Surgical Atlas of Sports Orthopaedics and Sports Traumatology

Andreas B. Imhoff
Matthias J. Feucht
Editors

Translated and Edited by
Mohamed Aboalata

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Preface

It has long been our aim to have an operative Atlas for our junior residents and orthopaedic specialists, which illustrates the major sport-orthopedic and sport-traumatologic surgical techniques.

Based on our internal operative guidelines could Matthias Feucht and I finally achieve that dream after many years of work.

The collection of clinical photographs, the many special drawings, X-ray and MRI images, surgical images, guidelines and the relevant references, however, has taken a lot longer to be complete than expected. I am very grateful to Matthias Feucht for his great help.

Many of our techniques come to cover the spectrum of the new specialist training program in orthopedics and trauma surgery, that is why we have tried in this atlas to illuminate and describe the surgical techniques according to the new combined postgraduate training concept.

The excellent, Operative atlas of orthopedic and trauma surgery training by Dieter Kohn and Tim Pohleman, published by springer in 2009 allows us to see our atlas as a supplement focusing on the sport-orthopedic and sport-traumatologic field. The minimally invasive arthroscopic procedures constitutes naturally the main part of this atlas.

Each chapter is structured to entitle the indications, the operation principle, the preoperative preparation with diagnostic tools, planning and the relevant information for patient to be declared, the surgical technique, the immediate postoperative management and rehabilitation measures. Pitfalls , Tips and Tricks and four to five references around the theme are included in each case.

We would like to thank the editorial office including Dr. Fritz Kraemer and Ms. Antje Lenzen as well as Mrs. Barbara Knüchel and Mrs. Frauke Bahle. A big thank also to Mr. Rüdiger Himmelhan and his team from Heidelberg for the excellent drawings. Despite the multiple corrections we have made, he continued to support us tirelessly and to refine the didactic presentations.

We hope you benefit as a reader from our illustrated procedures in the management of athletes and sports injuries.

Drawings and pictures of the surgery often say much more than long texts, which is why the techniques must be illustrated comprehensively and at the same time had to be short and checklist-like. It should be a teaching atlas for medical students, patients, orthopedic and trauma surgery residents and specialists as well as physiotherapists.

Andreas Imhoff, Editor,
Munich, Germany, July 2014

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List of Abbreviations

ACJ/AC Joint	Acromioclavicular joint
ACT/ACI	Autologous Chondrocyte Transplantation/ Implantation
ACL	anterior cruciate ligament
AHD	Acromiohumeral distance
aIGHL	anterior inferior glenohumeral ligament
ALP	anterolateral portal
AMIC/MACI	Autologous matrix-induced chondrocyte Implantation/ matrix-induced autologous chondrocyte Implantation
AJC	ankle joint center
ARAC	Arthroscopic resection of the acromioclavicular joint
AP	Anterior Portal
ASIS	anterior superior iliac spine
CHL	Coracohumeral ligament
CPM	continuous passive motion
DP	distal portal
ECRB	extensor carpi radialis brevis
ECRL	extensor carpi radialis longus
ED	extensor digitorum
EMG	electromyogram
FAI	femoroacetabular impingement
FHC	femoral head center
FHL	flexor hallucis longus
GIRD	glenohumeral internal rotation deficit
HTO	High tibial osteotomy
ICRS	International cartilage repair society
IGHL	Inferior glenohumeral ligament
ISP	Infraspinatus tendon
KJC	Knee joint center
LBT	Long biceps tendon
LCL	Lateral collateral ligament
LFTA/ATFL	Anterior talofibular ligament
LFC/CFL	Calcaneofibular ligament
LUCL	Lateral ulnar collateral ligament
MACT/MACI	Matrix associated chondrocytes transplantation/Implantation
MCL	Medial collateral ligament
MDP	middle distal portal
MGHL	middle glenohumeral ligament
mLDFA	mechanical lateral distal femoral angle
mMPTA	mechanical medial tibial angle
MPFL	medial patellofemoral angle
NCV	nerve conduction velocity
OATS	Osteochondral autograft transfer system
PCA	Patient controlled analgesia
PCL	posterior cruciate ligament
pIGHL	posterior inferior glenohumeral ligament
PLP	posterolateral portal
POL	posterior oblique ligament
PSI	posterosuperior impingement
PVNS	pigmented villonodular synovitis
SGHL	superior glenohumeral ligament
SLAP	superior labrum anterior to posterior lesion
SSC	subscapularis tendon
SSP	supraspinatus tendon
TM	teres major tendon
TTTG distance	tibial tuberosity-trochlear groove center

Shoulder

Patient Positioning, Arthroscopic Portals, Diagnostic Arthroscopy, Arthroscopic Sliding Knots

P. Minzlaff, S. Braun

A. B. Imhoff, M. J. Feucht (Eds.), *Surgical Atlas of Sports Orthopaedics and Sports Traumatology,*
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1.1 Patient Positioning

P. Minzlaff, S. Braun

1.1.1 Beach Chair (Sitting) Position

A special shoulder operating table is used. The head is positioned and stabilized securely and axially aligned in a head rest. The patient is in supine position with an elevated upper trunk (about 60°) and flexed hips (about 45–60°) and knees (about 30°) (Fig. 1.1). The arm to be operated is placed in a adjustable (movable) arm holder (e. g. Trimano, Arthrex) allowing free shoulder and scapula movement. A padding roll (pillow) is placed under the knees and gel pads are placed under each leg. The lateral popliteal nerve crossing below the fibular head must not be compressed due to the patients positioning. Excessive flexion of the hip joint can compromise the lateral cutaneous nerve of the thigh as well as the blood supply of the lower extremity and therefore must be avoided. The chest is securely stabilized with straps or side support. The sterile draping begins at the middle of the clavicle medially and ends at the level of the mammilla distally. The hand and forearm are covered up to the level of the elbow with a stockinette drapes and wrapped with an elastic bandage. This positioning is identical for all arthroscopic procedures and is slightly modified in case of endoprosthetic shoulder replacement. In these cases, a slight lateral displacement of the patient improves the adduction.

1.1.2 Lateral Decubitus Position

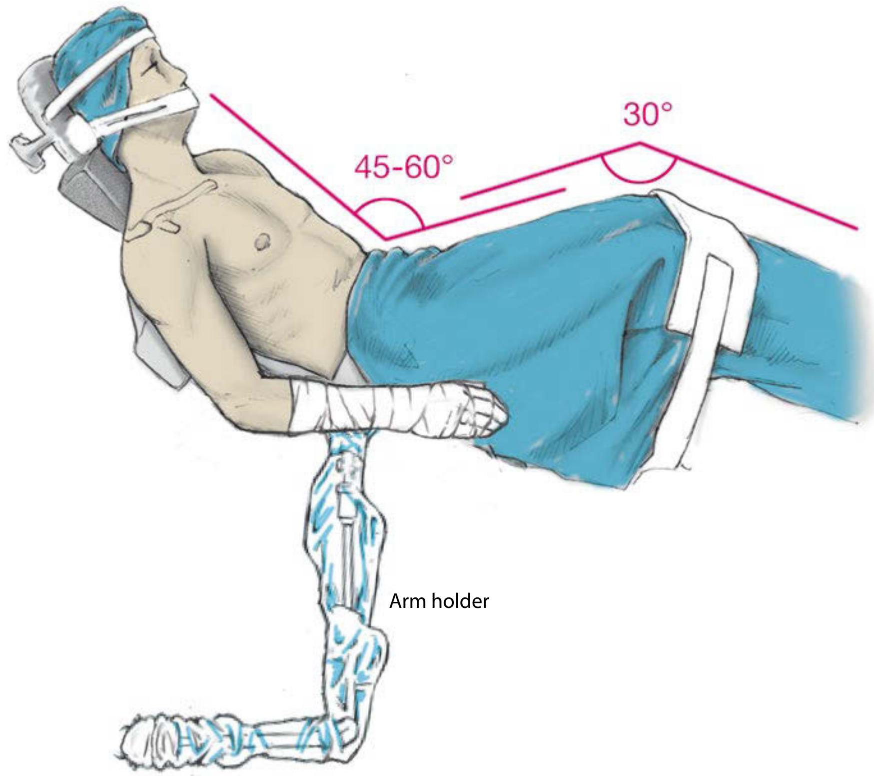
The lateral position is secured with side supports placed anteriorly and posteriorly at the level of the sternum and sacrum or through using a vacuum mattress with correct axial alignment of the head (Fig. 1.2). The arm to be operated is suspended under traction using a mechanical arm holder to distract the glenohumeral joint. A gel pad (roll) is placed under the chest at the level of the mammillas to avoid stress on the other shoulder.

1.2 Arthroscopic Portals (Fig. 1.3 and Fig. 1.4)

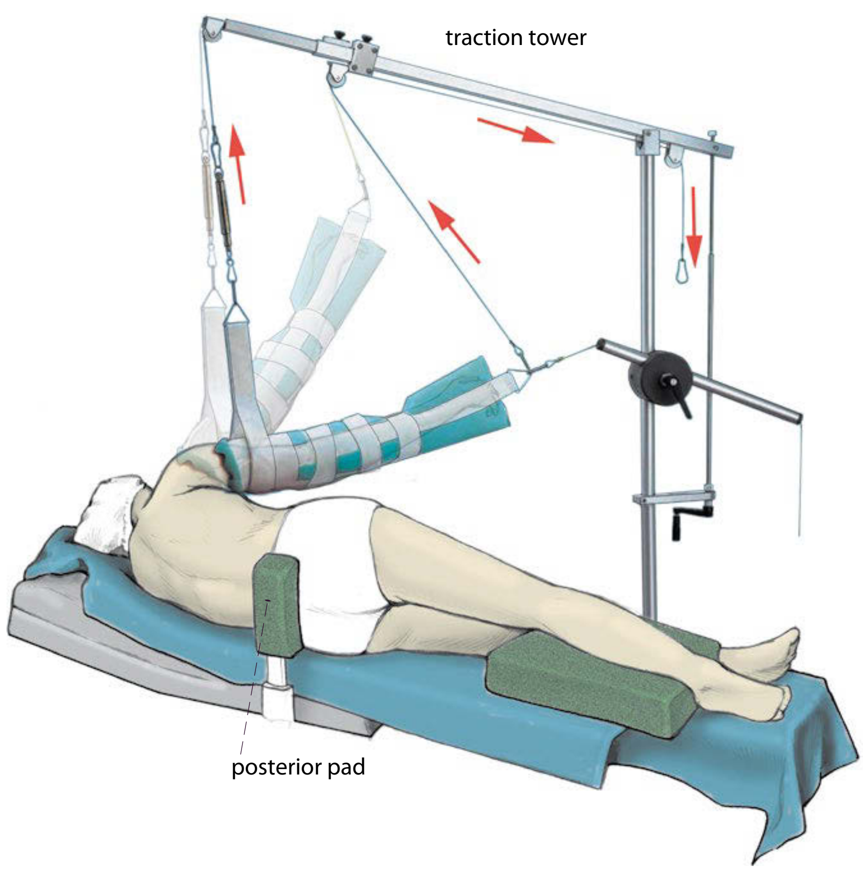
- The important bony landmarks (clavicle, AC joint, acromion, spine of the scapula and coracoid) as well as all planned arthroscopic portals are marked *with a surgical skin marker*.
- Infiltration of the planned portal sites with an local anaesthetic (Epinephrine 2 % in 5 ml, 1–2 ampoules are needed depending on the number of planned portals)
- Posterior standard portal: about 2 cm medial and 2 cm inferior to the posterolateral acromial edge "soft spot". (*infraspinatus gap*)
- Anterosuperior portal: through the rotator interval, medial to the long head biceps tendon, above the subscapularis muscle and slightly below the AC joint.
- Anteroinferior portal: slightly inferior to the anterosuperior portal, at the upper border of the subscapularis muscle. Cave: Cephalic vein and musculocutaneous nerve. (about 4–5 cm distal to the coracoid process)
- Deep anteroinferior portal (5:30 o'clock portal): about 8–10 cm distal to the coracoid process and 2 cm lateral to the anterior axillary fold, through the muscular portion (lower third) of the subscapularis muscle. The Axillary nerve is located about 2.4 cm and the anterior circumflex humeral artery about 1.4 cm distally to this portal.
- Neviaser portal: between the clavicle and scapular spine about 1 cm medial to the acromion (with the arm adducted)
- Lateral Portals: about 3 cm lateral to the acromion (lateral standard portal). An additional posterolateral portal (in line with the *posterolateral* acromial edge) or an anterolateral portal (in line with the *anterolateral* acromial edge) can be placed depending on the existing pathology.
- "Port of Wilmington": approximately 1 cm lateral and 1 cm anterior to the posterolateral acromial edge.
- Deep posterolateral portal: about 2 cm lateral and 6 cm inferior to the posterolateral acromial edge; for placement of the posteroinferior anchor in posterior shoulder stabilization in the lateral decubitus position.

1.3 Diagnostic Arthroscopy

The arthroscope is introduced through the standard posterior portal taking into account the *plane of the glenoid surface*. The trocar is directed towards the coracoid process. Diagnostic arthroscopy is started initially with air insufflation, then with Ringer's solution, to which Norepinephrine is added (1 mg:1000 ml Ringer's solution) under a constant fluid pressure of 50 mm Hg. All additionally required portals are created under arthroscopic visualization using a needle to identify the correct position of the portal in so-called "outside-in technique".



■ **Fig. 1.1** Beach-chair position: The patient is in supine position with an elevated upper trunk (about 60°) and flexed hips (about 45–60°) and knees (about 30°)



■ **Fig. 1.2** The lateral decubitus position

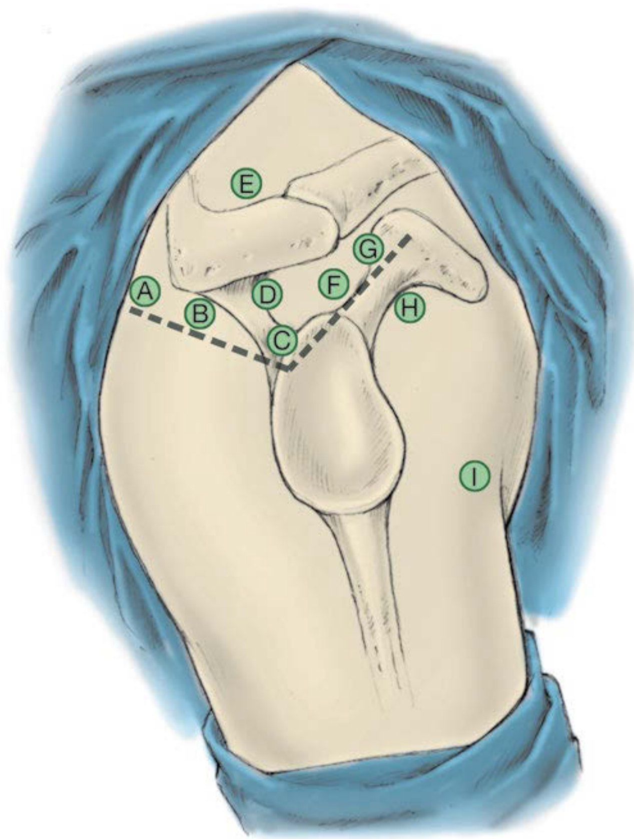


Fig. 1.3 Arthroscopic portals in beach-chair position (selective choice). *A* posterior standard portal, *B* posterolateral portal, *C* deep lateral portal, *D* high lateral portal ("port of Wilmington"), *E* Neviaser portal, *F* anterolateral portal, *G* anterosuperior portal, *H* anteroinferior portal, *I* deep anteroinferior Portal (5:30-o'clock portal)

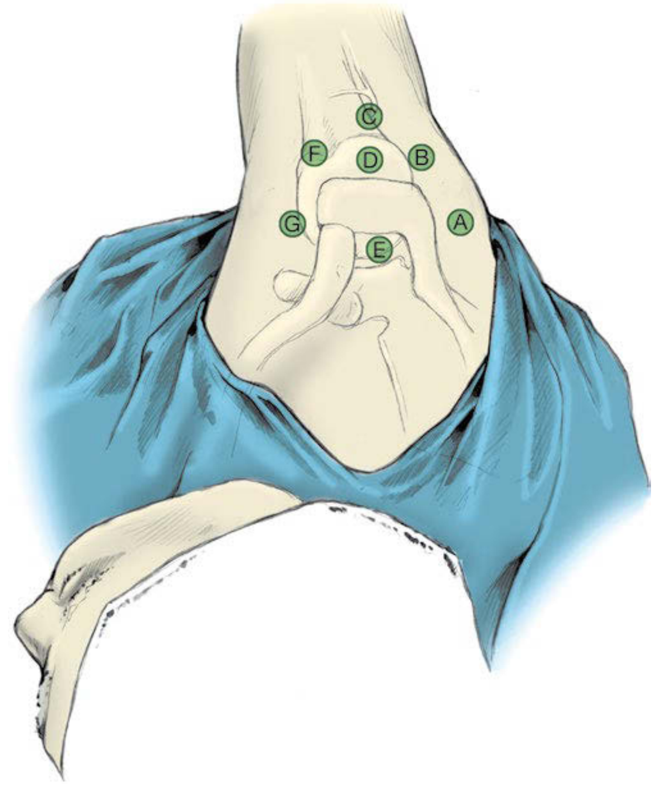


Fig. 1.4 Arthroscopic portals in lateral position (selective choice). *A* posterior standard portal, *B* posterolateral portal, *C* deep lateral portal, *D* high lateral portal (Port of Wilmington), *E* Neviaser portal, *F* anterolateral portal, *G* anterosuperior portal

Tab. 1.1 Advantages/Disadvantages of both positions

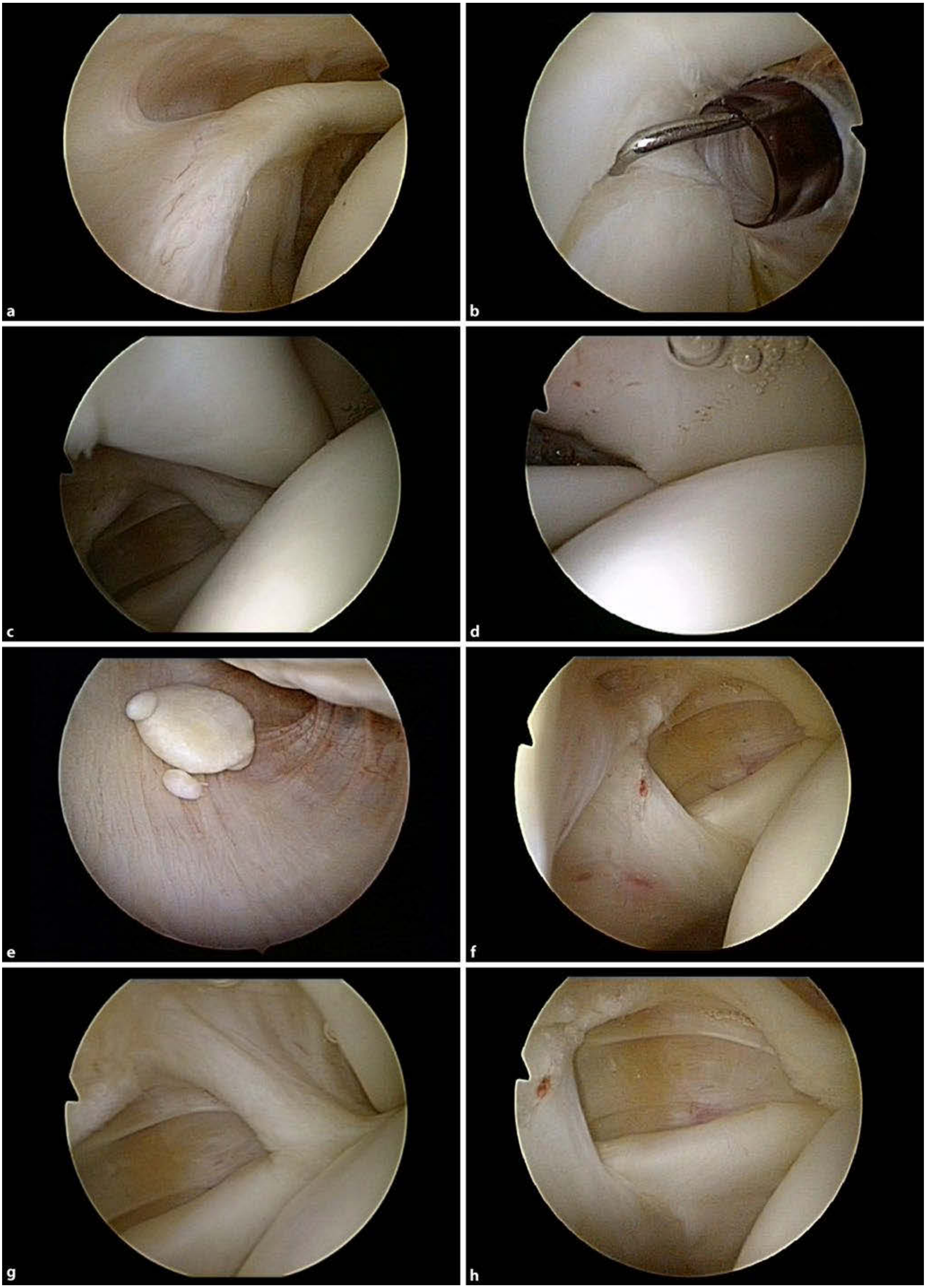
	Lateral decubitus position	Beach chair position
Advantages	Traction increases glenohumeral & AC joint spaces Traction accentuates labral lesions More suitable for arthroscopic posterior stabilization Lower risk of cerebral hypoperfusion	Better clinical examination under anesthesia is possible Conversion to open/mini-open technique without rearrangement (same positioning for all procedures)
Disadvantages	Need to reposition the patient when switching to open surgery	Higher risk of perioperative cerebral hypoperfusion Possibly mechanically compromised range of motion of the arthroscope in the posterior portal due to the operating table or the patient's head)

1.3.1 Diagnostic Inspection/Examination (Fig. 1.5)

- The biceps tendon anchor is initially identified (12 o'clock position of the glenoid) followed by inspection of the tendon for tears, fraying or inflammatory vascular congestion.
- The integrity of the pulley system is evaluated to exclude dislocation/subluxation of the long head of the biceps during internal and external rotation. Therefore, the course of the medially located superior glenohumeral ligament (SGHL) and the laterally located coracohumeral ligament (CHL) is assessed carefully.
- Inspection of the articular surface of the supraspinatus and infraspinatus tendon in slight abduction and external rotation. The two tendons can't be clearly delineated intraarticularly. The "rotator cable" (crescent-shaped thickening of the rotator tendon fibres) forms an arc

→

Fig. 1.5a–h Arthroscopic diagnosis. **a** biceps tendon anchor; **b** sublabral recess **c** biceps tendon, **d** supraspinatus tendon , **e** loose bodies in the inferior recess **f** MGHL; **g** SGHL, **h** rotator interval with subscapularis tendon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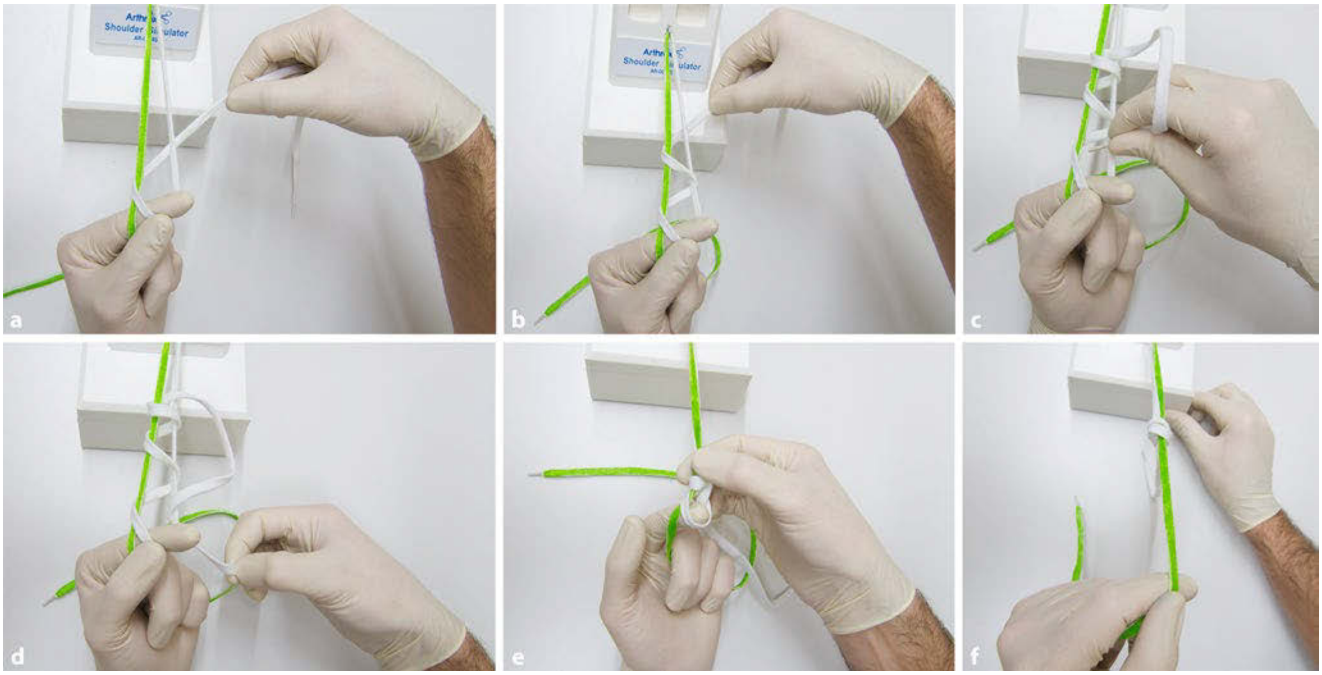

Fig. 1.6a–f Modified "fisherman's knot". **a** The "post" is held between the thumb and index finger of the left hand. The "loop" held with the right hand is passed from below over the index finger then outwards and below to pass around the tensioned sling of the loop already formed. **b** The "loop" strand is passed 2- to 3-times around this sling. **c** The tail of the loop strand is passed from below upwards between the two limbs of the sling of the loop and then backwards from above downwards close to the index finger proximal to the first loop passed. **d** The "loop" tail is pulled sideways. **e** The knot is advanced with the right hand towards the index finger and tightened. **f** The knot is advanced deeply by pulling on the "post" *and pushing the knot with knot pusher*

from the rotator interval to the lower edge of the infraspinatus tendon.

- Assessment of glenoid and anterior glenoid labrum, taking into account possible anatomic variations (e. g. sublabral foramen, Buford complex).
- The humeral head is inspected for cartilage lesions. The "Bare area" (a posterolateral frequently present cartilage-free zone) shouldn't be misinterpreted as a Hill-Sachs lesion.
- The inferior recess is inspected for loose bodies.
- The posterior labrum and the posterior aspect of the biceps anchor are evaluated for pathological and anatomic variations (e. g. SLAP lesions [SLAP = "superior labrum anterior to posterior"], and sublabral recess).
- The glenohumeral ligaments (SGHL, MGHL, and IGHL) are evaluated together with the insertion site of the subscapularis tendon in internal and external rotation.

1.4 Arthroscopic Sliding Knots

There are a large number of arthroscopic sliding knots, which can slide freely over suture strands passing through the tissue and the suture anchors. These knots are formed extraarticularly and through pulling one suture tail (the so called "post") with or without the aid of a knot pusher will be driven inside the joint to its final repair/fixation position.

If the suture is not freely *movable/sliding*, then a non-sliding knot is used. This is similar to tying knots in open surgical procedure, where separate half hitches are successively thrown und pushed with the aid of a knot pusher to the final position. Below we are going to describe the modified "fisherman's knot" and the "Weston knot" as examples of arthroscopic sliding knots. (Figs. 1.6 and 1.7). The stretched suture end is referred to here as "post" (green colored in figures) and the free end of the suture, which is passed over the "post", is referred to as a "loop" (white colored in the pictures). Additional half hitches thrown in opposite directions are necessary after any sliding knot to secure it and prevent slippage. The length of the loop strand should be initially much longer than the post as the knot is driven finally inside the joint by pulling on the post.

1.5 Tips & Tricks

- Long extended anesthesia tubes should be used in case of lateral decubitus positioning to allow free positioning of the head.
- The lateral decubitus position is preferred for posterior and multidirectional stabilization for its previously mentioned advantages.
- In case of beach chair positioning, the mean arterial blood pressure should be ensured and maintained to

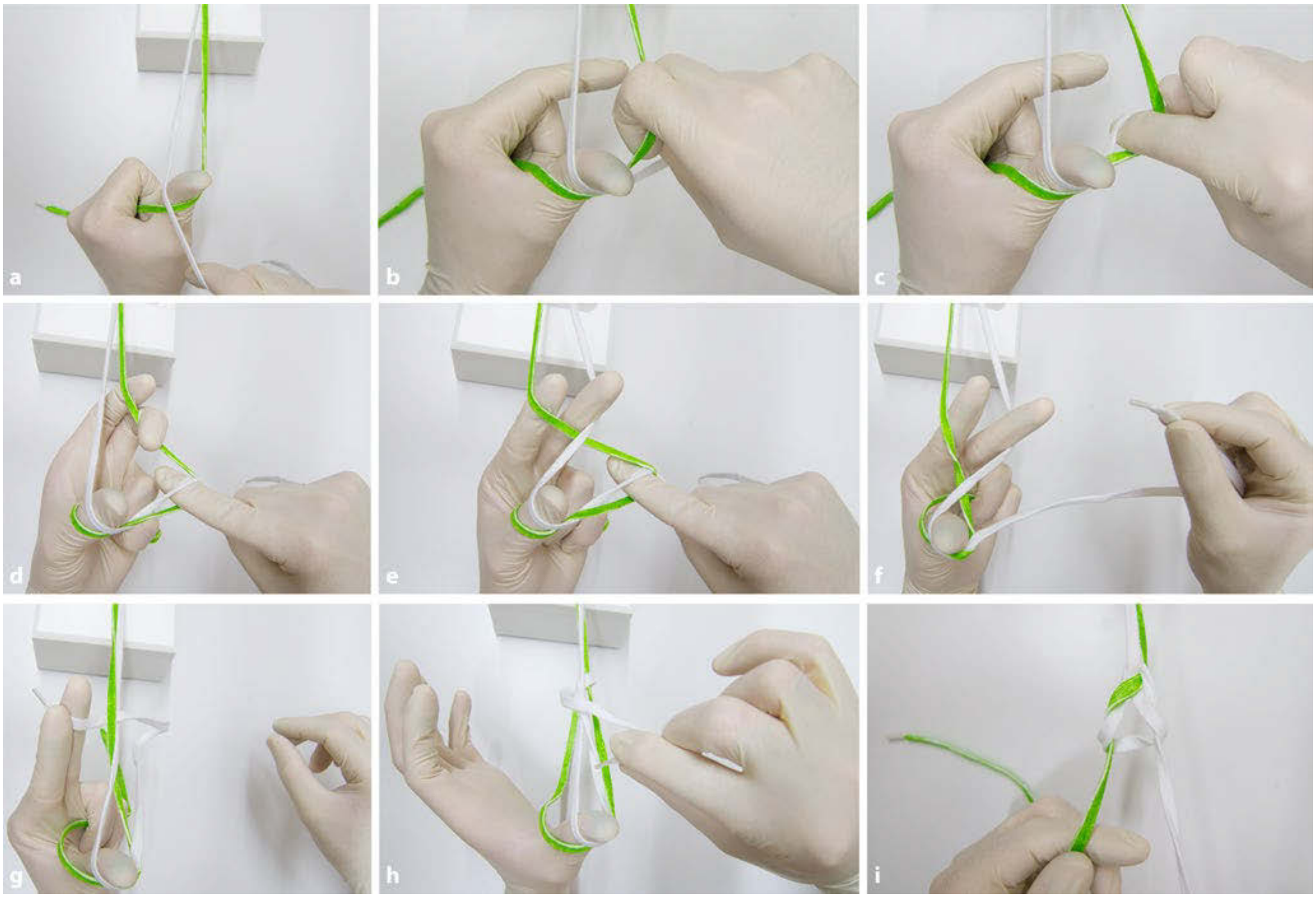

Fig. 1.7a–i Weston knot. a Both tails are placed in the palm of both hands and fixed through flexing fingers upon them. The thumb points upwards and is placed between both limbs. The "post" is grasped with the left hand so that it passes behind the thumb and both hand move to cross both strands in front of the left thumb and a first "loop" is formed behind the left thumb. **b** The right index finger is passed through the tensioned first loop. **c** The index finger gets the "loop" strand through the first loop and holds it on its dorsal aspect. **d** The fourth and fifth left fingers hold the "post" tail, the index and middle finger grasp the post a little bit distally and place it under the loop strand. **e** The index and middle fingers of the left hand span both strands to make a second loop and the right index finger pulls the tail of the "loop" strand (that was still hold) out. **f** the loop tail already passed out is delivered to the left index and middle fingers from above. **g** the loop strand is pulled to the left side and then hold once again with the right hand. **h** The "loop" tail is then passed again close to the thumb from above downwards through the first loop initially formed and pulled downwards. **i** The final knot is advanced distally by pulling on the "post" *and pushing the knot with knot pusher*

120 mm Hg before elevation of the trunk and positioning of the head (risk of cerebral hypoperfusion).
- A slight abduction and lateral traction of the humeral head through the assistant can facilitate the penetration of the capsule with the trocar while placing the posterior standard portal for diagnostic arthroscopy.
- The "bare area" should not be mistaken for a Hill-Sachs or cartilage lesion.
- Pathological labral detachment should be differentiated from anatomic variations like a sublabral foramen or Buford complex (anterosuperior labrum deficiency combined with a cord like MGHL).
- In 55 % of cases, the long head biceps tendon is inserted predominantly into the posterosuperior labrum (this is important for positioning of the anchor during SLAP repair).

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Subacromial Space

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2

2.1 Arthroscopic Subacromial Decompression (ASAD)

M. Feucht, S. Baun

2.1.1 Indication

Symptomatic outlet impingement (bony narrowing of the subacromial space by acromial spurs, Bigliani type II and III acromion morphology [Fig. 2.1], inferior AC joint osteophytes) after failure of conservative treatment trials or with concomitant rotator cuff lesions.

2.1.2 Operation Principle

Widening of the subacromial space and creating a flat inferior acromion surface by arthroscopic resection of the anteroinferior acromion with preservation of the coracoacromial ligament (Fig. 2.2). Optionally, concomitant resection of AC joint osteophytes (Coplaning).

2.1.3 Preoperative Assessment

Diagnosis

Clinical Evaluation

- Symptom-specific history: pain character (with load, at rest, at night), location and radiation of pain, previous infiltrations and operations.
- Symptom-specific examination: lower "painful arc" (60–120°), Neer sign, Hawkins-Kennedy sign and if applicable subacromial infiltration test.

Imaging (Radiographic Evaluation)

- X-rays of the shoulder in three views (true AP, y-view, axial) for evaluation of the acromion shape acromiohumeral distance and the undersurface of the AC joint (osteophytes)
- MRI scan to differentiate between intrinsic and extrinsic causes of impingement and to evaluate the rotator cuff tendons and other possible concomitant pathologies

Patient Information/Consent/Declaration

Specific operative risks: nerve injury (brachial plexus), injury of the subclavian artery, fracture of the acromion or clavicle

2.1.4 Operative Technique

Positioning and Preparation

- Beach chair position
- Positioning of the patient arm in arm holder

Arthroscopic Subacromial Decompression (ASAD)

A diagnostic arthroscopy and bursoscopy is performed through the standard posterior portal followed by partial subacromial bursectomy using a shaver or electrocautery probe introduced through the anterolateral working portal. The bony undersurface of the acromion is exposed with the shaver to visualize the entire anterior part of the acromion. The insertion of the coracoacromial ligament is released cautiously and sparingly with the electrocautery probe.

After clear visualization of the anterior and lateral margins of the acromion, a motorized bone shaver or burr is introduced through the anterolateral portal to begin resecting the bony undersurface of the anterior acromion edge. About half a shavers diameter is removed, in a lateral to medial direction, till reaching the AC joint (Figs. 2.3 and 2.4a). Significant inferior osteophytes of the AC joint are removed as well, if necessary.

The arthroscope is switched to the anterolateral portal to check the amount of bone resected. As needed, resection can be completed, with the shaver brought in through the posterior portal. The goal should be a flat undersurface of the acromion (Fig. 2.4b). There is merely much bone to be resected to convert a Bigliani type II or III acromion into a Type I. Finally, hemostasis and denervation of the raw bone surface is performed with an electrocautery probe.

2.1.5 Postoperative Management

- Positioning of the arm in an arm sling
- Monitoring of peripheral circulation, motor and sensory innervations.
- Postoperative X-Ray evaluation.

2.1.6 Follow-Up Management

Immobilization of the shoulder in a sling for 24 h which is then only used at night and with prolonged activities for further 3 weeks. Abduction and flexion should be limited to 90° in the first 4 weeks, free range of motion is allowed from the 5th week.

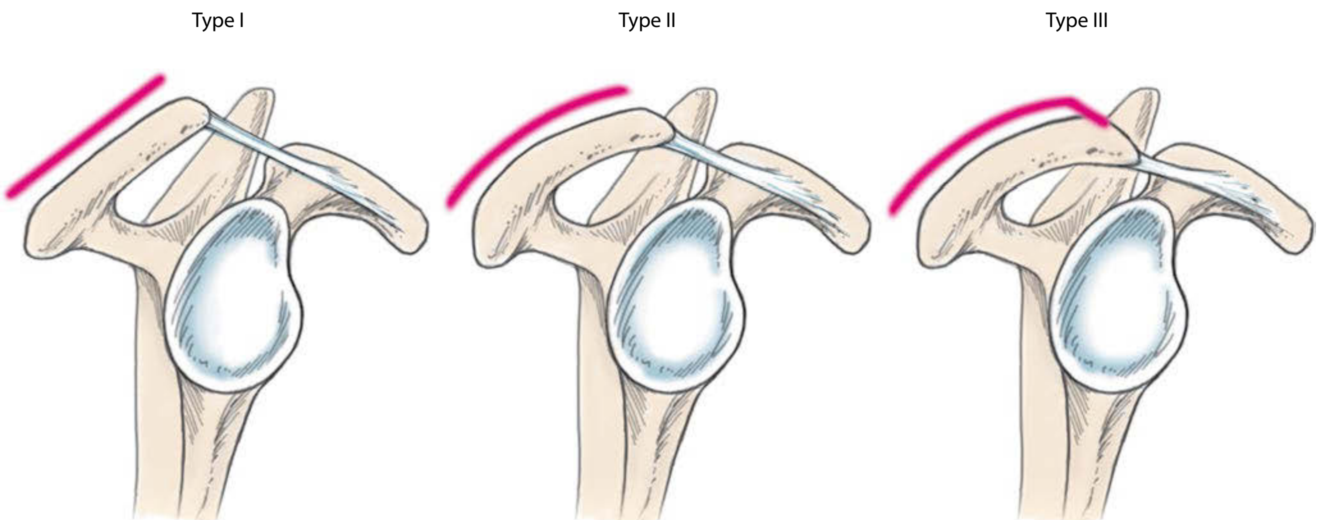

Fig. 2.1 Different types of acromion morphology according to Bigliani

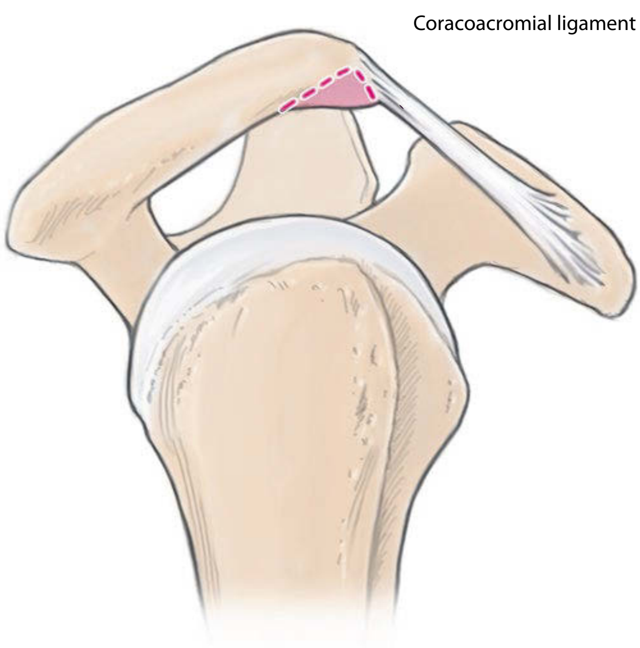

Fig. 2.2 The aim of the operation is a flat inferior surface of the acromion by resection of the anteroinferior acromion with preservation of the coracoacromial ligament

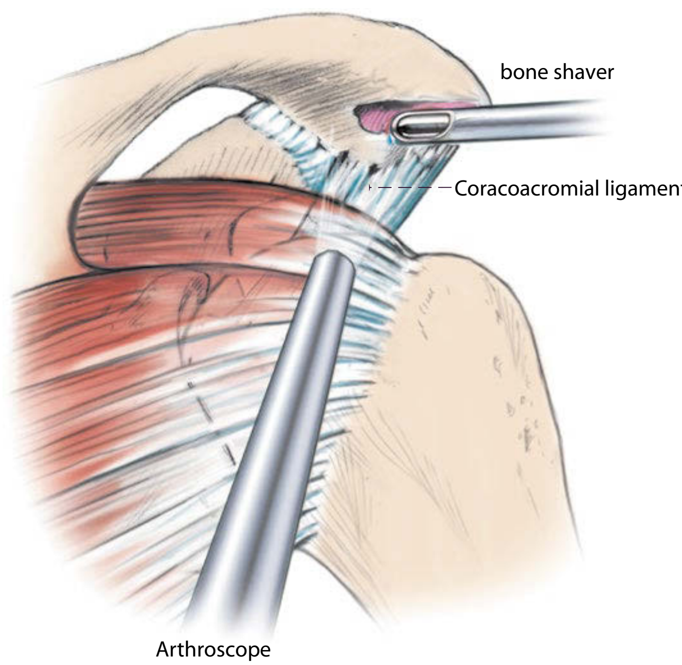

Fig. 2.3 Resection of the anteroinferior acromion edge with a bone shaver

2.1.7 Tips & Tricks

To ensure adequate resection of the anteroinferior acromion, the margins have to be clearly visualized. For easier arthroscopic orientation, the anterior margin can be marked with 2 needles. One needle is introduced along the margin of the anterolateral edge of the acromion towards the subacromial space and the second one is placed at the medial edge of the coracoacromial ligament just anterior to the AC joint.

To avoid bleeding from the thoracoacromial artery, the exposure of the anterior acromion margin should be done carefully with the use of electrothermal probe.

Care should be taken with complete resection of the coracoacromial ligament to avoid subsequent anterosuperior instability of the humeral head.

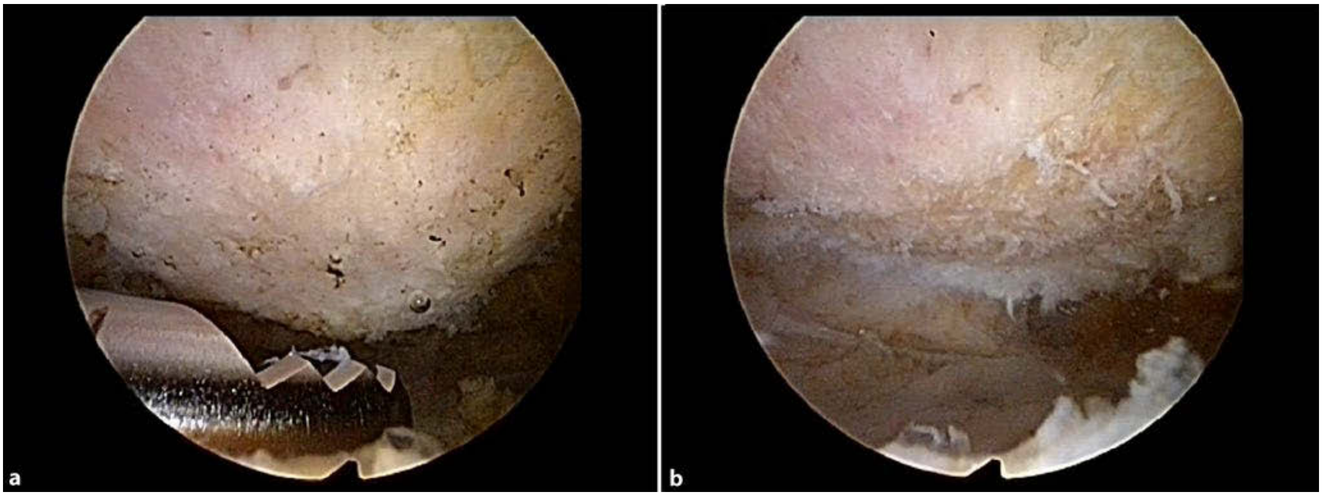

Fig. 2.4a,b Arthroscopic subacromial decompression. a Resection of the anteroinferior acromion edge with a bone shaver, **b** Final result with flat undersurface of the acromion

Fig. 2.5a–c Arthroscopic AC Joint resection. **a** Removal of the remnants of the intraarticular disc with the electothermal device. **b** Bone resection with a bone shaver. **c** Denervation of the acromial and clavicular sides of the joint as well as the capsular insertion sites with the electrothermal device

2.2 Arthroscopic Resection of AC joint (ARAC)

M. Feucht, S. Braun

2.2.1 Indication

- Symptomatic osteoarthritis of the AC joint after failure of initial trial of conservative therapy
- Symptomatic outlet impingement due to inferior AC joint osteophytes/spurs.

2.2.2 Operation Principle

Arthroscopic resection of osteoarthritic surfaces of the AC joint with preservation of the stabilizing posterior and superior parts of the joint capsule.

2.2.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom-specific history: previous injuries, previous infiltrations and operations, movement patterns related to occupation and sport with particular stress (e.g. Bench press), pain localization and radiation.
- Symptom-specific examination: localized tenderness over the AC joint, superior/high "painful arc" (pain after approx. 120° of abduction), "Cross-body adduction" test, evaluation of the stability of the AC joint, exclusion of concomitant cervical spine disease, Infiltration test.

Imaging

- X-rays of the shoulder in three views (true AP, Y-view, axial) as standard imaging modality and if necessary, additional Zanca-view for detailed evaluation of the AC Joint.
- MRI scan to assess the degree and activity of osteoarthritis and to exclude possible concomitant pathologies (e.g. partial rupture of the supraspinatus tendon secondary to outlet impingement)

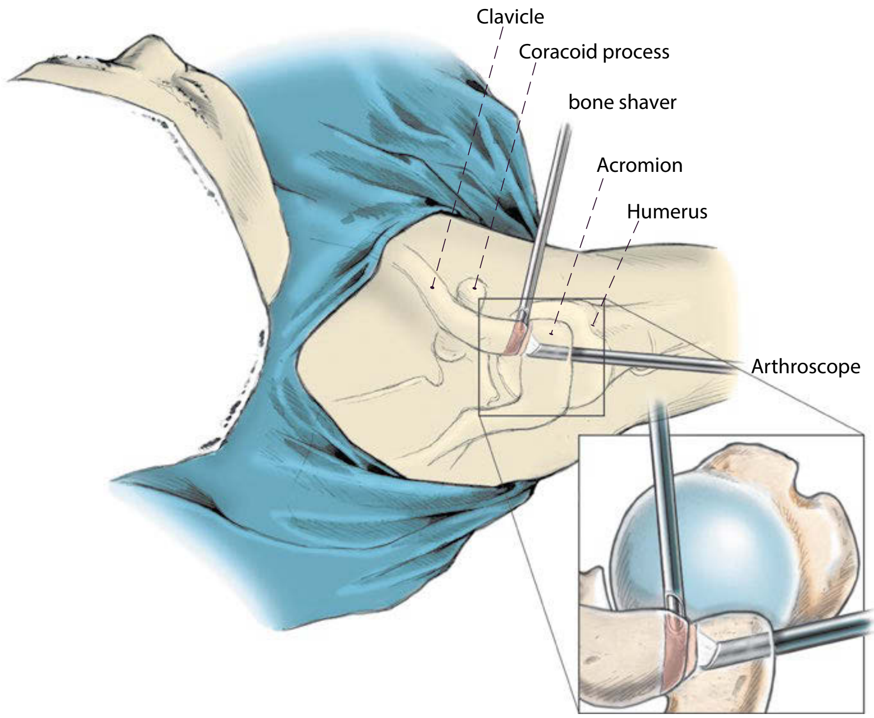

Fig. 2.6 Resection of about 3–5 mm of the lateral end of the clavicle (diameter oft he shaver blade) with a bone shaver and about 1–2 mm of the acromial side of the joint through the anterosuperior portal. The arthroscope is placed in the lateral portal

Patient information/Consent

Specific operative risks: nerve injury (brachial plexus), injury of the subclavian artery, AC joint instability.

2.2.4 Operative Technique

Positioning and Preparation

- Beach chair position
- Positioning of the patient arm in an arm holder

Arthroscopic Resection of the Acromioclavicular Joint

Diagnostic arthroscopy and bursoscopy is performed through the standard posterior portal followed by partial subacromial bursectomy using motorized shaver or electrocautery probe through a lateral working portal. The arthroscope is switched to the lateral portal and an anterosuperior working portal is established directly anterior to the AC joint in outside-in technique. Resection of the anterior and inferior joint capsule as well as any remnants of the articular disc with the electrocautery probe (Fig. 2.5a) exposing both clavicular and acromial articular sides of the joint.

About 3–5 mm of the lateral end of the clavicle (approx. one shavers diameter) is removed with a bone shaver or bur introduced through the anterosuperior portal, beginning the resection anterolaterally and progressing posteriorly and superiorly with preservation of the posterior and superior parts of the joint capsule (Figs. 2.6 and 2.5b). This is followed by resection of about 1–2 mm of the acromial side of the AC

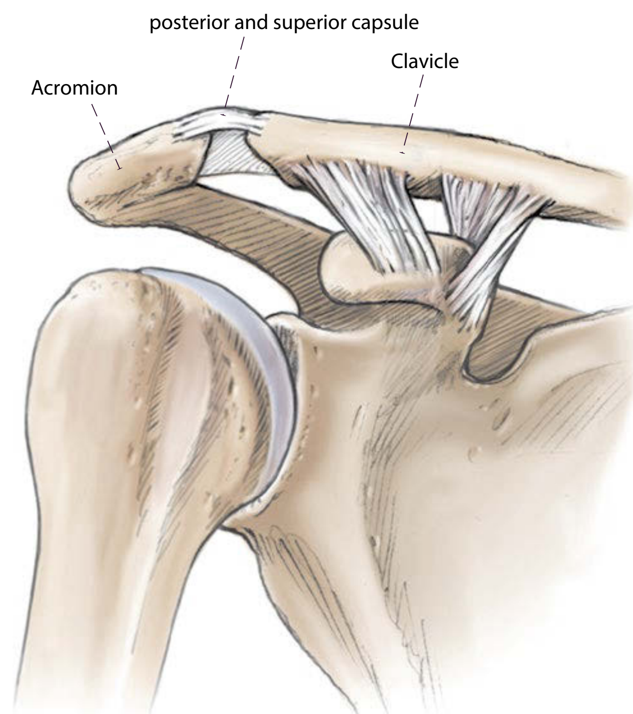

Fig. 2.7 The goal to be achieved is a domeshaped widening of the joint space with preservation of the superior and posterior parts of the joint capsule

Fig. 2.8 Easier intraoperative orientation with placement of two transarticular needles

joint. The goal to be achieved is a dome-shaped widening of the joint space (Fig. 2.7).

