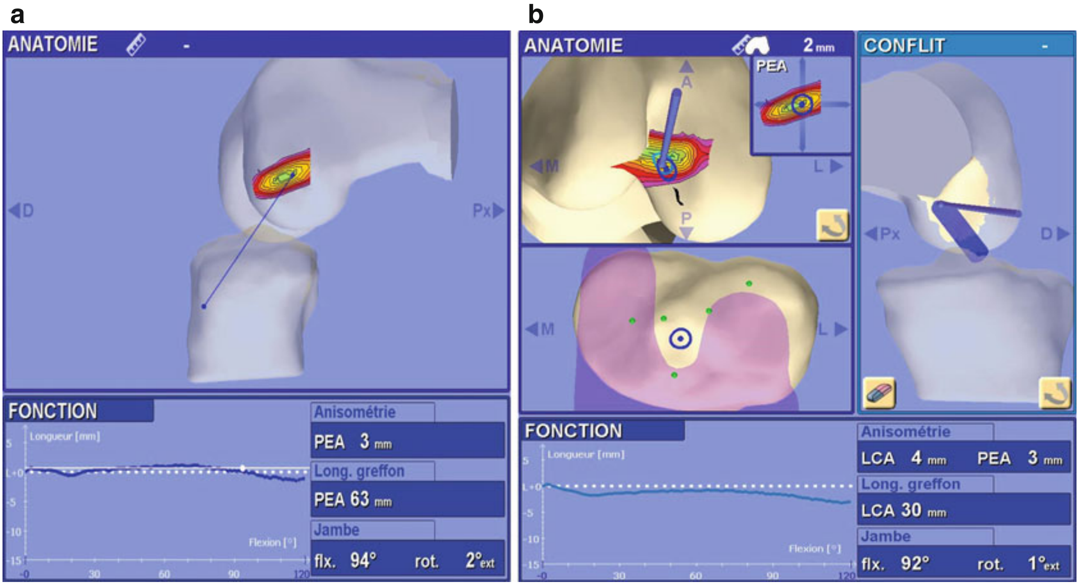
After femoral tunnel drilling, the anterior edge of the intra-articular femoral tunnel aperture is taken off with a curette to avoid a killer turn. The second tibial tunnel is drilled in the tibia from the Gerdy's tubercle to the tibial wound used to harvest the tendons. This last tunnel is drilled under the anterior tibial tubercle and returns to the starting point, making a kind of frame (Fig. 17.7).

17.2.2.4 Graft Passage and Fixation

Two different procedures are used depending on the kind of graft setting. First of all, the knee is flexed at 90°.

In the "2+2" manner, the graft is passed from the tibia to the femur through the first tibial tunnel, then through the femoral tunnel inside out. This part of the graft is secured with an absorbable interference screw in the tibia 8×25 (8 mm diameter, 25 mm length) and an 8×20 in the femoral tunnel with an outside in way.

In the "4+2" setting, the 4 strands part of the graft is tracked from the femur to the first tibial



a:

Anisométrie
PEA 3 mm
Long. greffon
PEA 63 mm
Jambe
flx. 94° rot. 2° ext

b:

Anisométrie
LCA 4 mm PEA 3 mm
Long. greffon
LCA 30 mm
Jambe
flx. 92° rot. 1° ext

Fig. 17.6 Navigation screens: (**a**) lateral view with isometric map of extra-articular tenodesis. (**b**) Intra-articular navigation windows with isometric map on the lateral part of the intercondylar notch. A virtual graft (*dark blue*) is provided by the computer as well as different parameters and graphic of graft length difference during flexion/extension