Finally, the raw acromial and clavicular bone surfaces as well as the insertion site of the resected capsule are denervated and coagulated with the electrocautery probe. The arthroscope is switched to the anterosuperior portal to check the extent of resection both statically and dynamically (through horizontal adduction movement (Fig. 2.5c).

2.2.5 Postoperative Management

- Positioning of the arm in an arm sling
- Monitoring of peripheral circulation, motor and sensory innervation
- Postoperative X-ray evaluation.

2.2.6 Follow-Up Management

Immobilization of the shoulder in a sling for 24 h, which is used for the subsequent 3 weeks only at night and with prolonged activities. Horizontal adduction should be avoided for 6 weeks postoperatively. Abduction and flexion should be limited to 60° in the 1.–2. weeks with free rotation, then gradual increase of abduction and flexion to 90° from the 3rd to the 6th weeks. Free range of motion is allowed starting from 7th week.

2.2.7 Tips & Tricks

During resection, the superior and posterior parts of the AC joint capsule should be preserved to maintain the stability of the joint.

The goal of the procedure is a dome-shaped widening of the joint space to about 5 mm (approx. diameter of a shaver blade) with maintenance of the posterior and superior capsule.

A downward pressure on the clavicle or marking the joint with 2 needles introduced intraarticularly into the subacromial space can help to improve visualization of the AC joint and subsequently a better arthroscopic orientation during exposure and resection (Fig. 2.8).

Repeated switching of the arthroscope into the anterosuperior portal is recommended for better visualization of resected space and hence to ensure a complete resection of the articular surfaces.

2.3 AC joint Stabilization (Acute)

M. Feucht, S. Braun

2.3.1 Indication

Acute AC joint dislocation (within 2–3 weeks after injury), Rockwood type IV–VI, and Type III dislocation with posterior instability component as well as in patients with high functional demands.

2.3.2 Operation Principle

Arthroscopically assisted anatomical reconstruction of the coracoclavicular ligaments (conoid and trapezoid ligaments) using two transclavicular and transcoracoidal passed flip button pulley system (e.g. AC-TightRope system, Arthrex).

2.3.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom-specific history: mechanism and time of the injury, individual functional demands (sports, work)
- Symptom-specific examination: inspection for bruises or abrasions, degree of elevation of the clavicle, piano key sign test, evaluation of the horizontal displacement of the clavicle as well as reducibility of the AC joint.

Imaging

- X-rays of the shoulder in three views (true AP, Y-view, axial view) to exclude fractures and to classify the injury, additional Zanca-view if needed for detailed evaluation of the AC joint.
- Optional MRI scan to exclude associated injuries (e.g., SLAP lesions, rotator cuff lesions)

Patient information/Consent

Specific operative risks: nerve injury (brachial plexus), injury of the subclavian artery, fracture of the clavicle or coracoid, pneumothorax, hemothorax, implant failure with recurrent instability, the potential need for open reduction or even switching to an alternative method (e.g., hook plate)

2.3.4 Operative Technique

Positioning and Preparation

- Beach-chair position
- Examination under anesthesia (displacement and reducibility of the ACG)
- Positioning of the patient's arm in an arm holder
- Marking the clavicular footprints of the coracoclavicular ligaments (conoid ligament 4.5 cm and trapezoid ligament 2.5 cm medial to the lateral end of the clavicle) and the mini-open-incision between these two points (Fig. 2.9)

Arthroscopically Assisted AC Joint Stabilization Using Two Flip Button Pulley Systems.

A diagnostic arthroscopy is performed through standard posterior portal to exclude intraarticular associated injuries followed by establishing a working anterosuperior portal as well as a second viewing anterolateral portal for better visualization of the coracoid base.

Soft tissues along the superior border of the subscapulris tendon are released until reaching the undersurface of the coracoid with an electrocautery probe introduced through the anterosuperior working portal. The arthroscope is switched to the anterolateral viewing portal to complete soft tissue release meticulously and thus exposing clearly the undersurface and the anteromedial edge of the coracoid (Fig. 2.15a).

The skin is incised, about 2–3 cm in length, perpendicular to the clavicle between the marked two clavicular foot prints, followed by incision of the deltotrapezial fascia along the line of trapezius muscle fibers to expose the clavicle.

The AC joint is anatomically reduced with the help of the arm holder and the reduction is checked with image intensifier before drilling the bone tunnels. Optionally, the arthroscope ca to check the reduction from the subacromial space. A temporary fixation of the AC joint with K-wire can be performed if there is a difficulty to attain or maintain reduction.

A drill guide (e.g. AC Guide, Arthrex) is introduced through the anterosuperior working portal and the tip of its coracoid drill stop is placed on the undersurface of the coracoid at the appropriate anatomical location of the ligaments (conoid ligament drill hole: at the base of the coracoid, 5 mm lateral to the medial edge; trapezoid ligament drill hole: 10 mm anterior to the previous tunnel, 5 mm medial to the lateral edge) (Fig. 2.15b).

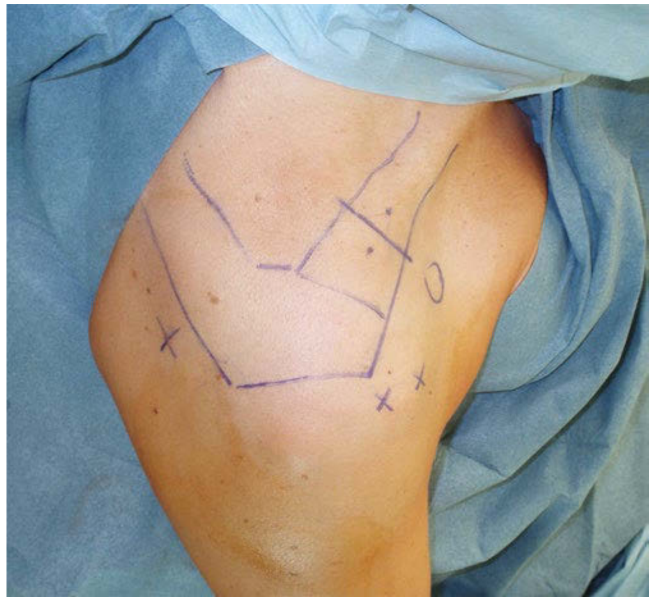

Fig. 2.9 Landmarks and approaches

Two 2.4-mm- guide pins are inserted transclavicular and transcoracoidal through the guide pin sleeve (Fig. 2.10). After checking the correct position of the pins, they are successively over drilled with cannulated 4-mm diameter drill bits, which are left in place after removal of the pins. There should be at least 12 mm bony bridge between the two guide pins.

A nitinol suture lasso is then passed through the cannulated drill in the conoid ligament tunnel (Figs. 2.11 and 2.15c) and withdrawn through the anterosuperior working portal with a grasper, followed by removal of the drill.

The Flip button pulley system (e.g. AC TightRope, Arthrex) is pulled under direct arthroscopic visualization from above downwards until the inferior button exits the inferior end of the coracoid tunnel (Fig. 2.12). The inferior button is then flipped under arthroscopic visualization and pulled proximally. The same sequence is repeated for the second Flip button (through trapezoid ligament tunnel).

The anatomical reduction of the AC joint is then checked radiologically (Fig. 2.13), followed by tightening and securing the sutures over the clavicular button with at least 5 knots with reversing the posts, starting with the medial system, representing the conoid ligament(Figs. 2.14 and 2.15d).

2.3.5 Postoperative Management

- Positioning of the arm in an arm sling
- Monitoring of peripheral circulation, motor and sensory innervations.
- Postoperative X-ray evaluation (Fig. 2.16)

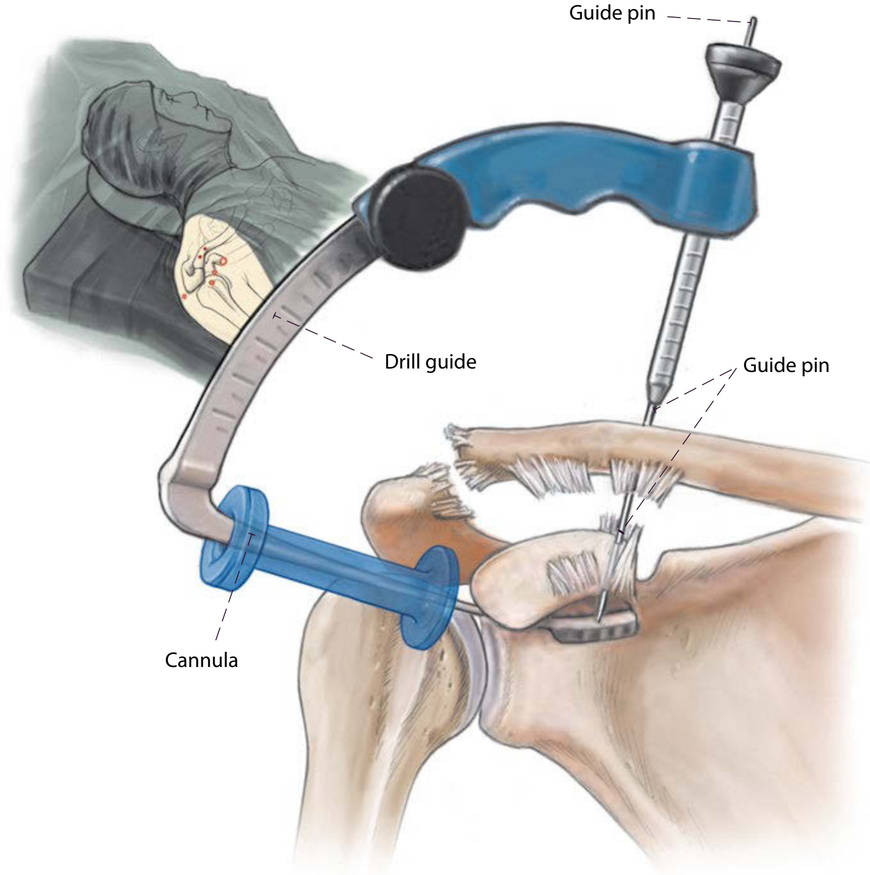

Fig. 2.10 Placement of the first guide pin through the aiming device (e. g. AC Guide, Arthrex)

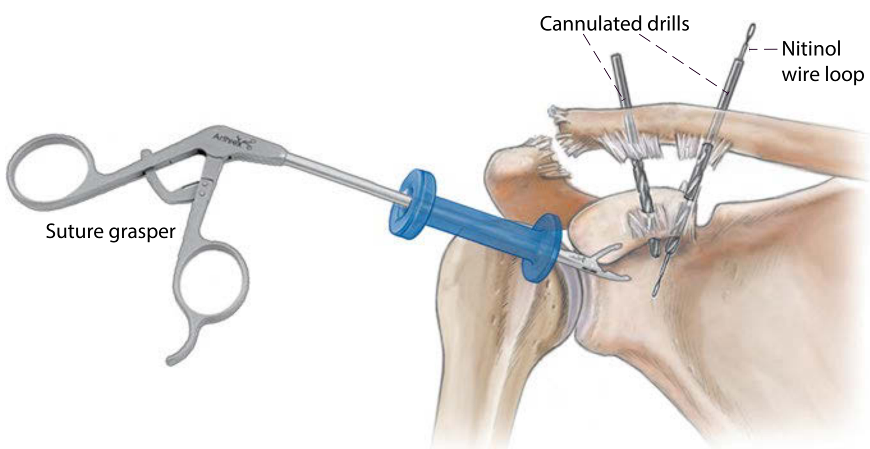

Fig. 2.11 Passing a nitinol suture lasso through the cannulated drill and withdrawing it through the anterosuperior working portal

2.3.6 Follow-Up Management

Immobilization in an arm sling for 6 weeks. The range of motion should be limited during physiotherapy and rehabilitation as follows:

- 1.–2. weeks passive: 30° abduction, 30° flexion, 80°internal rotation, 0°external rotation
- 3.–4. weeks active-assisted: 45° abduction, 45° flexion, 80° internal rotation, 0° external rotation
- 5.–6. weeks active: 60° abduction, 60° flexion, free internal and external rotation
- After the 7th postoperative week, free movements and after 3 months full load bearing are allowed.

2.3.7 Tips & Tricks

The patient head should be tilted about 20° to the opposite side during positioning to have a sufficient space for placement and drilling of the bone tunnels.

A careful release of the coracoid undersurface with complete exposure of the entire base as well as the medial and

Fig. 2.12 Pulling the first Flip button system

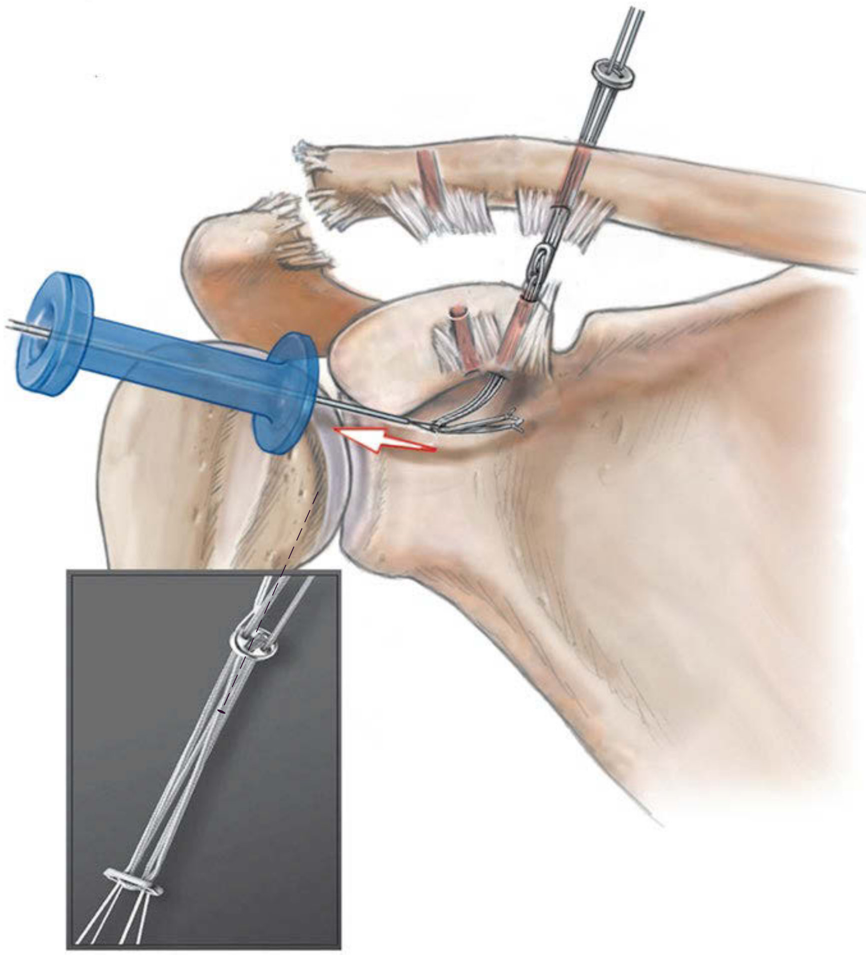

Fig. 2.13 Radiologically controlled reduction of the AC joint

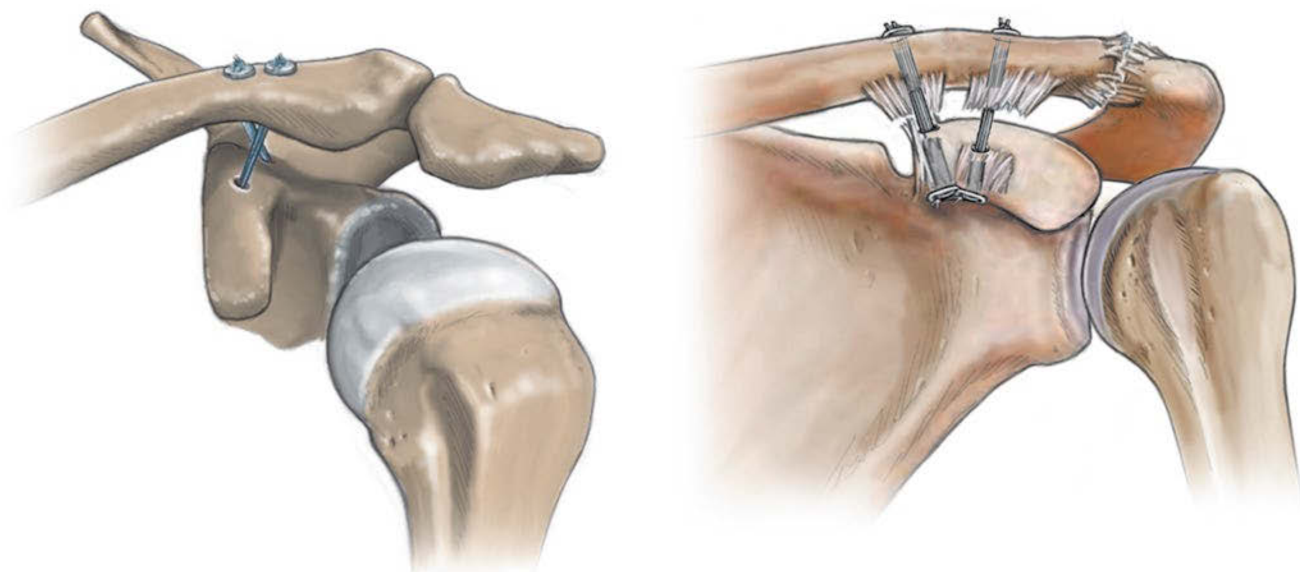

Fig. 2.14 Final AC joint-stabilisation with two Flip button pulley system

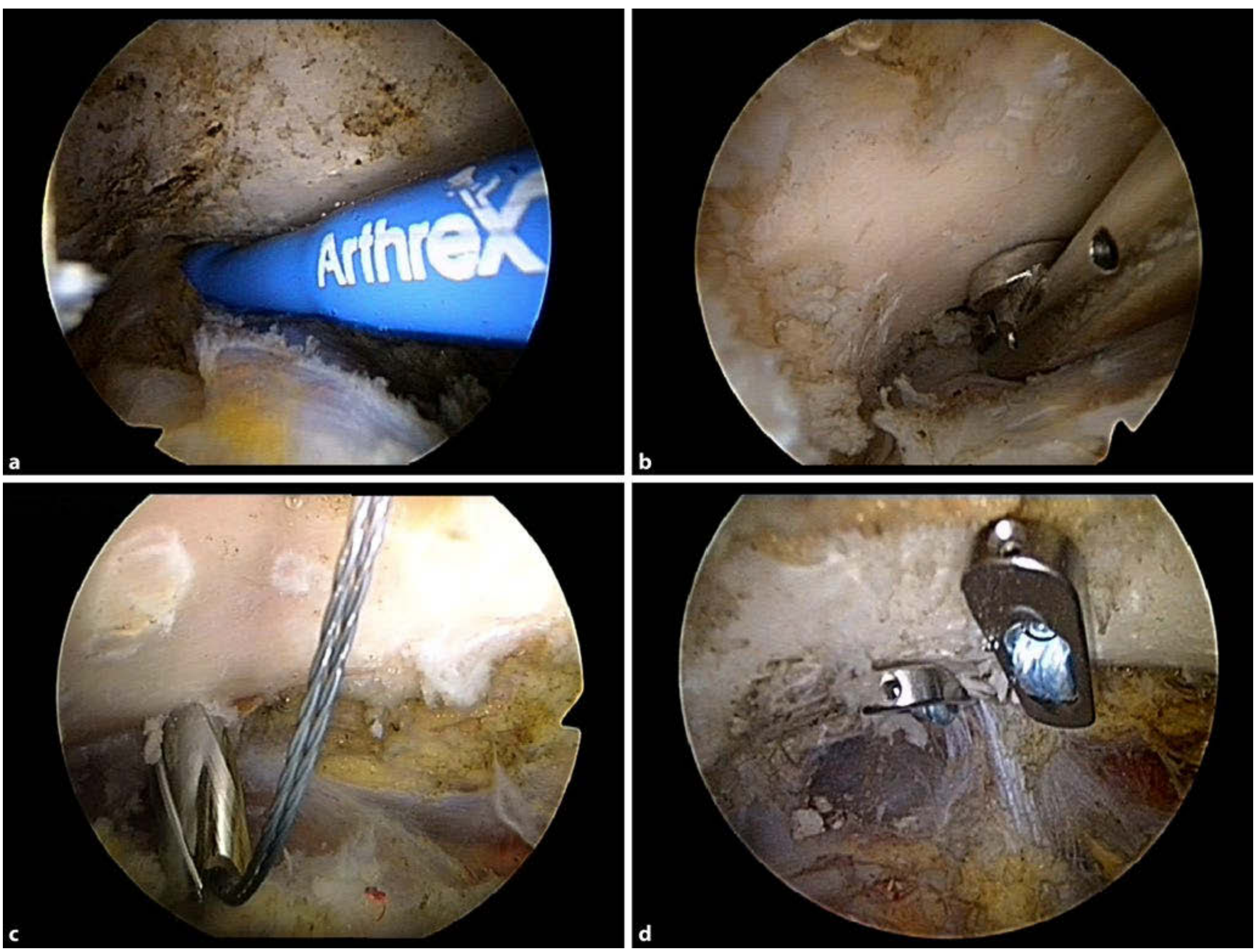

Fig. 2.15a–d Arthroscopically assisted ACJ stabilization. **a** Exposure of the undersurface of the coracoid, **b** Placement of the guide hook under the coracoid. **c** Passing a Nitinol Suture lasso through a cannulated drill, **d** Final result

■ **Fig. 2.16** Postoperative X-ray image after AC joint-Stabilization with two Flip button systems

lateral margin is crucial to ensure optimal positioning of the drill tunnels through the coracoid. Exposure of the tip of the coracoid is not needed.

Anatomical reduction of the AC joint should be carried out with the help of an arm holder under radiological control before introducing the drill guide and drilling the bone tunnels. The reduction should be checked again and corrected if necessary before tightening and securing the sutures (■ Fig. 2.10). Open reduction must be performed if closed reduction is not possible (e.g. due to soft tissue interposition).

For precise placement of the clavicular drill tunnels in the center of the clavicle, the anterior and posterior margins of the clavicle should be clearly visualized through insertion of 2 Hohmann retractors.

The placement of the guide wires as well as drilling the tunnels can be optionally performed under radiological control with an image intensifier.

Some authors recommend an additional acromioclavicular stabilization (e.g. with acromioclavicular cerclage) if there is marked horizontal AC joint instability.

2.4 AC joint Stabilization (Chronic)

M. Feucht, S. Braun

2.4.1 Indication

Chronic (> 3 weeks old), symptomatic Rockwood type III–VI AC joint dislocation.

Revision procedure after failed primary AC joint stabilization.

2.4.2 Operation Principle

Arthroscopically assisted anatomical reconstruction of both coracoclavicular ligaments using a Flip button pulley system (e.g. AC TightRope, from Arthrex) passed through the clavicle and coracoid in the course of the conoid ligament in addition to biological augmentation with autologous gracilis tendon graft passed in the course of the trapezoid ligament and looped around the coracoid and the clavicle in a modified figure of eight manner.

2.4.3 Preoperative Assessment

Diagnostics

Clinical Examination

- Symptom specific history: mechanism and time of injury, individual functional demands (sports, work), type and number of previous surgeries (if any), previous knee surgeries (harvesting of tendons)
- Symptom specific examination: degree of upward displacement of the clavicle, piano key sign, evaluation of the horizontal displacement of the clavicle and reducibility of the AC joint.

Imaging

- X-rays of the shoulder in three views (true AP, y-view, axial), optionally, an additional Zanca-view for detailed evaluation of the AC joint as well as panorama view of both shoulders with axial load of 5 kg on each side.
- Optionally, MRI scan to exclude possible associated injuries (e.g., SLAP lesions, rotator cuff lesions)
- CT scan for evaluation of the bony status of both clavicle and coracoid in case of revision surgery.

Patient Information/Consent

Specific operative risks: nerve injury (brachial plexus), injury of the subclavian artery, clavicle or coracoid fracture, pneumothorax, hemothorax, implant failure with recurrent instability, probability of open reduction (if required) or even switching to an alternative method of fixation. (e.g. hook

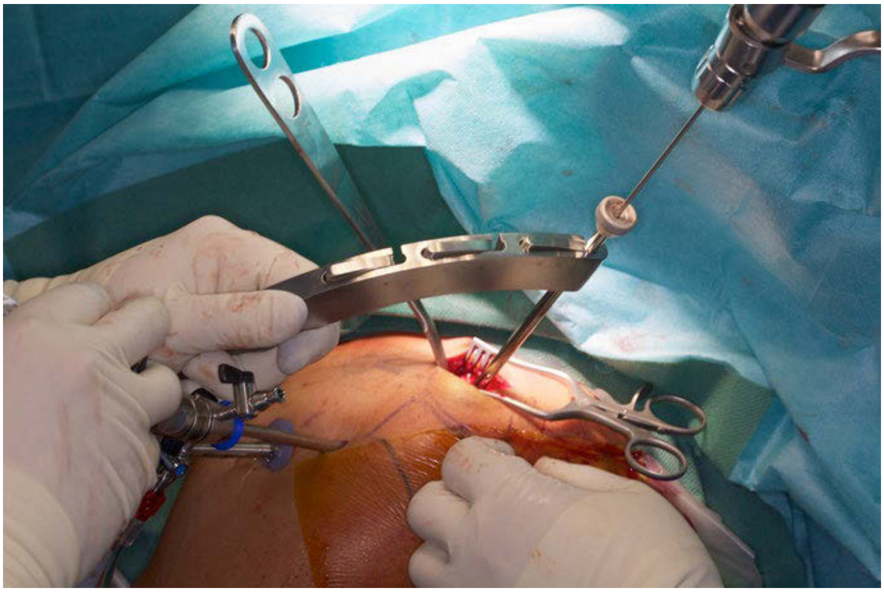

Fig. 2.17 Arthroscopic assisted placement of the guide pins

plate). Potential morbidity after harvesting gracilis tendon (Injury of saphenous nerve).

2.4.4 Operative Technique

Positioning and Preparation

- Beach-chair position. The ipsilateral knee is draped with placement of a thigh tourniquet.
- Examination under anesthesia (displacement and reducibility of the AC.joint)
- Positioning of the patient's arm in a arm holder.
- Marking the clavicular footprints of the coracoclavicular ligaments (conoid ligament 4.5 cm and trapezoid ligament 2.5 cm medial to the lateral end of the clavicle) as well as the mini- open-incision midway between these two points.

Arthroscopic Assisted ACJ Stabilization Using a Flip Button Pulley System and Gracilic Tendon Graft Augmentation.

The gracilis tendon graft is harvested and prepared as described in ► Sect. 13.1. A diagnostic arthroscopy is performed through the standard posterior portal to exclude intraarticular associated injuries. An anterosuperior working portal as well as a second viewing anterolateral portal are established in outside in technique for better visualization of the coracoids base.

The soft tissue along the superior border of the subscapulris tendon is released until reaching the undersurface of the coracoid process with an electrocautery probe introduced through the anterosuperior working portal. The arthroscope is then switched to the anterolateral viewing portal to complete soft tissue release meticulously and thus exposing clearly the undersurface and the anteromedial edge of the coracoid.

A 2–3 cm long skin incision is made perpendicular to the clavicle between the marked two clavicular footprints followed by incision of the deltotrapezial fascia along the line of trapezius muscle fibers to expose the clavicle.

The ACJ is anatomically reduced with the help of the pneumatic arm holder and the reduction is checked with image intensifier before drilling the bone tunnels. Optionally, the arthroscope can be used to check the reduction from the subacromial space. A temporary fixation of the AC joint with K-wire can be performed if there is a difficulty to attain or maintain reduction.

A drill guide (e.g. AC Guide, Arthrex) is introduced through the anterosuperior working portal and the tip of its coracoid drill stop is placed on the undersurface of the coracoid at the appropriate anatomical location of the ligaments (conoid ligament drill hole: at the base of the coracoid, 5 mm lateral to the medial edge; trapezoid ligament drill hole: 10 mm anterior to the previous tunnel, 5 mm medial to the lateral edge) (Fig. 2.15b).

Two 2.4-mm-guide pins are inserted transclavicular and transcoracoidal through the guide pin sleeve (Figs. 2.17 and 2.18a).

After checking the correct position of the guide pins, the pin in the course of the conoid ligament is over-drilled with a cannulated 4-mm diameter drill bit, which is left in place after removal of the pin. A Nitinol Suture lasso is then passed through the cannulated drill and withdrawn through the anterosuperior working portal with a suture grasper followed by removal of the drill. There should be at least 12 mm bony bridge between the two guide pins.

The second guide pin is then over drilled with the 4 mm cannulated drill, which is removed after passing a doubled

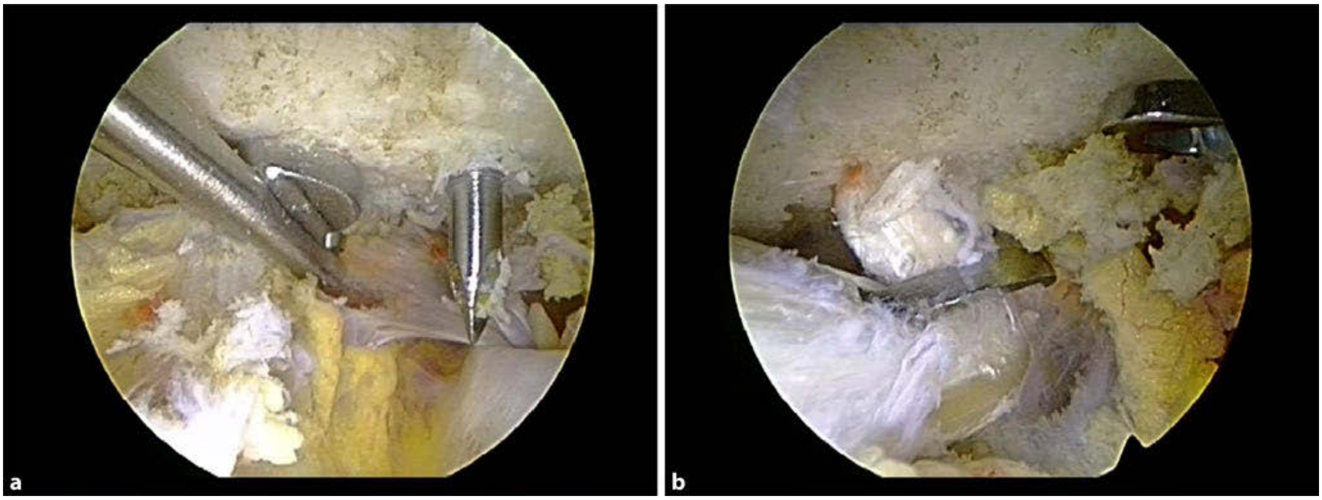

Fig. 2.18a,b Arthroscopic view. a Insertion of the two guide pins with the AC guide. **b** Pulling the gracilis tendon graft through the coracoid

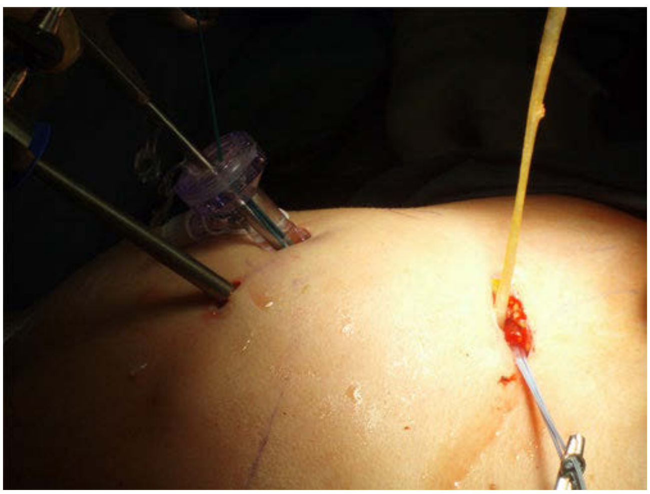

Fig. 2.19 Pulling the gracilis tendon

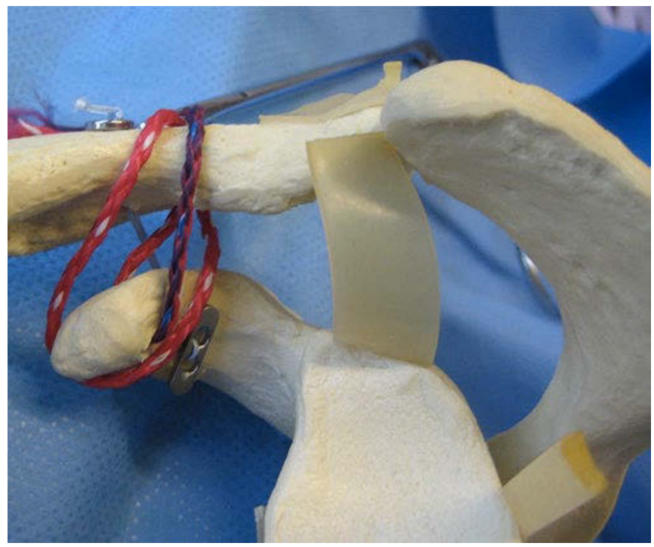

Fig. 2.20 Passing the gracilis tendon graft in a modified figure of eight manner in a saw bone model

shuttle suture. The gracilis tendon, threaded the loop of the shuttle suture, is pulled from the clavicular side downwards (Figs. 2.18b and 2.19) and the distal end of the graft is driven outside through the anterosuperior working portal.

The distal short tail of the graft, emerging from undersurface of the coracoid, is then pulled proximally with the help of a shuttle suture introduced anterior to the clavicle and lateral to the coracoid. The other long tail of the graft exiting the clavicular tunnel is pulled with the help of shuttle suture anterior the clavicle and passed medial to the coracoid into the joint. This tail is further pulled proximally with a grasper introduced posterior to the clavicle and lateral to the coracoid so that it passes under the coracoid and ultimately making a modified figure of eight around the clavicle and the coracoid (Fig. 2.20).

The anatomical reduction of the AC joint is checked with an image intensifier followed by tightening and securing the sutures over the clavicular button with at least 5 knots with reversing the posts. Both ends of the graft are then sutured together above the clavicle in side to side technique with non-absorbable sutures.

2.4.5 Postoperative Management

- Positioning of the arm in an arm sling
- Monitoring of peripheral circulation, motor and sensory innervations.
- Postoperative X-ray evaluation.

2.4.6 Follow-Up Management

Immobilization in an arm sling for 6 weeks, with limitation of the range of motion during physiotherapy and rehabilitation as follows:

- 1.–2. weeks passive : 30° abduction, 30° flexion, 80°internal rotation, 0°external rotation
- 3.–4. weeks active-assisted: 45° abduction, 45° flexion, 80° internal rotation, 0° external rotation
- 5.–6. weeks active: 60° abduction, 60° flexion, free internal and external rotation
- After the 7th postoperative week, free movements and after 3 months full load bearing are allowed.

2.4.7 Tips & Tricks

The patient head should be tilted about 20° to the opposite side during positioning to have a sufficient space for placement and drilling of the bone tunnels.

A careful release of the coracoid undersurface with complete exposure of the entire base as well as the medial and lateral edges is crucial to ensure optimal positioning of the drill tunnels through the coracoid.

Anatomical reduction of the ACJ should be carried out with the help of a pneumatic arm holder under radiological control before introducing the drill guide and drilling the bone tunnels. The reduction should be checked again and corrected if necessary before tightening and securing the Sutures. (◘ Fig. 2.10). Open reduction must be performed if closed reduction is not possible (e. g. due to soft tissue interposition).

For precise placement of the clavicular drill tunnels in the center of the clavicle, the anterior and posterior margins of the clavicle should be clearly visualized through insertion of 2 small Hohmann retractors.

The placement of the guide wires as well as drilling the tunnels can be optionally performed under radiological control with an image intensifier.

Some authors recommend an additional acromioclavicular stabilization (e. g. with acromioclavicular cerclage) if there is marked horizontal ACJ instability.

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Rotator Cuff Repair

M. Feucht, S. Baun, P. Minzlaff, N. Rosenstiel, M. Aboalata

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3.1 Repair of the Supraspinatus Tendon

M. Feucht, S. Baun

3.1.1 Indication

Symptomatic partial or complete tear of the supraspinatus tendon associated with functional deficit and/or pain. Specific contraindications for repair include: tendon retraction medially > grade 3 (Patte), muscle atrophy > grade 3 (Thomazeau), fatty infiltration > grade 3 (Goutallier), concomitant advanced osteoarthritis of the shoulder and superior migration of the humeral head (rotator cuff arthropathy) and upper brachial plexus lesions.

3.1.2 Operation Principle

Arthroscopic refixation of the supraspinatus tendon (SSP) at the greater tuberosity with suture anchors.

3.1.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom-specific history: Patient complaints (pain, weakness, limitation of the range of motion), previous shoulder trauma, duration of symptoms, previous treatment, sport and functional demands.
- Symptom-specific examination: Inspection for atrophy of the supraspinatus and infraspinatus muscles, evaluation of the passive and active range of motion (pseudo-paralysis), Starter test, Jobe test and signs of impingement.

Neurological/Vascular Condition

Exclusion of suprascapular nerve and brachial plexus lesions.

Imaging

- X-rays of the shoulder in three views (true AP, y-view, axial) for evaluation of the bony status, degree of osteoarthritis, centering of the humeral head relative to the glenoid, exclusion of bony outlet impingement.
- MRI (if necessary, with intra-articular contrast medium) to outline the tear pattern, evaluate the degree of tendon retraction, muscle atrophy and fatty muscle infiltration as well as exclusion of concomitant lesions.

Patient Information/Consent

Specific operative risks: persistent complaints postoperatively (Pain, weakness, limitation of motion), re-rupture of the repaired tendons (symptomatic/asymptomatic), inaccurate placement of anchors/failure or dislocation, osteolysis, postoperative shoulder stiffness, nerve injury (brachial plexus, axillary or musculocutaneous nerve), injury of the subclavian artery, and possibility of switching to open repair.

3.1.4 Operative Technique

Positioning and Preparation

- Beach chair position
- Examination under anesthesia.
- Positioning of the patient arm in an arm holder

Arthroscopic Reconstruction of the Supraspinatus Tendon (SSP)

Diagnostic arthroscopy via the standard posterior portal and evaluation of the geometry and extent of the tear. Beside the anterosuperior portal, additional 2–3 working portals (lateral, anterolateral and posterolateral or Neviaser portal) are usually needed depending on the tear location. The subacromial space is visualized arthroscopically and extensive bursectomy with electrothermal probe or motorized shaver. A subacromial bony decompression is performed if there is associated outlet impingement. The excursion and reducibility of rotator cuff tendons to the insertion site is evaluated using a tissue grasper introduced through a lateral portal to assess the degree of required release and mobilization.

Mobilization of the rotator tendons and release of adhesions is performed carefully with shaver or electrothermal probe. Massively retracted tears usually require a more extensive mobilization through an anterior and/or posterior interval slide. Anterior interval slide involves releasing the supraspinatus tendon anteriorly from the rotator interval with dividing the coracohumeral ligament. Posterior interval slide involves releasing the supraspinatus and infraspinatus from each other along the spine of the scapula taking care to protect the suprascapular nerve. Subsequent management is dependent on the geometry of the tear: crescent shaped tears can usually be repaired and re-attached to the greater tuberosity without tension in most cases (◘ Fig. 3.1). U-shaped tears often cannot be repaired without tension. Therefore a side to side repair technique is tried to convert the U-shaped tear into a crescent shaped tear (the so called *margin convergence* technique) which can then be re attached in most cases with minimal or no tension. (◘ Fig. 3.2). The sutures in side to side repair are passed using curved hollow needles (Lasso 30° or 45°) or special tissue penetrators and shuttle instruments (e.g. Bird Peak or Scorpion, Arthrex) in a medial to lateral sequence of stitches tied in the subacromial space. Usually 2–3 of such transverse stitches are necessary. In case of L-shaped or inverted L-shaped tears, the more mobile part of the tendon should be identified first (mostly the posterior part) and

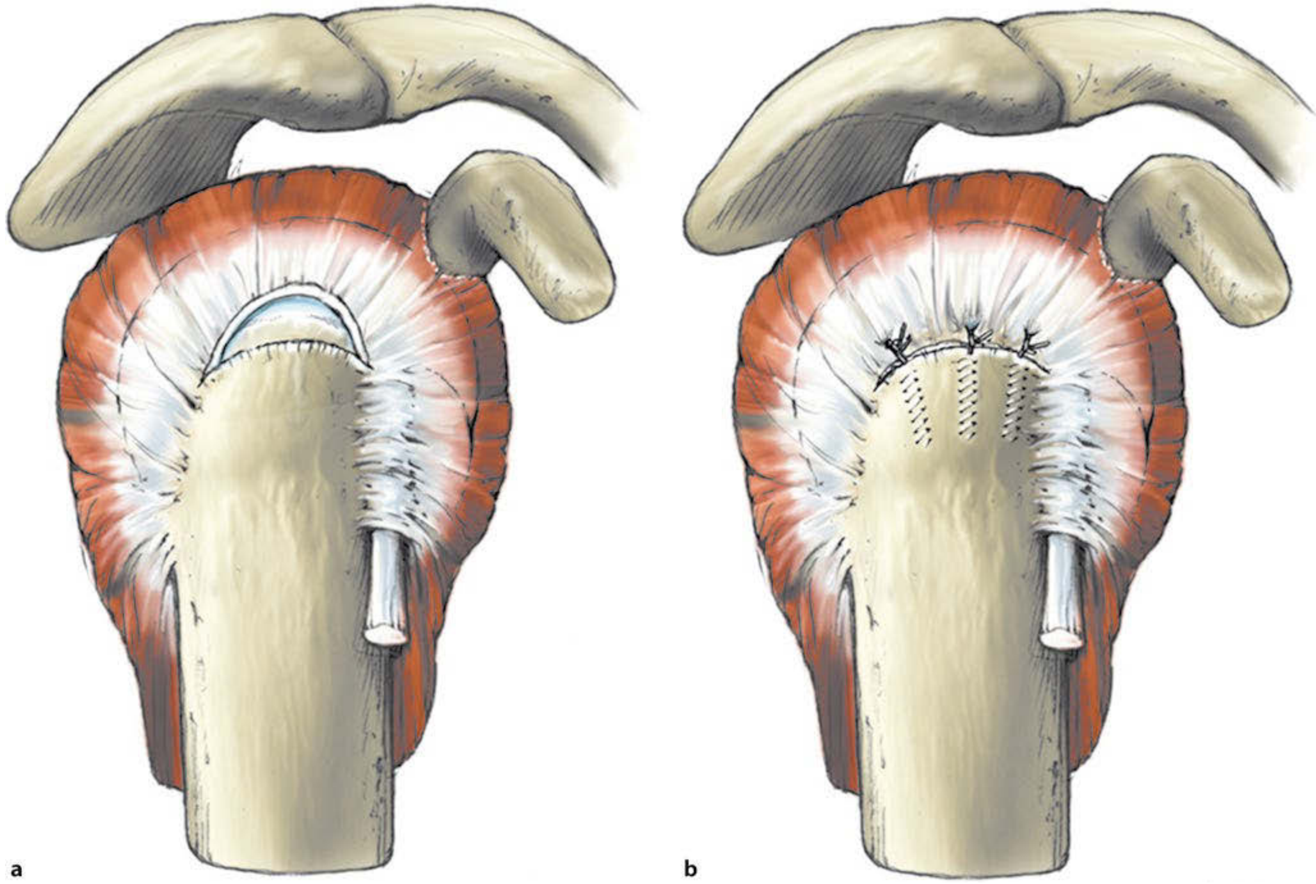
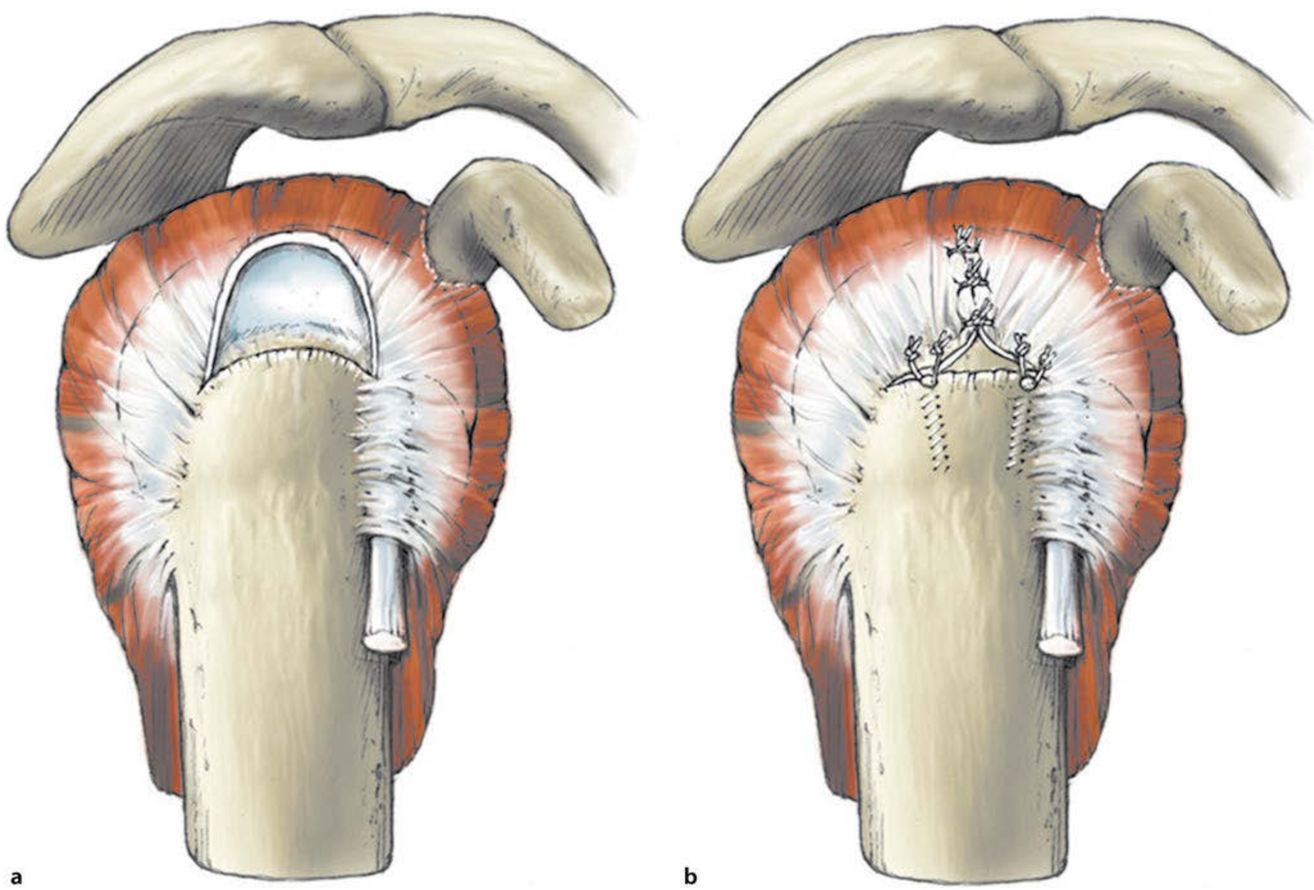


Fig. 3.1a,b Principle of repairing a crescent-shaped tear. **a** before, **b** after cuff repair with suture anchors



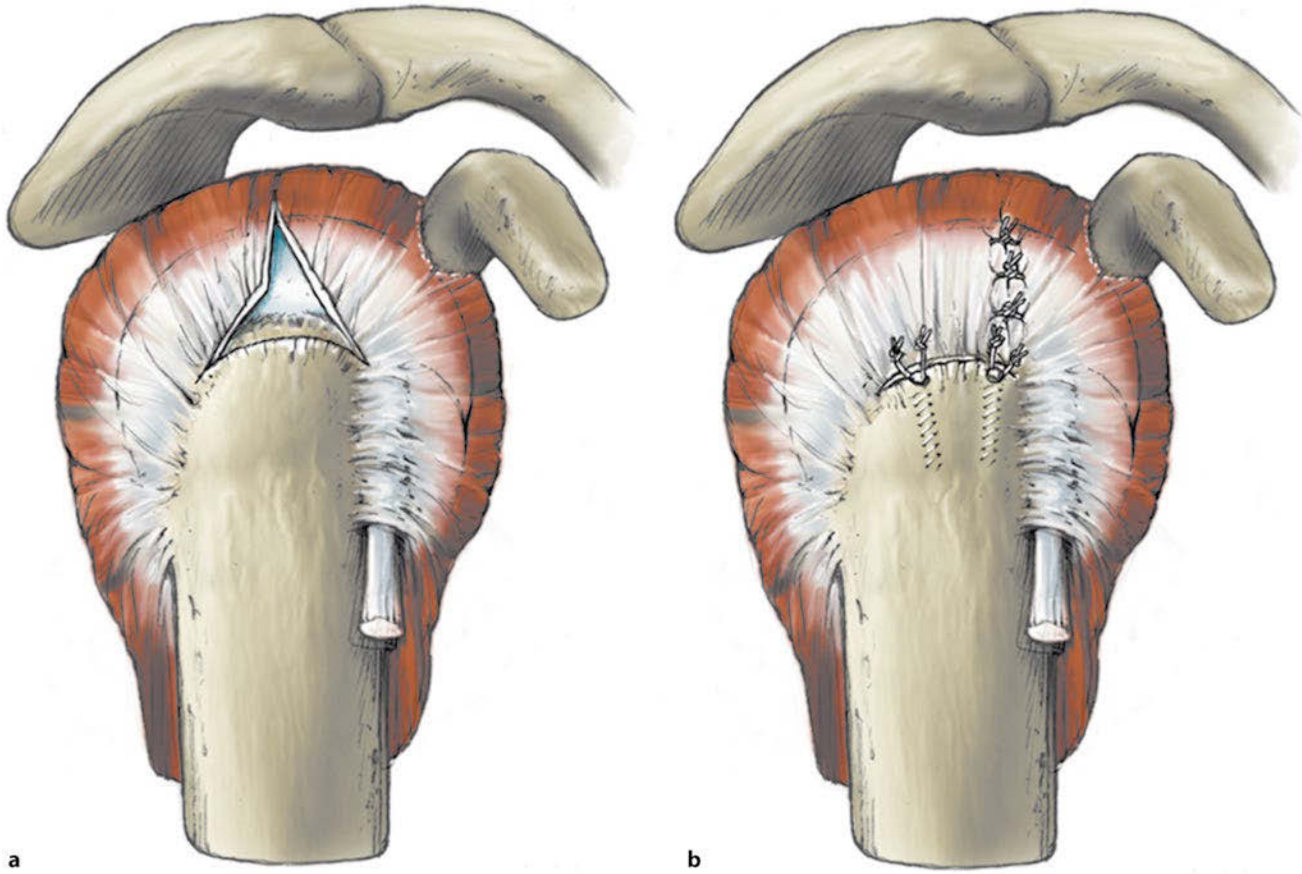


Fig. 3.3a,b Principle of repairing an L-shaped tear. **a** before, **b** after adaptation of the more mobile portion of the tendon to the less mobile portion of the tendon through side to side sutures and subsequent reinsertion to the bone with suture anchors

adapted to the other less mobile part with side to side stitches before reattachment to bone. (Fig. 3.3).

Repair of rotator cuff tears can be performed with either a single row technique (in which the anchors are placed in a row in the lateral part of the insertion footprint) or a double row technique (in which an additional second row of anchors is placed more laterally to the previous one). The double row technique is aimed to achieve the largest possible contact surface area between the repaired tendons and the foot print, a prerequisite that consequently improves healing.

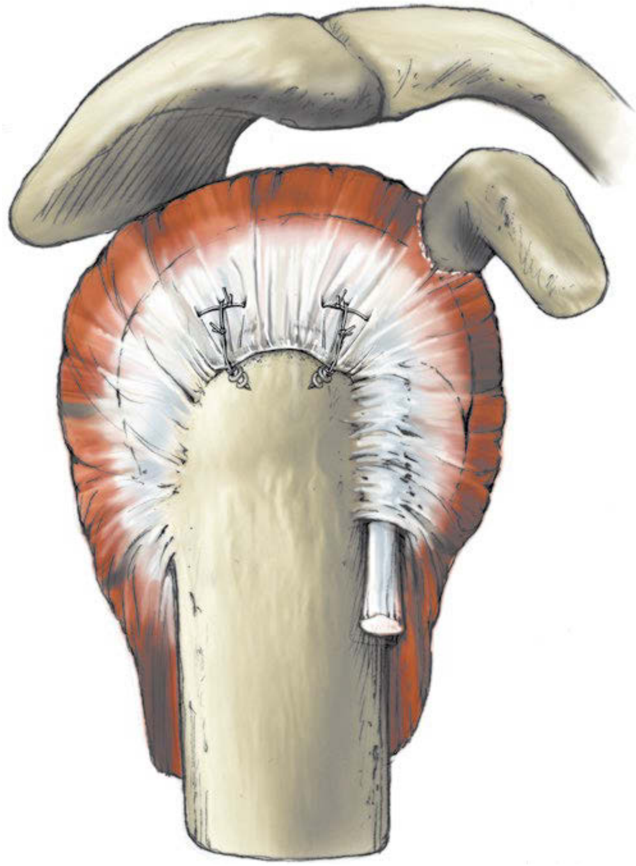
Single Row Technique

After debridement of the tear edges as well as the footprint with motorized shaver, a double loaded suture anchor (e.g. Corkscrew, Arthrex) is inserted at an angle of 45° (dead man angle) to the axis of the humeral shaft in the lateral part of the insertion footprint, just a little below the outer cortex, after drilling or tapping of guide holes, as specified by the manufacturer. Different techniques exist and can be used for refixation of rotator cuff tendons to the bone, e.g. simple mattress sutures or modified Mason-Allen-stitch. Suture passage through the tendon can be done with a variety of shuttling devices (e.g. Banana Suture Lasso, Arthrex) or special suture passing instruments (e.g. Scorpion, Arthrex). The modified Mason-Allen-Stich is performed as follows: one suture end is passed through the cuff tendon from the inferior to the superior surface and the other end of the same suture is passed in a similar way at about 8–10 mm more anteriorly to create a mattress stitch when tied. One end of the second suture is passed through the cuff tendon midway between the two ends of the mattress suture but more medial. Sliding knots are made and tied subacromial (e.g. modified "fisherman's knot" or "Weston knot," ► Chap. 1) and finally secured with a sliding knot (e.g. modified "fisherman's knot" or "Weston knot," ► Chap. 1) followed by 3 alternating half hitches, starting with the horizontal mattress suture and then the simple stich over it (Fig. 3.4)

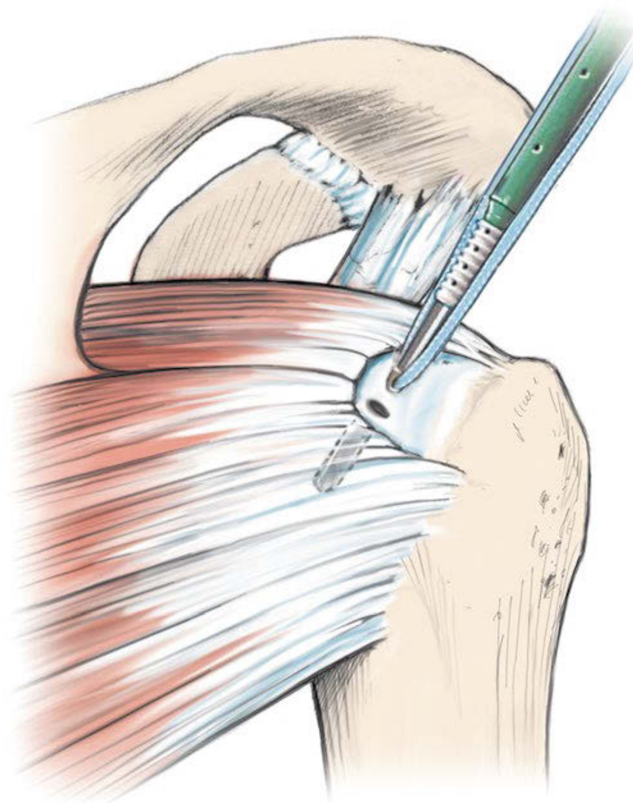
Fig. 3.2a,b Principle of repairing a U-shaped tear. **a** before, **b** after side to side sutures to decrease the size of the tear ("margin convergence") and subsequent reinsertion to the bone with suture anchors

Double Row Technique

In this technique, a row of anchors is placed directly at the margin of the articular surface of the humeral head and a second row is placed more laterally. The cuff tendon can then be reattached to the bone using either mattress sutures or what is called suture bridge fixation, in which the sutures are



■ **Fig. 3.4** Single row repair using suture anchors and modified Mason-Allen stitch



■ **Fig. 3.5** Insertion of the first anchor (SwiveLock, Arthrex) of the medial row in the prepared bone socket. The anchor is preloaded with a suture tape (FiberTape, Arthrex) already passed through the eyelet of the anchor

■ **Fig. 3.6a–c** Insertion of the medial row anchor: **a** The first SwiveLock anchor preloaded with FiperTape is screwed into the bone. **b** The anchor is driven to just below the cortical surface. **c** At least one more anchor is inserted in same way along the medial row.

tensioned over the cuff tendons. Our own preferred approach is to use a knotless system preloaded with suture tapes (e.g. Speed Bridge, Arthrex) as described below. The medial row anchors are placed first at the margins of the articular surface after predrilling a bone socket at an angle of 45° to the axis of the humeral shaft. A knotless anchor system is used (SwiveLock, Arthrex, Inc.) preloaded with suture tape (FiberTape, Arthrex) with both tails having the same length. The anchor is inserted into the prepared bone socket just below the cortical surface (■ Figs. 3.5 and 3.6a,b). Depending on the defect size, at least one additional anchor needs to be inserted in the same manner along the medial row (*one anchor for each 1 cm defect*) (■ Fig. 3.6c). Both tails of the suture tape are then passed through the tendon in an inferior to superior direction using a shuttling device (e.g. Banana Suture Lasso, Arthrex, ■ Fig. 3.7) or a special suture passing instrument (e.g. Scorpion, Arthrex) (■ Fig. 3.8).The bone sockets for the lateral row are then prepared. If 2 medial row anchors are used, 2 lateral row anchors are inserted (the 4 anchors then form a rectangle) and if 3 anchors are used in the medial row, the 2 lateral anchors are placed in between them so that the 5 anchors form a W-shaped configuration (so called Cassiopeia technique). One suture tape tail of each medial anchor is shuttled separately and both are preloaded in the eyelet of

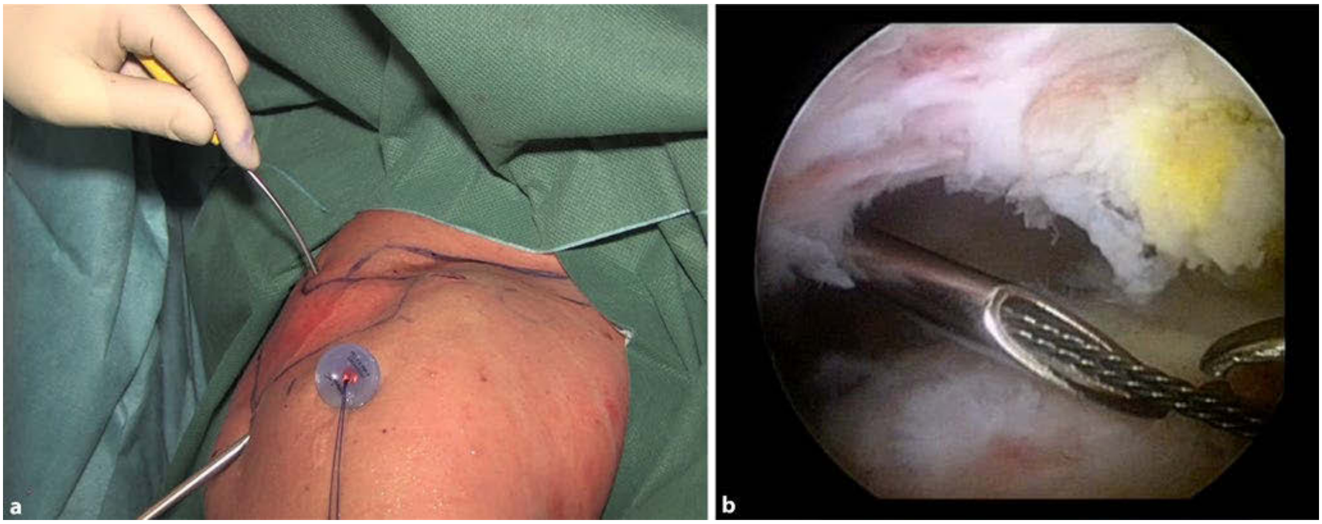


Fig. 3.7a,b Shuttle Instrument (Banana Suture Lasso, Arthrex) is passed via Neviaser portal. This technique facilitates significantly suture passage through cuff tendons particularly in ruptures with relatively far medial retraction. **a** penetration of the tendon with Banana SutureLasso; **b** the suture lasso is retrieved laterally with a grasper

a knotless anchor which is inserted into one of the prepared lateral bone sockets with adjusting the tension of the suture tapes individually (Figs. 3.9 and 3.10). The suture tape ends are then cut flush at the lateral anchor. The same procedure is repeated for the remaining tape ends. The tensioned suture tapes at the end of the procedure compress the rotator cuff tendon against the foot print and thus increasing the effective contact area between tendon and bone. (Figs. 3.11 and 3.12).

3.1.5 Postoperative Management

- Positioning of the arm in shoulder abduction orthosis.
- Monitoring of peripheral circulation, motor and sensory innervation
- Postoperative X-ray evaluation.

3.1.6 Follow-Up Management

Immobilization of the shoulder in a 30° shoulder abduction orthosis for 4–6 weeks. Limitation of the range of motion in the first 3 weeks to passive abduction/adduction 90/30/0° and passive flexion/extension 90/30/0°, from the 4th to the end of the 6th weeks: free passive abduction and flexion with active assisted abduction and flexion up to 90°. From the 7th week free active assisted movements are allowed and from the 9th week free active range of motion is allowed.

3.1.7 Tips & Tricks

All the required suture anchors should be inserted before tying the sutures as anchor placement and suture passage

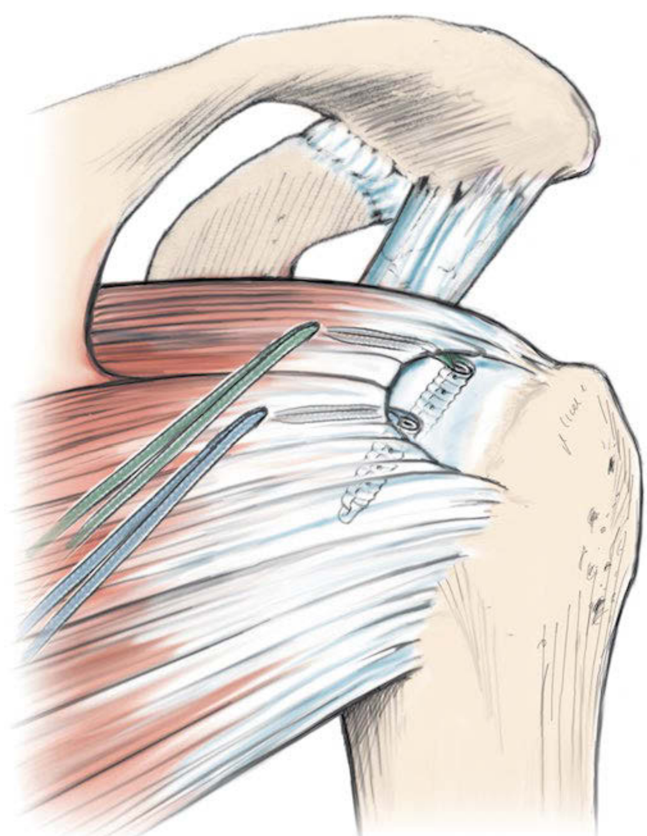


Fig. 3.8 Both tails of each suture tape of each anchors are passed through the cuff tendons with a shuttling device or a special antegrade suture passing instrument to the subacromial space

through the cuff tendons becomes more difficult if the tendon is fixed.

Excessive decortication of the greater tuberosity should be avoided when the footprint is prepared and freshened as this markedly affects the strength and stability of the anchors.

Fig. 3.9a–c Insertion of the lateral row anchors, **a** one tail from each suture tape is retrieved and passed through the eyelet of a SwiveLock anchor. **b** A bone socket is prepared for the first anchor of the lateral row, **c** insertion of the anchor after tensioning of the suture tapes individually

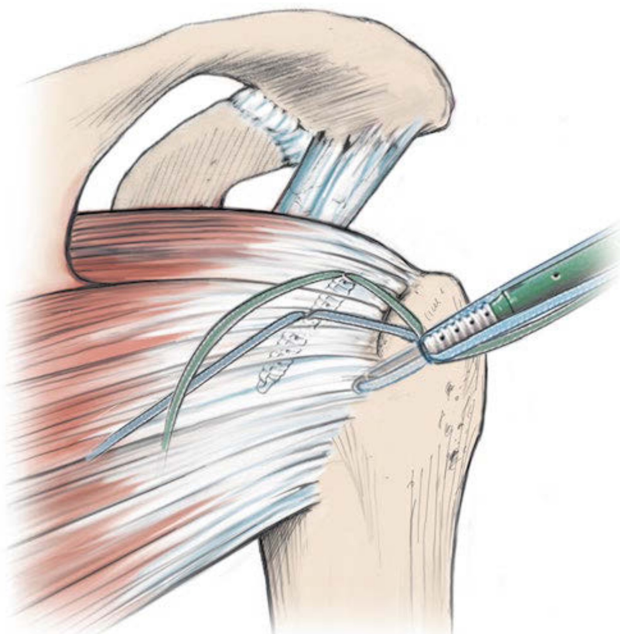


Fig. 3.10 The first anchor of the lateral row is inserted after loading its eyelet with one suture tape from each anchor of the medial row

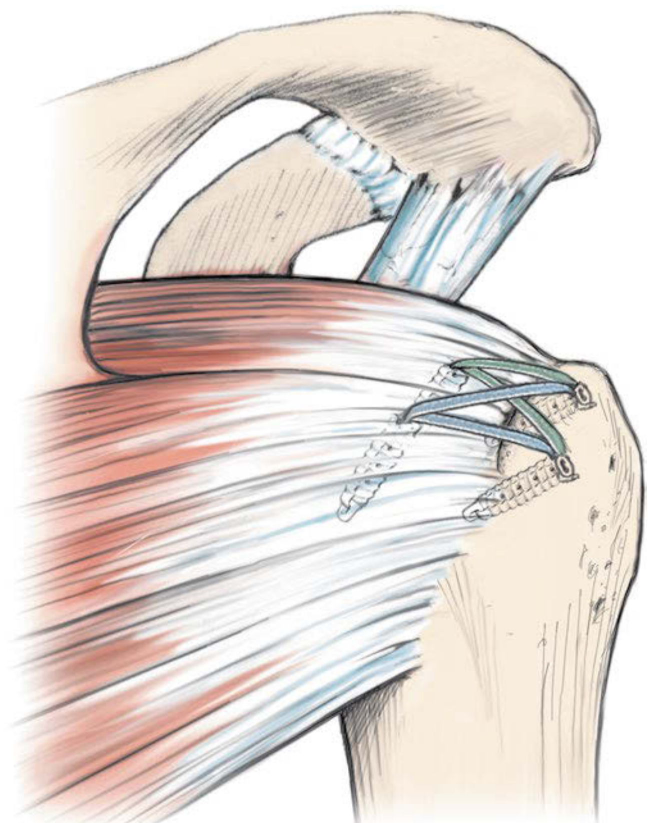


Fig. 3.11 Schematic illustration of a completed SpeedBridge repair technique

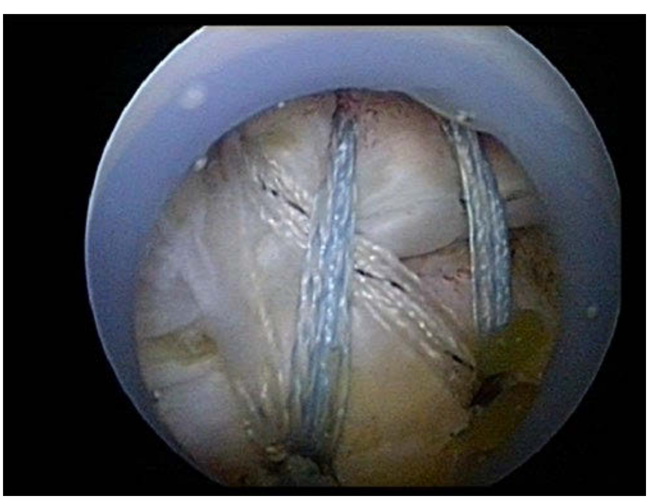
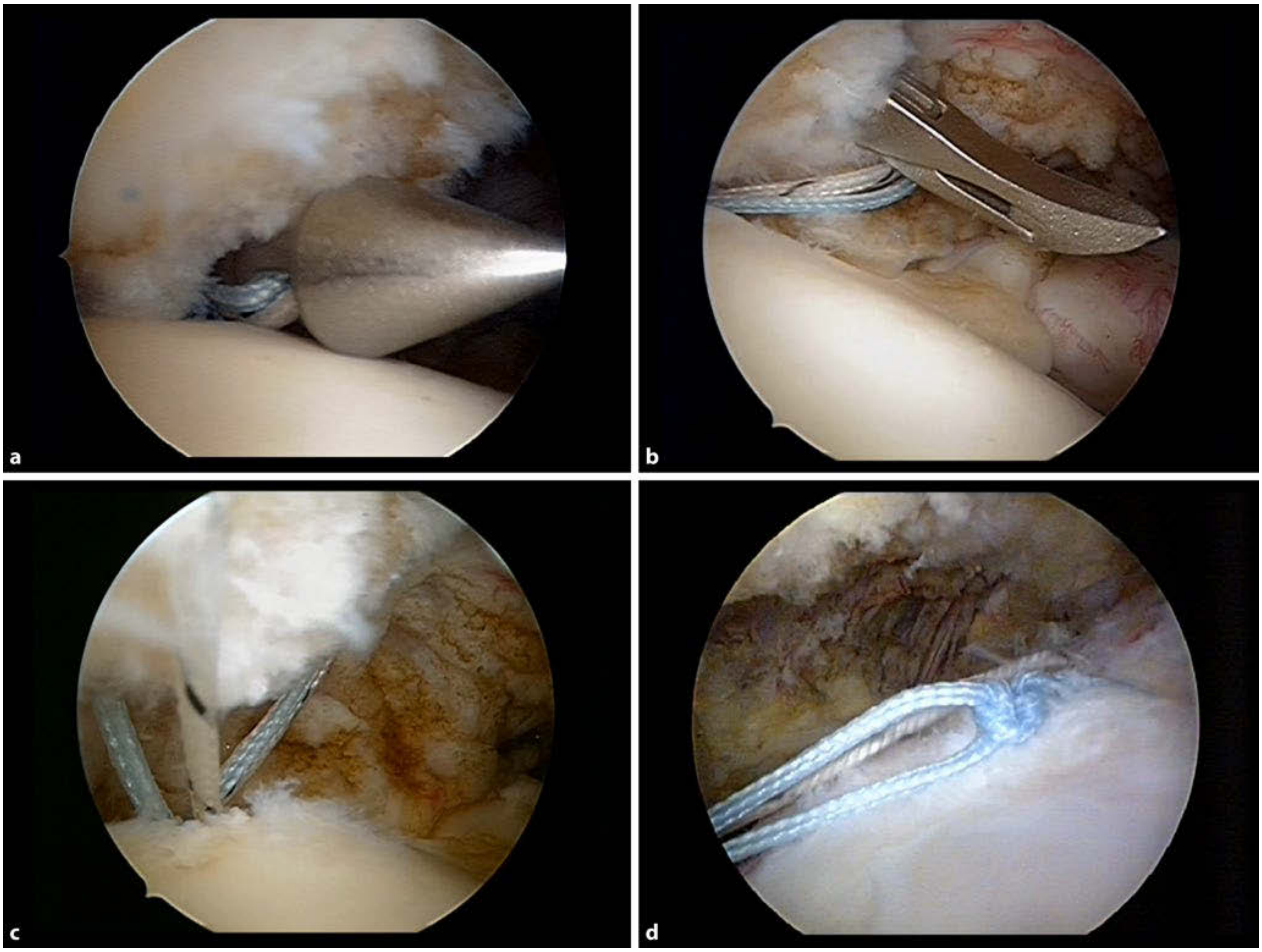


Fig. 3.12 Arthroscopic view of a completed SpeedBridge repair

Careful and neat suture management is essential when multiple anchors are used. For this purpose, all sutures which are not needed in the current step should be externally retrieved through an accessory portal.

The final fixation should be carried out in mild abduction of the arm so that the resultant construct is tension free.

Using a single suture anchor is often sufficient in repairing the so called PASTA lesions ("partial articular supraspinatus tendon avulsion"). After debridement of the tendon and footprint a single double loaded titanium anchor is inserted transtendinous and the sutures are then retrieved through the cuff tendon to the subacromial space using a shuttling device (e. g. Rhino Suture Passer, Arthrex) and tied over the



■ **Fig. 3.13a–d** PASTA repair with a double loaded titanium anchor. **a** Transtendinous anchor insertion. **b** Penetration of the tendon with shuttling instrument (curved suture passer); **c** Retrieval of sutures through the tendon; **d** tying the suture pairs subacromial

tendon pressing the largest possible area of the defect against the foot print.(■ Fig. 3.13). With large sized lesions 2 titanium anchor can be used and inserted at the anterior and posterior margins of the defect. The sutures from both anchors are tied together subacromial so that a double suture bridge is formed and press the defect area against the foot print. Self-drilling titanium anchors are advantageous in these transtendinous techniques to avoid multiple penetration of the cuff tendon (during pre-drilling and tapping as well as anchor insertion).

3.2 Repair of the Subscapularis Tendon

M. Feucht, P.Minzlaff, S. Baun

3.2.1 Indication

Symptomatic partial or complete tear of the supraspinatus tendon associated with functional deficit and/or pain with mild to moderate degree of muscle atrophy (< grade 3 acc. to Thomazeau), fatty infiltration (< grade 3 acc. to Goutallier).

Subscapularis insufficiency after previous open or arthroscopic procedures.

3.2.2 Operation Principle

Arthroscopic refixation of the ruptured tendon (SSC) to the original insertion (footprint) at the lesser tuberosity using suture anchors.

3.2.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom-specific history: Patient complaints (pain, functional disability), duration of complaints, previous trauma (external rotation trauma in adduction), previous treatments received, sporting and functional demands.

Fig. 3.14a,b Tensioning of the tendon with a temporary traction suture (**a**), Mobilization of the tendon and release of capsular adhesions particularly with the MGHL as well as adhesions to the coracoid and scapular neck with the electrothermal probe(**b**)

- Symptom-specific examination: Evaluation of the active and passive range of motion (increased passive external rotation), internal rotation against resistance, lift off test, internal rotation lag sign, belly-press test (Napoleon's sign), bear-hug test, exclusion of concomitant pathologies (esp. biceps tendon instability, pulley lesion)

Imaging

X-rays of the shoulder in three views (true AP, y-view, axial) for evaluation of the bony status, exclusion of bony tendon avulsion (especially in adolescents) und to assess the centricity of the humeral head.

MRI (if necessary, with intra-articular contrast medium) to outline the tear pattern, evaluate the degree of tendon retraction, muscle atrophy and fatty muscle infiltration and to exclude concomitant lesions (Instability of the long biceps tendon, pulley lesion)

Patient information/Consent

Specific operative risks: residual symptoms (Pain, weakness, limitation of motion), external rotation deficit, anchor malposition and dislocation, osteolysis, "frozen shoulder", nerve damage (Axillary nerve, musculocutaneous nerve, brachial plexus), injury of the subclavian artery, possibility of switching to open repair, re-rupture (symptomatic/asymptomatic), additional need for tenotomy or tenodesis of the long biceps tendon (LBT)

3.2.4 Operative Technique

Positioning and Preparation

- Beach chair position
- Positioning of the patient arm in an arm holder

Arthroscopic Reconstruction of the Subscapularis Tendon (SSC)

Diagnostic arthroscopy via the standard posterior portal. Additional working anterosuperior, anterior and anterolateral portals are created in outside-in technique. A tissue grasper introduced through the anterolateral portal is used to evaluate the mobility of the subscapularis tendon and the extent of mobilization and release required. A traction suture (e.g. PDS or FiberWire) can be passed through the tendon using a suture passing instrument and retrieved through the anterolateral portal (Fig. 3.14a). The subscapularis tendon is meticulously mobilized medially with a shaver or electrothermal probe with release of capsular adhesions, particularly with the medial glenohumeral ligament, as well as adhesions to the coracoid and scapular neck while the tendon is kept constantly under tension using the traction suture. (Fig. 3.14b). Switching the arthroscope to the anterosuperior portal is helpful in this step. The foot print on the lesser tuberosity is freshened after sufficiently mobilizing the tendon. According to the tear size, 1–4 anchors are needed and are inserted perpendicular to the humerus shaft axis through the anterosuperior and anterior portals starting from below upwards (Figs. 3.15 and 3.18a–c). The stability of the anchors is checked by pulling on the sutures. Under maintained tension through traction suture, the tendon is pierced from anterior to posterior with a curved hollow needle or a special shuttling instrument (e.g. Rhino Suture Passer, Arthrex) introduced through the anterosuperior portal and the sutures are shuttled through the tendon (Figs. 3.16 and 3.18d,e). Several suture techniques can be used, such as single or double mattress suture as well as modified Mason-Allen suture. The sutures are retrieved through the anterosuperior portal after passing through the tendon and tied with a sliding knot (e.g. modified "fisherman's knot" or "Weston knot," ▶ Chap. 1) followed by 3 alternating half hitches starting with the most

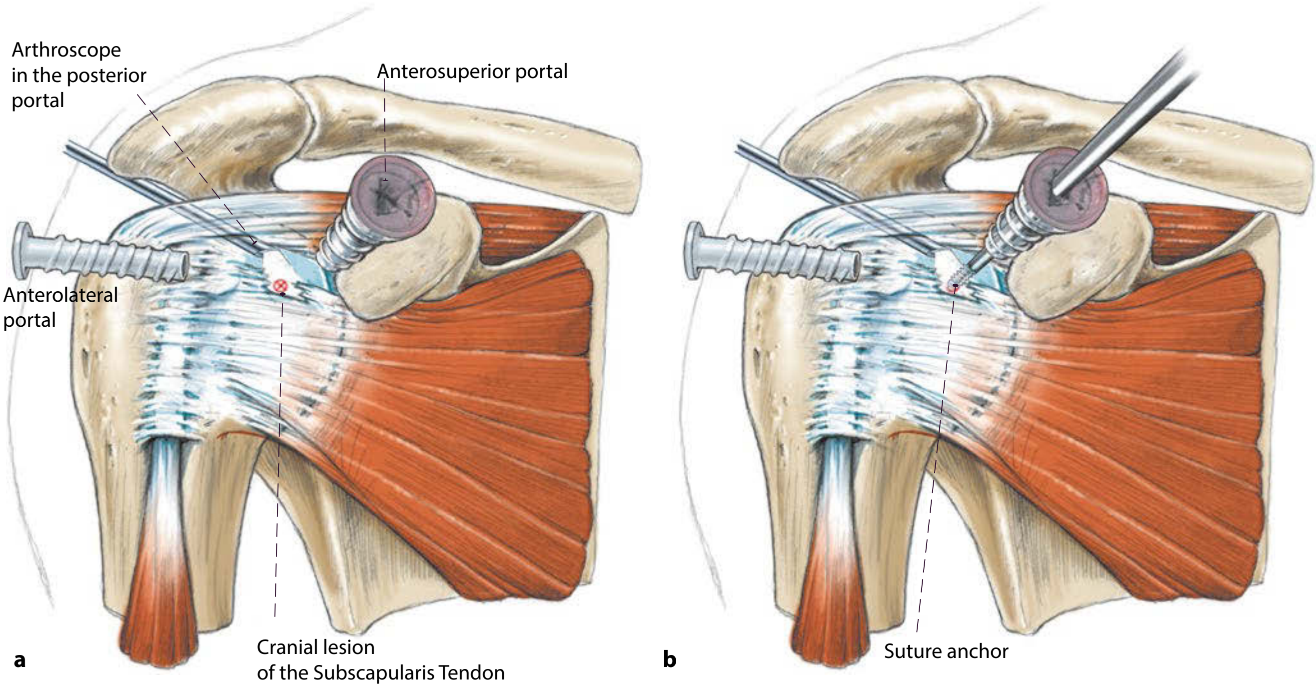


Fig. 3.15a,b **a** Diagrammatic illustration of the preferred position of the anchor in the footprint at the lesser tuberosity in proximal tears **b** insertion of the suture anchor via the anterosuperior portal

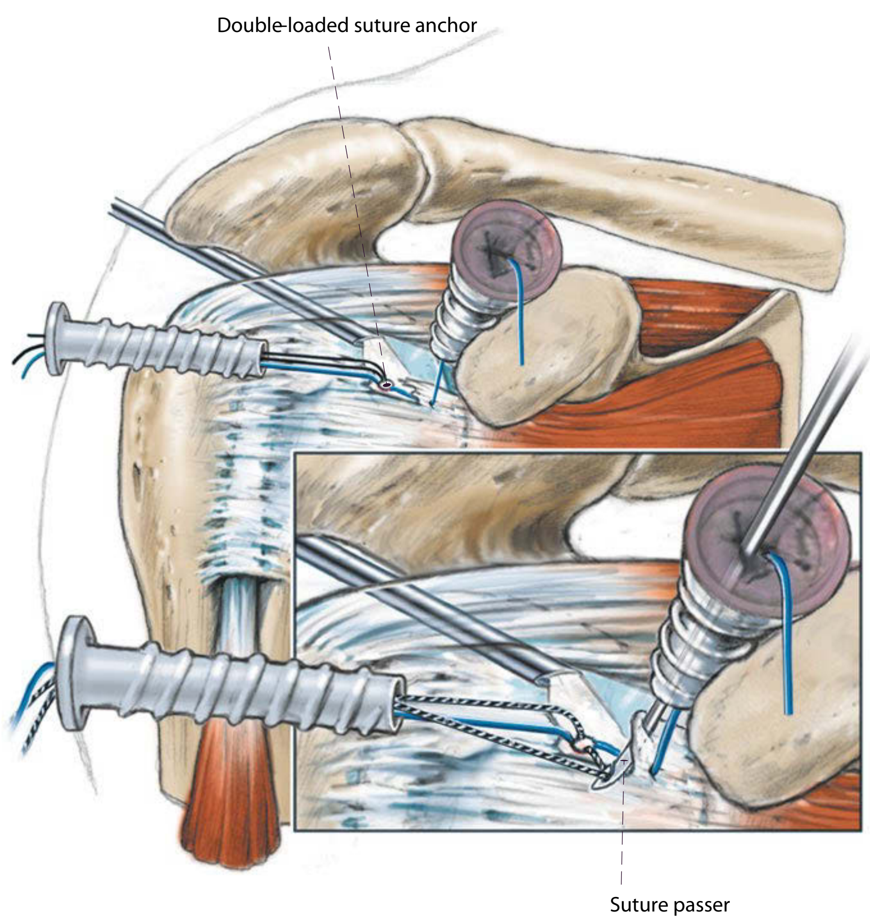


Fig. 3.16 A shuttling instrument (e.g. Rhino Suture Passer, Arthrex) is passed through the SSC tendon and the sutures are then shuttled through the tendon

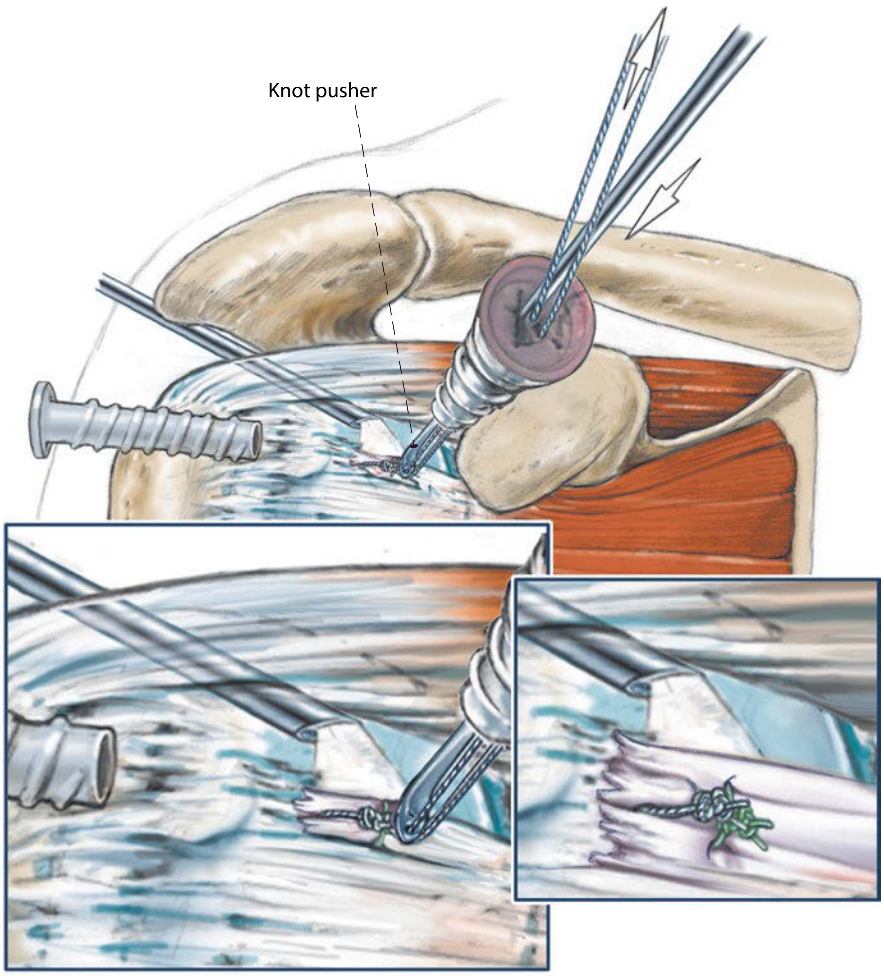


Fig. 3.17 The sutures are tied using a knot pusher through the anterosuperior portal.

inferior one (Figs. 3.17 and 3.18f). A better reconstruction of the nearly trapezoidal foot print with large sized tears may be achieved with a double row technique such as the suture bridge fixation with 4 knotless anchors preloaded with fiber tapes (Speed Bridge, Arthrex)(Fig. 3.19), which is described in details in ► Sect. 3.1.

3.2.5 Postoperative Management

- Positioning of the arm in shoulder abduction orthosis in 15° and internal rotation.
- Monitoring of peripheral circulation, motor and sensory innervation
- Postoperative X-ray evaluation.

3.2.6 Follow-Up Management

A shoulder abduction orthosis in 15° abduction and internal rotation is used for 4–6 weeks. The range of motion in the first 3 weeks is limited to passive abduction/adduction: 90°/30°/0°, passive flexion/extension: 90°/30°/0° and 0° external rotation,°, from the 4th to the end of the 6th week: : free passive abduction and flexion with active assisted abduction and flexion up to 90. From the 7th week free active assisted movements allowed and from the 9th week free active range of motion are allowed.

3.2.7 Tips & Tricks

The vast majorities of subscapularis tendon tears affect the superior third of the tendon and thus are well amenable to arthroscopic management. An open repair is indicated if the inferior edge of the tear can't be visualized arthroscopically.

The long biceps tendon and the pulley system should be evaluated for concomitant lesion while performing diagnostic arthroscopy. The integrity of the pulley system is evaluated dynamically through internal and external rotation of the shoulder. Instability (medial subluxation/dislocation) of the long biceps tendon is risky for the repair and should be managed with tenotomy or tenodesis before SSC repair.

If the pulley system is torn, the remaining fibers are often scarred and adherent to the superolateral edge of the subscapularis tendon forming together the so-called "comma sign" which shouldn't be misinterpreted as an intact insertion of

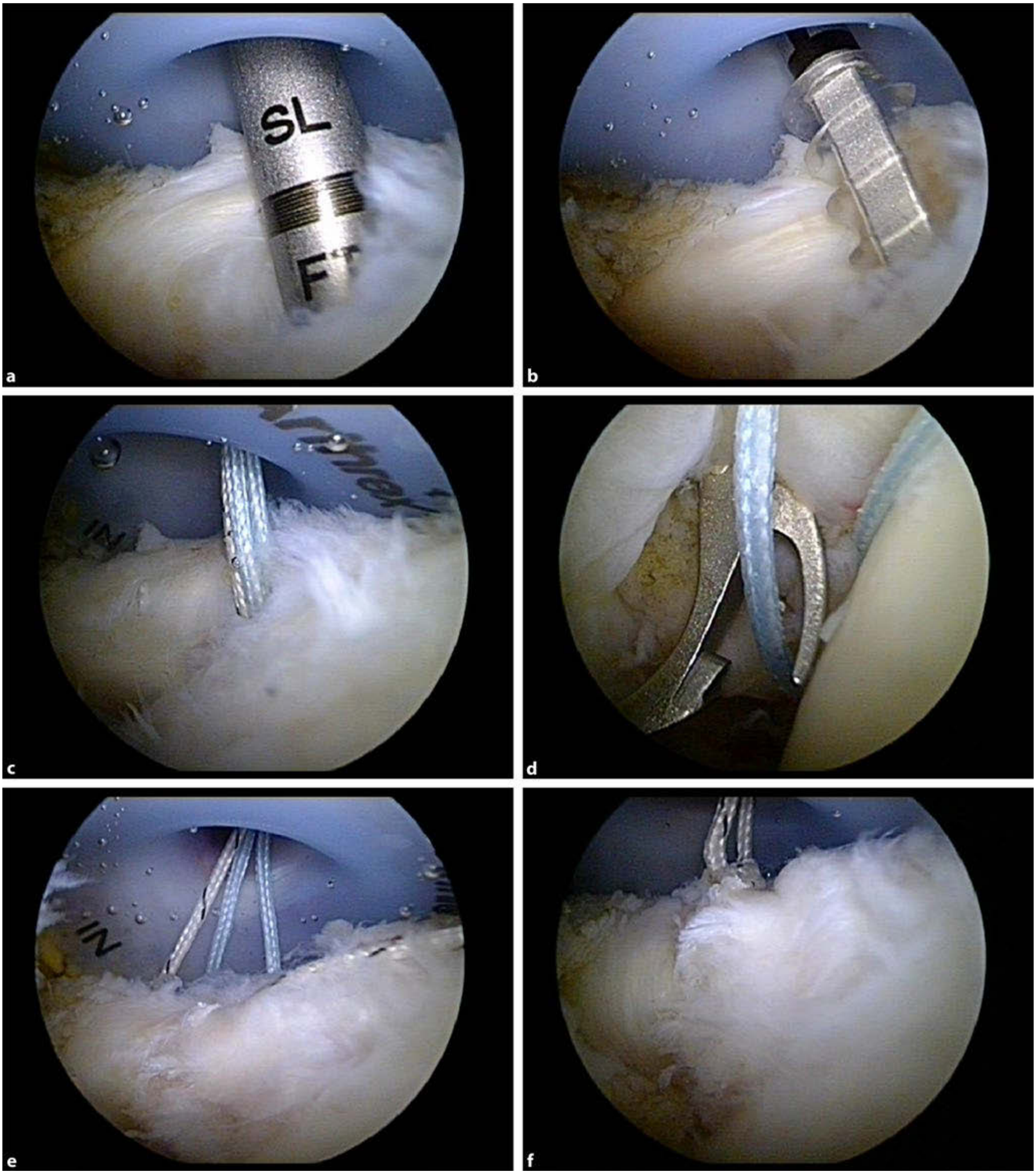


Fig. 3.18a–f Arthroscopic repair of superior SSC lesion. **a** a bone socket is created with specific punch **b** a double loaded suture anchor is screwed into the bone. **c** the 4 Suture limbs are shuttled through the tendon. **d** the tendon is penetrated with the shuttling instrument and **e** the sutures are then shuttled through the tendon **f** the suture limbs are then tied over the tendon

the SSC tendon. The comma sign can facilitate holding and mobilizing the subscapularis tendon.

Easier and more accurate evaluation of the humeral insertion of the subscapularis tendon can be achieved in mild abduction and internal rotation of the shoulder.

It is recommend to start with the subscapularis tendon if several rotator cuff tendons are to be repaired as extravasation and tissue swelling and consequently narrowing of the anterior compartment between coracoid process and humerus with prolonged duration of surgery will make visualization

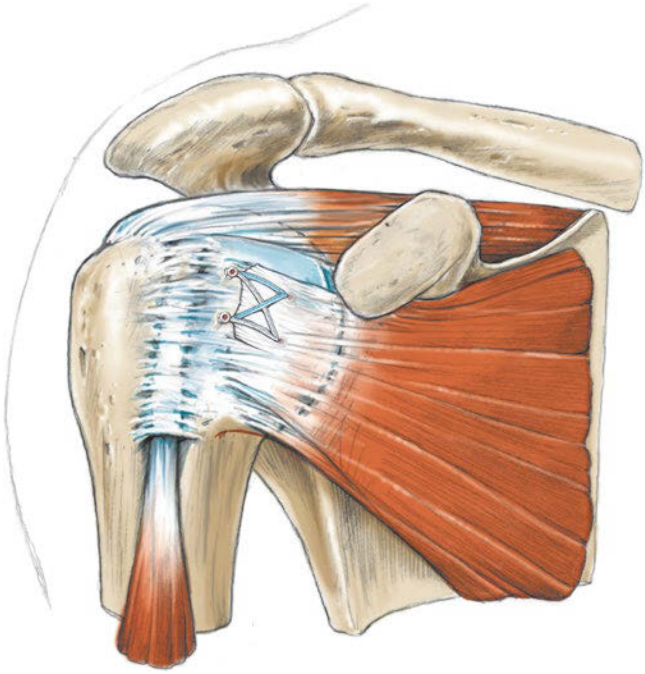


Fig. 3.19 SSC repair with double row technique (Speed Bridge, Arthrex)

and subsequently mobilization and repair of the subscapularis extremely difficult.

The sutures should be tied in mild abduction and 20° external rotation to avoid excessive tensioning of the repaired tendon and resultant external rotation deficit.

3.3 Repair of the Infraspinatus and Teres Minor Tendons

N. Rosenstiel, S. Braun

3.3.1 Indication

Symptomatic partial or complete tear of the rotator cuff tendons involving the infraspinatus and teres minor tendons. Specific contraindications for repair includes: tendon retraction medially > grade 3 (Patte), muscle atrophy > grade 3 (Thomazeau), fatty infiltration > grade 3 (Goutallier), advanced concomitant osteoarthritis of the shoulder and superior migration of the humeral head (Rotator cuff- Arthropathy) and upper brachial plexus lesions.

3.3.2 Operation Principle

Arthroscopic repair of the torn tendons to the area of insertion (foot print) at the greater tuberosity with suture anchors.

3.3.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom-specific history: Patient complaints (pain, functional disability), preceding adequate shoulder trauma (as a trigger), duration of symptoms, previous treatment modalities, previous cortisone injection, sport and functional demands.
- Symptom-specific examination: Inspection for atrophy of the supraspinatus, infraspinatus and deltoid muscles, evaluation of the passive and active range of motion (pseudo-paralysis/capsular pattern), palpation of crepitation in passive and active motions, external rotation against resistance at 0° and 90° of abduction, external rotation lag sign "drop-sign", Hornblower sign.

Neurological/Vascular Condition

Exclusion of suprascapular nerve lesions (infraspinatus) and axillary nerve lesions (teres minor).

Imaging

- X-rays of the shoulder in three views (true AP, y-view, axial) for evaluation of the bony status, degree of osteoarthritis, centering of the humeral head relative to the glenoid.
- MRI (if necessary, with intra-articular contrast medium) to outline the tear pattern, evaluate the degree of tendon retraction, muscle atrophy and fatty muscle infiltration as well as exclusion of concomitant lesions.

Patient Information/Consent

Specific operative risks: persistent complaints postoperatively (pain, weakness, limitation of motion), re-rupture of the repaired tendons (symptomatic/asymptomatic), inaccurate placement or dislocation of the anchors, osteolysis, frozen shoulder, early degenerative changes of the joint, nerve injury (axillary or musculocutaneous nerve as well as brachial plexus injury associated with subscapularis tendon injury), injury of the subclavian artery and possibility of switching to open repair.

3.3.4 Operative Technique

Positioning and Preparation

- Beach chair position (alternatively lateral decubitus position)
- Examination under anesthesia.
- Positioning of the patients arm in an arm holder

Arthroscopic Repair of the Infraspinatus (ISP)/ Teres Minor (SSP)

Diagnostic arthroscopy via the standard posterior portal to evaluate the geometry and extent of the tear as well as the posterosuperior capsulolabral complex. Often switching of the arthroscope to the anterosuperior or the anterolateral portal is necessary. The remaining steps are similar to large extent to the arthroscopic repair of the supraspinatus tendon. If the tear of the infraspinatus is very large the tendon can be retracted inferomedially and as a result difficult to be visualized arthroscopically. In such cases it would be helpful to switch the arthroscope to the lateral or anterolateral portal. 2–3 working portals are usually needed in addition to the standard posterior and anterosuperior portals depending on the site and extent of the tear (lateral, anterolateral, posterolateral and Neviaser portal). Repair of the tendon can be accomplished in single or double row technique. Placement of the anchors and final repair should begin posteriorly. The technical steps are analog to the technique described in ► Sect. 3.1

3.3.5 Postoperative Management

- Positioning of the arm in shoulder abduction orthesis.
- Monitoring of peripheral circulation, motor and sensory innervation
- Postoperative X-ray evaluation.

3.3.6 Follow-Up Management

Immobilization of the shoulder in a 30° shoulder abduction orthesis for 4–6 weeks. Limitation of range of motion in the first 3 weeks to passive abduction/adduction 90/30/0° and passive flexion/extension 90/30/0° with free rotation, from the 4th to the end of the 6th weeks: free passive abduction and flexion with active assisted abduction and flexion up to 90°. From the 7th week free active assisted movements allowed and from the 9th week free active range of motion are allowed.

3.3.7 Tips & Tricks

See also ► Sect. 3.1

The contact between the posterior part of rotator cuff and the posterosuperior glenoid during dynamic examination under anesthesia is not a pathological finding unless there are clinical symptoms and signs of degeneration or synovitis suggestive of posterosuperior impingement (PSI). If the mobility of the tendon with large retracted tears is not sufficient after extensive adhesiolysis, it can be increased via a posterior interval slide technique, in which the supraspinatus and infraspinatus tendons are released anterolaterally using an arthroscopic scissor or electrothermal probe along the spine of the scapula. To avoid injury of the suprascapular nerve when performing posterior interval slide, the rotator cuff tendon should be grasped with the tissue grasper at the glenoid level. Posteromedial release beyond the fat pad between supraspinatus and infraspinatus should also be avoided. With massive rotator cuff tears that can not be fully repaired, great attention should be given to restoring the infraspinatus and therefore maintaining the balance with the anterior forces ("force couple"). A mini-open approach with deltoid splitting can be used if the cuff tear is very posterior.

3.4 Tenodesis and Tenotomy of the Long Head Biceps Tendon (LHBT)

P. Minzlaff, S. Braun

3.4.1 Indication

Tenosynovitis, tendinitis, partial tears or hour glass deformity of the long head biceps tendon (LHBT), unstable tendon with dislocation or subluxation from the bicipital groove due to a pulley lesion, or as an additional procedure with rotator cuff repair

3.4.2 Operation Principle

Detaching the LHBT from its intraarticular insertion site (Tenotomy) and reattachment to the bone (at the bicipital groove or subpectoral) (Tenodesis)

3.4.3 Preoperative Assessment

Diagnosis

Clinical

- past medical history: Type and duration of symptoms, individual functional demands (e. g. work and sporting activities), injury pattern, time of injury.
- physical examination: Anteromedial shoulder pain, Tenderness over the bicipital groove, palpable snapping/clicking when rotating the shoulder (indication of LHBT instability), positive Palm up, Yergason, O'Brien or Speed-Test, impaired passive elevation (hour glass deformity)

Imaging

- X-rays of the shoulder in three planes (true a.p., y-view, axial)
- MRI to outline any possible tear, tendinitis or dislocation/subluxation of the LHBT and to rule out any concomitant lesions (e. g. rotator cuff tear).

3

Preoperative Patient Information/Consent

Possible complications: Injury of the axillary nerve, musculocutaneous nerve, brachial artery/vein (with subpectoral tenodesis), bone drilling with risk of fracture (with tenodesis), cosmetic deformity due to the distalized muscle belly (with tenotomy or failed tenodesis), possibly postoperative weakness of elbow flexion and supination – however so far no proven difference between tenodesis and tenotomy, no active biceps exercise for 6 weeks postoperatively.