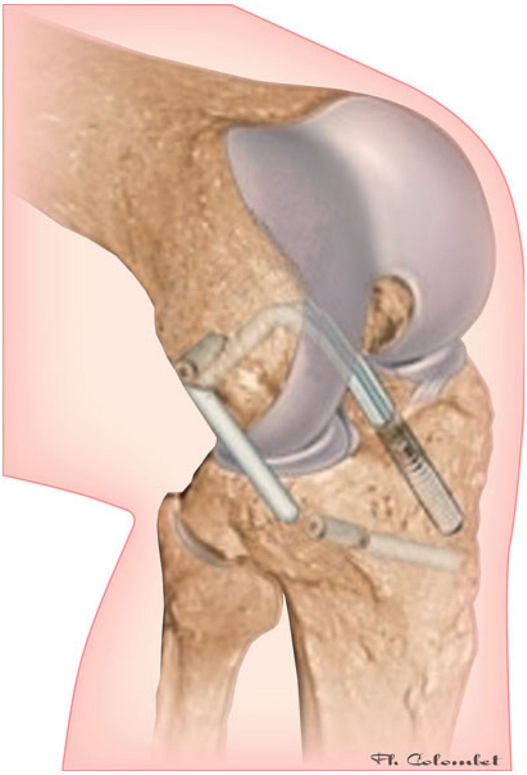


Fig. 17.7 Different graft passages in the femur tunnel and in the two tibial tunnels, the graft return to its initial point making a complete frame

tunnel, with the Mersilene tape outside in in the femoral tunnel and inside out in the medial tibial tunnel. It is secured in the same manner with absorbable screws, usually sized 9 mm in diameter, because this part of the graft is larger than in the “2+2” setting.

At this step, the intra-articular part of the reconstruction is finished. The next step is the same in both graft setting. A two-strand graft is getting out from the femoral tunnel in both cases. This part of the graft is passed very carefully under the iliotibial band. We recommend using a probe to lift of the iliotibial band and place a clamp under to pass the graft and control with a retractor that the graft is under the band.

The lateral aperture of the second tibial tunnel is slightly enlarged with a cone-shaped reamer. This will be very helpful to introduce the last screw. Then the graft is passed in the last tunnel tracked with the Ti-cron loop. We recommend placing the screw guide wire in the tunnel before passing the graft because it is difficult to place it correctly when the graft is inside the tunnel. An 8×20 absorbable screw is placed with the tibia in neutral position.

17.2.3 Laxity Measurement

We conducted a study on laxity measurement time 0 before and after reconstruction. In twenty-one patients, the navigation was used to measure the knee kinematics in response to the anterior drawer test, Lachman test, maximum internal/external rotation test, and pivot-shift test. Two sequential reconstruction protocols were used to assess the contribution of the extra-articular tenodesis and single anteromedial bundle anterior cruciate ligament reconstruction to restraining tibial translations and coupled axial rotation occurring with the manually performed clinical laxity tests.

Results: At 90° of flexion, addition of lateral tenodesis had a significant effect on internal coupled rotation ($p=0,003$). Addition of intra-articular reconstruction to lateral tenodesis had a significant effect ($p=0,001$) in reducing by 4 anterior tibial translation of the medial compartment, and the effect was also significant ($p=0, 0001$) in reduction of lateral compartment translation. On the rotational envelope, lateral tenodesis had a significant effect ($p=0, 0001$) in reduction of maximum internal rotation. We concluded that extra-articular procedure has no significant effect to improve anterior tibial translation and improve the internal tibial rotation control only at 90 ° of flexion.

17.2.4 Discussion

The most important step of this technique is the decision for the “2+2” or “4+2” graft setting; the decision is tricky. It is needed to know the limits of such a technique. The first limitation of this technique is small and short hamstring tendons. The concept is based on the addition of a percutaneous extra-articular tenodesis to a standard anteromedial single-bundle hamstring ACL reconstruction. An inappropriate graft diameter could lead to failure by graft rupture; the graft may not be able to support constrains during strenuous activity. Not enough graft inside tunnels could provide graft fixation failure. A minimum of 15-mm graft inside the tunnel is needed for a good fixation. In case the graft length within the tunnel is close to 15 mm, a double fixation has to be used. In addition to the interference screw, the Mersilene tape should be secured on a staple or on a post outside the tunnel. For the tibial fixation of the tenodesis part, the Ti-cron loop should be knot over a staple or on soft tissue around the aperture. We also need a good bone stock around the tunnels; in patients with tunnel enlargement, a two-stage surgery is recommended. For high-level cutting sports patients going to revision ACL reconstruction, it is mandatory to use a "4 + 2" graft setting with a minimum of 7-mm-diameter graft for the intra-articular reconstruction. If we are not able to prepare a correct diameter graft size, we must not apply this technique. We reserve the "2 + 2" setting for revision surgery in patients with a non-cutting sport activity.