3.4.4 Operative Technique

Positioning and Preparation

- Beach chair position
- Positioning of arm in an adjustable (movable) arm holder (e.g. Trimano, Arthrex)
- Marking the incision for subpectoral tenodesis at the anterior aspect of the arm: about 3 cm long, beginning about 1 cm above the inferior border of the pectoralis major tendon.

Tenotomy of the Long Head Biceps Tendon

Diagnostic arthroscopy via the posterior standard portal is performed initially to confirm the indication for the procedure. (◘ Fig. 3.20a,b). The tendon is transected close to the biceps anchor at the superior labrum using an arthroscopic scissor (◘ Fig. 3.20c) or electrothermal probe (e.g. Opes, Arthrex. ◘ Fig. 3.20d) introduced through the anterosuperior portal. The tendon retracts distally either spontaneously or following manual compression of the biceps muscle (◘ Fig. 3.20e–g). The tendon sometimes incompletely retracts and might get jammed in the bicipital groove (Autotenodesis). The biceps anchor must be carefully debrided with the electrothermal probe to avoid postoperative pain resulting from prominent remnants of the tendon (◘ Fig. 3.20). Tenotomy is not recommended to be done at the level of the intraarticular portion of the tendon.

Tenodesis of the Long HeadBiceps Tendon

Subpectoral Tenodesis

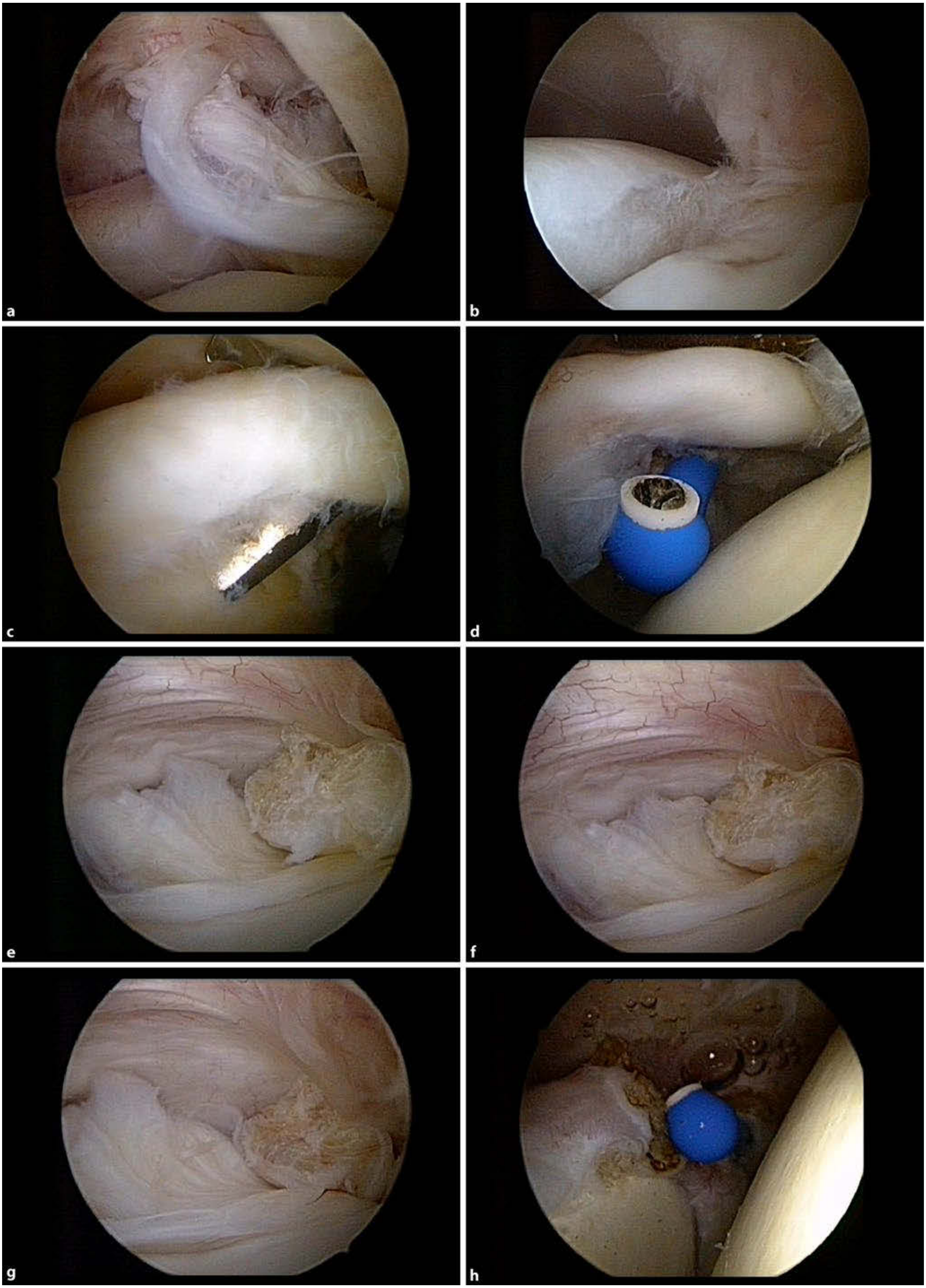
Tenotomy is performed arthroscopically in the fashion described above. The arm is positioned in 10–15° of abduction, slight external rotation and 30° of flexion. The pectoralis major tendon is palpated and the overlying skin is incised about 1 cm lateral to axillary fold beginning about 1 cm above the inferior boarder of the pectoralis tendon and ending 2 cm distally (◘ Fig. 3.21a). The inferior border of the pectoralis major tendon is exposed and the fascia overlying the biceps brachii and the coracobrachialis muscle is incised longitudinally. The brachialis muscle is retracted laterally and the coracobrachialis and short head of the biceps medially with Langenbeck retractors. This is followed by blunt finger dissection along the anterior aspect of the humeral shaft to identify the biceps tendon. The biceps tendon is luxated using a right angle clamp (◘ Fig. 3.21b) and stitched with a non-absorbable suture (e.g. FiberWire, Arthrex) using a Krackow stitch over approximately 20 mm, starting about 20 mm proximal to the musculotendinous junction (◘ Fig. 3.22). The remaining proximal part of the tendon is then resected. About 1–2 cm of the humeral shaft proximal to the pectoralis major tendon and just distal to the bicipital groove is completely stripped and dissected. A guide wire is inserted unicortical and perpendicular to the humeral shaft axis and overdrilled until reaching the opposite cortex (◘ Fig. 3.23a). The thickness of the tendon is previously measured to determine the appropriate diameter of the drill hole. The tendon is fixed inside the bony tunnel using a biotenodesis screw or a suture anchor (e.g. SwiveLock without eyelet, Arthrex; ◘ Fig. 3.23b). Usually the diameter of the bony tunnel is about 6.5 mm and tenodesis is accomplished with a 6.25 mm SwiveLock adequately. The length of the used screw should be correlated to the depth of the tunnel to avoid any protrusion of the screw above the level of the humeral shaft. One suture limb is passed through the screw and one suture limb stays outside the screw. The tendon is fixed inside the tunnel by driving in the screw. Tying knots with the two suture limbs increases the primary stability of the fixation.

Intra-articular Tenodesis

The tendon is marked at the planned tenodesis level in neutral position using an electrothermal probe (e.g. Opes, Arthrex), which is slightly distal to the tendon's entrance into the bicipital groove. A suture is passed through the tendon arthroscopically forming a simple loop. Tenotomy is then performed via the anterosuperior portal and the tendon is luxated outside the joint and stitched in the way described above starting from the previously marked level and ending about 15 mm proximally. The diameter of the tendon is measured using a tendon-measuring device. The skin is incised at the planned level of the tenodesis and the bone is notched using an awl. A guide-wire is inserted perpendicular to the humeral shaft and parallel to the acromion. A bony tunnel is created by reaming over the guide wire. Thereby the diameter of the tendon as well as the length of the screw/anchor has to be taken into account. The tendon is subsequently securely fixated in a similar manner as described above. The remaining proximal part is carefully resected (◘ Fig. 3.24).

→

◘ **Fig. 3.20a–h** Tenotomy of the long head biceps tendon. **a** anteromedial pulley lesion **b** posterolateral pulley lesion with dislocation of the LHBT from the sulcus **c** tenotomy with arthroscopic scissor **d** tenotomy with electrothermal probe **e** sectioned LHBT **f** LHBT while slipping from the joint **g** further slipping of LHBT achieved with manual compression; **h** debridement of the biceps anchor with electrothermal probe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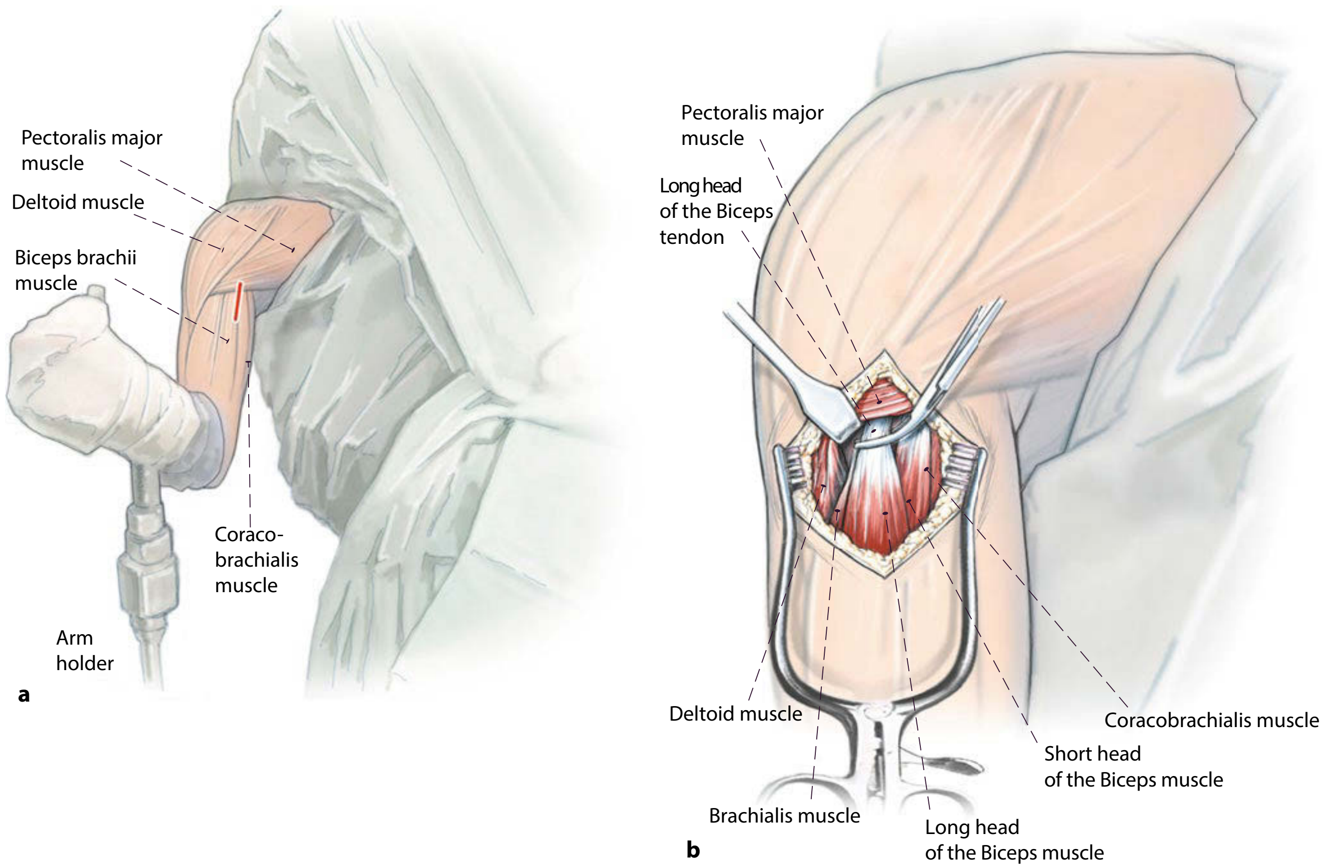


Fig. 3.21a,b Subpectoral tenodesis. **a** vertical skin incision approximately 1 cm lateral to the anterior axillary fold beginning 1 cm proximal to the inferior border of the pectoralis major tendon **b** A right angle clamp is passed behind the biceps tendon to luxate it

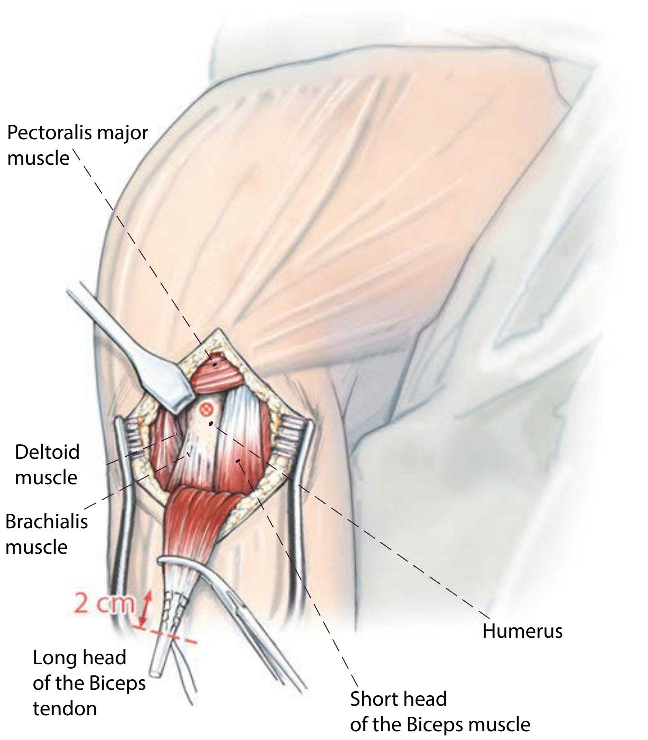


Fig. 3.22 Subpectoral tenodesis: Stitching and cutting the remnants of the retrieved LHBT

3.4.5 Postoperative Management

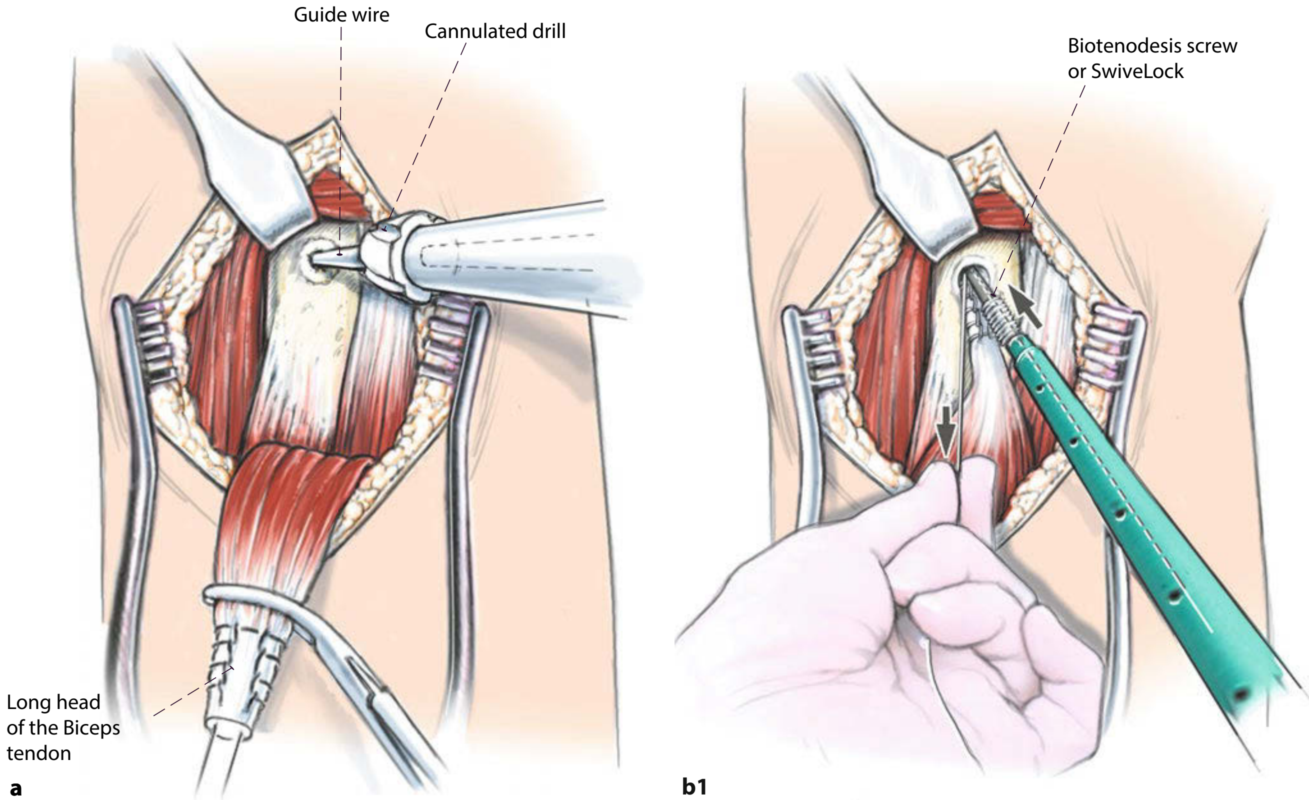
- An arm sling is optionally used for few days
- Monitoring of peripheral circulation, motor and sensory innervation
- Postoperative X-ray (evaluation of the bone tunnel with tenodesis)

3.4.6 Follow-Up Management

No active biceps exercises during the 1.–6. postoperative weeks without further limited range of motion of the shoulder joint.

3.4.7 Tips & Tricks

Tenotomy must be performed close to the biceps anchor. Tendon remnants close to its origin must be meticulously debrided and coagulated as a remaining stump can lead to persistent pain postoperatively. The depth of the bone tunnel should be measured once again before final tenodesis to avoid any overlapping of the screw (shorter screw can then



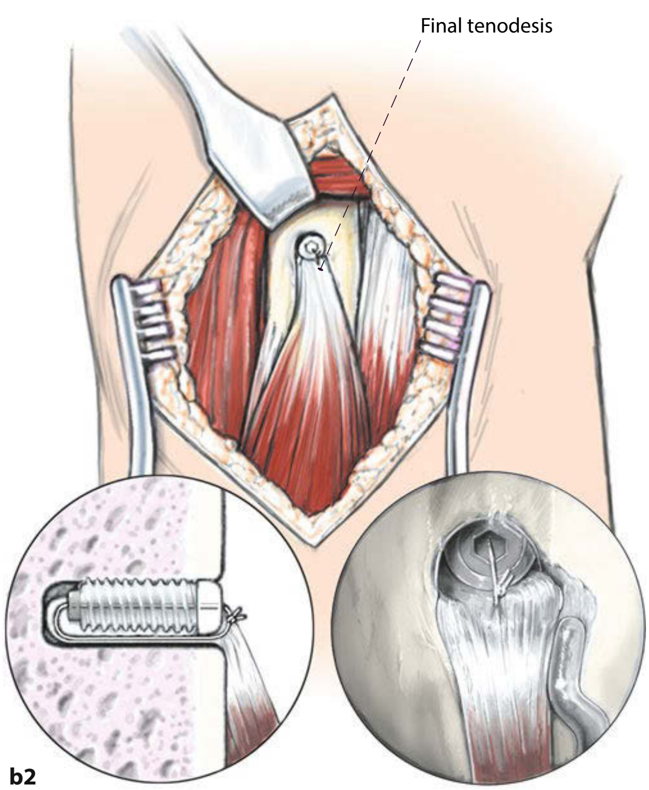


Fig. 3.23a,b Subpectoral tenodesis. **a** drilling and reaming of the bone tunnel with **a** cannulated reamer over a guide wire **b** tenodesis screw fixation

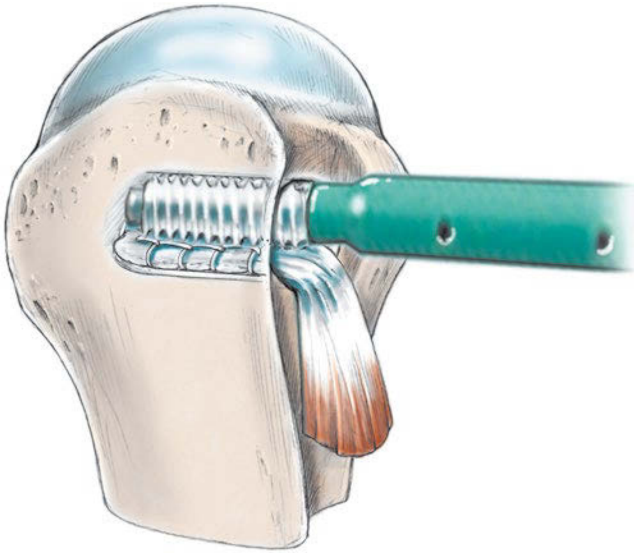


Fig. 3.24 Intra-articular tenodesis: Screw insertion in the bicipital groove

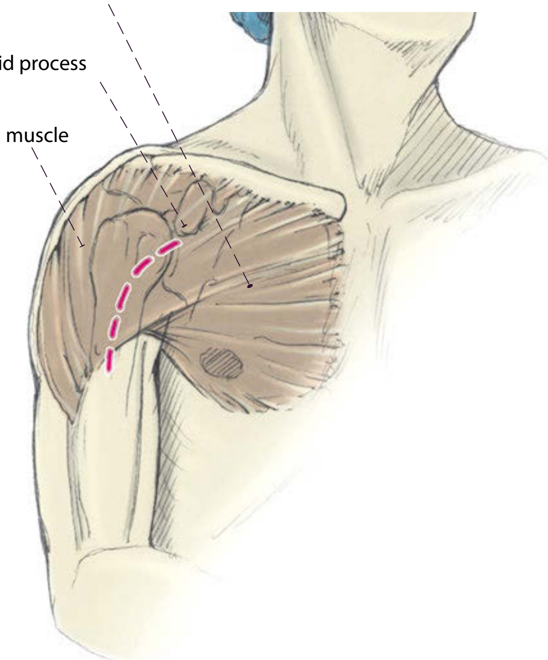


Fig. 3.25 Deltopectoral approach: Skin incision

be used). Excessive medial traction with retractors in subpectoral tenodesis can result in injury of the musculocutaneous nerve.

3.5 Transfer of the M. Pectoralis Major Tendon

P. Minzlaff, S. Braun

3.5.1 Indication

Complete and irreparable tear of the M. subscapularis tendon (chronic tear, fatty degeneration > grade 2 according to Goutallier) in young and active patients.

3.5.2 Operation Principle

Restoration of glenohumeral stability and rebalancing of the transverse force couple by transfer of the upper two-thirds of the M. pectoralis major from its insertion site onto the lesser tuberosity.

3.5.3 Preoperative Assessment

Diagnosis

Clinical

- past medical history: Type and duration of symptoms, individual functional demands (e.g. work and sporting activities), injury pattern, time of injury.
- physical examination: Anterior shoulder pain, weakness of internal rotation, increased passive external rotation, internal rotation lag sign, positive napoleon-, lift-off- and bearhug test.

Imaging

- X-rays of the shoulder in three planes (true a.p., y-view, axial) to rule out associated bony lesions, and to evaluate the centralization of the humeral head and the degree of osteoarthritis.
- MRI to visualize the tear pattern, the amount of tendon retraction and fatty degeneration of the subscapularis muscle.

Patient Information/Consent

Possible complications: nerve injury (musculocutaneous nerve) with denervation of the coracobrachialis, biceps and parts of the brachialis muscle and subsequently weakness of elevation and flexion of the shoulder and flexion and supination of the elbow; failure of the used fixation device (e.g. anchor, screw), re-tear of the transferred tendon, exhausting and long-lasting postoperative treatment period including physiotherapy, the need of postoperative wearing a specific orthosis with limited external rotation,

3.5.4 Operative Technique

Positioning and Preparation

- Beach chair position in an adjustable (movable) arm holder (e.g. Trimano, Arthrex)

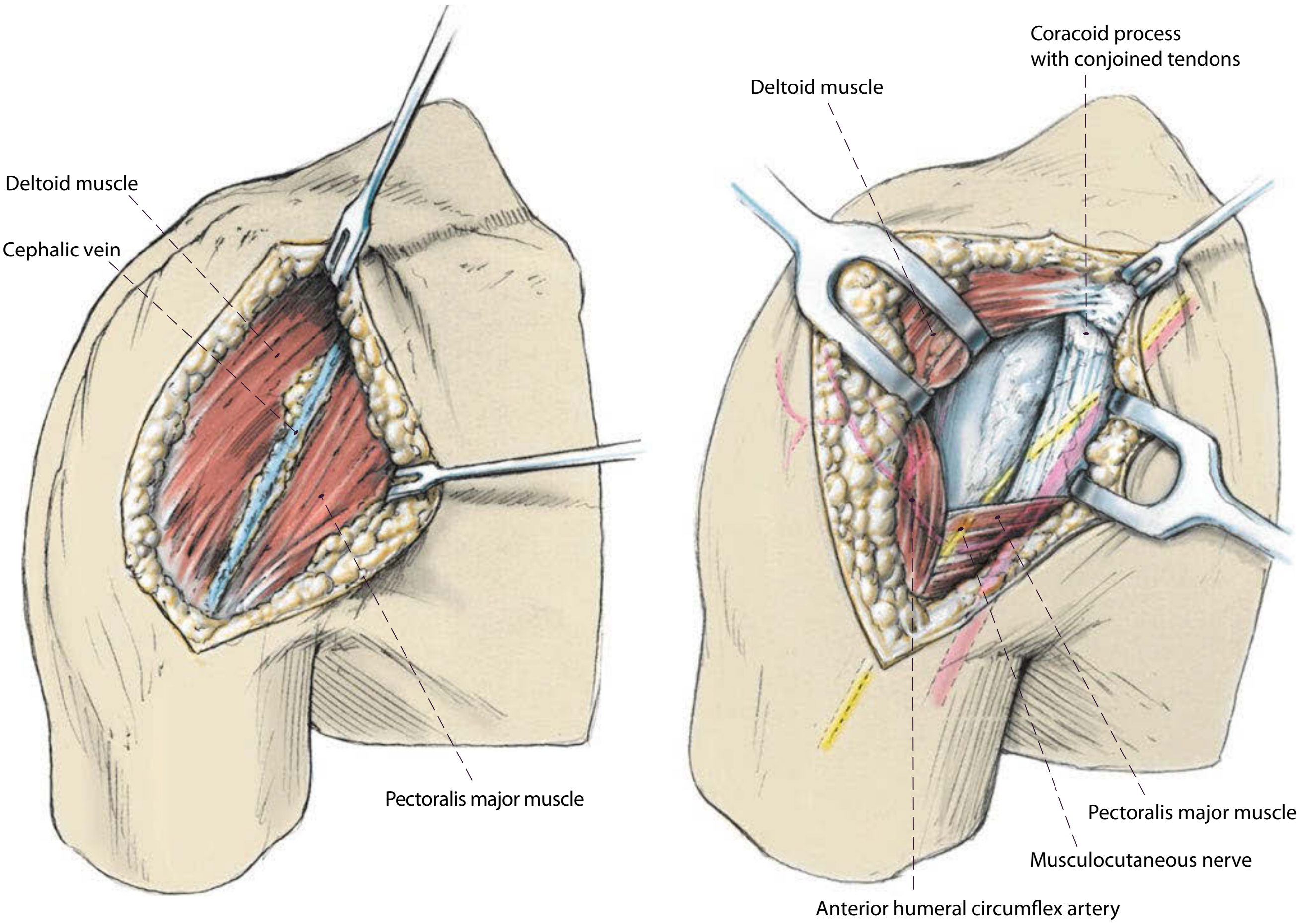


Fig. 3.26 Deltopectoral approach: superficial and deep dissection

- Marking the important anatomical landmarks (clavicle, acromion, coracoid) and the planned incision (deltopectoral) of about 10 cm length.

Open Transfer of the Pectoralis Major Tendon

Deltopectoral approach: Skin incision of about 10 cm beginning at the coracoid process along the deltopectoral groove (Fig. 3.25). The cephalic vein is exposed and retracted either laterally or medially. Subsequently a deep dissection between the deltoid and pectoralis major muscle is performed and the fascia overlying the coracoid process and the lesser tuberosity is incised to expose the tip of the coracoid process and the common tendinous origin of the M. coracobrachialis and the short head of the M. biceps brachii ("conjoined tendons") (Fig. 3.26). The humeral insertion site of the M. subscapularis the bicipital groove, and the long head biceps tendon (LHBT), which is commonly medially dislocated, are identified. A tenotomy or tenodesis of the LHBT is performed. The cranial edge of the M. pectoralis major is identified and the upper two thirds of the tendon are detached from the bone at its insertion at the greater tuberosity crest (Fig. 3.27). The muscle is split in line of its fibers and the clavicular part is separated from the sternal part and armed with sutures. The conjoined tendons are elevated with a right angle clamp close to the coracoid and the detached part of the M. pectoralis major is passed underneath them (from medial to lateral and superficial to the musculocutaneous nerve). (Fig. 3.28). The tendon is subsequently fixed to the lesser tuberosity (M. subscapularis foot print) transosseously with non-absorbable sutures or with the use of suture anchors (e. g. Bio-Corkscrew FT anchor, Arthrex, Fig. 3.29). 2–4 suture anchors are used in either single or double row (according to the size of the tendon) for fixation.

3.5.5 Postoperative Management

- A shoulder abduction orthosis in 30° abduction is used for 4–6 weeks.
- Monitoring of peripheral circulation, motor and sensory innervation
- Postoperative X-ray evaluation after removal of drains.

3.5.6 Follow-Up Management

No active biceps exercises during the 1.–6. postoperative weeks (if tenodesis or tenotomy of LHBT is performed).

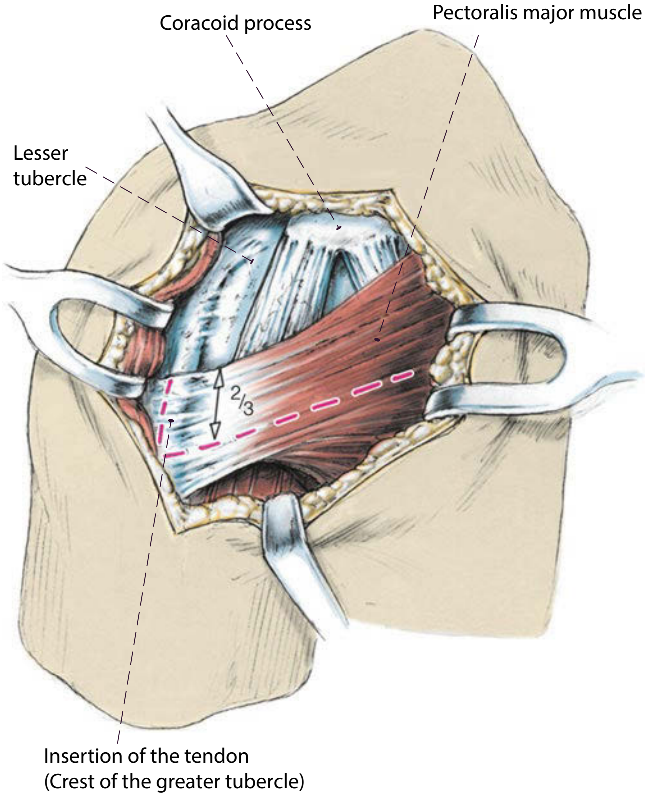


Fig. 3.27 Exposure of the M. pectoralis major tendon to the insertion at the greater tuberosity crest and detaching of the upper two thirds

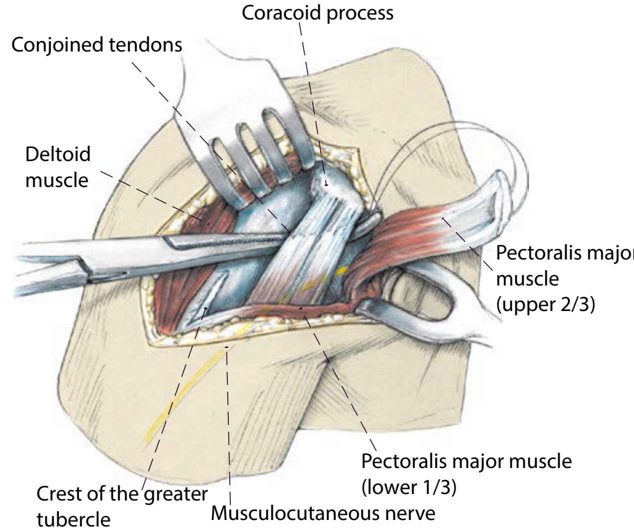


Fig. 3.28 The detached M. pectoralis major tendon is passed posterior to the "conjoined tendons"

The range of motion in the first 3 weeks is limited to passive abduction/adduction: 90°/30°/0°, passive flexion/extension: 90°/30°/0° and internal rotation/external rotation free/0°/0°, from the 4th to the end of the 6th week: free passive abduction and flexion with active assisted abduction and flexion up to 90° and free active assisted internal rotation. From the 7th week postoperative free active assisted movements are allowed and from the 9th week free active range of motion are allowed.

3.5.7 Tips & Tricks

Elevation of the "conjoined tendons" to allow the passage of the M. pectoralis major tendon must be close to the coracoid process to protect the musculocutaneous nerve.

Excessive decortication of the lesser tuberosity compromises the primary stability of the anchors.

3.6 Transfer of the Latissimus Dorsi Tendon

M. Aboalata, S. Braun

3.6.1 Indication

Irreparable massive posterosuperior rotator cuff tears with loss of the active external rotation and weakness of elevation and abduction of the shoulder in patients who are not candidates for a reverse shoulder prosthesis because of the young age and/or high functional demands.

Main criteria for diagnosis of an irreparable rupture are:

- Proximal migration of the humeral head with acromiohumeral distance < 6 mm
- Atrophy of the affected muscle > grade 3 (Thomazeau classification)
- Fatty degeneration > grade 3 (Goutallier classification)
- Retraction of the rotator cuff tendon grade 3 (Patte)

Specific contraindications:

- Lesions of the axillary nerve or loss of function of the deltoid muscle.
- Insufficiency of the subscapularis muscle
- Shoulder stiffness/limitation of the passive shoulder range of motion
- Advanced osteoarthritis
- Lack of patient compliance

3.6.2 Operation Principle

Improvement of mobility and strength of the shoulder (particularly the external rotation of the adducted arm), pain relief and depression of the humeral head by transfer and fixation of the latissimus dorsi tendon to the humeral head at the area of insertion of the supra- and infraspinatus tendons.

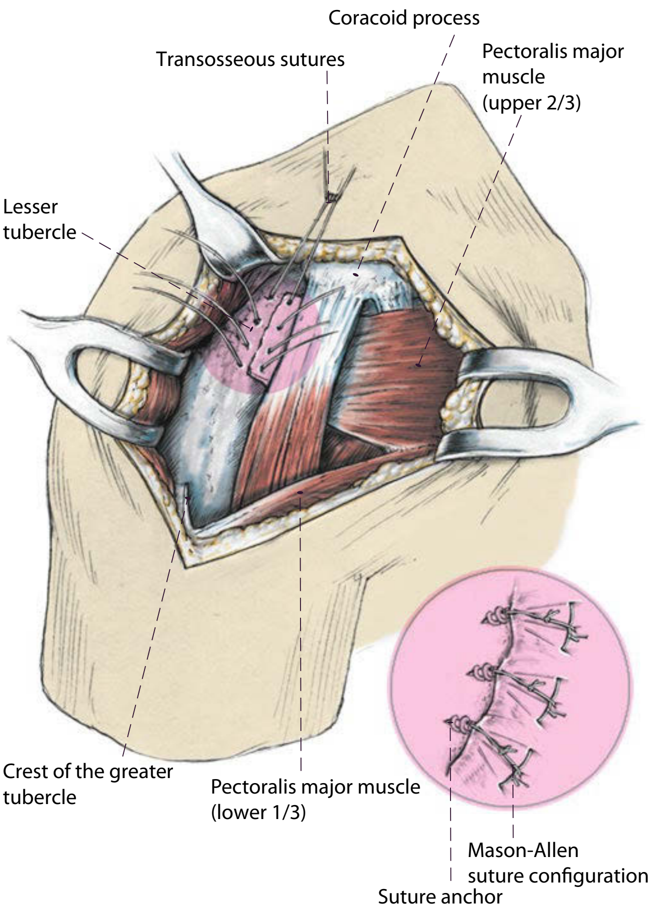


Fig. 3.29 Fixation of the tendon with transosseous sutures or suture anchors to the lesser tuberosity (SSC Footprint)

3.6.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: Shoulder pain and limitation of the range of motion, duration of symptoms, conducted treatment, functional demands.
- Symptom specific examination: Documentation of the passive and active range of motion, tests of the rotator cuff: starter test, external rotation weakness, external rotation lag sign, Hornblower test, Napoleon test, lift off test, bear hug test, impingement signs.

Nerovascular Status

Evaluation of the peripheral nerves, particularly the axillary and radial nerves.

Imaging

- X-rays of the shoulder in three views (true AP, y-view, axial) to assess the osseous condition, degree of osteoarthritis, centralization of the humeral head as well as measuring the acromiohumeral distance.
- MRI (optionally with intraarticular contrast agent) to delineate the extent of the tear, degree of tendon retraction, muscle atrophy and fatty degeneration as well as to exclude concomitant pathologies.

Patient Information/Consent

Surgery specific risks: no reliable prediction of the postoperative results regarding function and pain, affection of the axillary or radial nerve, limited motion up to shoulder stiffness, primary or secondary insufficiency of the tendon transfers, muscle flap necrosis, demanding rehabilitation (6 weeks wearing an abduction external rotation splint or a shoulder abduction spica, physiotherapy for at least 3 months and rehabilitation period of about 6–9 months to learn the new movement pattern).

3.6.4 Operative Technique

Positioning and Preparation

- Lateral decubitus position is preferred (beach chair position is also possible)
- Draping the whole arm up to the neck and including the anterior and posterior thorax.

Latissimus Dorsi Transfer

About 6 cm long anterolateral deltoid splitting approach (Fig. 3.30a). Subacromial bursectomy and acromioplasty are performed. By default, a long biceps tendon tenodesis or tenotomy is performed. The infraspinatus and supraspinatus tendons are released, with caution to avoid injury of the suprascapular nerve (avoid dissection more than 1.5 medial to the glenoid rim). The tendon stumps of the infraspinatus and supraspinatus are debrided.

Another ca. 15 cm long Z- shaped incision is made, beginning at the anterior (upper) margin of the latissimus dorsi muscle and extending to the posterior axillary fold as well as in a longitudinal direction distally (Fig. 3.30b).

Dissection and mobilization of the upper part of the latissimus dorsi muscle after releasing it from the teres major muscle (Fig. 3.31). Neurovascular bundle is protected and the anterior end of the tendon is sharply detached from the humerus. The free end of the tendon is whipstitched with a strong suture (e. g. FiberWire, Arthrex).

The interval between the posterior margin of the deltoid muscle and the long head of the triceps brachii muscle is dissected and the interval between the deltoid and the rotator cuff is prepared and a clamp is passed through this interval from anterior to pull the free end of the latissimus dorsi muscle (Fig. 3.32). Basically there are three variants for the transfer of the latissimus dorsi, they are shown in Fig. 3.33.

If possible, repair of the rotator cuff is first performed using suture anchors. The latissimus dorsi tendon is then fixed

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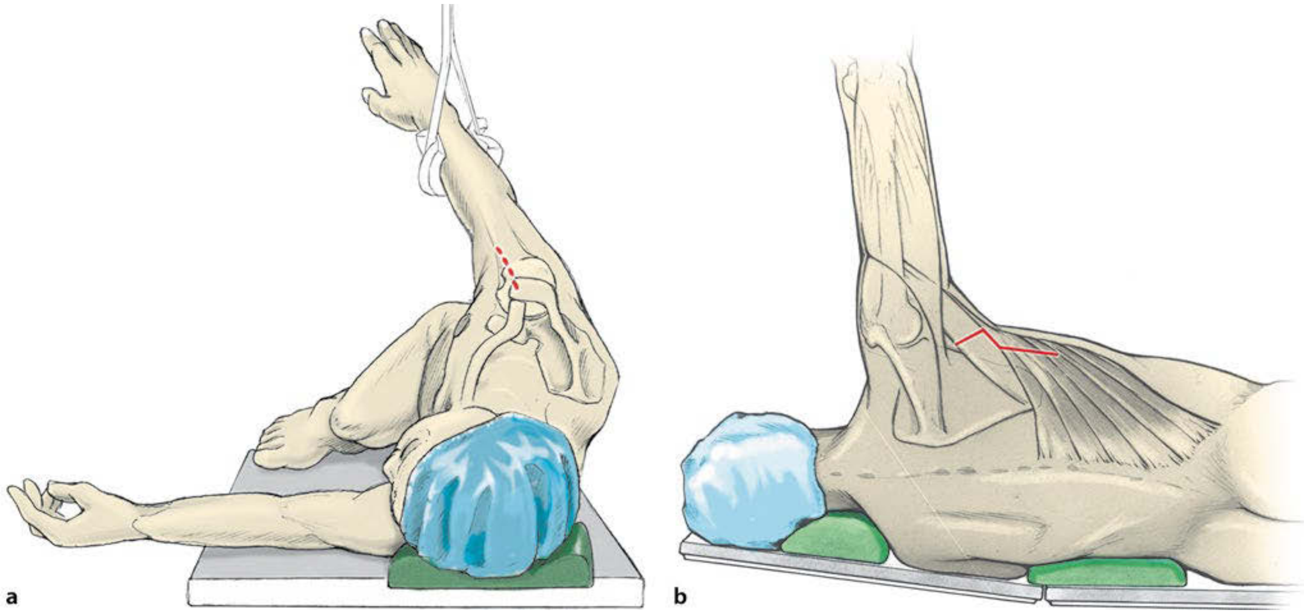

Fig. 3.30a,b Diagrammatic illustration of the two incisions. **a** Deltoid splitting approach; **b** Z-shaped incision beginning at the upper margin of the latissimus dorsi

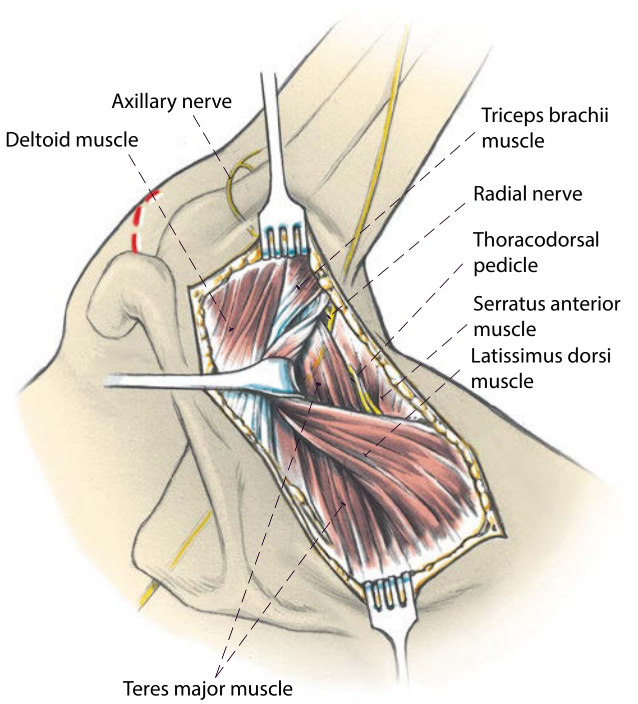

Fig. 3.31 Preparation and mobilization of the upper part of the latissimus dorsi

to the greater tuberosity using suture anchors or transosseous sutures in 45° abduction and external rotation of the shoulder. The tendon should reach anteriorly the level of the upper border of the subscapularis tendon so that both tendons could be sutured together.

If the supraspinatus tendon can't be or can be only partially repaired, the tendon is sutured to the medial border of the latissimus dorsi tendon.

3.6.5 Postoperative Management

- A shoulder abduction spica or an abduction-external rotation shoulder brace in 45° abduction, flexion and external rotation is used.
- Monitoring of peripheral circulation, motor and sensory innervation
- Postoperative radiographs

3.6.6 Follow-Up Management

A shoulder abduction spica or an abduction-external rotation shoulder brace is used for 6 weeks. Only passive physiotherapy is allowed during the first 3 postoperative weeks with brace removal during exercises and limitation of the range of motion to internal rotation/external rotation: 0°/0°/free, abduction/adduction: 90°/45°/0°. Elbow exercises are very important to be practiced simultaneously in this phase.

From the 4^{th} postoperative week active-assisted abduction/adduction: 90°/45°/0° are allowed with the rotation still only passive. From the 6^{th} postoperative week the spica is removed

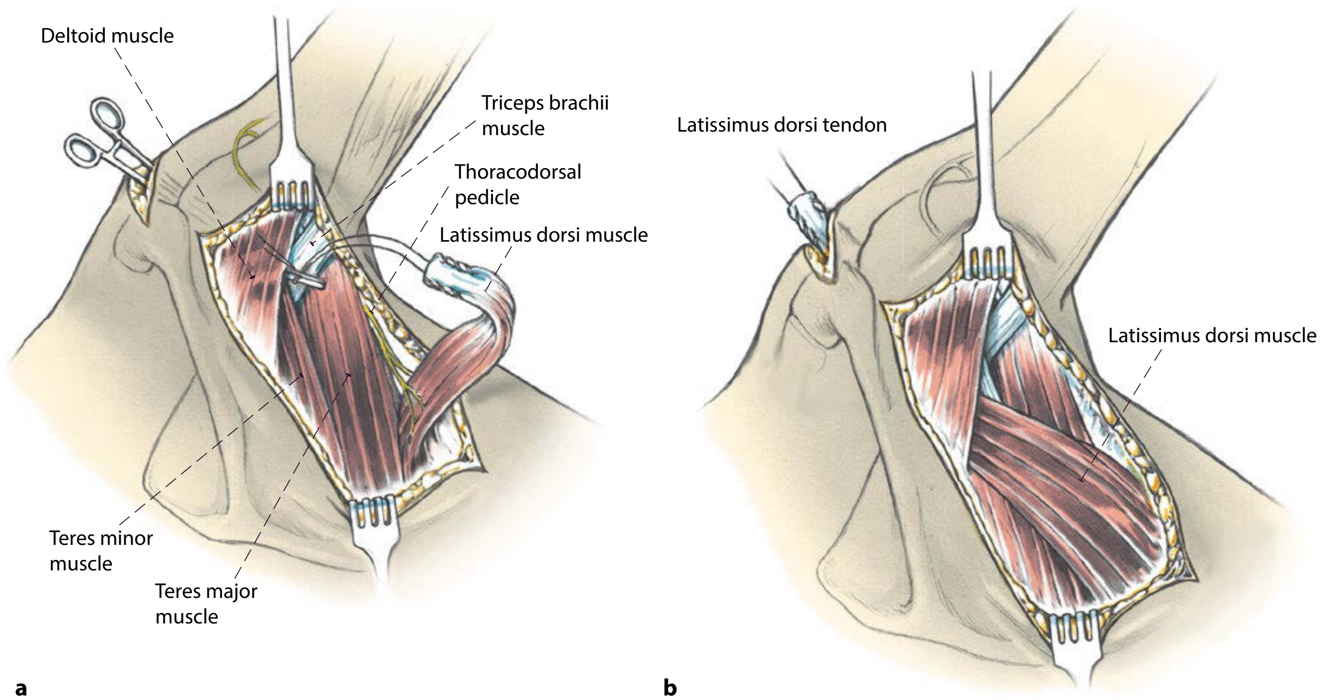

Fig. 3.32a,b **a** A clamp is passed through the deltoid splitting incision into the interval between the deltoid and long head of the triceps brachii; **b** Pulling the detached latissimus dorsi tendon anteriorly (axillary nerve, deltoid muscle, triceps brachii muscles, radial nerve, thoracodorsal nerve, serratus anterior nerve, latissimus dorsi muscle, teres major muscle)

and a shoulder abduction pillow is used. Physiotherapy is intensified to learn the new altered movement pattern. Active-assisted abduction/adduction: 90°/0°/0°, active-assisted internal/external rotation: 30°/0°/free. From the 8th postoperative week free active-assisted range of motion is allowed. From the 10th week free active range of motion.

3.6.7 Tips & Tricks

Deltoid splitting approach shouldn't extend more than 5 cm distal to the anterior acromion neck to avoid iatrogenic injury to the axillary nerve.

The latissimus dorsi muscle must be thoroughly dissected and mobilized to allow a tension-free fixation to the humerus.

3.7 Operative Removal of Calcium Deposits (Calcific Tendinitis)

M. Aboalata, S. Braun

3.7.1 Indication

Persistent symptomatic calcific deposit after failed conservative treatment for at least 3 months.

The disease can be divided into 3 phases: pre-calcific stage, calcific stage and post-calcific stage.

The calcific stage is subdivided into formative, resting and resorptive phases.

Patients who could benefit from the operative removal of calcific deposits are mainly those in the formative phase. Operative treatment is contraindicated in the often most painful resorptive phase.

Stage concept for management of calcific tendinitis:

- Stage 1: conservative (NSAIDs)
- Stage 2: extracorporeal shock wave therapy or needling
- Stage 3: arthroscopic removal of calcific deposits

3.7.2 Operation Principle

Restoration of a pain-free shoulder function by arthroscopically removing the calcific deposits.

3.7.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: Cardinal symptom is the pain depending on the stage of the disease and the size and location of the depots. The pre-calcific stage as well as the formative and resting phases are often asymptomatic (sleeping deposits). In the resorptive phase there are sudden and very strong shoulder pain, mostly at night

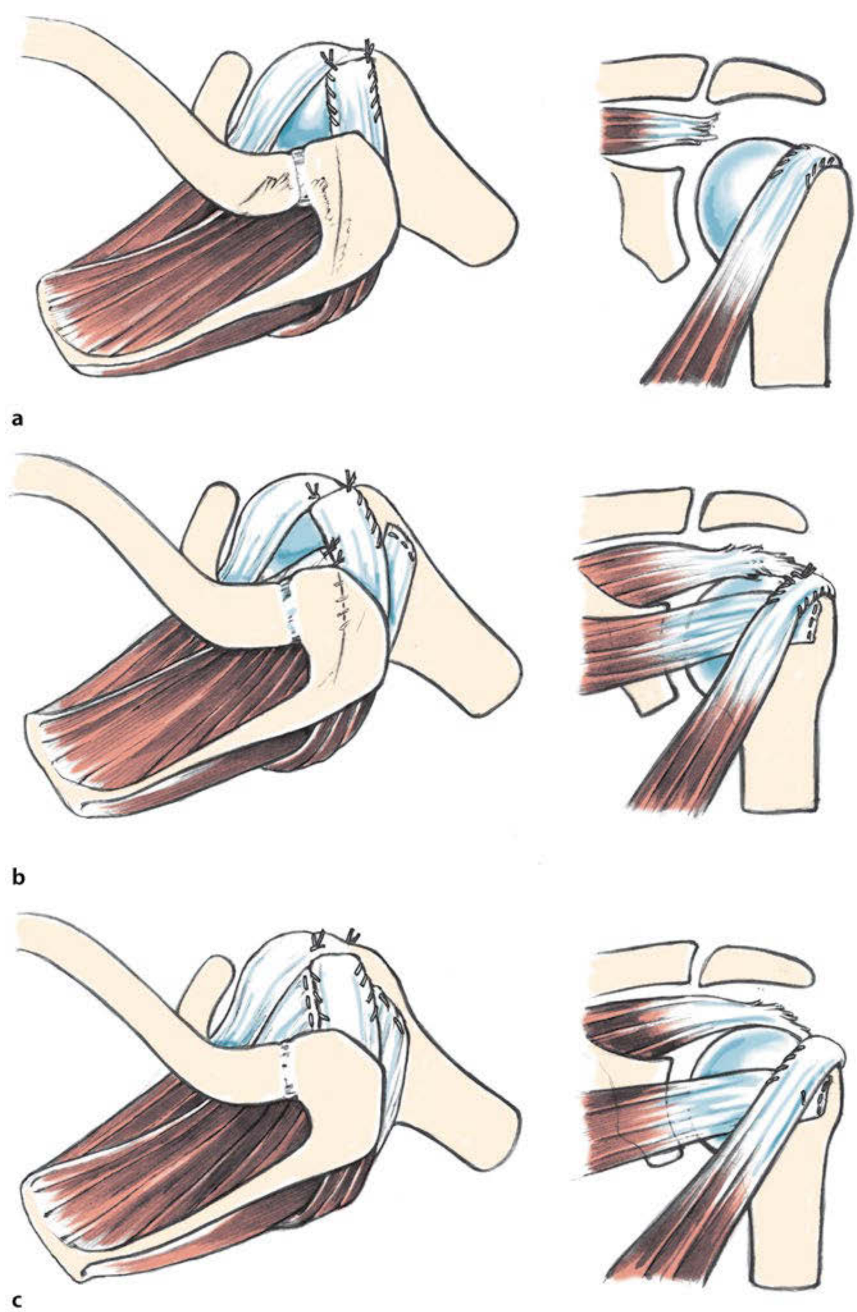

Fig. 3.33a–c Possible variants for transfer of the latissimus dorsi. **a** reconstruction of both the infraspinatus and supraspinatus tendons is not possible. In such case, the transferred muscle acts as a humeral head depressor and active external rotator. **b** The infraspinatus is repairable and the supraspinatus tendon is not or only partially repairable. In this case, the latissimus dorsi muscle performs the function of the supraspinatus muscle. **c** The infraspinatus and supraspinatus tendons can be repaired. However, an already advanced fatty degeneration entitles a high risk of re-rupture and the transferred muscle acts as an augmentation to the repaired tendons in this case

and with lying on the affected shoulder as well as with motion and during rest.
- Symptom specific examination: posture of the arms (internally rotated and close to the body), pain-related limitation of abduction, impingement symptoms due crystal-induced bursitis, crepitus on abduction, rotator cuff and biceps tendon tests to exclude associated lesions.

Imaging
- X-rays of the shoulder in three views (true AP, y-view, axial). The AP view should be carried out in neutral and external rotation position to deposits in the infraspinatus. The calcific deposits are usually located 1–2 cm medial to the tendon insertion at the greater tuberosity.
- Several classifications based on the X-ray morphology of the deposits have been proposed. The most common is the Gärtner and Simons classification (Table 3.1).
- Ultrasonography can detect the calcific deposits with a high sensitivity
- MRI scan is of secondary importance in the diagnosis of calcific tendinitis. The calcific deposit appear in T1-weighted sequence as a hypointense structure. MRI however should be made to assess possible concomitant pathologies.

Patient Information/Consent

Surgery-specific risks: restriction of movement up to stiff shoulder, incomplete removal of the calcific deposits (residual deposits after surgery is common), persistence of symptoms, recurrence, injury of the rotator cuff with subsequent need for repair.

3.7.4 Operative Technique

Positioning and Preparation

- Beach chair position
- Examination under anesthesia (ROM)
- Positioning of the patients arm in arm holder.

Arthroscopic Removal of Calcific Deposits

Diagnostic arthroscopy of the glenohumeral joint via the standard posterior portal. Assessment of the rotator cuff and the long biceps tendon for any lesions requiring intervention and masked by the symptoms of the calcific tendinitis.

Calcific deposits are localized by probing the affected tendon with a needle based on the radiographic and ultrasonographic location of the deposits relative to the fixed bony landmarks. Calcific deposits may be recognized intraarticularly in some cases by the pathological vascular pattern.

Correct localization is detected when the lumen of the needle appears filled with the calcific material. The position is then marked with a PDS suture passed through the needle. The arthroscope is then switched to the subacromial space and an anterolateral portal is established. Subacromial bursectomy is done for a better visualization of the rotator cuff.

The tendon is well dissected at the marked area and opened superficially with a short longitudinal incision in the direction of fibers (for example, with No. 11 scalpel via the anterolateral portal). This is followed by removal of the calcific deposits. To protect the tendon, the shaver should not be routinely used and the calcific deposits are curetted with a sharp spoon curette or teased out of the tendon with a blunt obturator/hook. Finally, a thorough irrigation of the subacromial space is done to decrease the risk of postoperative crystal-induced bursitis (Fig. 3.34).

3.7.5 Postoperative Management

- The arm is rested in a sling
- Monitoring of peripheral circulation, motor and sensory innervation
- Postoperative radiographs

Table 3.1 Gärtner and Simons classification (radiolucency and appearance of the calcium deposit)

Type	Radiological morphology	Stage
I	Dense calcific deposits, clearly circumscribed with sharp margins	Formative/resting phase with macroscopic chalky hard consistency
II	Transparent or cloudy without sharp margins, morphologically similar to either I or III	Early resorptive phase
III	Cloudy, transparent not sharply circumscribed	Late resorptive phase

3.7.6 Follow-Up Management

The arm is positioned in a sling for 24 h, then at night and during prolonged walking for 2–3 weeks. In the first 5 postoperative weeks passive pendulum exercises in the pain-free range of motion. Free motion is allowed from the 6th week.

3.7.7 Tips & Tricks

The calcific deposits can be localized either subacromial or intraarticular. Subacromial bursa is often significantly inflamed. An electrocautery device should be always available to control bleeding from the bursa.

The tendon is often eroded with large superficial calcific deposits so that probing with a needle for localization can often be avoided.

Complete removal of the calcific deposits radiologically is often not possible. Opening the calcific deposit allows ingrowth of granulation tissue which in turn triggers an intrinsic resorption mechanism, through which the residual calcification is usually completely resorbed within the first postoperative year.

Reduction of the deposit is sufficient in most cases to reduce the mechanical impingement significantly. Opening the calcific deposit alone results in marked improvement of symptoms as a result of decrease of the intratendinous pressure.

A concomitant subacromial decompression should be only performed in cases with evident bony impingement, e. g. acromial spur.

The need for a rotator cuff repair depends on the size of the resulting defect. In our opinion, repair of the rotator cuff with side-to-side sutures is needed in only rare conditions, to approximate the defect ends and to avoid progression of the defect.

3

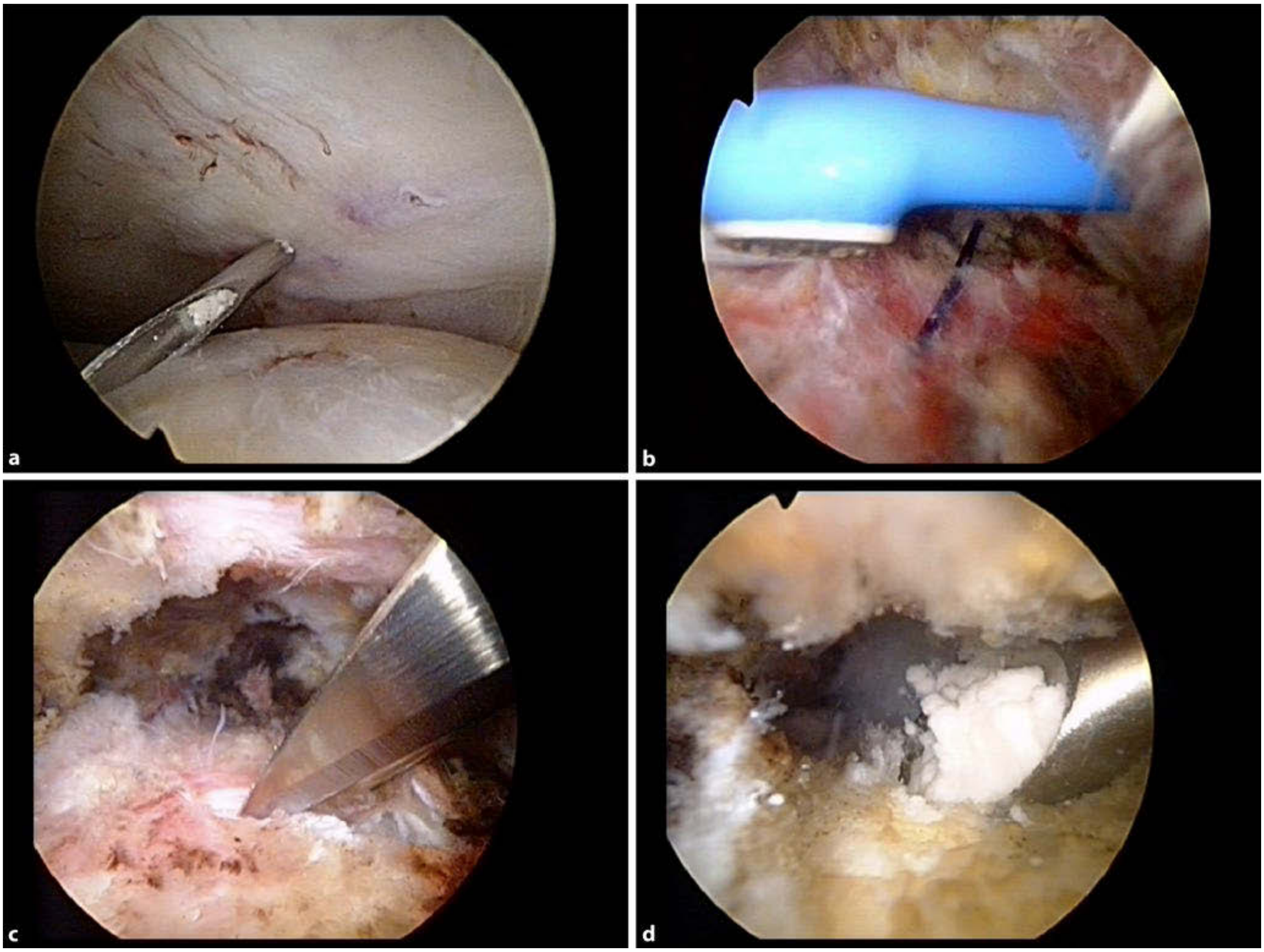

Fig. 3.34a–d Arthroscopic removal of calcific tendinitis. **a** localization of the calcific deposit by probing with a needle (calcific material in the lumen indicates successful localization); **b** subacromial bursectomy and preparation of the tendon at the marked position; **c** opening the tendon with a scalpel in the direction of fibers; **d** curetting the calcific deposits with a sharp spoon curette.

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Instability

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A. B. Imhoff, M. J. Feucht (Eds.), *Surgical Atlas of Sports Orthopaedics and Sports Traumatology*,
DOI 10.1007/978-3-662-43776-6_4,

4.1 Anterior Shoulder Stabilization

M. Feucht, S. Braun

4.1.1 Indication

Symptomatic post-traumatic anterior shoulder instability in young patients as well as in patients with high functional demands.

Anterior instability as a main component of symptomatic multidirectional instability after failure of conservative treatment.

4.1.2 Operation Principle

Arthroscopic anterior stabilization of the shoulder by anatomically reattaching the torn capsulolabral complex to the glenoid rim using suture anchors and at the same time plicating the anterior inferior glenohumeral ligament (aIGHL)

4.1.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: time, mechanism and direction of the first dislocation, reduction method (spontaneous, patient himself, external), number of recurrent dislocations, treatment history, sport/functional demands, relevant comorbidities (e.g. epilepsy, Marfan syndrome, Ehlers-Danlos syndrome, psychological disorders)
- Symptom specific examination: range of motion (increased passive range of motion), scapular dyskinesia, anterior and posterior drawer tests, load-and-shift test, anterior and posterior apprehension tests, relocation test, Jerk test, sulcus sign in internal and external rotation, Gagey hyperabduction test.

Neurovascular Condition

Evaluation of the peripheral nerves (axillary and suprascapular nerve)

Imaging

- X-rays of the shoulder in three views (true AP, y-view, axial) to detect bony lesions (bony bankart lesion, glenoid fractures, Hill-Sachs lesions)
- MRI (optionally with intraarticular contrast medium) to evaluate the capsulo-labral lesion, capsular volume and any associated injuries (e.g. SLAP lesion, rotator cuff tear)
- CT for suspected relevant glenoid bone defect or Hill-Sachs lesion

Patient Information/Consent

Specific operative risks: re-dislocation, limitation of movement (mainly external rotation), “frozen shoulder”, nerve injury (axillary nerve, musculocutaneous nerve, brachial plexus), injury of the subclavian artery, implant failure, dislocation or protrusion of anchors with the risk of cartilage damage, osteolysis, switching to an open procedure.

4.1.4 Operative Technique

Positioning and Preparation

- Beach chair position (lateral decubitus position is preferred with multidirectional instability)
- Examination under anesthesia (degree and direction of instability, hyperlaxity, range of motion)
- Positioning of the patient arm in an arm holder

Arthroscopic Anterior Stabilization of the Shoulder Using Suture Anchors

Diagnostic arthroscopy is performed via the posterior standard portal. An anterosuperior working portal is established and the stability of the labrum and the biceps tendon anchor is evaluated using an arthroscopic probe.

The labrum is mobilized using a Bankart knife until it can be easily repositioned. The glenoid rim is freshened with the Bankart rasp until a bleeding bone surface is created. The planned insertion sites of the suture anchors at the 5:30 -, 4:30 -, and 3:00 o ’clock positions (right shoulder joint) are marked using an arthroscopic burr or Rongeur (◘ Fig. 4.1).

The deep anteroinferior portal is created through the lower third of the subscapularis, about 8–10 cm distal to the coracoid and 1 cm lateral to the axillary fold (◘ Fig. 4.2).

For the first suture anchor at the 5:30 o’clock position, a guide instrument (e.g. Spear, Arthrex) is introduced via the anteroinferior portal and placed at the bone-cartilage junction of the glenoid margin in the previously created hole, followed optionally by tapping this hole and then insertion of the suture anchor (e.g. Bio-Fastak 3 mm, Arthrex) (◘ Figs. 4.3 and 4.4a). The sutures are then pulled to confirm the anchor stability.

The capsulolabral complex is pierced with a curved hollow suture passer (through the anteroinferior portal) from inferior towards the anchor, so that the whole capsulolabral complex including the aIGHL is incorporated. A suture lasso (shuttle loop) is then passed through the hollow suture passer (◘ Fig. 4.4b), the suture passer is then removed and the suture lasso together with a suture limb are retrieved out the anterosuperior portal.

The suture limb is passed through the loop of the suture lasso which is then retrieved out through the capsulolabral complex so that finally both suture limbs of the anchor come out the anteroinferior portal (alternatively, this step can be

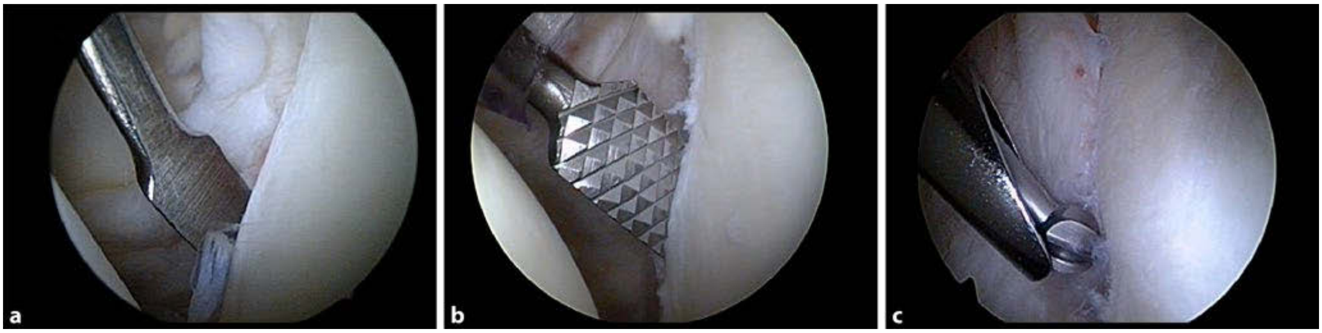


Fig. 4.1a–c **a** Mobilization the labrum with the Bankart knife **b** freshening of the glenoid rim with the Bankart rasp **c** The planned anchor sites at the 5:30 -, 4:30 -, and 3:00 o 'clock position are marked with an arthroscopic burr

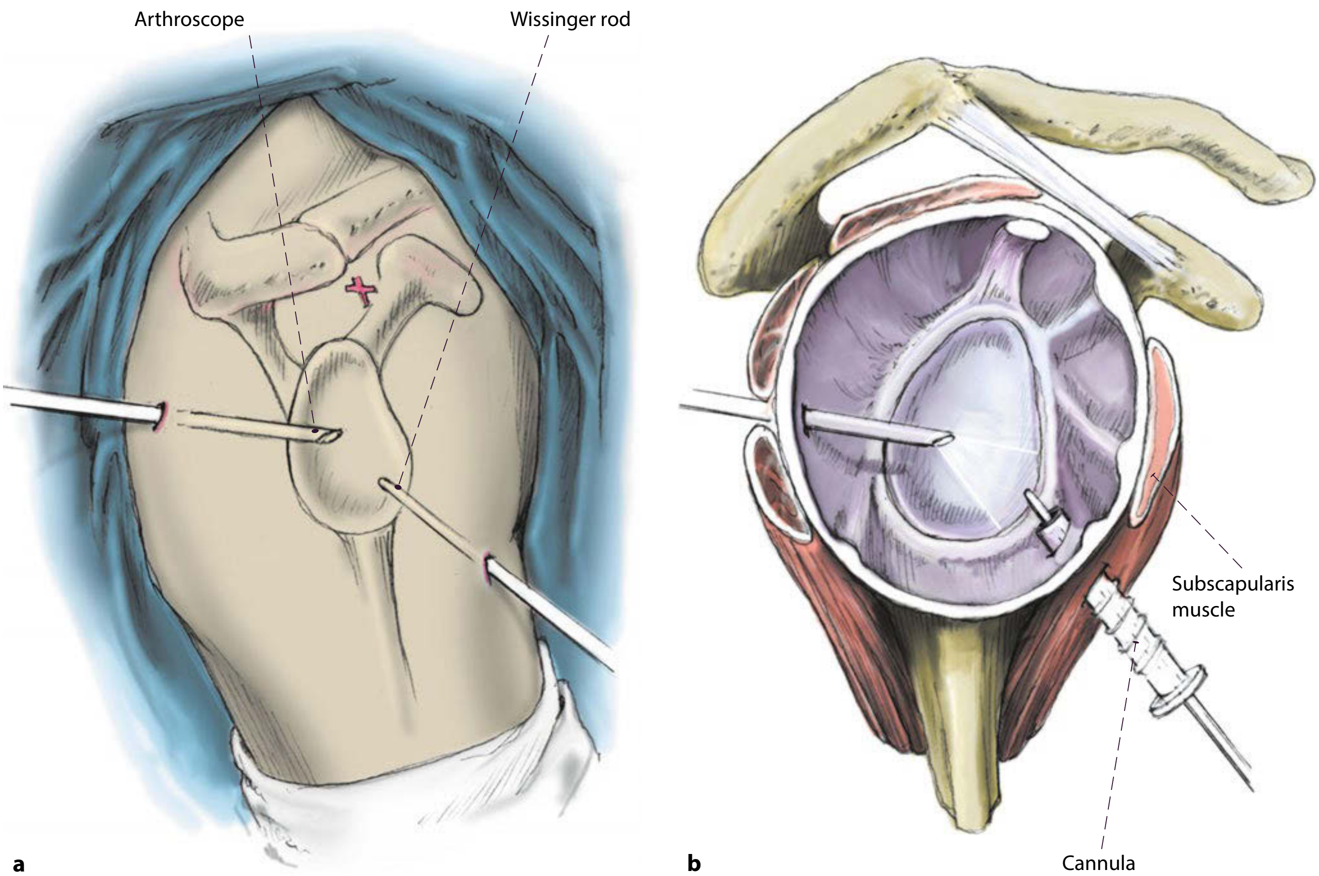


Fig. 4.2a,b Establishing the deep anteroinferior portal. **a** A switching stick is introduced at an angle of about 135 degrees towards the 5:30 position of the glenoid, as far as possible to the humeral side. **b** An arthroscopic cannula (9 cm long and 8.25 mm diameter, e.g. Arthrex) is inserted over the switching stick through the lower third of the subscapularis muscle

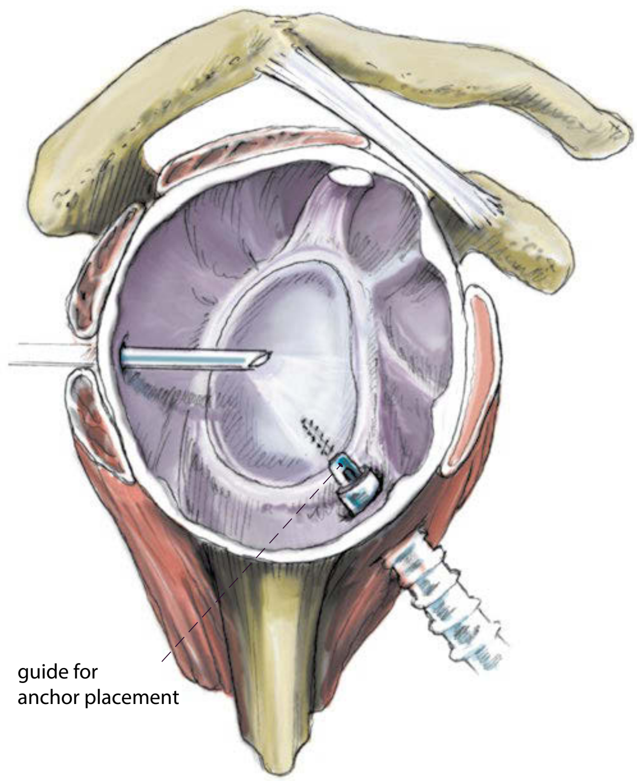


Fig. 4.3 Insertion of the first anchor at the 5:30 o ’clock position via the deep anteroinferior portal

performed intra-articular). The suture limb passing through the capsulolabral complex serves as a “post” over which the knot is tied. (Fig. 4.4c).

The Labrum is fixed with an arthroscopic sliding knot (e. g. modified “fisherman’s knot” or “Weston knot” (▶ Chap. 1) followed by three reversing half hitches (Fig. 4.4d).

Two additional suture anchors are usually inserted at the 4:30 and 3:00 o ’clock position in the same technique (Figs. 4.4f and 4.5). Refixation of the capsulolabral complex as well as the mobility are confirmed by passively moving the shoulder under arthroscopic visualization.

4.1.5 Postoperative Management

- Positioning of the arm in an arm sling
- Monitoring of peripheral circulation, motor and sensory innervation
- Postoperative X-ray evaluation.

4.1.6 Follow-Up Management

Immobilization of the shoulder in a sling for 24 h, then for 4 weeks at night and during prolonged activities. The range of motion in the 1st–3rd weeks is restricted to 45° abduction and flexion, 80° internal rotation and 0° external rotation, in the 4th–6th week the range is increased to 90° abduction and flexion, 80° internal rotation and 0° external rotation. From the 7th week free range of motion. Sport specific training is started after 3 months, overhead sports are not allowed earlier than 6th months postoperatively.

4.1.7 Tips & Tricks

Reconstruction of the capsulolabral complex is not sufficient alone in case of glenoid bone defects larger than 20–25 % of the glenoid surface area as well as with engaging Hill-Sachs lesions. The operative procedure should include the treatment of these lesions (e. g. by J-plasty of the glenoid or Remplissage procedure for Hill-Sachs defects) or an alternative procedure should be selected (e. g. Laterjet coracoid transfer).

Normal anatomical variants such as the sublabral foramen or Buford complex should be differentiated from labral lesions, as capsulolabral reconstruction in such cases would result in significant reduction of external rotation.

We recommend the routine use of the deep anteroinferior portal, which allows the most inferior placement of the first anchor exactly in the direction of the glenoid and thus results in a more biomechanically favorable shift of the capsulolabral complex. The insertion of the inferior anchor is particularly difficult when a more superiorly located portal is used (Fig. 4.6).

The anchor should be inserted into the bone at an angle of about 135° to the glenoid surface level. If the anchor is inserted too steep or too shallow, cartilage damage or anchor dislocation may occur (Fig. 4.7). The anchor should also be inserted deep enough below the cartilage level to avoid cartilage injury.

It is important during labrum refixation not only to repair the capsulolabral complex to the edge of the glenoid but also to plicate and shift the anterior inferior glenohumeral ligament cranially and thus decreasing the volume of the inferior pouch.

Knots should be placed away from the glenoid surface to avoid damaging the cartilage of the humeral head or the glenoid (Fig. 4.8).

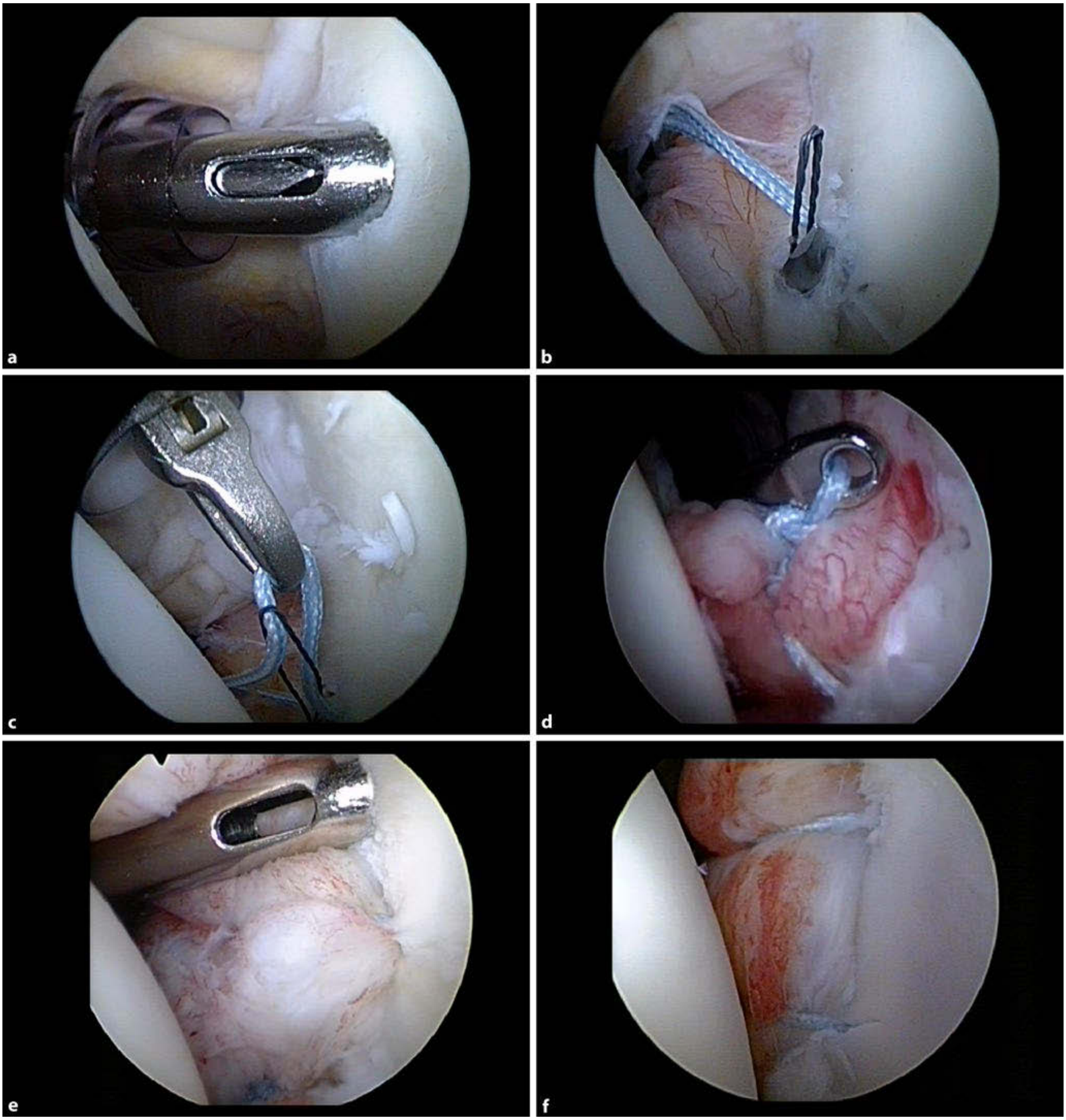


Fig. 4.4a–f **a** Insertion of the first anchor at the 5:30 o 'clock position **b** piercing the capsulolabral complex with a curved hollow suture passer **c** passing a suture limb through the suture lasso **d** tying the sutures using a knot pusher, **e** insertion of an additional anchor at the 4:30 o 'clock position, **f** final result with reattached capsulolabral complex

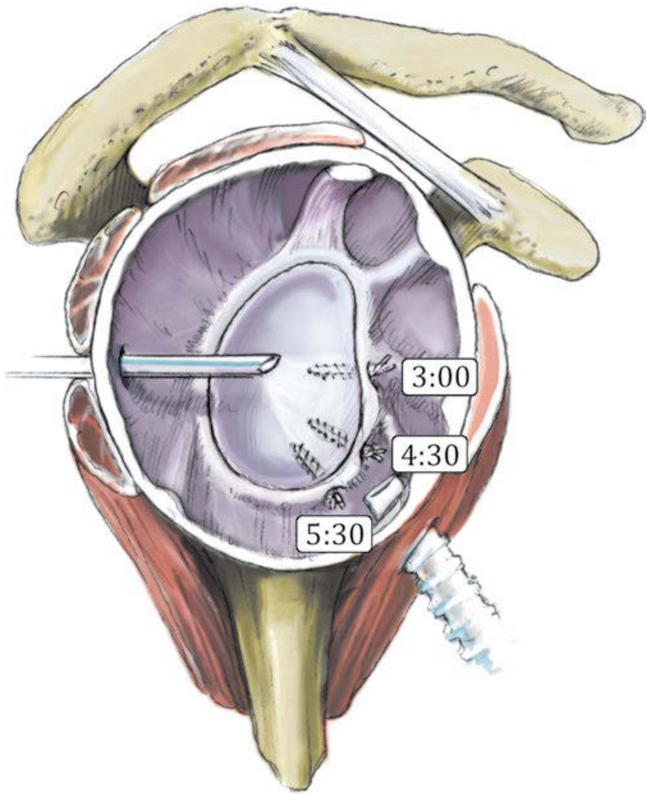


Fig. 4.5 Repaired anteroinferior labrum using suture anchors at the 5:30 - 4:30 - and 3:00 o 'clock positions

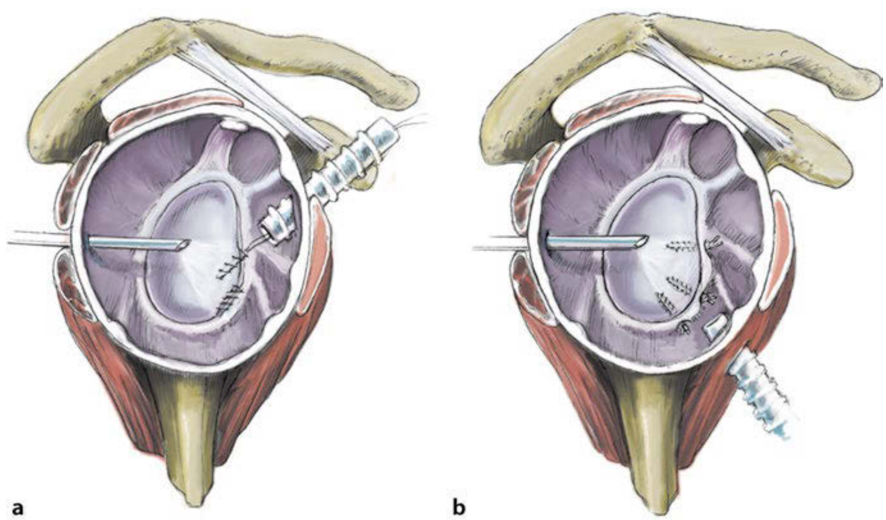


Fig. 4.6a,b Unlike to a more superiorly located anterior portal (**a**) the deep anteroinferior portal allows a more inferior insertion of the first anchor exactly in the direction of the glenoid and thus results in a more biomechanically favorable shift of the capsulolabral complex (**b**)

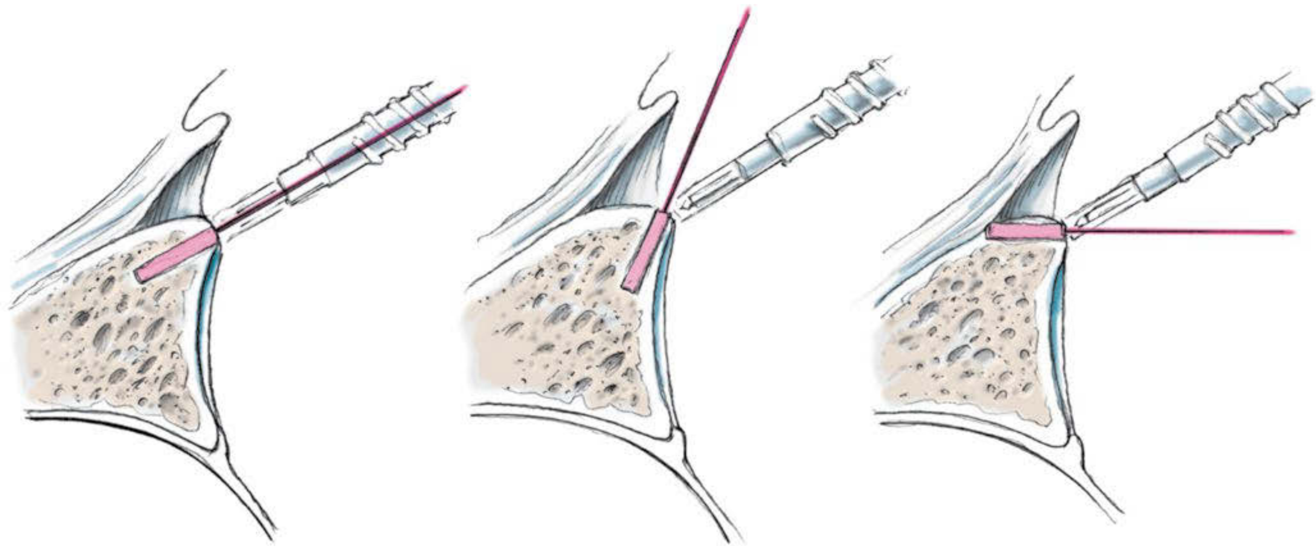


Fig. 4.7a–c The suture anchors are inserted at an angle of approximately 135° to the glenoid plane (**a**) too steep (**b**) or too flat positions (**c**) lead to inadequate anchor stability or damage of the glenoid cartilage

4.2 Posterior Shoulder Stabilization

M. Feucht, S. Braun

4.2.1 Indication

Symptomatic posterior shoulder instability in young patients as well as in patients with high functional demands.

Posterior instability as a main component of multidirectional instability after failure of conservative treatment.

4.2.2 Operation Principle

Arthroscopic posterior stabilization of the shoulder by anatomically reattaching the torn capsulolabral complex to the glenoid rim using suture anchors and at the same time plicating the posterior inferior glenohumeral ligament (pIGHL)

4.2.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: time, mechanism and direction of the first dislocation, reduction method (spontaneous, patient himself, external, with/without anesthesia), number of recurrent dislocations, voluntary components, treatment history, sport/functional demands, relevant comorbidities (e. g. epilepsy, chronic polyarthritis, Marfan syndrome, Ehlers-Danlos syndrome, psychological disorders)
- Symptom specific examination: range of motion (increased passive range of motion), scapular dyskinesia, anterior and posterior drawer tests, load-and-shift test, anterior and posterior apprehension tests, relocation test, Jerk test, sulcus sign in internal and external rotation, Gagey hyperabduction test.

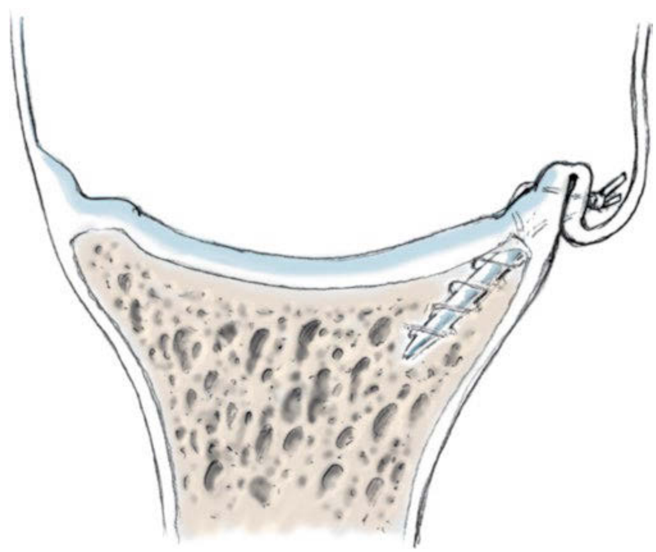


Fig. 4.8 Placement of the knot away from the glenoid surface (medial)

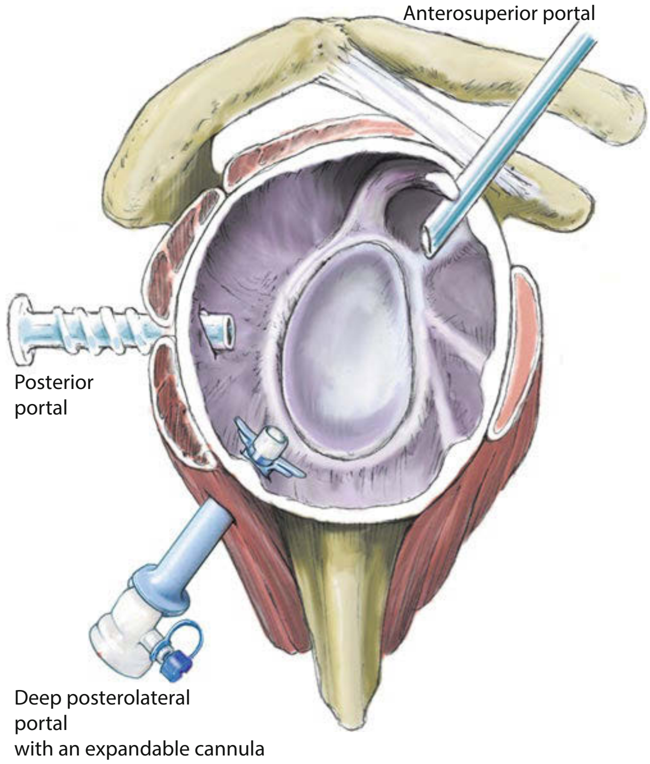
Neurovascular Condition

Evaluation of the peripheral nerves (axillary and suprascapular nerve)

Imaging

- X-rays of the shoulder in three views (true AP, y-view, axial) to detect bony lesions (glenoid fractures, reverse Hill-Sachs lesion)
- MRI (optionally with intraarticular contrast agent) to evaluate the capsulolabral lesion, capsular volume and any associated injuries (e. g. SLAP lesion, rotator cuff lesion)

■ **Fig. 4.9** Establishing the deep posterolateral portal in cannula technique



■ **Fig. 4.10** Portals used for posterior stabilization

- CT with suspected relevant glenoid bone defect or reverse Hill-Sachs lesion as well as for evaluation of the glenoid version.

Patient Information/Consent

Specific operative risks: re-dislocation, limitation of movement, "frozen shoulder", nerve injury (axillary nerve, musculocutaneous nerve, brachial plexus), injury of the subclavian artery, implant failure, dislocation or protrusion of anchors with the risk of cartilage damage, osteolysis.

4.2.4 Operative Technique

Positioning and Preparation

- Lateral decubitus position (alternatively, beach chair position is also possible)
- Examination under anesthesia (degree and direction of instability, hyperlaxity, range of motion)
- Positioning of the patient arm in an arm holder to allow distal and lateral traction.

Arthroscopic Posterior Shoulder Stabilization Using Suture Anchors

Diagnostic arthroscopy via the posterior standard portal. An anterosuperior portal is established in outside-in technique and the arthroscope is switched to this portal. The labrum is extensively mobilized from the posterior glenoid margin with a Bankart knife through the posterior portal (■ Fig. 4.14a) until it can be easily repositioned. The glenoid rim is freshened with the Bankart rasp until a bleeding bone surface is created. The planned insertion sites for the suture anchors at the 7:00 -, 8:30 - and if necessary 10 o'clock positions (right shoulder joint) are marked using an arthroscopic burr or Rongeur. The deep posterolateral portal is created about 2 –4 cm lateral and 4–5 cm inferior to the posterolateral acromial edge (■ Figs. 4.9 and 4.10).

For the first suture anchor at the 7:00 o 'clock position, a guide instrument (e.g. Spear, Arthrex) is introduced via the deep posterolateral portal and placed exactly at the bone-cartilage junction in the previously created mark (■ Fig. 4.14b), followed by tapping the hole and then insertion of the suture anchor (e.g. Bio-Fastak 3 mm, Arthrex) (■ Figs. 4.3 and 4.4a). The sutures are then pulled to confirm the anchor stability.

The capsulolabral complex is pierced with a curved hollow suture passer (through the deep posterolateral portal) that is passed from the inferior aspect lateral to the labrum to exit intraarticular between the labrum and the glenoid (■ Fig. 4.11). A suture lasso (shuttle loop) is then passed through the hollow suture passer (■ Fig. 4.14c), the suture passer is then removed and the suture lasso together with a suture limb are retrieved out the posterior portal.

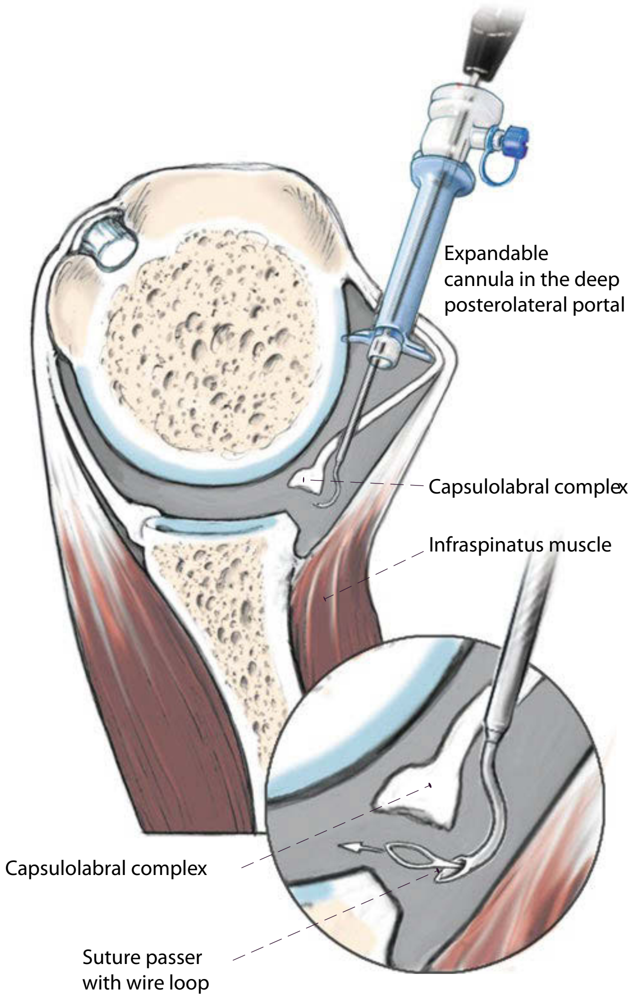


Fig. 4.11 Piercing the capsulolabral complex with a curved suture passer

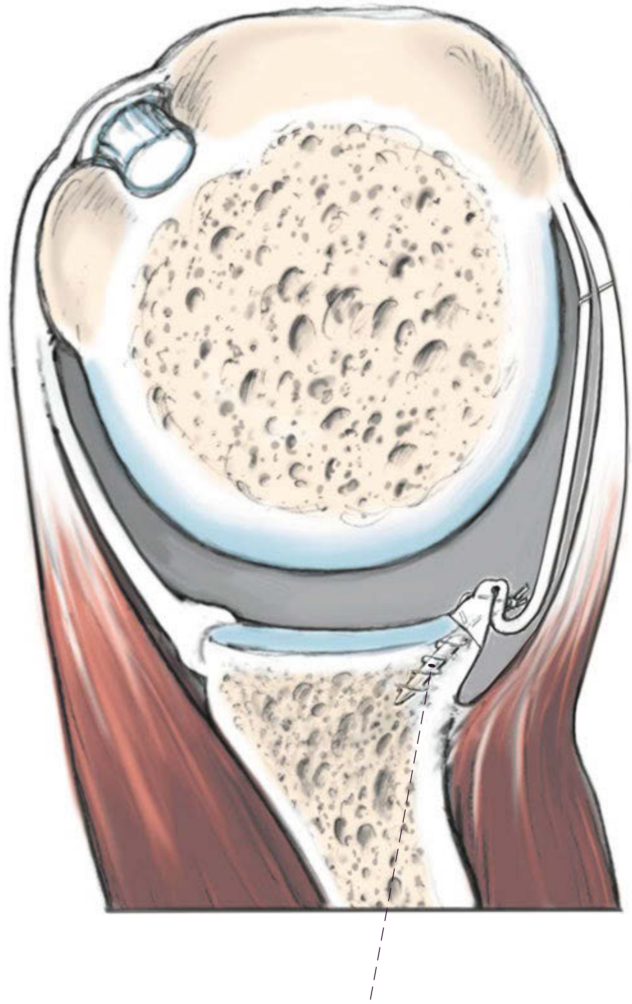


Fig. 4.12 Tying the anchor sutures and refixation of the capsulolabral complex

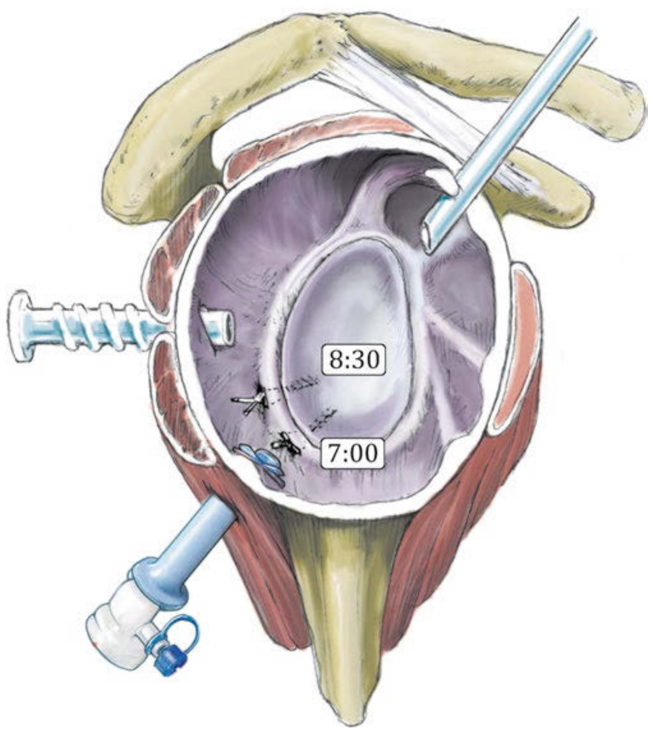
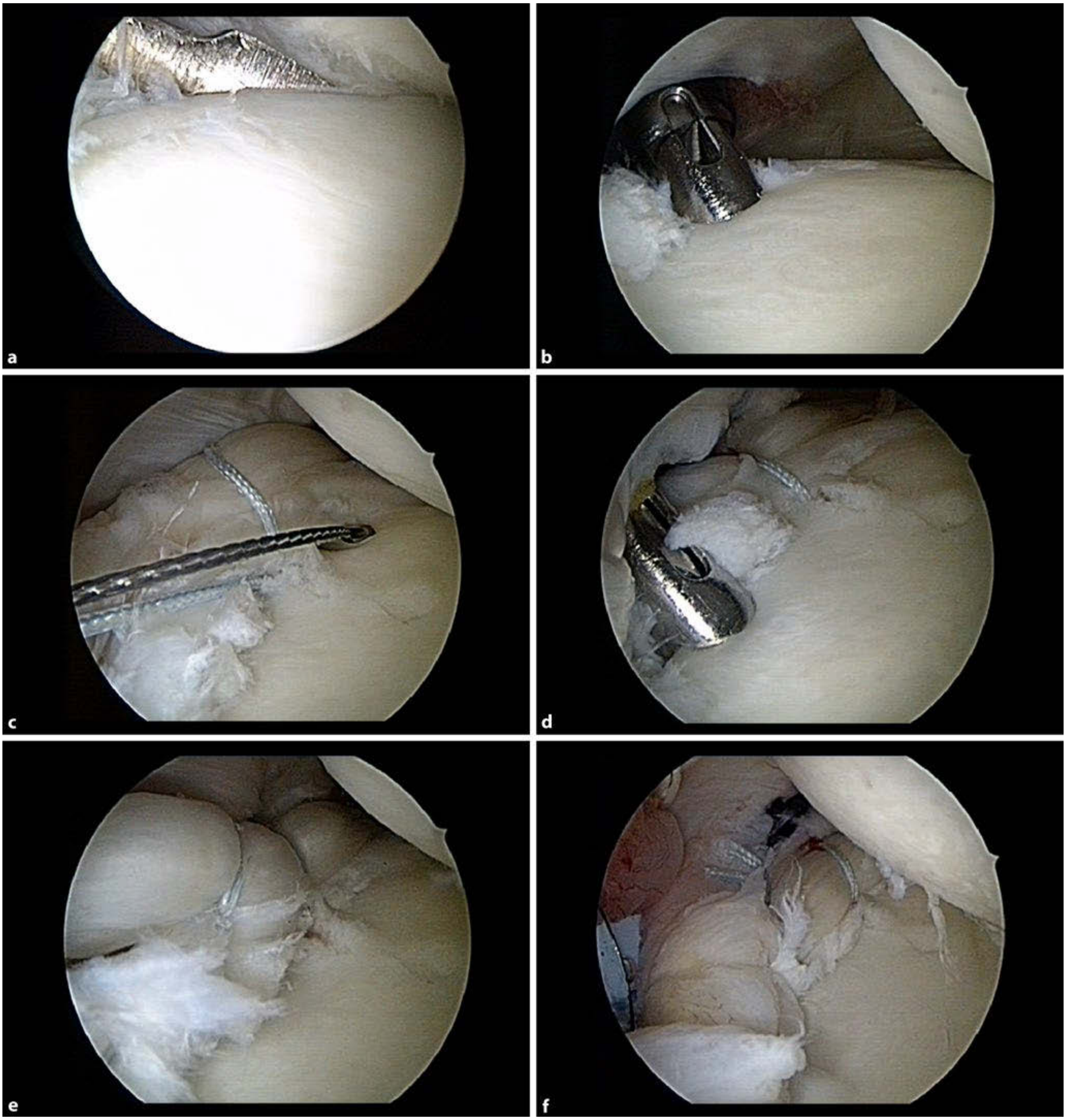


Fig. 4.13 Refixed posteroinferior labrum with suture anchors in the 7:00 and 8:30 o'clock positions



■ **Fig. 4.14a–f** Arthroscopic posterior shoulder stabilization. **a** Mobilization of the labrum with the Bankart knife; **b** Insertion of the first suture anchor; **c** Piercing the capsulolabral complex with a shuttling instrument to pass a suture lasso; **d** insertion of the second suture anchor; **e** refixed labrum after tying the sutures of the second anchor; **f** final results after insertion of the third suture anchor

The suture limb is passed through the loop of the suture lasso which is then retrieved out through the capsulolabral complex so that finally both suture limbs of the anchor come out the posterolateral portal. The suture limb passing through the capsulolabral complex serves as a "post" over which the knot is tied.