The use of navigation is another limit; most of surgeons do not use navigation system for surgery. However, the tunnels can be performed without navigation. The first tibial tunnel is drilled outside in as usual using a standard director aimer™ (Smith & Nephew) in order to reach the anteromedial bundle (AMB) tibial footprint of the native ACL. Then the femoral tunnel is drilled outside in using a femoral aimer. The inside joint target is the center of the AMB insertion on the femur, and outside the joint, the landmark is situated 1 cm proximal and posterior to the femoral lateral tubercle. This situation was validated with navigation and confirmed by previous studies [83, 84]. However, the use of navigation provides perfect 3D conditions to optimize tunnel position as extra-articular tenodesis is not anatomic; an appropriated tool is needed to find the best isometric points.

The placement of the femoral screw has to be carefully done. The head of the screw must be inside the tunnel; if it is not, the patient will complain of pain and dysfunction during flexion extension.

Indication of lateral tenodesis is controversial; it has been established long time ago by Amis and Scammell [70] that in isolated ACL-deficient knee, there is nonsignificant biomechanical advantage from adding an extra-articular reconstruction. However, Zaffagnini et al. [89] reported in an RCT 5-year follow-up study a significant advantage in subjective evaluation, a faster return to sport, less kneeling pain, and a higher capacity of return to normal muscle trophism.

If we look at the literature, other techniques have been reported. In 2006, Ferretti et al. [79] published a similar technique with four-strand hamstring graft in revision of ACL reconstruction. The additional lateral tenodesis was performed with the iliotibial band let attached on the Gerdy's tubercle and passed under the lateral collateral ligament, then returned to the initial point and sutured. He concluded that this technique is a reasonable alternative for revision anterior cruciate ligament reconstruction. However, patients should be informed that despite the achievement of a stable knee following reconstruction, degenerative joint disease frequently occurs. Marcacci et al. [86] reported in 2009 an 11-year follow-up study using a similar technique than ours with hamstring passed "over the top" and fixed on the Gerdy's tubercle with a staple. This technique was used for primary ACL reconstruction. He showed satisfactory results and no significant cartilage degradation of the knee compared to ACL reconstruction without extra-articular augmentation. In his technique, there are some weak points: the non-isometric placement of the graft on the femur, the tibial fixation of the tenodesis with a staple without any bone tunnel, always only two strands to reconstruct the ACL and some damages could appear on the Kaplan's fibers.

17.2.5 Conclusion

Extra-articular tenodesis can be used in addition to intra-articular ACL reconstruction using the same graft and performed with mini-invasive technique. This technique is indicated in revision of ACL reconstruction without technical error. The tenodesis placement could be optimized with navigation system.

17.3 Rotatory Instability After ACL Tear and Reconstruction

Andrea Ferretti, Edoardo Monaco, and
Antonio Vadala

17.3.1 Introduction

Anterior cruciate ligament (ACL) reconstruction is one of the most common orthopedic procedures performed worldwide with a very high success rate. However, despite very satisfactory clinical outcomes, the surgeon often detects the persistence of a certain rotatory instability, even in cases of reconstructions with no detectable intra- or postoperative complications and regardless of the type of graft used. The cause of this phenomenon is not completely understood yet, and this is nowadays the goal of many researchers whose aim is to be able to finally reconstruct a knee with the original rotational stability. In this chapter, we will aim to analyze the relationship between the rotatory instability and normal and torn ACL.