The labrum is fixed with an arthroscopic sliding knot (e.g. modified "fisherman's knot" or "Weston knot" (▶ Chap. 1) followed by three reversing half hitches (■ Fig. 4.12).

One or two additional suture anchors (as required) are inserted in the same technique in a caudal to cranial direction (■ Figs. 4.13 and 4.14d–f). Refixation of the capsulolabral complex as well as the joint mobility are confirmed by passively moving the shoulder under arthroscopic visualization.

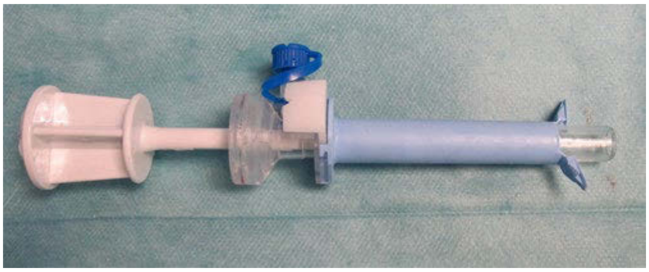


Fig. 4.15 Cannula with deployable wings (Gemini, Arthrex)

4.2.5 Postoperative Management

- The shoulder is immobilized in neutral rotation in a shoulder positioning pad (e.g. SLK 90°, Medi).
- Monitoring of peripheral circulation, motor and sensory innervation
- Postoperative X-ray evaluation.

4.2.6 Follow-Up Management

Immobilization of the shoulder in neutral rotation in a shoulder positioning pad for 6 weeks. The range of motion in the 1st–3rd weeks is restricted to 45° abduction, 30° flexion, 30° internal rotation and 60° external rotation, in the 4th–6th week the range is increased to 90° abduction, 60° flexion, 45° internal rotation and 75° external rotation. Free external rotation is allowed in the 7th–8th weeks. From the 9th week free range of motion. Sport specific training is started after 3 months, overhead sports are not allowed earlier than 6th months postoperatively.

4.2.7 Tips & Tricks

Reconstruction of the capsulolabral complex alone is not sufficient in case of large defects of the posterior glenoid as well as the humeral head (reverse Hill-Sachs-Lesion). The operative procedure should include the treatment of these lesions (e.g. bony reconstruction with auto- or allograft, McLaughlin procedure) A corrective osteotomy should be considered in cases with more than 20° retroversion of the glenoid.

For the deep posterolateral portal, we recommend the use of an arthroscopic cannula with intraarticular deployable wings (Fig. 4.15). The wings prevent the cannula from falling out, and moreover, the working space can be increased by pulling on it.

The anchor should be inserted at an angle of about 135° to the glenoid level. If the anchor is inserted too steep or too shallow, cartilage damage or early anchor dislocation may occur. The anchor should be also inserted deep enough below the cartilage level to avoid cartilage injury.

It is important during labrum refixation not only to repair the capsulolabral complex to the edge of the glenoid but also to plicate and shift the posterior inferior glenohumeral ligament cranially and thus decreasing the volume of the inferior pouch.

Knots should be placed away from the glenoid surface to avoid damaging the cartilage of the humeral head or the glenoid.

4.3 Multidirectional Shoulder Instability

N. Rosenstiel, S. Braun

4.3.1 Indication

Symptomatic, post-traumatic or atraumatic multidirectional shoulder instability with ligamentous hyperlaxity in young patients as well as patients with high functional demands after failure of conservative treatment. Multidirectional hyperlaxity with involuntary dislocation or unidirectional instability with multidirectional hyperlaxity. At least 3–6 months of unsuccessful conservative treatment should be tried before deciding operative treatment.

4.3.2 Operation Principle

Arthroscopic anterior and posterior stabilization of the shoulder by reattaching the labrum using suture anchors and at the same time plicating the anterior inferior glenohumeral ligament (aIGHL) and the posterior inferior glenohumeral ligament (pIGHL).

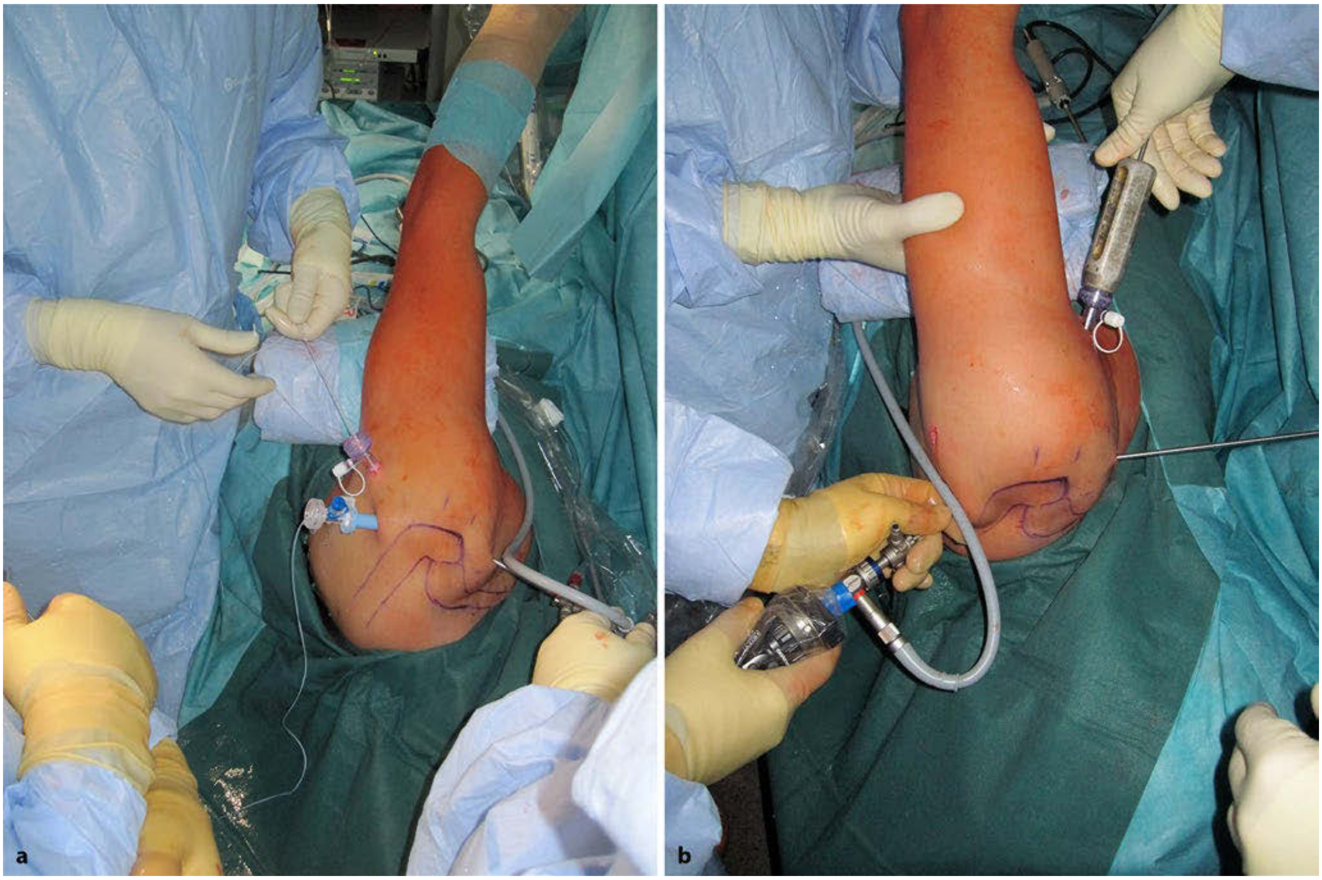
With markedly increased capsular volume as well as enlarged rotator interval (positive sulcus sign in external rotation) it is mandatory to plicate the capsule arthroscopically or to tighten the rotator interval through rotator interval closure.

4.3.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: time, mechanism and direction of the first dislocation, reduction method (spontaneous, patient himself, external, with/without anesthesia), previous shoulder dislocations or injuries, number of recurrent dislocations, treatment history, sport/functional demands, relevant comorbidities (e.g. epilepsy, chronic polyarthritis, Marfan syndrome, Ehlers-Danlos syndrome, psychological disorders)
- Symptom specific examination: range of motion (increased passive range of motion), muscular pattern,



■ **Fig. 4.16a,b** Portals used for anterior and posterior shoulder stabilization. **a** Arthroscopic cannulas placed in the standard posterior portal and the deep posterolateral portal; **b** establishing the deep anteroinferior portal with the arthroscope in the standard posterior portal

scapular dyskinesia, increased anteroposterior translation, load-and-shift test, sulcus sign in internal and external rotation, Gagey hyperabduction test, anterior and posterior apprehension tests, relocation test, Jerk test, signs of generalized hyperlaxity.

Imaging

- X-rays of the shoulder in three views (true AP, y-view, axial) to detect bony lesions (glenoid fractures, reverse Hill-Sachs lesion)
- MRI (optionally with intraarticular contrast agent) to evaluate the capsulolabral lesion, capsular volume and any associated injuries (e.g. SLAP lesion, rotator cuff lesion)
- CT with suspected relevant glenoid bone defect, Hill-Sachs lesion or reverse Hill-Sachs lesion as well as for evaluation of the glenoid version.

Patient Information/Consent

Specific operative risks: re-dislocation, limitation of movement (mainly internal and external rotation), "frozen shoulder", nerve injury (axillary nerve, musculocutaneous nerve, brachial plexus), injury of the subclavian artery, implant failure, dislocation or protrusion of anchors with the risk of cartilage damage, osteolysis, switching to an open operative procedure if needed, postoperative immobilization for 6 weeks.

4.3.4 Operative Technique

Positioning and Preparation

- Lateral decubitus position with long connecting anesthesia tubes to allow positioning of the patients head in the theatre.
- Examination under anesthesia (degree and direction of instability, hyperlaxity, range of motion)
- Positioning of the patient arm in an arm holder that allows traction

Arthroscopic Anterior and Posterior Shoulder Stabilization Using Suture Anchors

In addition to the standard posterior portal and the anterosuperior working portal, the deep anteroinferior and the deep posterolateral portals are created for fixation of the anteroinferior and the posteroinferior capsulolabral complexes respectively (■ Fig. 4.16). Diagnostic arthroscopy (■ Fig. 4.17) is performed and the stability of the labrum and the biceps tendon anchor is evaluated using an arthroscopic probe.

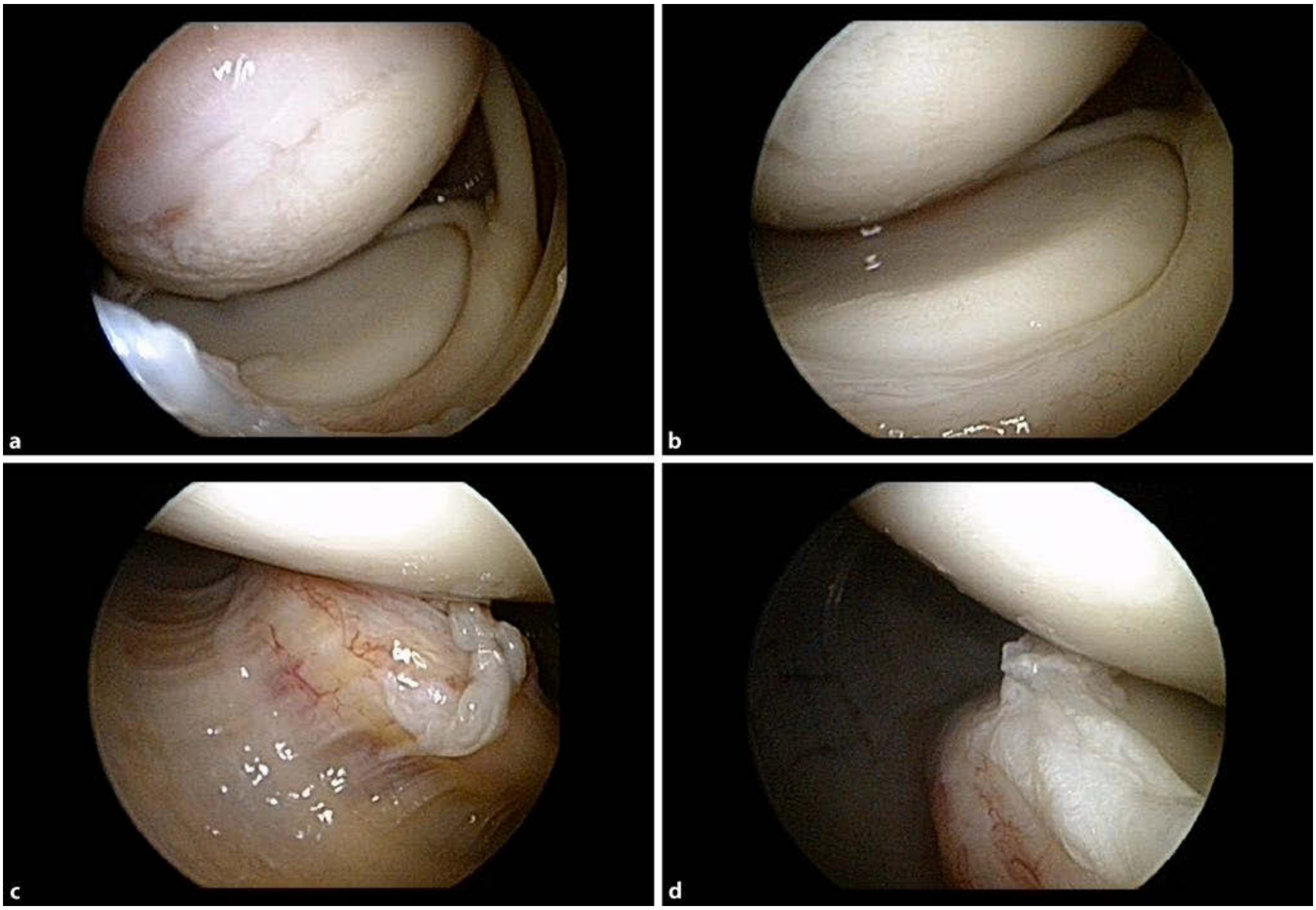


Fig. 4.17a–d Typical appearance in multidirectional instability. It show a lax capsuloligamentous structures (a) partly detached labrum (b) and rounded glenoid edge (c and d)

This is followed by posterior and subsequently anterior stabilization, starting in each procedure with the most inferiorly located anchor. The labrum is extensively mobilized with the Bankart knife until it could be easily repositioned. The glenoid rim is freshened with the Bankart rasp until a bleeding bone surface is created.

The planned sites for the suture anchors posteriorly at the 7:00 -, 8:30 - and possibly 9:00 o 'clock positions (right shoulder joint) and anteriorly at the 5:30 -, 4:30 -, and 3:00 o 'clock positions are marked using an arthroscopic burr or Rongeur.

The anchors are then inserted followed by fixation of the capsulolabral complexes in the same technique (Fig. 4.18) described in ► Sects. 4.1 and 4.2.

Refixation of the capsulolabral complex as well as the mobility are confirmed by passively moving the shoulder under arthroscopic visualization.

Capsular Plication

In addition to an insufficient labrum, multidirectional instability often shows an excessive laxity of the capsuloligamentous complex. Capsular plication (anterior, posterior or combined) is performed if the laxity is not improved after arthroscopic shoulder stabilization. In this procedure, the part of the capsule to be plicated is freshened with a soft tissue shaver. Subsequently, the capsule is pierced with an angled suture passer loaded with a PDS suture starting away from the glenoid to capture about 1–2 cm from the capsule and exits close to the glenoid. The PDS suture is then tied decreasing the capsular volume (Fig. 4.19). The capsule could be plicated in a W-shaped configuration. Plication should be repeated 2–3 times to sufficiently reduce the capsular volume.

Rotator Interval Closure

Rotator interval closure should be performed to supplement capsulolabral reconstruction if there is a positive sulcus sign in external rotation during the shoulder examination under anesthesia.

One or two PDS sutures are passed using a suture passer via the anterosuperior portal through the capsule at the superior margin of the subscapularis tendon and retrieved back using a sharp penetrating instrument passed anterior to the supraspinatus tendon and then tied extracapsular (Fig. 4.20).

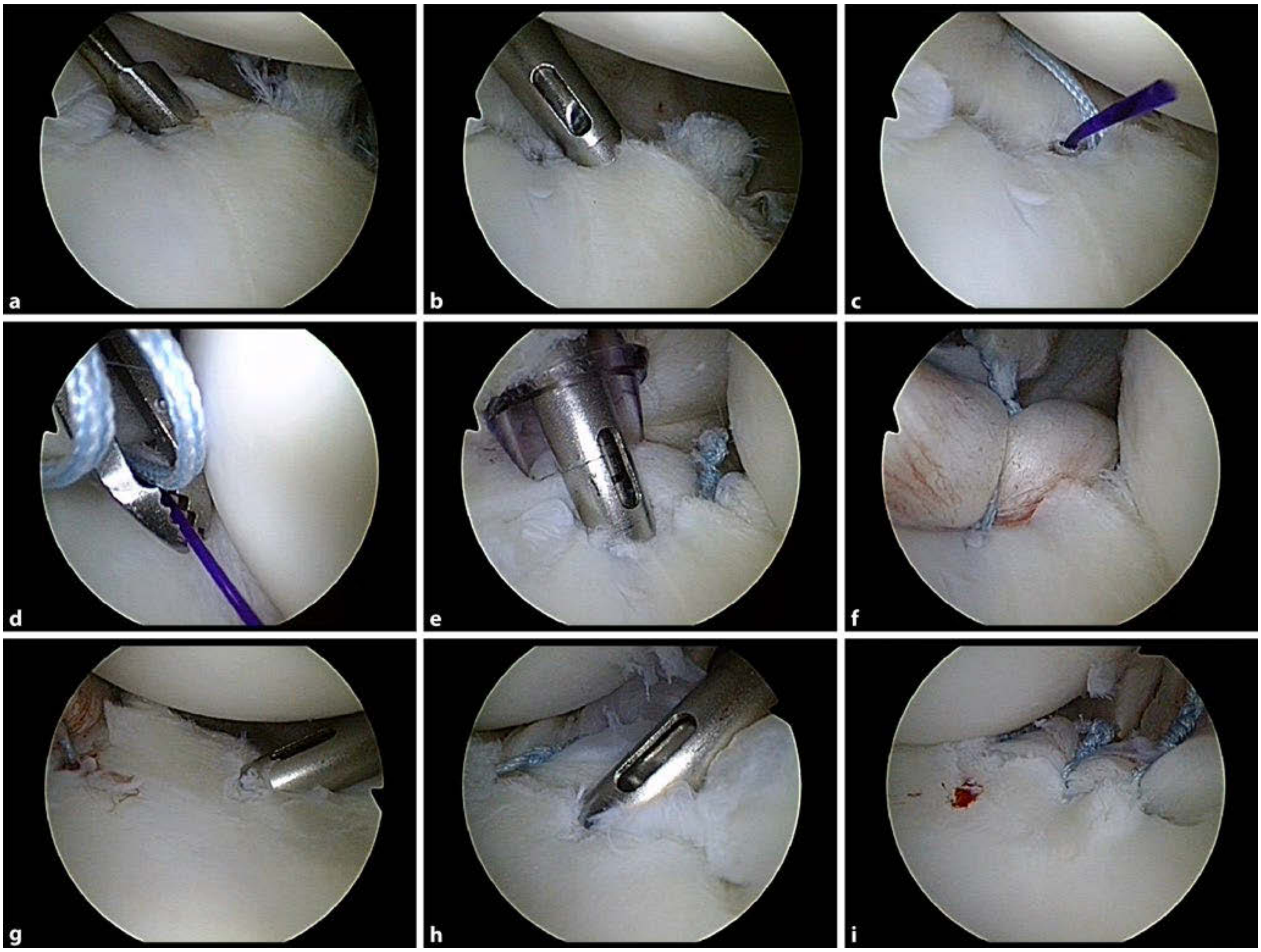


Fig. 4.18a–i Arthroscopic posterior and anterior shoulder stabilization. **a** mobilization of the capsulolabral complex; **b** insertion of the first anchor posteroinferior; **c** piercing the capsule-labrum complex with the shuttling instruments; **d** retrieval of sutures out; **e** insertion of the second posterior anchor; **f** posterior neolabrum after repair using 2 suture anchors; **g** insertion of the first anteroinferior anchor; **h** insertion of the second anterior anchor; **i** anterior neolabrum after repair using 3 suture anchors

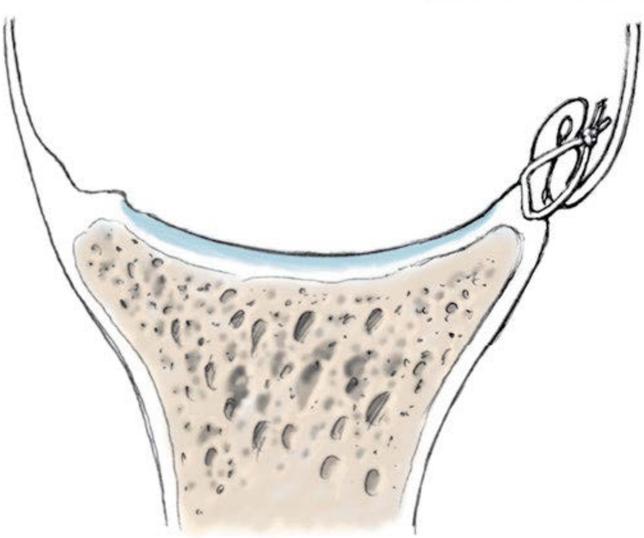


Fig. 4.19 Capsular plication with a PDS suture

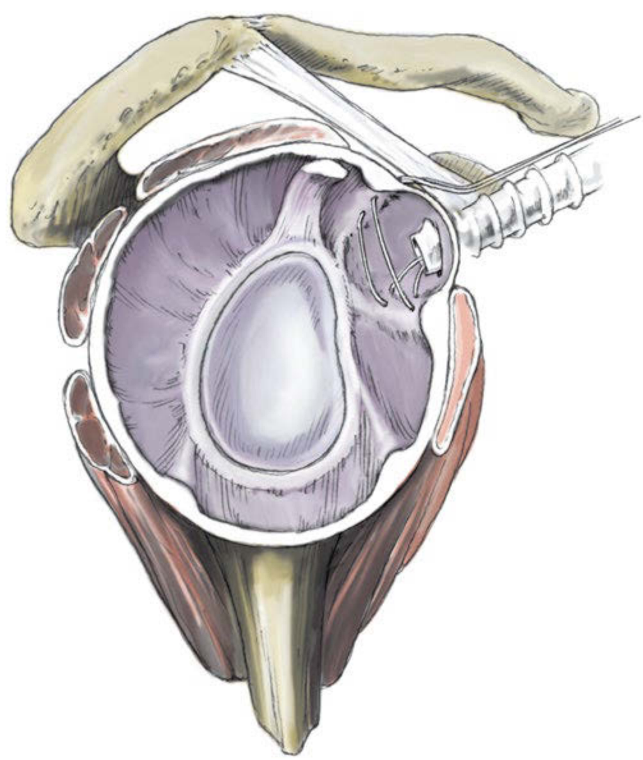


Fig. 4.20 Rotator interval closure using PDS sutures

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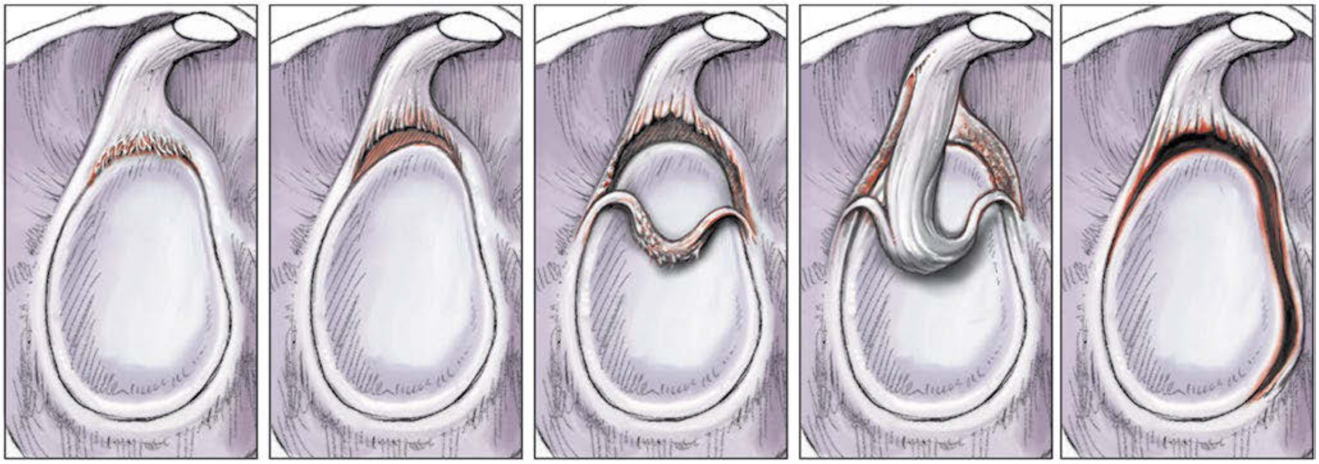


Fig. 4.21 Schematic illustration of the different SLAP lesions. Type I: fraying of SLAP complex; Type II: detachment of the SLAP complex from the superior glenoid rim; Type III: bucket-handle tear of the superior labrum; Type IV: longitudinal splitting of the labrum and the long biceps tendon; Type V: detachment of both the SLAP complex and the anterior labrum

4.3.5 Postoperative Management

- The shoulder is immobilized in neutral rotation in a shoulder positioning pad (e.g. SLK 90°, Medi).
- Monitoring of peripheral circulation, motor and sensory innervation
- Postoperative X-ray evaluation.

4.3.6 Follow-Up Management

Immobilization of the shoulder in neutral rotation in a shoulder positioning pad for 6 weeks. The range of motion in the 1^{st}–3^{rd} weeks is restricted to 45° abduction, 30° flexion, 30° internal rotation and 0° external rotation, in the 4^{th}–6^{th} week the range is increased to 90° abduction, 60° flexion, 45° internal rotation and 0° external rotation. In the 7^{th}–8^{th} week's 90° flexion is allowed, otherwise free mobility. From the 9^{th} week free range of motion. Overhead sports not allowed earlier than 6^{th} months postoperatively. A more restrictive limitation of the range of motion is needed with additional capsular plication.

4.3.7 Tips & Tricks

The medial glenohumeral ligament could be incised at the upper edge and separated from the subscapularis tendon using a blunt instrument to achieve a better capsular mobility during capsular plication. Interval closure should be left to the end of the procedure, otherwise the portals will be close so early.

4.4 SLAP Lesions Type II–V

M. Feucht, S. Braun

4.4.1 Indication

Symptomatic SLAP lesion Snyder and Maffet type II–V (Fig. 4.21).

4.4.2 Operation Principle

The treatment principle differs according to the lesion type:

- **Type II**: arthroscopic refixation of the SLAP-complex to the superior glenoid with suture anchors
- **Type III:** Arthroscopic resection of the bucket handle torn flap displaced into the joint. Refixation of the SLAP-complex with suture anchors is considered with tears of the biceps tendon anchor in a well-vascularized area near to the bone of the supraglenoid tubercle.
- **Type IV:** Tenotomy or tenodesis of the long biceps tendon is generally performed; repair of the ruptured biceps tendon may be taken into consideration in selected cases. Additionally, a SLAP repair is performed if the biceps tendon anchor is unstable and re-fixable.
- **Type V:** Arthroscopic repair of both the SLAP lesion and the anterior capsulolabral lesion using suture anchors.

4.4.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: mechanism of injury (macrotrauma/repetitive microtrauma due to overhead sports) onset of pain (acute/chronic), previous shoulder dislocations, subjective feeling of instability, snapping or locking.
- Symptom specific examination: O'Brien test, Palm up test, Speed test, Biceps load test, thrower test, examination to delineate associated instability.

Imaging

- X-rays of the shoulder in three views (true AP, y-view, axial) to exclude bony lesions.
- MRI to evaluate the biceps tendon anchor and possible associated lesions (e.g. Bankart lesion or posterosuperior rotator cuff lesions in over-head athletes); native MRI is sufficient in acute injuries while MRI with intraarticular contrast medium could be optionally performed to increase the diagnostic accuracy.

Patient Information/Consent

Specific operative risks: dislocation or protrusion of anchors with the risk of cartilage damage, osteolysis caused by the anchors, limitation of movement (mainly external rotation in type V), "frozen shoulder", nerve injury (axillary nerve, musculocutaneous nerve, brachial plexus), injury of the subclavian artery, recurrent rupture of the biceps tendon anchor, rupture of the long biceps tendon with distalization of the muscle belly.

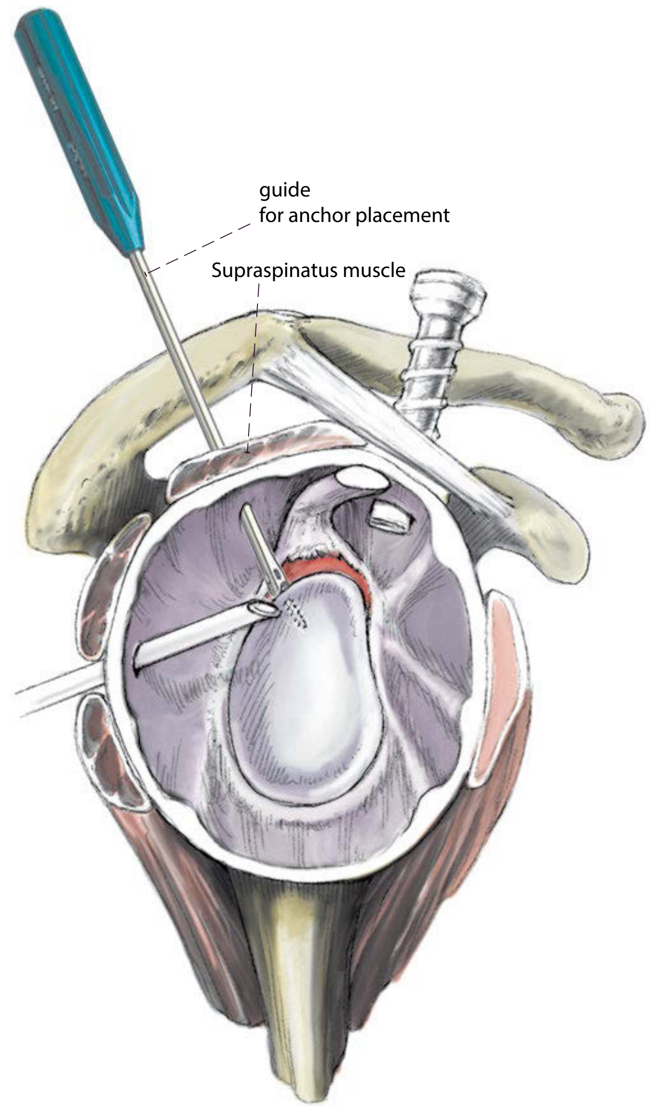


Fig. 4.22 Insertion of the first suture anchor using a guide instrument through a stab incision through the supraspinatus muscle lateral to the acromion

4.4.4 Operative Technique

Positioning and Preparation

- Beach chair position
- Examination under anesthesia (degree and direction of possible associated instability)
- Positioning of the patient arm in an arm holder

Arthroscopic SLAP Repair

Diagnostic arthroscopy is performed via the posterior standard portal. An anterosuperior working portal is established and the stability of the biceps tendon-labrum complex is evaluated using an arthroscopic probe to verify the lesion type.

The superior glenoid edge is freshened using an arthroscopic burr or a shaver introduced via the anterosuperior portal. The planned sites for anchor insertion, anterior and posterior to the biceps tendon insertion, are extensively released to avoid protrusion of the anchors. The anterior capsulolabral complex is additionally mobilized in case of type V SLAP lesion, followed by freshening of the glenoid edge and creation of marking holes at the planned anchor positions.

For the first suture anchor, an additional stab incision is made about 1 cm anterior to the posterior acromion edge and directly lateral to the acromion ("port of Wilmington"). A guide instrument (e.g. Spear, Arthrex) is then passed through the supraspinatus muscle and placed at the previously created marking hole posterior to the biceps tendon insertion (Fig. 4.22).The exact position of the portal should be accurately determined and probed using a needle from outside (Fig. 4.23a). Drilling and tapping followed by insertion of the suture anchor (e.g. Bio-Fastak, Arthrex. Fig. 4.23b). The sutures are then pulled to confirm the anchor stability and then retrieved out through the anterosuperior portal.

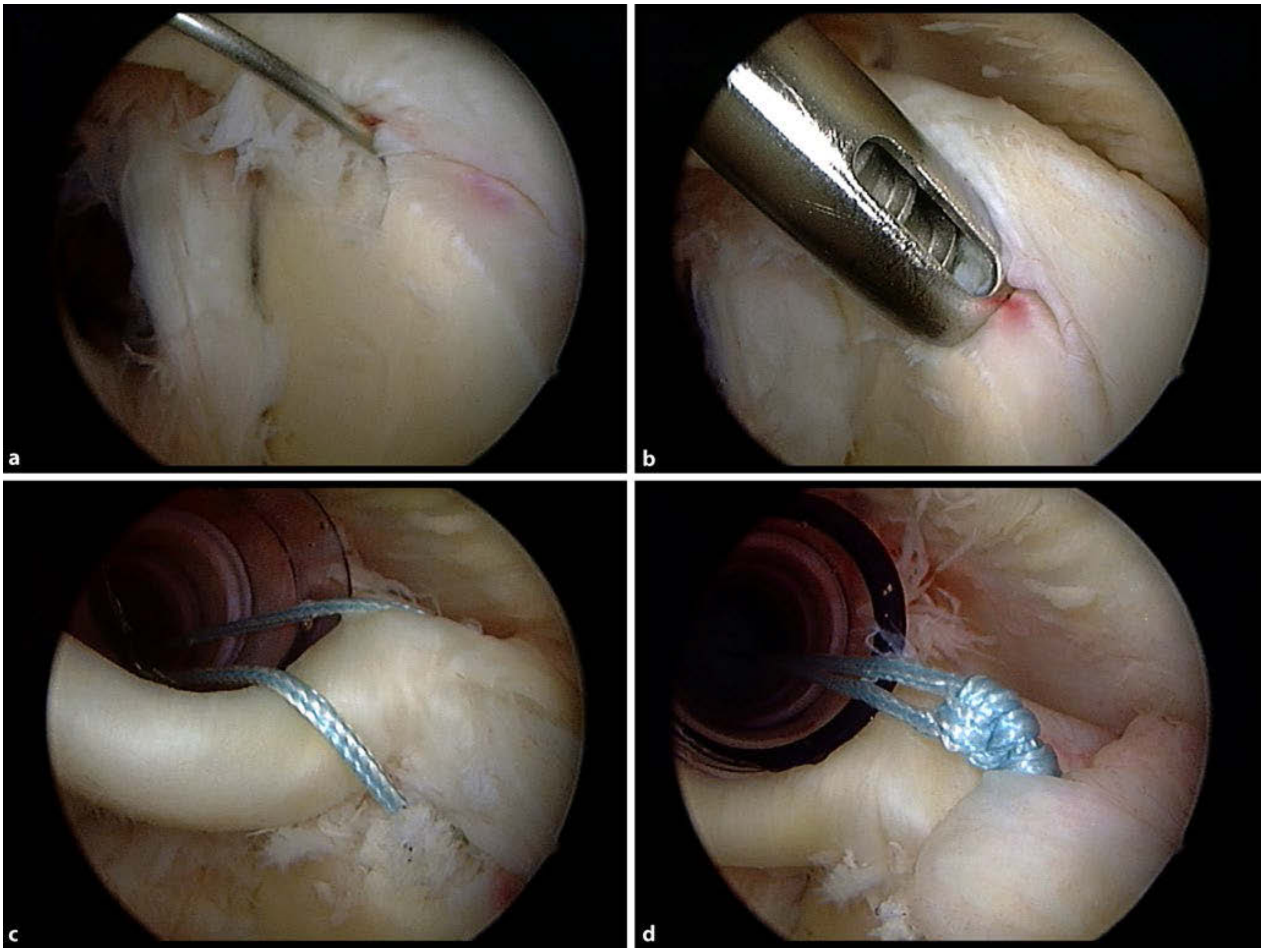


Fig. 4.23a–d Arthroscopic SLAP repair. **a** localization of the stab incision with a needle **b** insertion of the first suture anchor posterior to the biceps tendon **c** one anchor suture is shuttled medially through the SLAP complex d knotting the anchor sutures

The posterosuperior SLAP-complex is pierced from medial to lateral using a sharp tissue penetrating forceps (e.g. Bird Peak, Arthrex, Inc.) or a curved suture passer through the anterosuperior portal.

One suture limb is passed either directly using the tissue penetrator or indirectly using the suture passer to pass a suture lasso, which is then retrieved through the anterosuperior portal and used to shuttle one anchor suture (Fig. 4.23c).

The posterosuperior SLAP-complex in then refixed with an arthroscopic sliding knot (e.g. modified "fisherman's knot" or "Weston knot" (▶ Chap. 1) followed by three reversing half hitches through the anterosuperior portal (Fig. 4.4d).

A second suture anchor is then inserted anterior to the biceps tendon anchor in the same technique. One anchor suture is then shuttled through the anterosuperior SLAP-complex and both anchor sutures are then tied as described above. In type II and III SLAP lesions with unstable biceps tendon insertion, usually 2–3 suture anchors are needed for fixation (Fig. 4.24). With type V lesions, the anterior capsulolabral complex should be stabilized (in the same technique described in ▶ Sect. 4.1) before insertion of the anterior anchor.

4.4.5 Postoperative Management

- Positioning of the arm in an arm sling
- Monitoring of peripheral circulation, motor and sensory innervation
- Postoperative X-ray evaluation.

4.4.6 Follow-Up Management

Immobilization of the shoulder in an arm sling with avoidance of active biceps exercises for 6 weeks. The range of motion in the 1st–3rd weeks is restricted to 45° abduction and flexion, 80° internal rotation and 0° external rotation, in the 4th–6th weeks: the range is increased to 60° abduction, 90° flexion, 80° internal rotation and 0° external rotation. From the 7th week free range of motion. Sport specific training is started after 3 months, overhead sports not allowed earlier than 6th months postoperatively. After repair of type V lesions, the range of external rotation is limited to 30° in the first 3 weeks.

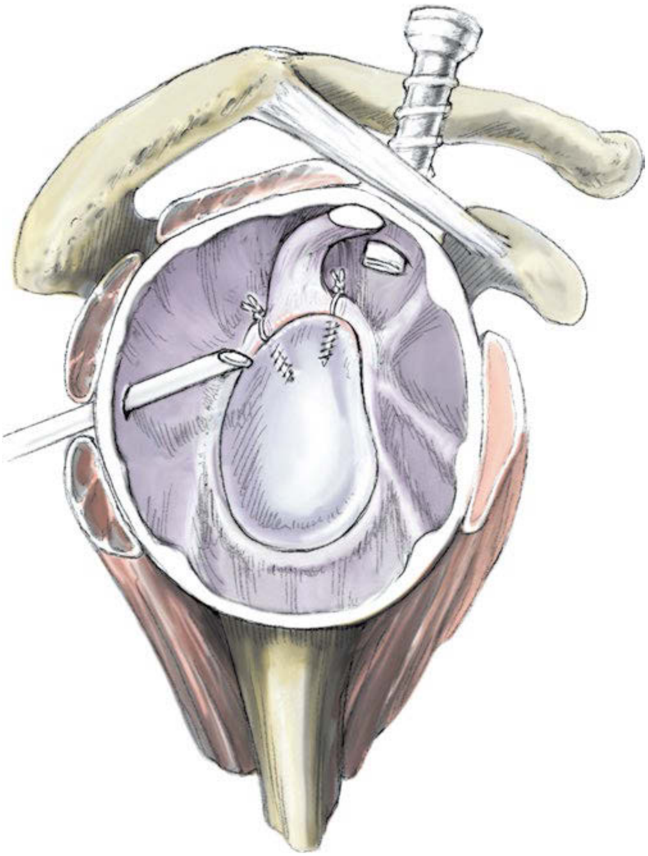


Fig. 4.24 SLAP repair with 2 suture anchors

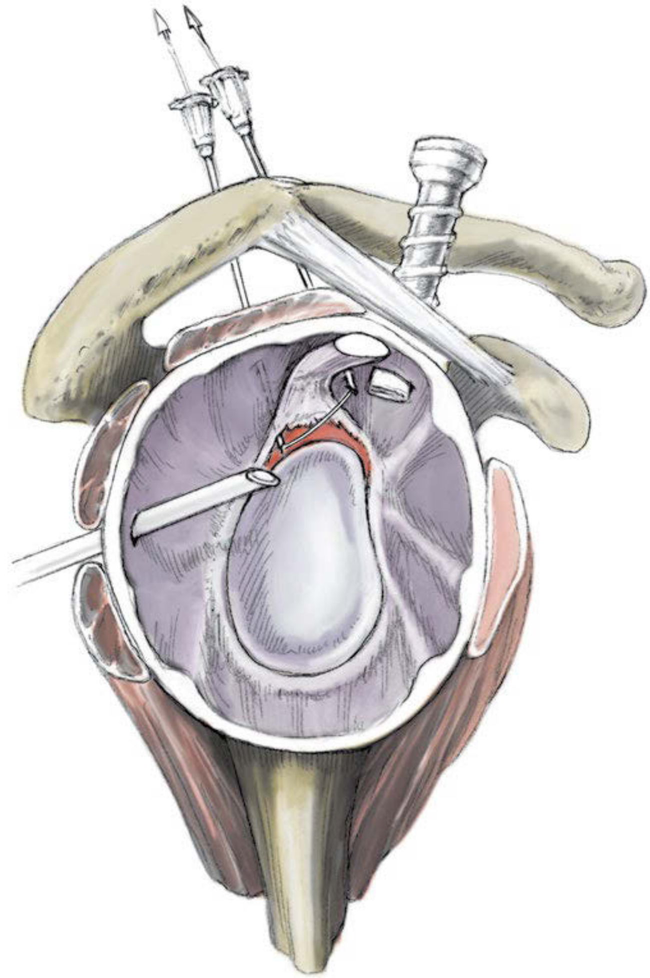


Fig. 4.25 Suspension sling

4.4.7 Tips & Tricks

The anatomy of the labrum-biceps tendon complex is highly variable. Normal variants such as the sublabral recess must be differentiated from actual type II lesion, as they do not require specific treatment.

To create enough space for preparation of the glenoid, the detached SLAP complex can be suspended with a suture loop ("suspension sling"), and can be then pulled in a posterosuperior direction away from the glenoid rim: 2 needles are inserted into the joint in the region of the supraspinous fossa, placing one anterior and the other posterior to the posterosuperior labrum. A PDS suture is introduced into the joint through each needle and retrieved through the anterosuperior portal, the sutures are tied extraarticular and then pulled back into the joint. The labrum can now be kept away from the work space by pulling on the extraarticular suture ends (Fig. 4.25).

During SLAP repair, the insertion type of the long biceps tendon according to Vangsness et al. must be taken into consideration. In case of type I and II insertions, in which most of the labral attachment is posterior, 2 posterior anchors may be necessary.

During repair of type V lesion, it is recommended to insert first the suture anchor posterior to the biceps tendon insertion due to increasing difficulty to visualize this area when the shoulder progressively swells. This is followed by refixation of the anterior capsulolabral complex. Last step is to complete the SLAP repair by inserting the second anchor anterior to the biceps tendon insertion.

The anchor should be inserted into the bone at an angle of about 135° to the glenoid surface level. If the anchor is inserted too steep or too shallow, cartilage damage or early anchor dislocation may occur.

4.5 Posterosuperior Impingement

N. Rosenstiel, P. Braun

4.5.1 Indication

Symptomatic posterosuperior (internal) impingement of the shoulder (Fig. 4.26) with involvement of one or more of the following structures after failed trial of conservative treatment:

- SLAP complex
- Articular side of the rotator cuff (Supraspinatus tendons)

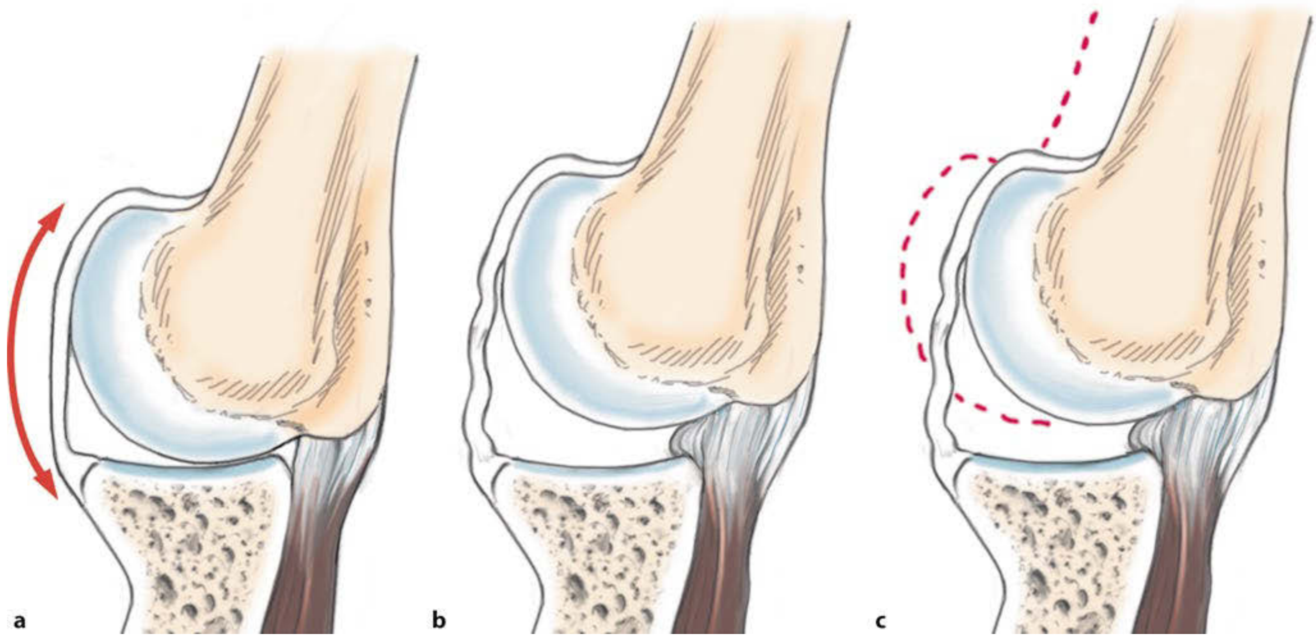


Fig. 4.26a–c Posterosuperior impingement: the arm in high abduction and external rotation position. **a** Abutment of the greater tuberosity on the posterosuperior glenoid causes increased traction on the anteroinferior capsule. **b** This results in posterior displacement of the glenohumeral contact point, which leads to decreased tension on the anteroinferior capsule. **c** comparison between the physiological neutral position (broken line) and the changed position as a result of internal impingement

- Greater tuberosity
- Inferior glenohumeral ligament or inferior capsule
- Posterosuperior glenoid/labrum

Conservative treatment is carried out in a four-phased schema:
- Acute phase: to promote the healing of acute injuries (e. g. anti-inflammatory drugs, limitation of the range of motion, very limited physiotherapy) and pain reduction
- Building/intermediate phase: strengthening, stretching, and normalization of the neuromuscular rhythm.
- Stabilization phase: strength endurance and beginning of overhead sports training
- Return to activity: intensification of the overhead sports up to the original level of performance through position specific training

4.5.2 Operation Principle

The principle of the operative procedure differs according to the type of injury, usually a combination of the following procedures is required:
- Repair of the superior labrum (SLAP repair)
- Repair of anteroinferior and/or posterior capsulolabral complex
- Rotator cuff repair
- Anteroinferior capsular plication.

4.5.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: previous injuries, infiltrations and operations, pain character and localization (pain, instability, limitation of motion), symptoms duration and triggers, feelings of instability, sport specific history
- Symptom specific examination: Impingement tests, instability tests, rotator cuff tests, painful external rotation in abduction (ABER position "abduction and external rotation"), with loss of strength, tenderness over the posterior joint line, increased external rotation, decreased internal rotation (GIRD syndrome = "glenohumeral internal rotation deficit"); (GIRD; Fig. 4.27)

Imaging

- X-rays of the shoulder in three views (true AP, y-view, axial).
- MRI (Arthrography) to differentiate between the intrinsic and extrinsic causes of impingement and to evaluate the rotator cuff tendons, the biceps tendon and its anchor as well as the labrum, additionally in the ABER position.

Patient information/consent

Specific operative risks: Are those associated with the different intraoperative procedures (SLAP-repair: ► Sect. 4.4, anterior

◻ **Fig. 4.27** Typical clinical picture of a GIRD syndrome of the right shoulder with increased high external rotation and simultaneous decreased high internal rotation

and/or posterior shoulder stabilization ▶ Sects. 4.1, 4.2 and 4.3, rotator cuff repair chapter ▶ Sects. 3.1, 3.2 and 3.3, capsular plication ▶ Sect. 4.3), higher risk of not reaching the preoperative level of performance with overhead athletes.

4.5.4 Operative Technique

Positioning and Preparation

- Beach chair position (alternatively lateral decubitus position)
- Positioning of the patient arm in an arm holder

Surgical Technique

Diagnostic arthroscopy and dynamic shoulder examination (in the ABER position) via the posterior standard portal to assess particularly the superior labrum with biceps tendon/biceps tendon anchor, the anterior and anteroinferior capsulolabral complex, the rotator cuff (esp. supra- and infraspinatus) and the greater tuberosity ("kissing lesion" between the undersurface of the rotator cuff and the posterior labrum).

The operative procedure should be based on the results of arthroscopic examination and correlated with the patient's symptoms and the clinical findings. Usually a combination of the following procedures is required: Repair of the superior labrum (SLAP refixation, ▶ Sect. 4.4), reconstruction of the anteroinferior and/or the posterior capsulolabral complex (▶ Sects. 4.1, 4.2 and 4.3), rotator cuff repair ▶ Sects. 3.1, 3.2 and 3.3 and capsular plication (▶ Sect. 4.3).

4.5.5 Postoperative Management

Depends on the performed operative procedure (see respective chapters)

4.5.6 Follow-Up Management

Depends on the performed operative procedure (see respective chapters)

4.5.7 Tips & Tricks

Lesions of the supraspinatus tendon are usually located in the anterior part close to the greater tuberosity. Intratendinous articular surface ruptures often occur.

Cysts and impressions of the posterior part of the greater tuberosity, seen as an increased signal intensity on MRI, indicate a posterosuperior impingement.

4.6 Reconstruction of Glenoid Bone Defects

S. Braun

4.6.1 Indication

Primary or revision procedures in recurrent shoulder dislocation with:

- Glenoid bone defects (erosion-type) more than 15–25 % of the glenoid surface area
- Glenoid bone defects (fragment-type) more than 15–25 % of the glenoid surface area that are not amenable to fixation or reconstruction

Specific contraindications:

- Recurrent shoulder dislocation without glenoid bone defect
- Recurrent habitual shoulder dislocation with generalized hyperlaxity

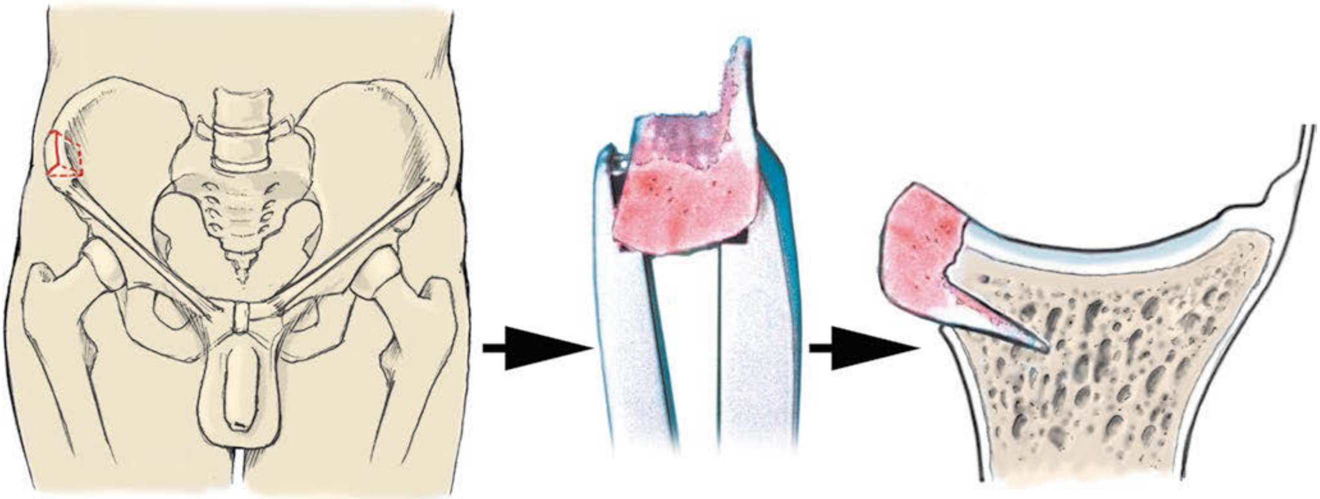


Fig. 4.28 Operation principle: anatomical reconstruction of the anterior glenoid rim and surface with a J-shaped bicortical bone graft harvested from the iliac crest

- Multidirectional instability (with or without generalized hyperlaxity)
- Open growth plates in the pelvic region

4.6.2 Operation Principle

Anatomic reconstruction of the anterior glenoid rim and surface with a J-shaped bicortical iliac bone graft (Fig. 4.28)

4.6.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom-specific history: time and mechanism of the first dislocation, reduction method (spontaneous, patient himself, external, with/without anesthesia), previous shoulder dislocations or injuries, number of recurrences, mechanism and method of reduction of any recurrence (renewed trauma, trivial incident spontaneous), treatment history, sport/functional demands, relevant comorbidities (e.g. epilepsy, chronic polyarthritis, Marfan syndrome, Ehlers-Danlos syndrome, psychological disorders)
- Symptom-specific examination: range of motion (increased passive range of motion), anterior and posterior translation, load and shift test, sulcus sign in internal and external rotation, Gagey hyperabduction test, anterior and posterior apprehension tests, relocation test, Jerk test, exclusion of generalized ligamentous hyperlaxity.

Neurovascular Examination

Assessment of the peripheral nerves (particularly the axillary nerve) and the peripheral vascularity.

Imaging

- X-rays of the shoulder in three views (true AP, y-view, axial) as a basic diagnostic tool.
- MRI (optionally with intraarticular contrast agent) to assess the capsulo-labral lesions, capsular volume and any associated injuries (e.g. SLAP lesion, rotator cuff)
- CT for accurate assessment of the anterior glenoid rim, size and location of the bone defect, 3-D CT reconstruction of the CT helps in better planning of the desired procedure.

Patient Information/Consent

Specific operative risks: re-dislocation, limitation of movement (mainly external and internal rotation), “frozen shoulder”, nerve injury (axillary nerve, musculocutaneous nerve, brachial plexus), injury of the axillary vessels, implant failure, loosening or resorption of the bone graft, dislocation or protrusion of the anchors or screws with the risk of cartilage damage, osteolysis, fracture of the bone graft with recurrent traumatic dislocation, high risk of osteoarthritis despite anatomical reconstruction of the glenoid surface due previous dislocations, prolonged postoperative pain or bleeding at the site of the bone graft harvesting from the iliac crest.

4.6.4 Operative Technique

Positioning and Preparation

- Beach chair position with more horizontal positioning of the upper part of the body, to allow better access to the ipsilateral anterior part of the iliac crest.
- Positioning of the patient arm in an arm holder
- Examination under anesthesia (degree and direction of instability, hyperlaxity, range of motion)
- Diagnostic arthroscopy via the posterior standard portal.

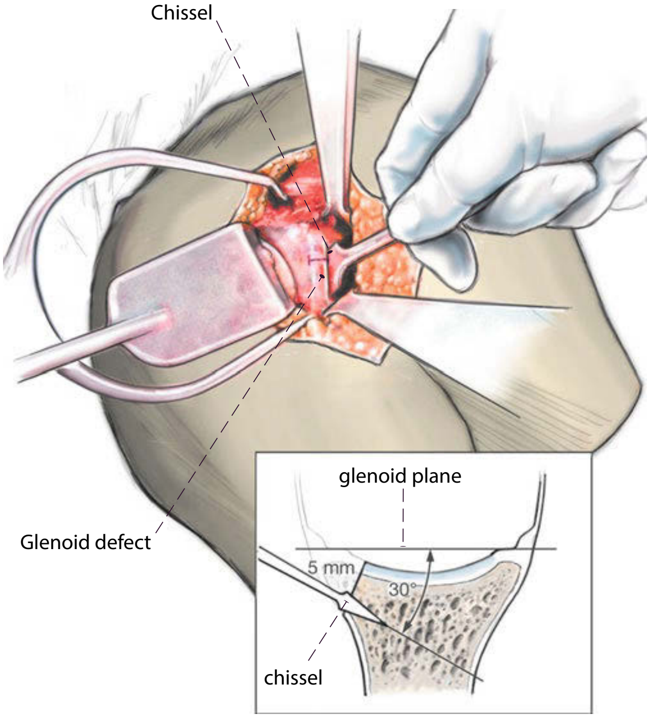


Fig. 4.29 Partial osteotomy of the glenoid neck with an osteotome at an angle of 30° to the glenoid plane.

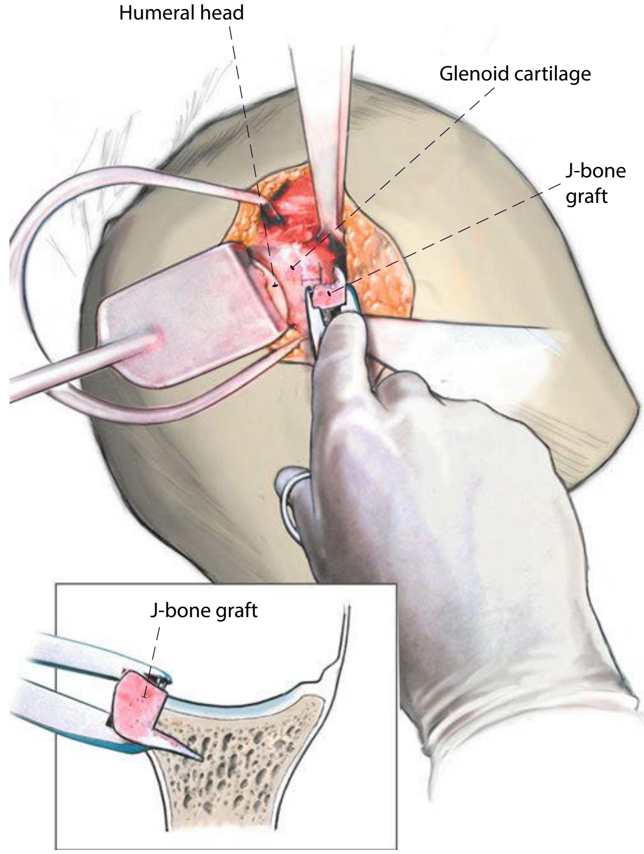


Fig. 4.30 Insertion of the J-bone graft into the osteotomy

Anatomical Glenoid Reconstruction with J-shaped Iliac Crest Bone Graft

Limited deltopectoral approach: about 5–8 cm skin incision, starting proximal and medial to the palpable coracoid tip. Dissection along the deltopectoral groove and exposure of the cephalic vein. The vein is retracted laterally to avoid disruption of the venous drainage of the deltoid muscle, otherwise, side branches should be ligated to allow medial retraction of the vein.

The conjoint tendon and the coracoid are exposed and the subscapularis tendon and its muscular part are identified in mild external rotation (identification of the subscapularis tendon is easier when it is moderately tensioned).

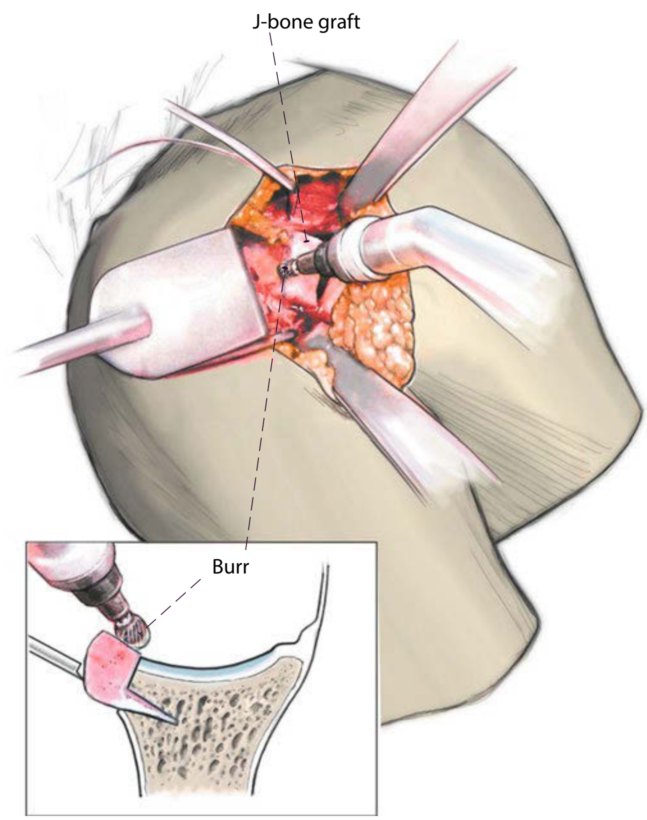
To expose the anterior glenoid rim, the subscapularis tendon is split at the junction between the upper tendinous third and the middle third (muscle fibers) and there is no need to release the tendon insertion from the lesser tuberosity. A Gelpi self-retaining retractor is used to retract the split tendon and expose the joint capsule.

The exposed joint capsule is then sharply released from the subscapularis tendon, especially laterally. The capsule is incised parallel to the split of the subscapularis. For better exposure of the anterior glenoid rim, a T-shaped incision can be performed with the base of the T lying ideally along the glenoid. This makes a subsequent additional capsular shift possible. The capsule is retracted both cranially and distally using traction sutures.

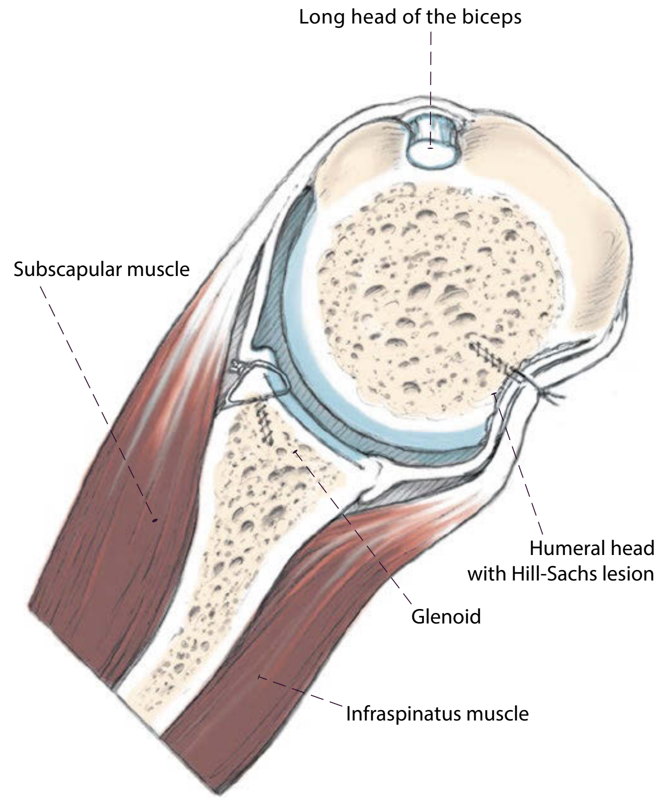
The humeral head is retracted posterolaterlly using a Fukuda retractor to expose the anterior glenoid rim. The anterior glenoid rim and the scapular neck are completely dissected and exposed. Hohmann retractors are placed at the at 3 and 6 o'clock to allow an adequate exposure of the bony glenoid defect zone. This is carefully exposed and freshened using a periosteal elevator. The defect zone is then analyzed and measured in situ. Harvesting the bicortical J span graft from the ipsilateral iliac crest is determined by the intraoperative as well as the radiological (3D-CT) dimensions of the defect zone.

Approach to the ipsilateral anterior iliac crest and harvesting the span graft: skin incision of 3–5 cm just lateral to the palpated iliac crest, sharp dissection directly down to the bone, electrothermal device is used to incise and reflect the periosteum together with a periosteal elevator, so that closure of the periosteum could be possible. The planned iliac crest span graft is marked with the electrothermal device adding about 2–3 mm on each side to allow modeling of the graft later on. The bone block should not be harvested too small.

The bone graft is harvested using an oscillating saw, a sharp osteotome or chisel. It is recommended here to harvest the bone block from the upper cortical margin as well as the outer cortex of the iliac crest. The cancellous bone at the base of the block is removed, resulting in a J-shaped graft. The fine modeling of the graft can be performed with a burr,



◘ **Fig. 4.31** Adapting the J-graft to the glenoid with a burr



◘ **Fig. 4.32** Principle of Hill-Sachs Remplissage. The defect is obliterated and the external rotation is limited through tenodesis of the infraspinatus tendon using suture anchors into the defect. This prevents the engagement of the Hill-Sachs defect over the anterior glenoid rim. Additionally, the usually torn anteroinferior capsulolabral complex is refixed using suture anchors

the angles and edges of the graft chip are carefully trimmed and prepared.

Placement of the bone graft: A 10- or 15-mm chisel is used to create a partial osteotomy on the glenoid neck in a 30° angle inclination to the glenoid surface (◘ Fig. 4.29), into which the wedge shaped J-Span graft can be inserted. The distance between the osteotomy and the joint surface should be about 5 mm, which corresponds to the width of the base of the bone graft to avoid protruding above the articular surface. The depth of the osteotomy is tailored to the length of the bone graft and should not be parallel to the joint surface to avoid fracture.

The J-Span graft is inserted gently using a bone forcep into the osteotomy and impacted firmly after perfect positioning with a bone impactor (◘ Fig. 4.30). Shear forces must be avoided during impaction to avoid fracture of the graft. Subsequently, the graft is smoothened and leveled to the joint surface using a motorized burr (◘ Fig. 4.31). It should be ensured that there will be no contact between the bone block and the humeral head up to 60° abduction and 30° flexion. Otherwise, the block must be debulked and trimmed again with the burr. Finally, the capsule is closed using the previously placed stay sutures directly or after performing a capsular shift. The subscapularis split is closed with strong sutures (non-absorbable, e.g. FiberWire, Arthrex).

4.6.5 Postoperative Management

- Positioning of the arm in an arm sling
- Monitoring of peripheral circulation, motor and sensory innervation
- Postoperative X-ray or CT evaluation.

4.6.6 Follow-Up Management

Immobilization of the shoulder in a sling for 4–6 weeks. The range of motion in the 1st–3rd weeks is restricted to 30° abduction and flexion, 80° internal rotation and 0° external rotation, in the 4th–6th week the range is increased to 60° abduction and 90° flexion, 80° internal rotation and 0° external rotation. From the 7th week free range of motion. Sport specific training is started after 3 months, overhead sports not allowed earlier than 6th months postoperatively.

4.6.7 Tips & Tricks

An adequate depth of the osteotomy is a prerequisite for a well-fitting of the J-bone graft.

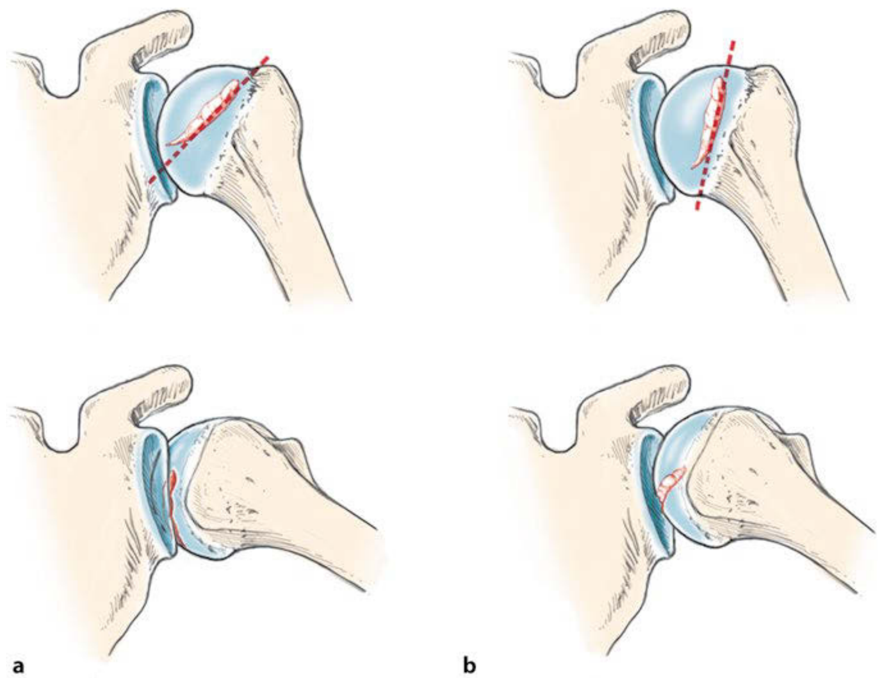


Fig. 4.33a,b Different forms of Hill-Sachs lesions. **a** Engaging lesion: with abduction and external rotation movement, the defect comes to lie parallel to the anterior glenoid margin and can drop over it anteriorly (engage). **b** non engaging lesion: the defect is not parallel to the anterior glenoid margin in abduction and external rotation and therefore will not engage

The bone graft should be harvested a little bit large enough to allow in situ remodeling with the burr.

The osteotomy should be about 5 mm medial to the articular surface and created slowly and cautiously at an angle of 30° to it to avoid glenoid fracture.

If the keel of the J-graft is broken, the bone block could be fixed using a cannulated screw inserted over a predrilled K-wire, thus providing additional protection if the primary stability is doubtful.

4.7 Remplissage of Hill-Sachs Lesions

S. Braun

4.7.1 Indication

Engaging Hill-Sachs defect after anteroinferior shoulder dislocation

4.7.2 Operation Principle

The operation aims to prevent engagement of the bony defect, which may exist in the vicinity of an anteroinferior dislocation in the posterolateral humeral head area, at the anterior glenoid margin during external rotation-abduction movements. This involves filling the impression in the humeral head through infraspinatus tenodesis using suture anchors. This results in limitation of the external rotation and subsequently avoiding engagement of the defect (Fig. 4.32). Usually, an additional repair of the anteroinferior capsulolabral complex is performed.

4.7.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom-specific history: time and mechanism of the first dislocation as well as reduction method (spontaneous, patient himself, external, with/without anesthesia), previous shoulder dislocations or injuries, number of recurrences, mechanism and method of reduction of any recurrence (renewed trauma, trivial incident spontaneous), snapping or blocking with particular movements, treatment history, sport/functional demands, relevant comorbidities (e. g. epilepsy, chronic polyarthritis, Marfan syndrome, Ehlers-Danlos syndrome, psychological disorders), generalized ligamentous hyperlaxity.
- Symptom-specific examination: evaluation of the range of motion taking into account possible engagement of the humeral head in abduction and external rotation, anterior and posterior translation of the humeral head, load and shift test, anterior and posterior apprehension tests, relocation test, Jerk test, sulcus sign in internal and external rotation, Gagey hyperabduction test.

Neurovascular Examination

Assessment of the peripheral nerves (particularly the axillary nerve) and the peripheral vascularity.

Fig. 4.34a–c Arthroscopic view of an engaging Hill-Sachs defect. **a** large Hill-Sachs defect in neutral position of the head of the humerus. **b** with increasing abduction and external rotation the defect comes to lie parallel to the anterior glenoid rim. **c** With more abduction and external rotation the defect engages the anterior glenoid edge. HS Hill-Sachs defect, G glenoid

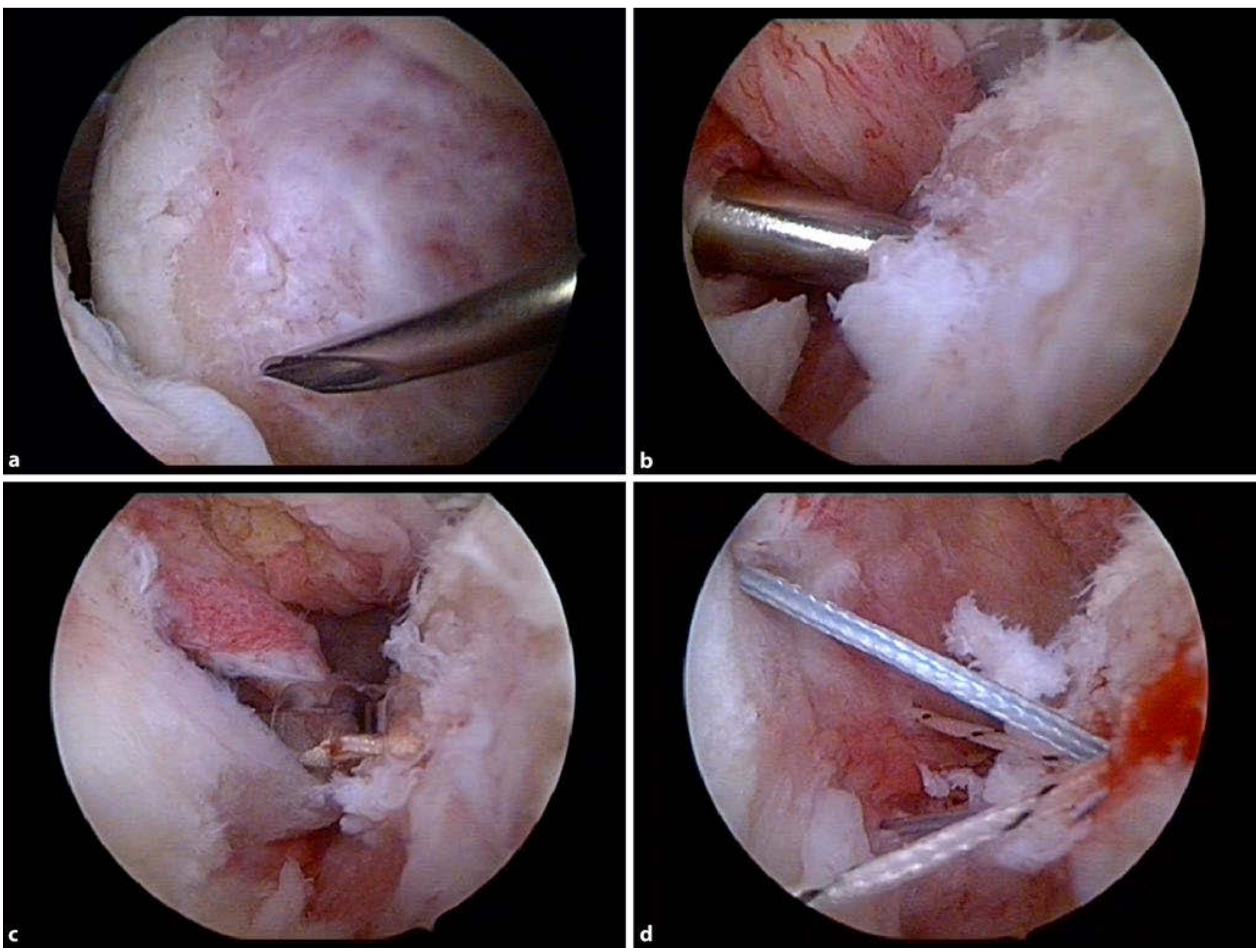


Fig. 4.35a–d Arthroscopic remplissage of Hill-Sachs lesions. **a** deep posterolaterl portal is created after probing with a needle; **b** The arthroscope is switched into the anterolateral portal and the defect zone is freshened (in this example through microfracturing using a punch), **c** A suture anchor is inserted into the defect zone **d** Sutures are shuttled through the joint capsule and infraspinatus, so that finally mattress sutures could be tied subacromially

Imaging

- X-rays of the shoulder in three views (true AP, y-view, axial) to evaluate bony lesions and the degree of existing osteoarthritis.
- MRI (optionally with intraarticular contrast agent) to assess the capsulo-labral lesions, capsular volume and any associated injuries (e. g. SLAP lesion, rotator cuff)
- CT (wherever possible with 3D reconstruction) for accurate assessment of the size and location of the Hill-Sachs lesion.

Patient Information/Consent

Specific operative risks: re-dislocation, limitation of movement (mainly external and possibly internal rotation), “frozen shoulder", nerve injury (axillary nerve, musculocutaneous nerve, brachial plexus), injury of the axillary vessels, implant failure, dislocation or protrusion of the anchors or screws with the risk of cartilage damage, osteolysis, risk of osteoarthritis.

4.7.4 Operative Technique

Positioning and Preparation

- Beach chair position or alternatively lateral decubitus position which allows an easier access to the Hill-Sachs lesions.
- Examination under anesthesia (degree and direction of instability, hyperlaxity, range of motion).
- Diagnostic arthroscopy via the standard posterior portal. Here, particular attention to the assessment of the Hill-Sachs lesion is needed. The arm is slowly moved into abduction and external rotation and the possibility of engagement of the Hill-Sachs defect over the anterior glenoid rim is checked under arthroscopic visualization.

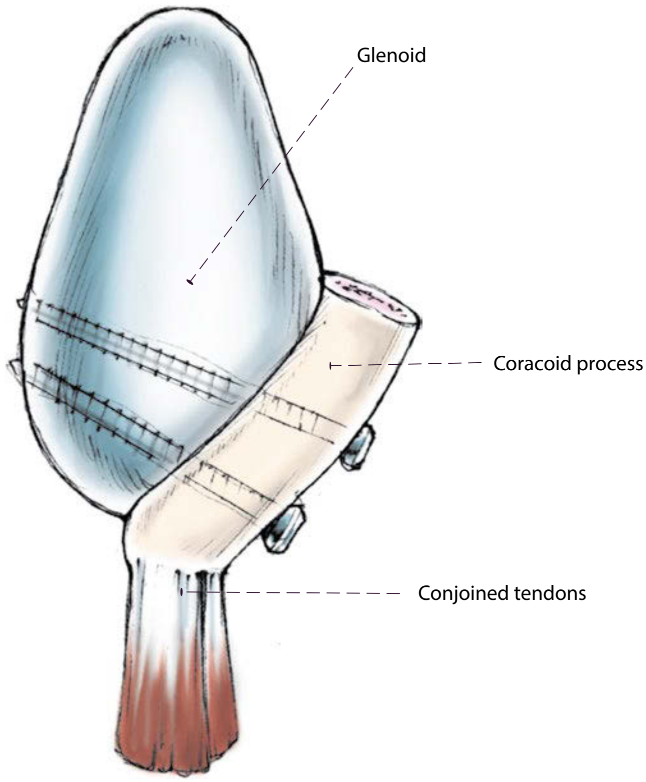
It should be noted that only those defects that lie parallel to the anterior glenoid rim in abduction and external rotation and could be rotated further anteriorly, could be classified as engaging defects (◘ Figs. 4.33 and 4.34).

Remplissage of Hill-Sachs Lesions with Tenodesis of the Infraspinatus Tendon.

A deep posterolateral portal is created using a needle for localization about 3–4 cm distal to the posterolateral edge of the acromion to allow direct access to the Hill-Sachs defect (◘ Fig. 4.35a). A working cannula is inserted to allow easier suture management. Cannulas with deployable wings (e.g., Gemini cannula, Arthrex), which allow traction on the capsule and thus increase the intraarticular space and allow a better visualization are ideal here.

The arthroscope is placed in the anterolateral portal (dorsal to the long biceps tendon) to provide a direct view of the of the Hill-Sachs defect. Freshening and gentle debridement of the Hill-Sachs lesion with a burr or shaver to allow subsequent healing of the infraspinatus in this area. Optionally, a microfracture with awls or a punch could be performed for anchor placement (◘ Fig. 4.35b).

Depending on the extent of the Hill-Sachs lesion, 1 or 2 suture anchors (e.g. Bio-Corkscrew FT 5.5, Arthrex) are inserted into the defect through the cannula (◘ Fig. 4.35c). The inferior anchor should be inserted first. The working cannula is then withdrawn into the subacromial space. A sharp suture passer (e.g. penetrator or Bird-beak, Arthrex) could be used to penetrate the infraspinatus and the joint capsule and the sutures are retrieved individually into the subacromial space shuttled outside through the working cannula, so that finally mattress sutures could be tied in the subacromial space (◘ Fig. 4.35d).



◘ **Fig. 4.36** Operation principle: transfer of the coracoid process with the attached end of the "conjoined tendons" to the glenoid defect

The arthroscope is switched to the subacromial space and the corresponding suture threads are tied in a mattress suture to fix the rotator cuff under direct visualization. The arthroscope is switched again intraarticular, to check the Remplissage. Here, the Hill-Sachs lesion should be filled with the infraspinatus and engagement of the defect over the anterior glenoid rim is no longer possible. The extent of external rotation is evaluated under direct visualization to notice the mechanical limitation of the post-operative rehabilitation program.

4.7.5 Postoperative Management

- Positioning of the arm in an arm sling
- Monitoring of peripheral circulation, motor and sensory innervation
- Postoperative X-ray evaluation.

4.7.6 Follow-Up Management

Immobilization of the shoulder in a sling for 6 weeks. The range of motion in the 1st–3rd weeks is restricted to 45° abduction and flexion, 80° internal rotation and 30° external rotation, in the 4th–6th week the range is increased to 90° abduction and flexion, 80° internal rotation and 0° external rotation. From the 7th week free range of motion. Sport specific training

4

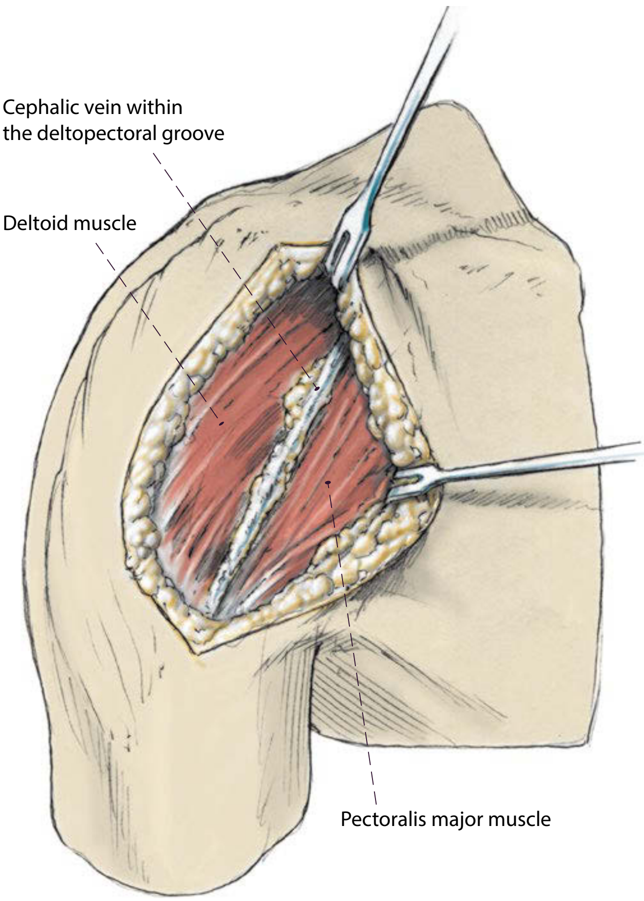


Fig. 4.37 Short deltopectoral approach, starting proximal and medial to the tip of the coracoid.

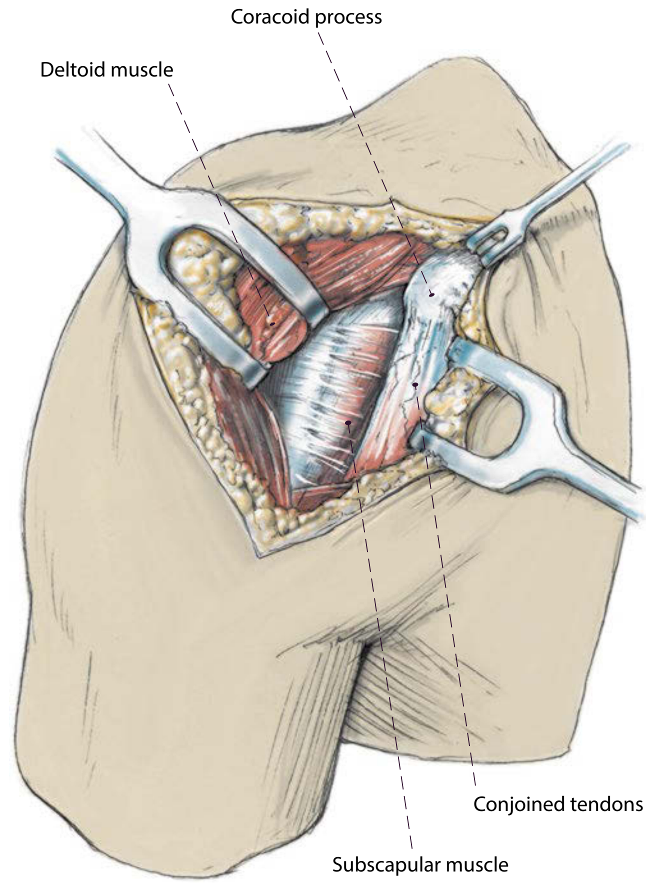


Fig. 4.38 Exposure of the coracoid process and the "conjoined tendons"

is started after 3 months, overhead sports not allowed earlier than 6th months postoperatively.

4.7.7 Tips & Tricks

The Remplissage procedure is usually combined with the anterior shoulder stabilization described in ▶ Sect. 4.1.4. It is recommended to perform the Remplissage before the antero-inferior stabilization. Very large Hill Sachs defects, in which the Remplissage will result in an unacceptable reduction of the humeral articular surface area, require an alternative procedure, for example, filling of the bone defect (▶ Sect. 5.3) or a prosthetic resurfacing (▶ Sect. 6.1).

4.8 Laterjet Coracoid Transfer

S. Braun

4.8.1 Indication

Glenoid bone defects larger than 20–25 % of the glenoid surface area. Failed arthroscopic or open anterior stabilization with recurrent dislocation. In high-risk athletes with higher demands of stability also as a primary procedure.

Specific contraindications: bone defects or glenoid fractures of more than one third of the glenoid surface area; in such cases, the bone substance of the transferred coracoid process is not sufficient in most cases to reconstruct the glenoid.

4.8.2 Operation Principle

Transfer of the coracoid process with the attached "conjoined tendons" (insertion of the coracobrachialis and the short head of the biceps brachii) to the area of glenoid defect (Fig. 4.36).

The stabilization of the shoulder result through 2 effects:

- Bony effect: filling of the glenoid defect
- Soft tissue effect: dynamic stabilization and reinforcement of the anterior band of the inferior glenohumeral ligament by the "conjoined tendon", which is tensioned in abduction and external rotation of the humeral head.

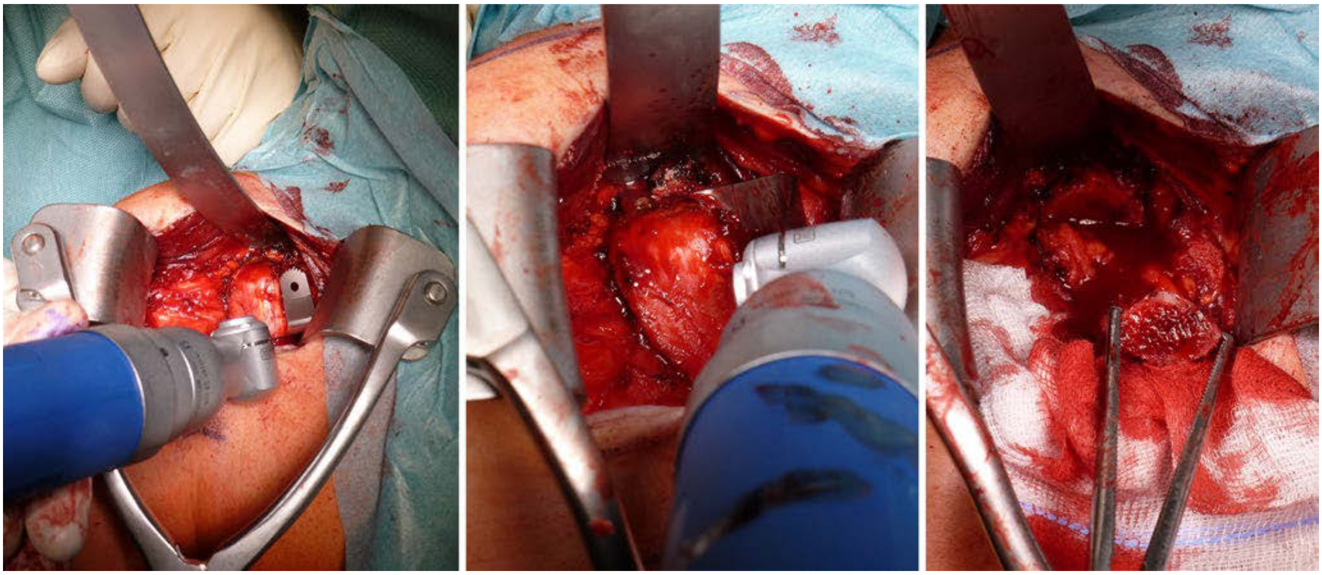


Fig. 4.39 Osteotomy of the coracoid process using an angled blade saw at the junction to the coracoid base

4.8.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom-specific history: time and mechanism of the first dislocation, reduction method (spontaneous, patient himself, external, with/without anesthesia), previous shoulder dislocations or injuries, number of recurrences, treatment history, sport/functional demands, relevant comorbidities (e. g. epilepsy, chronic polyarthritis, Marfan syndrome, Ehlers-Danlos syndrome, psychological disorders).
- Symptom-specific examination: range of motion (increased passive range of motion), anterior and posterior translation, load and shift test, sulcus sign in internal and external rotation, Gagey hyperabduction test, anterior and posterior apprehension tests, relocation test, Jerk test, generalized hyperlaxity signs.

Neurovascular Examination

Assessment of the peripheral nerves (axillary and musculocutaneous nerves).

Imaging

- X-rays of the shoulder in three views (true AP, y-view, axial)
- MRI (optionally with intraarticular contrast agent) to assess the capsulo-labral lesions, capsular volume and any associated injuries (e. g. SLAP lesion, rotator cuff)
- CT for accurate evaluation of the anterior glenoid rim, extent of glenoid defect as well as the coracoid configuration.

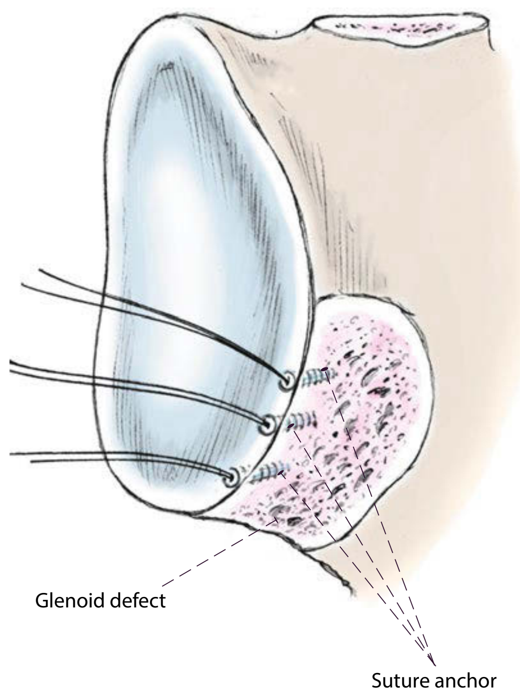


Fig. 4.40 Placement of suture anchors at the osteochondral junction of the anterior glenoid edge for repairing the capsule later

Patient Information/Consent

Specific operative risks: re-dislocation, limitation of movement (mainly external rotation), “frozen shoulder”, nerve injury (axillary nerve, musculocutaneous nerve, brachial plexus), injury of the subclavian artery, implant failure, dislocation or protrusion of the anchors or screws with the risk of cartilage damage, osteolysis, risk of osteoarthritis.

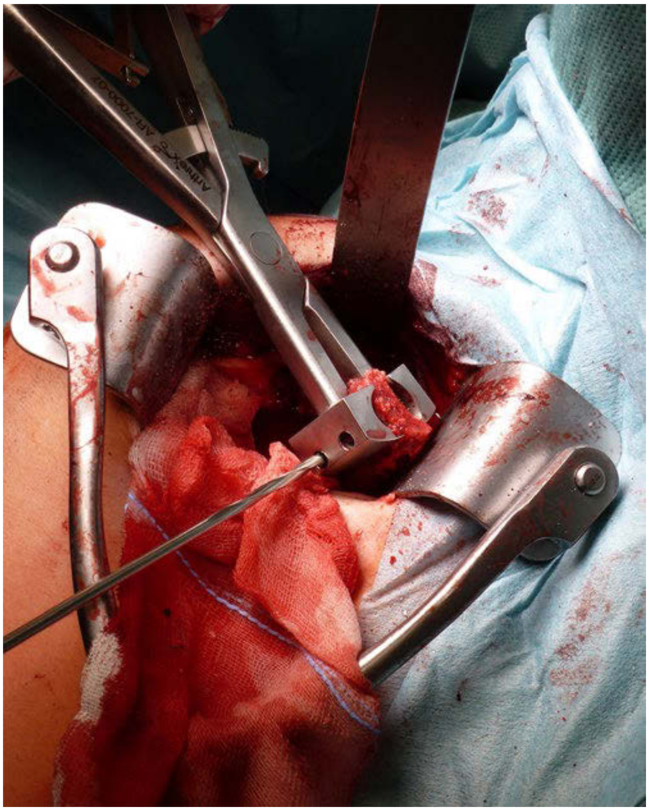


Fig. 4.41 Drilling two holes in the coracoid bone block

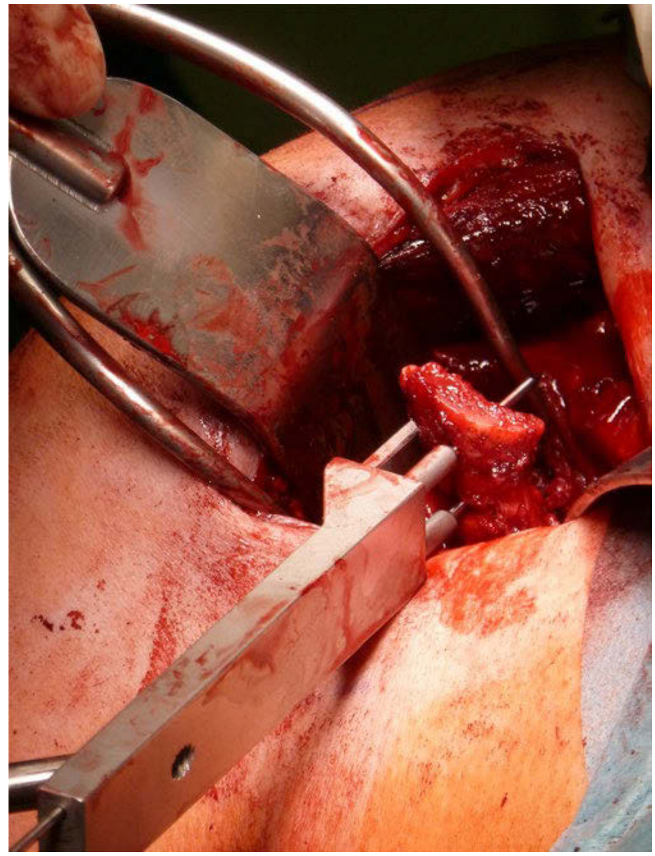


Fig. 4.42 Fixation of the coracoid bone block to the glenoid with the aid of the special drill guide and offset

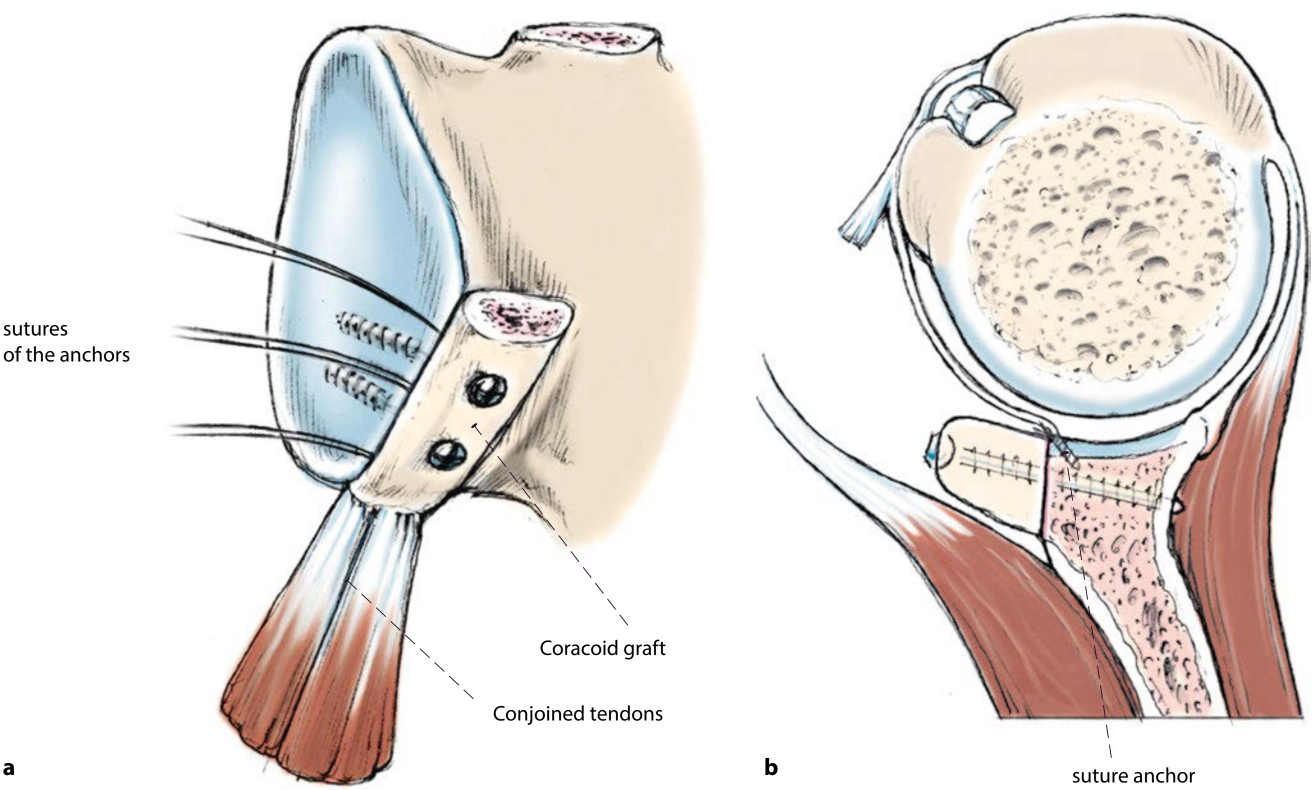


Fig. 4.43a,b After loose fixation of the coracoid block with screws (**a**) the capsule is interposed using the previously placed suture anchors, so that the coracoid block remains extraarticular (**b**)

4.8.4 Operative Technique

Positioning and Preparation

- Beach chair position
- Examination under anesthesia (degree and direction of instability, hyperlaxity, range of motion).
- Diagnostic arthroscopy via the standard posterior portal.