17.3.2 Anatomy and Function

The main function of the ACL is to control tibial anterior translation with a secondary effect on knee internal rotation. An anterior cruciate ligament lesion may produce a knee rotatory instability whose consequence might be the onset of a degenerative articular disease with possible resulting damage on menisci and cartilage eventually resulting in a knee osteoarthritis. Both ACL functions are possible due to the presence of other articular structures which are linked to the ACL in maintaining knee stability. It is well documented how the ACL is made of two different bundles, the anteromedial (AM) and the posterolateral (PL), with different specific functions but working synergically so as not to be considered separate structures: the AM bundle mainly works on anteroposterior stability and the PL bundle on rotational stress.

One of the main aspects of ACL anatomy, in regard to surgical reconstruction, is the exact position of its femoral and tibial insertion. The femoral insertion has been the most commonly studied since the first attempts of open intra-articular reconstructions because it is thought to be the most difficult to reproduce due to its very posterior positioning on the medial surface of the external femoral condyle [90]. It was common opinion that the positioning of the graft could never be posterior enough, so many surgeons tried to perform an *over-the-top* technique; however, it is now appreciated that the native ACL femoral insertion site is located along osseous landmarks on the posterior aspect of the medial wall of the lateral femoral condyle, termed the lateral intercondylar and bifurcate ridges [91]. The lateral intercondylar ridge corresponds to the feature termed the resident ridge reported by Clancy et al. [92]. Identification of this ridge when present has been shown to be an accurate and reliable method to locate the native ACL insertion site and the true entry point of the femoral tunnel [93].

17.3.3 Diagnosis

Diagnosis of ACL rupture is basically clinical and is usually performed with the Lachman and the pivot-shift tests, whose sensibility and specificity have been widely documented. The Lachman test assesses tibial anterior translation on the femur while the pivot-shift test assesses both tibial translation and rotation, reproducing the most common traumatic mechanism of rupture of the ligament. Moreover, the pivot-shift test better correlates with patient's disability. For this reason, the pivot-shift test is thought to be the most reliable test for detecting rotatory instability of the knee following an ACL tear [94]. The pivot shift is usually graded in three degrees (grade I: glide, grade II: jerk, grade III: subluxation), but it is highly dependent on the ability and experience of the operator. Since the importance of this test is evaluating both ACL deficiency and the effects of different surgical techniques of reconstruction, many authors have proposed various methods of objectively evaluating and quantitatively measuring the test such as the use of a navigation device

Fig. 17.8 The pivot-shift phenomenon as detected by a navigator: tibial anteroposterior diagram and rotation in a knee with intact ACL (**a**) and in an ACL-deficient knee (**b**)

(Fig. 17.8), mechanical or electromagnetic tool, and conventional radiological or magnetic resonance dynamic methods [4, 22, 38, 59, 95–97]. However, none of these methods have become widespread among surgeons, and many of them remain operator dependent. As a matter of fact, the pivot-shift test is still the most popular test for assessing the rotatory instability of the knee after an ACL rupture and reconstruction.

17.3.4 ACL Tear and Rotatory Instability

The relationship between ACL lesions and the resulting rotatory instability of the knee has mainly been studied on cadaver knees. In fact, in vivo studies where the instability was compared to the contralateral healthy knee, we can never assume that the lesion of the ACL was the only damage that occurred in the knee as a consequence of the initial trauma or as a result of progressive stretching of other structures due to the lack of the torn ACL. Around the middle 1970s, the Hospital for Special Surgery of New York group was the first to publish several studies on the anatomy and function of the ACL conceived as a "complicated two part ligament," assessing the consequences of selected lesions of one of its two components on the anteroposterior and rotational stability, calculated with a sophisticated goniometric methods [98]. The authors concluded that "significant rotational instability was evident when the entire anterior cruciate ligament was severed, but isolated lesions of either component (AM or PL bundle) did not cause rotational instability that would be likely to be detected clinically." About 10 years later, Nielsen et al. [99], in a similar study, concluded that "the knee joint remains grossly stable after partial rupture of the ACL while sectioning the entire ACL caused an increase in internal rotation in the extended-semiflexed position; combined lesions to the ACL and LCL caused instability and a consistent pivot-shift in applying a valgus torque in flexion." Ten years later, Matsumoto and Seedhom [100], using biplane photography, documented a pivot shift after lesion of the entire ACL, also showing that this phenomenon is not just a consequence of an increase in internal rotator instability but of a rotation occurring from a different mechanism. Recently, in a study we performed on 10 cadaver knees, we evaluated internal rotator instability after sectioning either component of the ACL, showing that an isolated section of the PL bundle did not produce an increase in internal rotator instability; on the contrary, the section of the entire ACL did produce an increase in internal instability in most cases. In our trials, only after a complete section of the entire ACL did we detect a grade + pivot shift (glide) in three cases and a ++ pivot shift (jerk) in seven cases; a +++ pivot shift (subluxation) was never detected after isolated complete section of the ACL [101].

However, in regard to rotatory instability, ACL lesions, and the pivot-shift test, we should remember that the pivot-shift test assesses rotatory instability and in particular, according to Hughston

[102], the anterolateral instability, whose origin is more complicated than a simple result of ACL lesion. Mueller et al. [103] and Feagin et al. [104] stated that even though the pivot shift is related to an ACL tear, it is significantly increased by concomitant lesions of the external compartment and in particular of the "middle one third of the lateral capsular ligament" also known as anterolateral femoral tibial ligament (ALFTL) (Hughston). Actually, in our study cited above on cadaver knees, we detected a significant increase in rotatory instability along with a +++ pivot shift in all the cases in which, after tearing the entire ACL, even a partial lesion (1 cm) of the ALFTL was performed. Even more recently, Mushal et al. [105] showed, also with the use of a navigation system, a significant increase of the anterior tibial translation in the external compartment during the pivot-shift maneuver in ACL-deficient knees after external meniscectomy. The same group of researchers had previously shown that the anterior translation of the external part of the tibia was strictly correlated to the pivot-shift score [106]. A similar result was achieved by Diermann et al. using a robotic/UFS testing system [95].

In conclusion, we can state that, while an isolated lesion of the PL bundle does not seem to increase internal rotation, lesion of the entire ACL produces a slight increase of internal rotation but, most of all, a different pattern of rotation whose fulcrum moves from the central pivot of the joint to the medial collateral ligament (MCL), with following increase of the anterior translation of the external tibial plateau. The pivot-shift test, in assessing this particular biomechanical pattern of instability, is related not only to the lesion of the ACL, but it is strongly influenced by associated lesions, in particular those of the lateral compartment (ALFTL, LCL, lateral meniscus).

17.3.5 Effects of the ACL Reconstruction on Rotatory Instability

Even though ACL reconstruction is a very widely used operation with a very satisfactory success rate which allows the majority of active patients involved in sports activities to resume their preoperative levels, the persistence of a certain rotatory joint laxity might produce subsequent meniscal or chondral damage leading to a clear degenerative arthritic disease. Even though the pivot-shift assessment has always been part of the evaluation scoring scales used, it has often been underestimated; only within the last few years has this topic come back to scientific attention, thanks to Freddi Fu's studies on the functional anatomy of the ACL, on its two distinct bundles, and most of all, on failure of the single-bundle reconstruction to restore exact joint stability especially in regard to internal rotation. As a result, many surgeons, with the aim of improving their success rates, have in turn started using the double-bundle reconstruction of the ACL. In recent years, particularly in the first years of the third millennium, many clinical and laboratory studies have been published on the advantages of reconstruction of the two bundles, thus supporting Fu's theory [107–109]. In particular, clinical studies with a minimum follow-up of 2 years in which double-bundle reconstructions were used showed to be better than the single-bundle, both in terms of knee stability and in terms of recurrence rate. Moreover, other studies, such as the one by Robinson et al. [110] on cadaver knees with the use of a navigation system, further provided objective data about how, in ACL reconstructions, the AM and PL bundles act differently in stabilizing the knee, particularly during the pivot-shift test, where the PL bundle is important in controlling not only anterior laxity toward knee extension but also the rotational component. In net contrast with what was reported by the above-mentioned authors, in a similar study, we performed on cadaver knees with the use of a navigation system, we found that the further addition of the PL bundle to an AM single-bundle reconstruction did not provide any additional stability to the knee in regard to internal rotation. How might these different results be explained since the methodologies of the studies were similar? The explanation may likely be in the different surgical way of reconstructing the AM bundle; in fact, in Robinson's study, the AM bundle was positioned slightly more anterior and vertical than in our study, where we tried to place the femoral insertion, approached with an out-in technique, more horizontal and the most posterior, thus in accordance with the actual anatomy of the ACL. This is a very important topic which deserves deeper examination [111]. Since the beginning of the reconstruction of the ACL with open techniques, it was mandatory for the surgeon to scrupulously respect the anatomy of the ACL with a very posterior positioning of the femoral insertion. Since this goal could not be reached by drilling the femoral condyle from the articular joint, surgeons started using the out-in technique which allowed, through dedicated guides, adequate reproduction of the anatomical position of the femoral insertion. With the advent of arthroscopic techniques, this goal was supposed to be achieved more easily because of a better vision of the most posterior part of the external femoral condyle; on the contrary, after a few years, the majority of surgeons preferred to perform less invasive techniques (single-incision techniques) performing transtibial femoral tunnel drilling, often resulting in a non-anatomical positioning of the ACL. It seems as if, despite the advantages provided by the scope, the arthroscopists preferred mini-invasiveness over respect of the ACL anatomy and function. Those like us who have always carried out the out-in technique, because of the possibility of performing the femoral tunnel independently from the tibial tunnel, more accurately determining the entrance of the tunnel in the joint, have always judged non-anatomical ACL reconstruction techniques as being wrong reconstructions. Lately, more recent biomechanical studies [112] on the different positioning of the femoral tunnel have confirmed that double-bundle reconstructions do not provide significant improvement on rotational instability compared to those of “anatomical” single-bundle techniques. It is surprising that it took two decades to correctly reevaluate the anatomy and the function of the ACL to correctly perform an ACL reconstruction [67].

However, since the rotatory instability is a complex phenomenon not simply dependent on the ACL rupture or the anatomical reconstruction, other hypotheses have been proposed to correct this type of instability. Among these, an important aspect is represented by the peripheral plasties [113, 114], whose biomechanical role in controlling the rotational instability and the pivot shift has been widely proven even in recent studies published by our group: internal rotation was better restored in cases in which the anatomic ACL reconstruction was performed along with a peripheral plasty than in cases treated with a double-bundle technique [115]. More recently, Colombet et al. [116] did not reach the same conclusions as us; however, they did not put any tension on the lateral sling, thus losing a big part of the efficacy of the technique itself. Even more controversial is the clinical effectiveness of the peripheral plasties in long-term follow-up, even though Zaffagnini et al. [117], in assessing three groups of patients treated with hamstrings (STG), bone-patellar-tendon-bone (BPTB), and ST plus peripheral plasty obtained the best results in the third group. In our experience, we found peripheral plasty useful in patients with severe rotatory instability (+++ pivot shift), in women and in cases of revision.

17.3.6 Conclusions

A complete lesion of the ACL often causes a rotatory instability of the knee detectable with the pivot-shift test. During this complex phenomenon the tibia tends to internally rotate with respect to the femur, thus changing its rotational fulcrum which moves medially closer to the medial collateral ligament, with following anterior translation of the external tibial plateau. The severity of the pivot shift, commonly scored in three degrees, essentially depends on the amount of constitutional tibial rotation and on the presence of concomitant associated lesions, such as the ALFTL and the external meniscus. In order to obtain the best rotatory stability, the ACL reconstruction must be performed accurately reproducing its anatomical positions (either single- or double-bundle). Non-anatomical reconstructions are basically erroneous and non functional. Peripheral plasties may contribute to better control of rotatory instability and may be indicated in selected types of patients.

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