Open Coracoid Transfer with Capsular Interposition

Short deltopectoral approach: about 5–8 cm skin incision, starting proximal and medial to the palpable coracoid tip. Dissection along the deltopectoral groove and exposure of the cephalic vein (Fig. 4.37). The vein is retracted laterally to avoid disruption of the venous drainage of the deltoid muscle, otherwise, side branches should be ligated to allow medial retraction of the vein.

The coracoacromial ligament is incised about 1 cm proximal to its coracoid insertion and the coracohumeral ligament is released. Exposure of the "conjoined tendons" and the coracoid in a medial direction (Fig. 4.38) and identification of the pectoralis minor tendon.

The tendon of the pectoralis minor muscle is released directly at the coracoid preserving the tendon stump. Dissection is carried out using electrocautery, taking care not to reach the tip of the coracoid laterally to avoid compromising the blood supply to the bone block. The base of the coracoid is carefully exposed at the junction of the horizontal and the vertical parts. Osteotomy of the coracoid is performed with an angled blade saw at the junction to the coracoid base (Fig. 4.39), anterolateral to the coracoclavicular ligaments to harvest a bone block of about 2.5–3 cm length. The "conjoined tendons" remain attached to the bone block. The arm should remain adducted in this step, to relax the neurovascular bundle under the pectoralis minor (axillary artery and brachial plexus) and not to be pulled close to the coracoid.

Meticulous and blunt mobilization of the "conjoined tendons" from the lateral aspect to avoid injury to the musculocutaneous nerve, which enters the coracobrachialis muscle from its medial aspect. The subscapularis tendon is longitudinally split in line of its fibers at the junction of the upper and middle thirds, exposing the underlying joint capsule, which is incised in the same way. The exposed anterior glenoid rim is prepared and freshened. 2–3 suture anchors (e. g. BioFastak, Arthrex) could be inserted at the 5:30, 4:30 and 3:00 clock positions to allow repairing of the capsule later (Fig. 4.40).

The coracoid is prepared with a burr to adapt to the curvature of the glenoid. Two holes are drilled in the coracoid block (4-mm drill bit) using a special forceps and drill guide (Coracoid drill guide, Arthrex) (Fig. 4.41). The coracoid block is then fitted to the glenoid, temporary fixed with K-wires, superiorly and inferiorly, optionally using a drill guide with an offset (parallel drill guide, Arthrex. Fig. 4.42) to avoid protrusion above the glenoid edge. The K-wires are overdrilled with a 3-mm cannulated drill. The K-wires and the drill bit should be directed at an angle of 45° to the glenoid surface. Depth measurement followed by screw fixation of the bone block without tightening (using cannulated 3.7-mm or 4.5-mm screws). The level of the screw heads is checked to avoid protrusion into the joint. Capsular interposition with the previously inserted suture anchors, so that the bone block is then definitely fixed extra-articular with the already placed screws (Fig. 4.43).

4.8.5 Postoperative Management

- Positioning of the arm in an arm sling
- Monitoring of peripheral circulation, motor and sensory innervation
- Postoperative X-ray/CT evaluation.

4.8.6 Follow-Up Management

Immobilization of the shoulder in a sling for 6 weeks. The range of motion in the 1st–3rd weeks is restricted to 45° abduction and flexion, 80° internal rotation and 30° external rotation, in the 4th–6th week the range is increased to 90° abduction and flexion, 80° internal rotation and 0° external rotation. From the 7th week free range of motion. Sport specific training is started after 3 months, overhead sports not allowed earlier than 6th months postoperatively.

4.8.7 Tips & Tricks

Cannulated screws are often not sufficiently stable, alternatively 4.5-mm malleolar screws could be used.

It is important that the coracoid bone block is placed flush to the level of the glenoid articular surface and shouldn't be placed too far laterally or medially. If the coracoid block is prominent after fixation, it can be further resected with a burr.

Arthroscopic techniques for coracoid transfer are described, however, these are very challenging and therefore should be restricted to the experienced surgeon.

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Chondral and Osteochondral Lesion

A. Schmitt, S. Vogt

A. B. Imhoff, M. J. Feucht (Eds.), *Surgical Atlas of Sports Orthopaedics and Sports Traumatology,*
DOI 10.1007/978-3-662-43776-6_5,

5.1 Microfracture

A. Schmitt, S. Vogt

5.1.1 Indication

Symptomatic focal chondral defects measuring 1–2 cm^2, ICRS (International Cartilage Repair Society) grade III–IV.

Limited/relative indication with bipolar chondral lesions (“kissing lesions”).

Specific contraindications: osteoarthritis, osteochondral defects, osteonecrosis.

5.1.2 Operation principle

Induction of regenerative cartilage tissue formation through releasing mesenchymal stem cells after penetration of the subchondral lamella.

5.1.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: pain character, limitation of movement, instability, trauma.
- Symptom specific examination: tenderness, painful motion, range of motion, crepitation.

Imaging

- Conventional X-ray of the shoulder in 3 views (true AP, Y-view and axillary view) to evaluate deformities, calcification, necrosis, cysts and osteoarthritic changes
- MRI to assess the extent of the cartilage damage, associated subchondral reactions, osteoarthritic changes and the presence of loose bodies.
- CT with intraarticular contrast agent injection, when MRI is not possible e. g. presence of metallic implants
- Special radiological studies could be helpful (e. g. MRI T2-Mapping)

Patient Information/Consent

Specific operative risks: insufficient regenerative tissue, subsequent failure of the regenerative tissue, induction of osteonecrosis, progressive cartilage damage, osteoarthritis, revision with possible shift to other cartilage restorative procedures, risk of developing postoperative frozen shoulder and postoperative load-free period of 6 weeks.

5.1.4 Surgical Technique

Positioning and Preparation

- Beach chair position
- The patient arm is positioned in an arm holder

Arthroscopic Microfracture

A diagnostic arthroscopy is performed via the posterior standard portal. An anterosuperior working portal is established in outside-in technique. After arthroscopic evaluation and documentation of the chondral lesion, a ring curette or a sharp spoon curette is used to create a stable rim of the surrounding normal cartilage (◘ Fig. 5.1a). The defect is debrided down to the subchondral bone with removal of the calcified cartilage layer as well as any possible sclerotic herds (◘ Fig. 5.1b). This could result in punctate bleeding.

The subchondral bone is opened using microfracture awls (◘ Fig. 5.1c). Awls of different curvatures are available and the most suitable one (depending on the location of the cartilage lesion) should be used so that the penetration is as perpendicular to the subchondral lamella as possible. The depth of perforation should be about 3 mm (successful penetration is evidence by flow of blood or bone marrow substance). Microfracture holes should be 3–4 mm apart. The anterolateral or posterior portals could be used as working portal, depending on the location of the chondral lesion (◘ Figs. 5.2 and 5.3).

5.1.5 Postoperative Management

- The arm is placed in a sling
- Monitoring of peripheral circulation, motor and sensory innervation.
- Postoperative radiological evaluation.

5.1.6 Follow-Up Management

Immobilization of the arm in a sling for 2 day postoperatively to stabilize the blood/bone marrow clot. Avoidance of loading activities of the shoulder for 6 weeks postoperatively.

Passive shoulder exercises in full range of motion should be started from the 2^{nd} postoperative day. Active motion of the shoulder should be avoided for 4 weeks postoperatively. Active assisted exercises in the 5^{th} and 6^{th} postoperative weeks. Starting from the 7^{th} postoperative weeks, active range of motion is allowed with gradually increased shoulder loading.

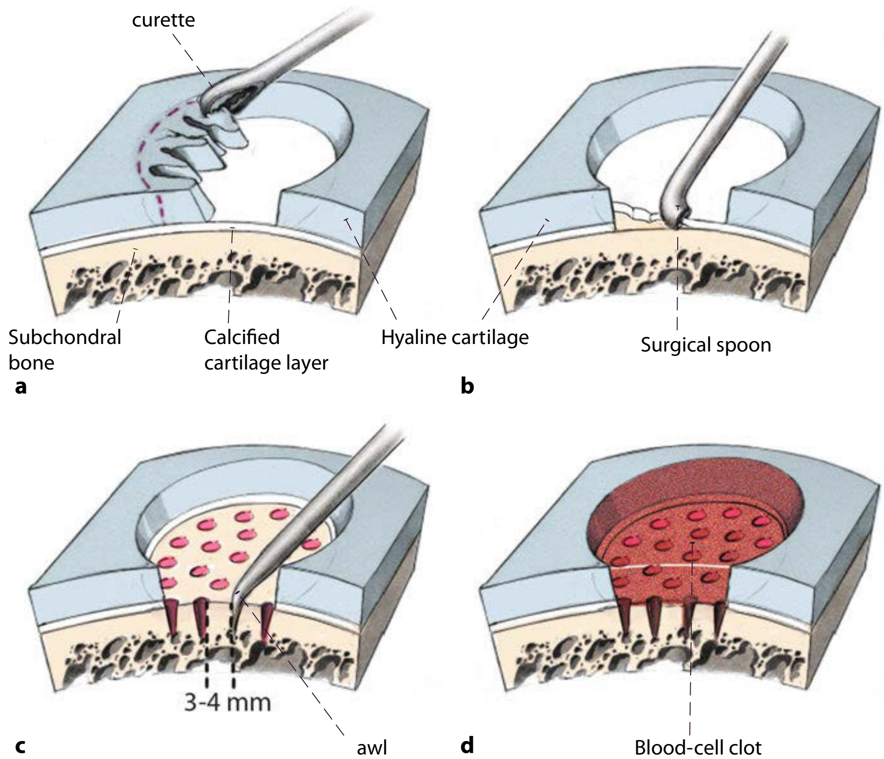


Fig. 5.1a–d Schematic representation of microfracture: **a** creating a stable rim in the surrounding normal cartilage using a ring curette; **b** removal of the calcified cartilage layer with a sharp spoon curette, **c** perforation of the subchondral bone with the microfracture awl e; **d** defect filled with blood clot

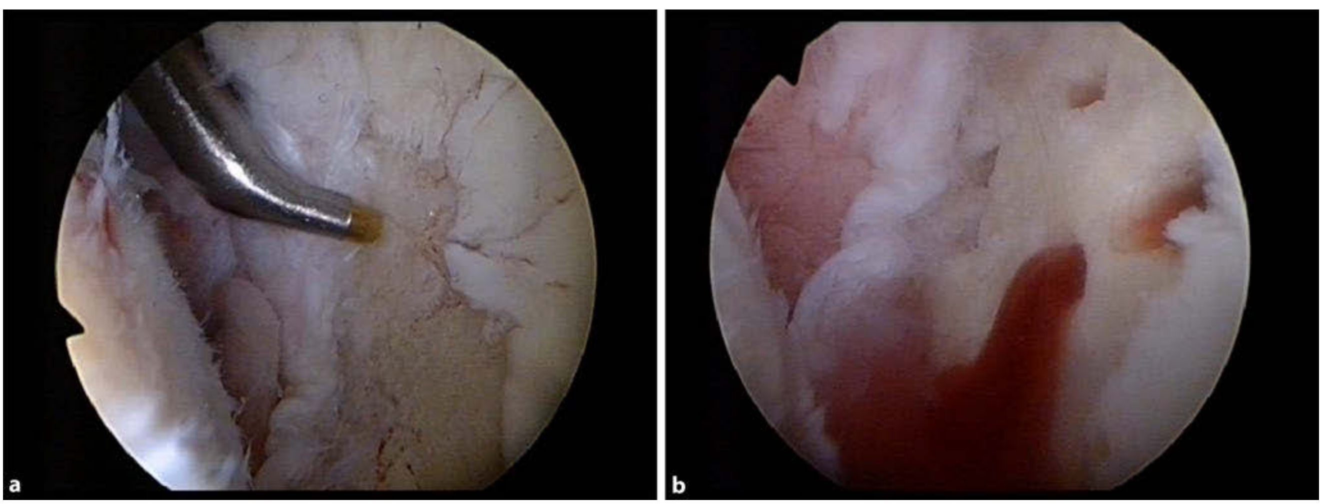


Fig. 5.2a,b Microfracture of the glenoid. **a** opening of the subchondral bone with the microfracture awl; **b** outflow of blood from the opened bone marrow space after stopping fluid inflow

Fig. 5.3 Microfracture of the humeral head

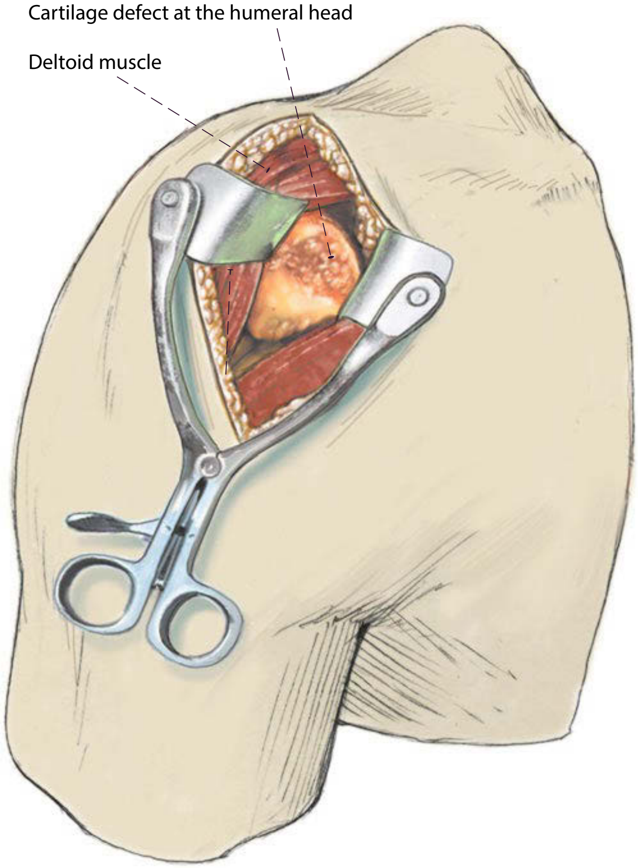


Fig. 5.4 Exposure of a chondral lesion of the humeral head through a deltopectoral approach

5.1.7 Tips & Tricks

Good preparation of the defect area (debridement of sclerosis, creation of stable cartilage margins) before performing the microfracture.

Creating a stable defect margin is of particular importance because at the beginning of regeneration process, the newly formed tissue is still weak and unstable and requires protection from the surrounding normal cartilage.

Microfracture is sometimes difficult to be performed in cases of chronic cartilage defects with markedly hard or sclerotic layer over the subchondral bone. In such cases, preliminary few perforations are performed to evaluate the thickness of the hardened bone and followed by removal of the sclerotic layer down to the subchondral bone and finally microfracture.

Perforations should be as close as possible to the surrounding healthy cartilage in the marginal zone.

Preservation of adequate bone bridges between the perforations should be kept in mind to maintain the stability of the subchondral plate. Moreover, the perforations should be orthograde (perpendicular) to the subchondral bone, otherwise the holes may converge towards each other with the risk of collapse of the subchondral bone.

To ensure sufficient opening of the subchondral lamella, the inflow of arthroscopy medium is stopped or the tourniquet is released, which should result in outflow of blood, bone marrow and fat cells from the perforations.

Intraarticular drains are strictly forbidden to avoid unintended disruption of the newly formed blood clot. If a drain is necessary, it should be without vacuum suction!

5.2 Chondrocyte Transplantation (ACT/MACT)

5.2.1 Indication

Symptomatic focal chondral lesions between 2–9 cm^2 in size (ICRS grade 3 and 4).

Strict/limited indication with bipolar chondral lesions (affecting both articulating surfaces).

Specific contraindication: osteoarthritis, osteochondral defects, age > 45 years old (this could be exceeded in selected cases, if there is no signs of osteoarthritis).

5.2.2 Operation Principle

Autologous cartilage is harvested in the first step operation. After in vitro cultivation of the chondrocytes extracted from the cartilage, they are re-implanted to cover the defect (► Sect. 18.2).

5.2.3 Preoperative Assessment

Diagnosis

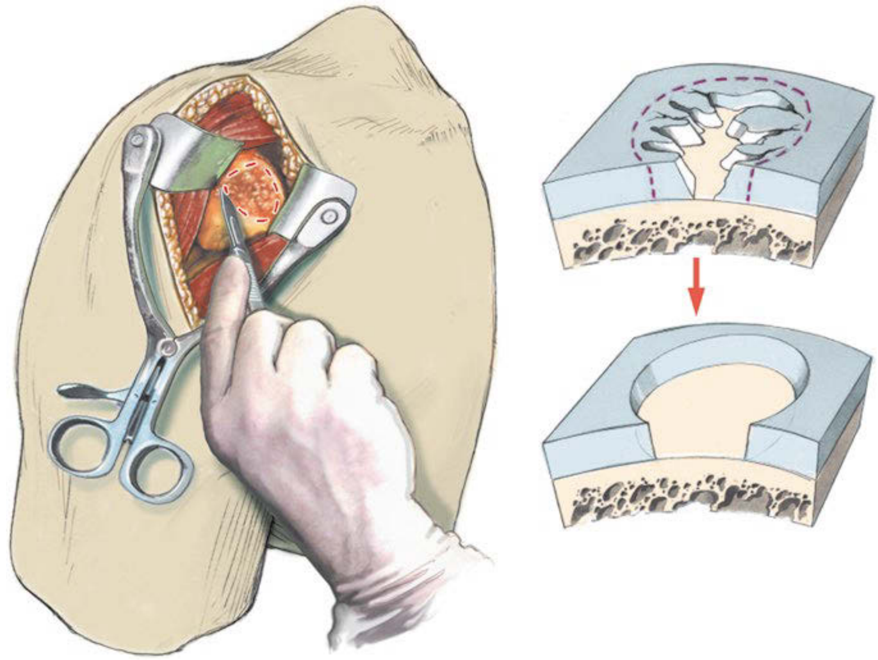
Clinical

- Symptom specific history: pain character, limitation of motion, instability, trauma.
- Symptom specific examination: tenderness, painful movement, range of motion, crepitation.

Imaging

- Conventional X-ray of the shoulder in 3 views (true AP, Y-view and axillary view) to evaluate deformities, calcification, necrosis, cysts and osteoarthritic changes
- MRI to assess the extent of the cartilage damage, associated subchondral reactions, osteoarthritic changes and the presence of loose bodies.
- CT with intraarticular contrast agent injection, when MRI is not possible e. g. presence of metallic implants
- Special radiological studies could be helpful (e. g. MRI T2-Mapping)

Fig. 5.5a,b Creation of stable **a** stable margin of the surrounding intact cartilage. a scalpel is used to incise cartilage surrounding the defect **b** the aim is to create a vertical margin of the surrounding cartilage perpendicular to the subchondral bone



Planning

An initial operative procedure is performed for arthroscopic harvesting of small cartilage biopsy or osteochondral plugs (according to the provider) from the shoulder joint (posterosuperior humeral head).

The cartilage cells obtained are then cultivated and proliferated in a certified laboratory. Re-implantation of the cell occurs after sufficient cell proliferation (usually 4–6 weeks after harvesting).

Patient Information/Consent

Specific operative risks: the need for a two-stage procedure, potential loss of the harvested chondrocytes (death, contamination, inadequate proliferation), failed healing, necrosis, malposition or dislocation of the transplanted cells, progressive cartilage damage, osteoarthritis, revision with possible shift to other cartilage restorative procedures, risk of postoperative "frozen shoulder", the need for rest and avoidance of loading activities for 6 Weeks.

5.2.4 Surgical Technique

Positioning and Preparation

- Beach chai position
- Positioning of the patient's arm in an arm holder.

Autologous Chondrocytes Transplantation (ACT) with Periosteal Flap

Diagnostic arthroscopy to evaluate and document the cartilage lesions is performed at the beginning and followed by arthrotomy through a deltopectoral approach (Fig. 5.4). The defect is debrided and sclerotic parts are removed without violating the subchondral lamellae. A Stable margin of the surrounding normal cartilage is created using a scalpel and a ring curette (Fig. 5.5).

A sterile aluminum foil (e.g. from the suture package) is used to make a tailored template of the defect area by placing and pressing it over the defect area. The template is then cut out and used to accurately cut the already harvested periosteal flap to the same shape and size (e.g. from ipsilateral proximal tibia ► Sect. 18.2).

The periosteal flap is sutured in a watertight manner with interrupted sutures (e.g. PDS II, 6-0) to the cartilage surrounding the defect. Additional sealing of the sutures with fibrin glue is optional. The chondrocytes suspension is injected under the periosteal flap through a fine needle.

Matrix Associated Chondrocytes Transplantation (MACT)

The defect is exposed and prepared as described above. A template for the defect is made using a sterile aluminum foil (e.g. from the suture package or already in MACT set), which is placed and pressed over the defect. The template is then cut out and used to accurately cut the MACT matrix to the same size and shape. The matrix is then in vitro seeded with the cultivated patient's chondrocytes (Fig. 5.6.)

After adherence time of about 20 min, the chondrocytes seeded matrix is sutured to the cartilage margins of the defect using interrupted suture (PDS II 6/0) (Fig. 5.7). Additional sealing of the sutures with fibrin glue is optional (Fig. 5.8). Matrices already seeded with chondrocyte in vitro could be used and sutured directly over the defect.

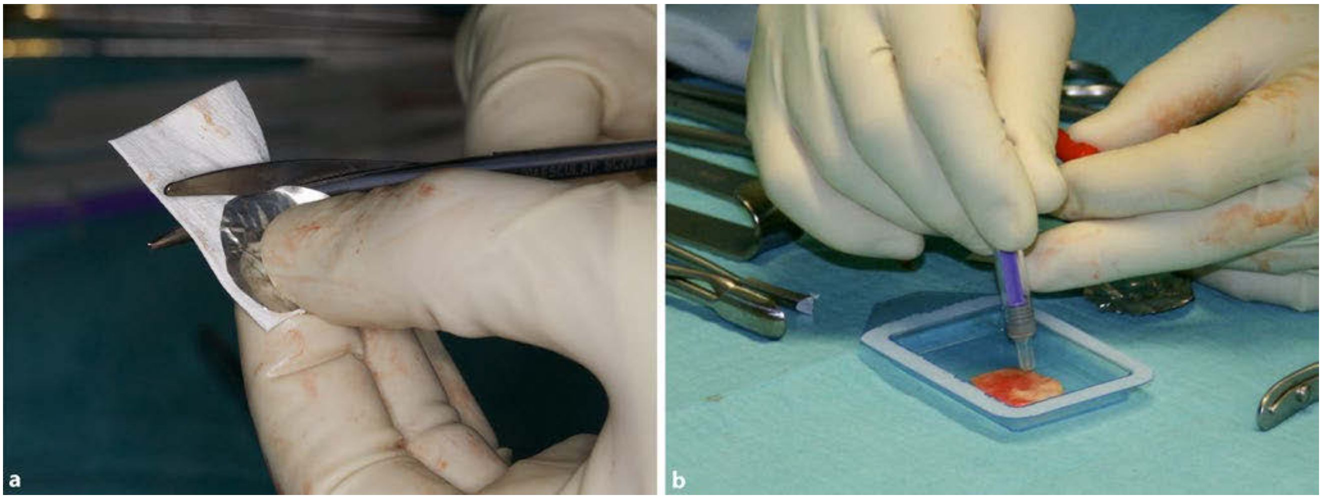


Fig. 5.6a,b Preparation of the MACT matrix. **a** cutting the matrix to the same size and shape of the defect using a tailored template; **b** seeding the matrix with the chondrocytes suspension

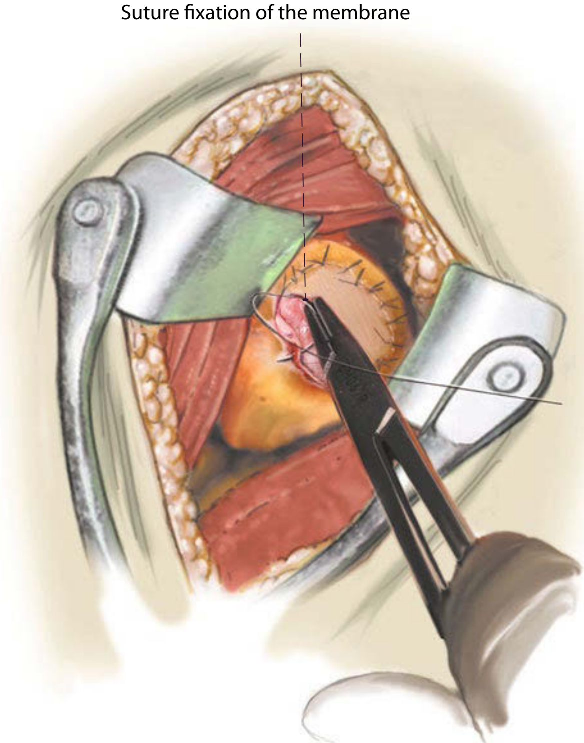


Fig. 5.7 Suturing the matrix to the defect margins

5.2.5 Postoperative Management

- A shoulder abduction brace is used to immobilize the shoulder in 15° abduction.
- Monitoring of peripheral circulation, motor and sensory innervation.
- Postoperative radiographic evaluation.

5.2.6 Follow-Up Management

Immobilization of the shoulder in a shoulder abduction brace in 15° abduction for 6 weeks postoperatively. Loading activities of the arm to be avoided for 6 weeks. External rotation beyond 0° as well as active internal rotation are avoided for 6 weeks postoperatively. Passive exercises in the first 4 postoperative weeks. Active assisted exercises in the 5th and 6th weeks. Free active movements are allowed from the 7th postoperative weeks.

5.2.7 Tips & Tricks

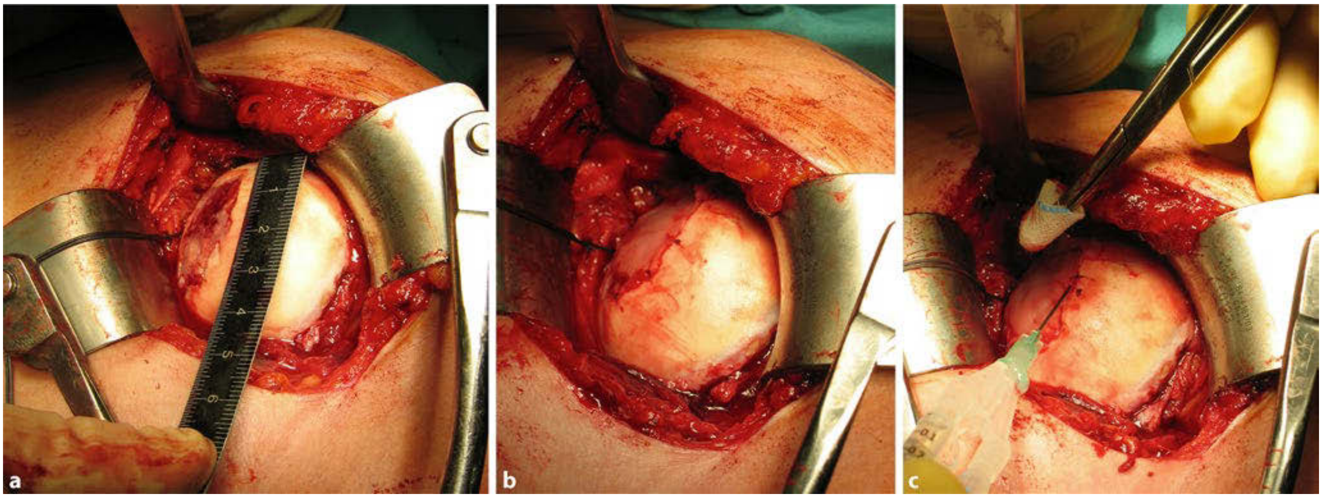
For MACT with collagen membrane as well as with three-dimensional matrix, the polarity/orientation of the matrix must be kept in mind (see related instructions of the manufacturer).

To improve healing of the defect, the defect area down to the subchondral bone must be completely freed from sclerotic areas, which e.g. have arisen through previous microfracture.

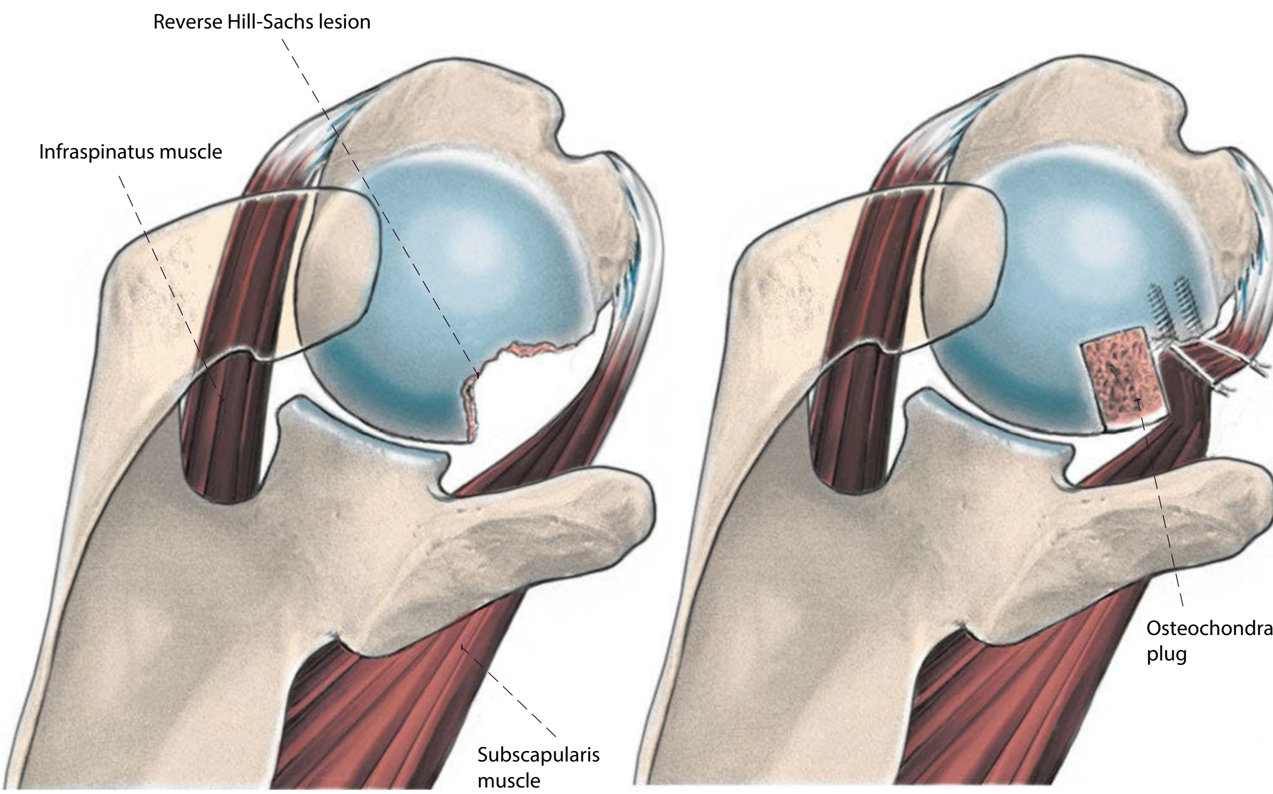
It is essential to prevent perforation of the subchondral bone during preparation of the defect bed, otherwise the blood and stem cells will migrate and mix with the implanted chondrocytes and can interfere with adequate defect healing. If the subchondral plate is accidentally injured, the defect bed could be sealed off with fibrin glue.

It is recommended to seed the membrane with the cells before debridement and preparation of the defect bed and thereby efficiently using the time needed for seeding the membrane with cells, and so reducing the operative time.

When using a drain, it should be without suction (only overflow) and placed in the contralateral suprapatellar pouch.



■ **Fig. 5.8a–c** MACT for large sized chondral lesions of the humeral head. **a** measuring the size of the defect: **b** suturing the seeded membrane; **c** sealing the sutures with fibrin glue



■ **Fig. 5.9** Treatment of a large, engaging reverse Hill-Sachs lesion with implanting an osteochondral (or osseous) cylindrical graft and tenodesis of the subscapularis tendon into the defect zone

5.3 Autologous Osteochondral Transplantation and Mosaicplasty

5.3.1 Indication

Symptomatic focal osteochondral lesion of 1–3 cm^2 in size (ICRS/OCL grade 3 and 4), focal osteonecrosis/isolated cysts, Age < 45 years old.

The indication should be carefully weighed as the long-term results are still not yet satisfying. Not recommended with isolated chondral lesions.

Specific contraindications: Osteoarthritis

Special indication: engaging Hill-Sachs lesion or reverse Hill-Sachs lesion (■ Fig. 5.9). Alternatively, pure osseous graft could be used for such lesions.

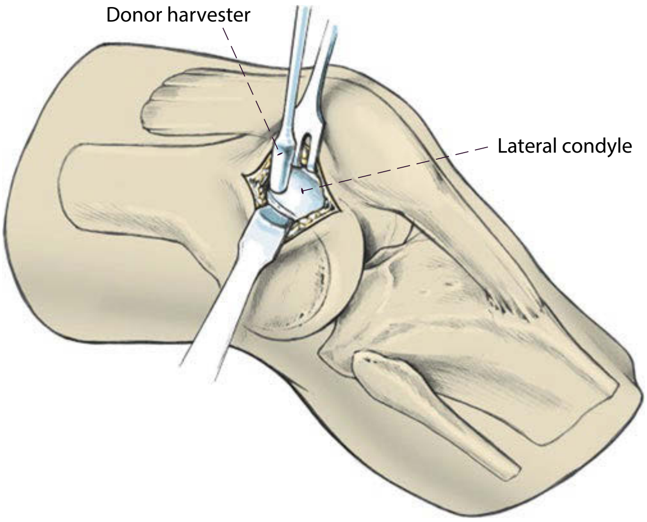


Fig. 5.10 Harvesting the donor cylinder from the proximal lateral trochlea

5.3.2 Operation Principle

Transfer of one or more osteochondral (cartilage and bone) cylinders from areas of low weight bearing of the knee joint (e.g. proximal lateral trochlea) to replace the defect. Osseous cylinders (e.g. from the iliac crest) could be alternatively used, particularly for defect fillings (Hill-Sachs and reverse Hill-Sachs lesion).

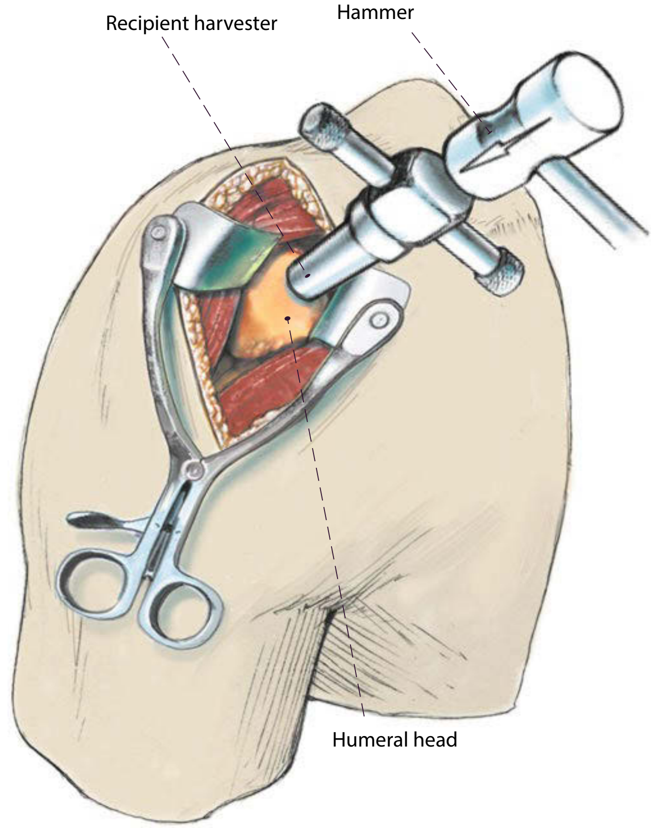


Fig. 5.11 Removal of the osteochondral lesion at the humeral head using a hollow chisel (recipient harvester) after exposing the lesion through a deltopectoral approach

5.3.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: pain character, limitation of motion, instability, trauma.
- Symptom specific examination: tenderness, painful motion, rage of motion, crepitation.

Imaging

- Conventional X-ray of the shoulder in 3 views (true AP, Y-view and axillary view) to evaluate deformities, calcification, necrosis, cysts and osteoarthritic changes
- MRI to assess the extent of the osteochondral lesion, osteoarthritic changes and the presence of loose bodies.
- CT with intraarticular contrast agent injection as an alternative to MRI e.g. in presence of metallic implants
- Special radiological studies could be helpful (e.g. MRI T2-Mapping)

Patient information/Consent

Specific operative risks: graft necrosis, lack of bony integration, cyst formation, cartilage surface incongruity (step formation), avoidance of loading activities for 6 Weeks postoperatively, donor site morbidity at the knee, and risk of developing osteoarthritis of the glenohumeral and knee joints.

5.3.4 Surgical Technique

Positioning and Preparation

- Beach chai position
- Positioning of the patient's arm in an arm holder.

Autologous Osteochondral Transplantation of the Glenohumeral Joint

Diagnostic arthroscopy and evaluation of osteochondral lesion using an arthroscopic hook. An open procedure is mandatory, particularly for glenoid defects. Defects of the humeral head may be managed arthroscopically or open depending on their location and size. The open procedure is favored when multiple cylinders are going to be transplanted, to ensure an optimal congruence. The arthroscopic working portal is created according to site of the lesion. With an open procedure, the deltopectoral approach is usually the most suitable one, whereas a posterior approach is used for posteriorly located humeral head lesions.

Regarding the glenoid, a non orthograde oblique graft is usually needed. This must be considered during harvesting

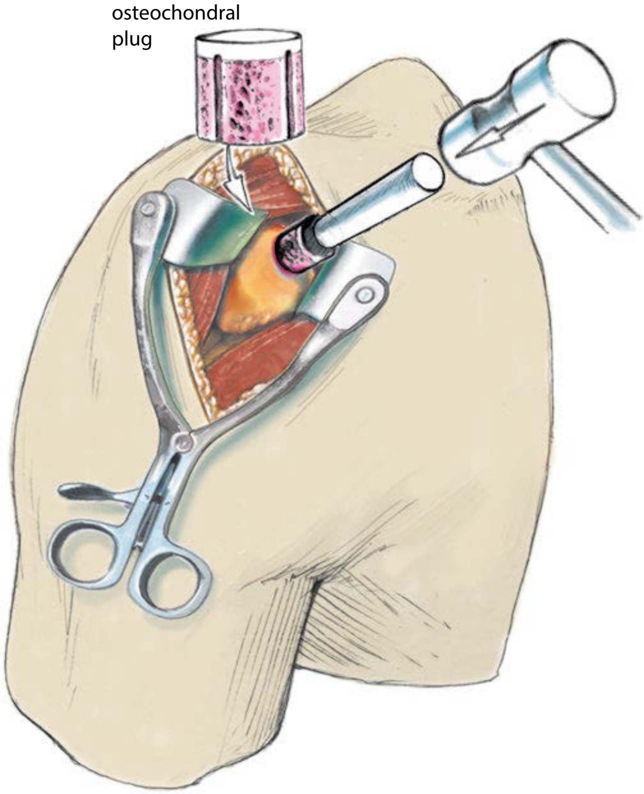


Fig. 5.12 Insertion of the donor cylinder from the knee joint into the prepared socket in the humeral head

the donor cylinder from the knee. The surgical procedure of osteochondral cylinder harvesting and transplantation is similar to the technique described in details in ► Sect. 18.3 (Figs. 5.10, 5.11 and 5.12).

5.3.5 Postoperative Management

- Arm sling is used for positioning.
- Monitoring of peripheral circulation, motor and sensory innervation.
- Postoperative radiographic evaluation.

5.3.6 Follow-Up Management

Arthroscopic osteochondral transplantation: free passive motion is started at the 1st postoperative day. Loading activities of the shoulder are avoided for 6 weeks after surgery. Active-assisted movement of the shoulder could be started from the 1st postoperative day (pain adapted). Active exercises could be started from the 3rd postoperative week. Increasing Loading activities from the 7th week.

Open osteochondral transplantation (deltopectoral approach, release/re-attachment of the subscapularis):

A shoulder abduction brace in 15° abduction is used for 6 weeks after surgery. Loading activities of the shoulder are avoided for 6 weeks. External rotation > 0° and active internal rotation are avoided for 6 weeks postoperatively. Passive ROM exercises allowed in the initial 4 postoperative weeks. In the 4th–6th postoperative weeks active-assisted exercises. From the 7th postoperative week free active range of motion.

5.3.7 Tips & Tricks

Orthograde implantation of the graft at the glenoid is particularly not possible. Therefore, the corresponding angle must be considered during graft harvesting from the knee in order to obtain a congruent surface.

For general Tips & Tricks for osteochondral transplantation refer to ► Sect. 18.3.

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Shoulder Osteoarthritis

I. Banke, S. Lorenz

A. B. Imhoff, M. J. Feucht (Eds.), *Surgical Atlas of Sports Orthopaedics and Sports Traumatology,*
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6.1 Resurfacing Arthroplasty

I. Banke, S. Lorenz

6.1.1 Indication

Focal chondral and osteochondral lesions of the humeral head, avascular necrosis, Hill-Sachs and reverse Hill-Sachs lesions, in a biologically young patient (age < 50 years) and in patients with high functional requirements.

6.1.2 Operation Principle

Arthroscopically assisted (Partial Eclipse™, Arthrex) or open (HemiCAP™, Arthrosurface) partial resurfacing arthroplasty of the humeral head. The prosthesis is composed of two components, a fixation screw (taper) and the actual resurfacing component, the posterior surface of which should ensure osteointegration.

6.1.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: Etiology, symptoms, functional demands, subjective instability, metal allergy, previous treatment modalities (intraarticular injections, e. g. cortisone), previous surgeries, relevant concomitant diseases (e. g. rheumatoid arthritis)
- Symptom-specific examination: range of motion (active/passive), painful motion, tenderness and pain on compression, function of the shoulder girdle muscles, stability and impingement tests.

Neurovascular Condition

Evaluation of the peripheral nerves (particularly the axillary nerve).

Imaging

- X-rays of the shoulder in three views (true AP, y-view, axial) for assessment of the osseous status (osteochondral lesion, Hill-Sachs and reverse Hill-Sachs lesions) and exclusion of advanced glenohumeral osteoarthritis
- MRI (with intra-articular contrast medium) to evaluate the site and extent of the defect and the osteochondral condition (bone edema, osteonecrosis) and any concomitant lesions (e. g. with traumatic origin)
- CT (with intravenous or intra-articular contrast medium) with specific indications (e. g. exact localization and sizing of the osteochondral lesion, Hill-Sachs defects and the extent of humeral head osteonecrosis)

Patient Information/Consent

Specific operative risks: Implantation failure (size, angle, height) with the risk of glenoid cartilage damage, material failure (fracture, dislocation), material wear, early loosening, dislocation, nerve injury (particularly axillary nerve), fracture, allergy/hypersensitivity reaction, conversion to open approach with Partial Eclipse, progressive joint degeneration, the need for a conventional prosthesis over time.

6.1.4 Operative Technique

Positioning and Preparation

- Beach chair position
- Positioning of the patient arm in an arm holder

Arthroscopically Assisted Partial Resurfacing (Partial Eclipse™, Arthrex)

A diagnostic arthroscopy performed followed by exact evaluation of the defect margins and assessing the stability of surrounding normal cartilage using an arthroscopic probe. A drill guide with guide instruments is inserted into the joint and the size of the humeral head defect is measured to determine the appropriate diameter of the implant (Fig. 6.1). Transhumeral over-drilling over a guide wire targeting the defect followed by inserting a guide sleeve and pin for the reamer which is introduced via the anterosuperior portal. Retrograde reaming of the defect. Insertion of the implant through the anterosuperior portal and the rotator interval (Fig. 6.2), connecting both components with an implant grasper and retrograde screwing the implant into the humerus (Fig. 6.3).

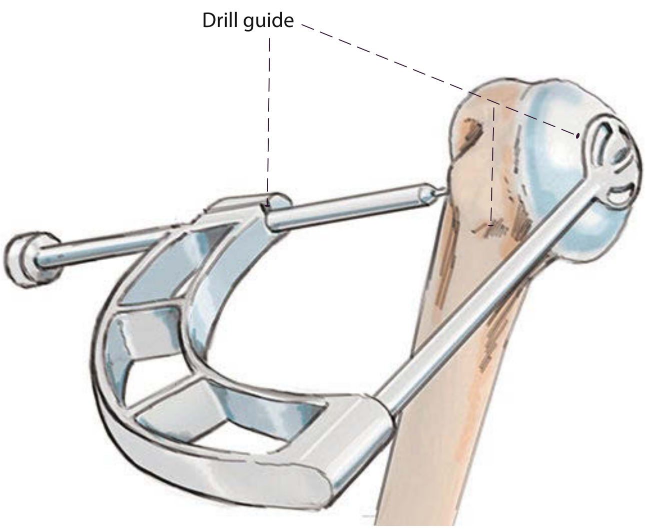
Open Partial Resurfacing (HemiCAP™, Arthrosurface)

Deltopectoral approach and incision of the subscapularis muscle. Exposure of the defect and assessing the stability of the surrounding normal cartilage. A drill guide is placed perpendicular to the defect center, over-drilling and insertion of the fixation screw down to the level of the cartilage.

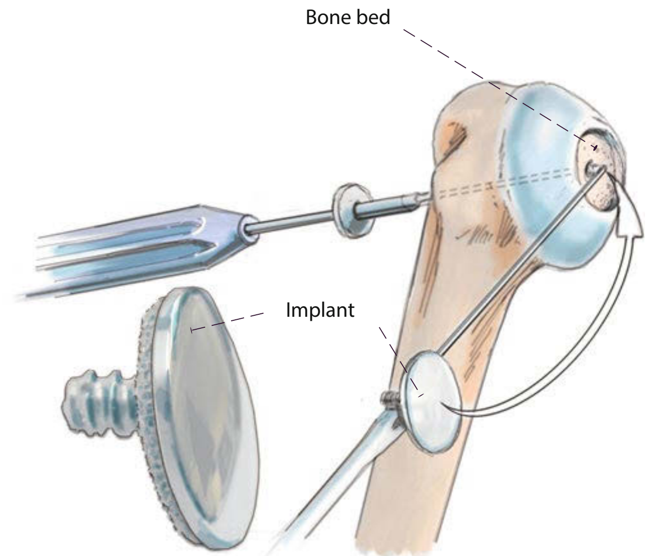
A sizing unit (card) is used to assess the size and the radius of curvature of the defect and thus determining the appropriate reamer and implant sizes. After creating a sharp cartilaginous margins, the defect is reamed down to the head of the inserted fixation screw. Definitive fixation of the articular component to the fixation screw is performed using an impactor (Fig. 6.4).

6.1.5 Postoperative Management

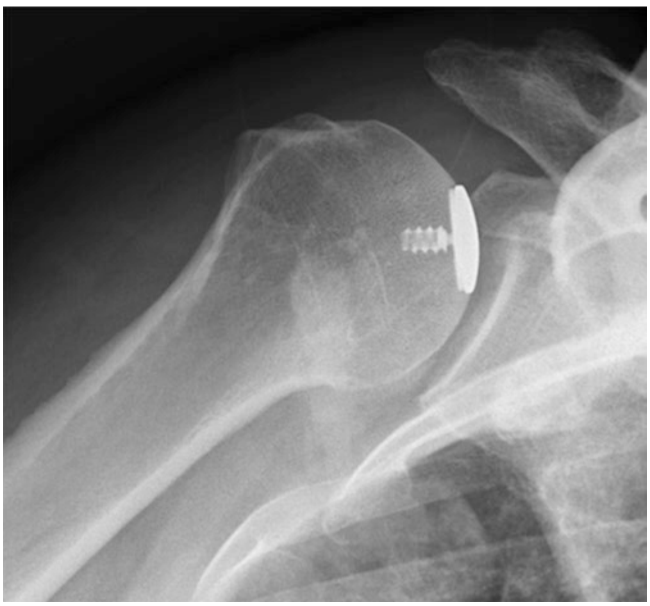
- Positioning of the arm in an arm sling
- Monitoring of peripheral circulation, motor and sensory innervation
- Postoperative X-ray evaluation (Figs. 6.3 and 6.4)



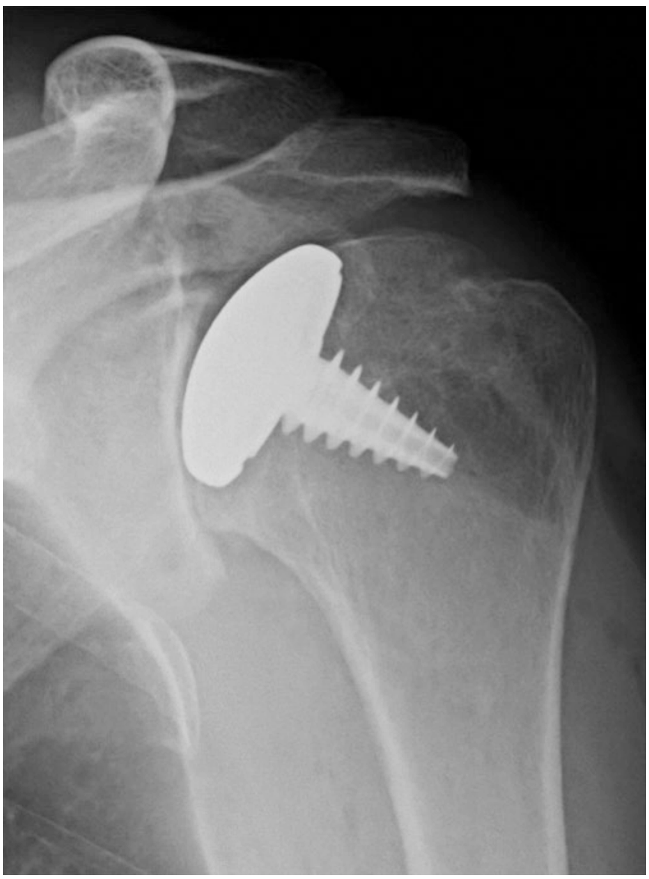
■ **Fig. 6.1** Insertion of the drill guide and measuring the size of the humeral head defect to determine the diameter of the implant



■ **Fig. 6.2** After reaming of the defect, insertion of the implant via the anterosuperior portal over the seating instrument, centrally placed in the defect



■ **Fig. 6.3** Postoperative radiograph after partial resurfacing of the humeral head with the Partial Eclipse (Arthrex)



■ **Fig. 6.4** Postoperative radiograph after partial resurfacing of the humeral head with the HemiCAP (Arthrosurface)

6.1.6 Follow-Up Management

Partial Eclipse

Immobilization of the shoulder in a sling for 2 weeks. Passive mobilization for 6 weeks postoperatively without limitation of motion. From the 7th postoperative week transition to active-assisted and active mobilization. From the 3rd postoperative month strengthening exercises and beginning of sport.

HemiCAP

Shoulder abduction brace in 15° abduction for 6 weeks. Range of motion: 1.–3. postoperative weeks: passive abduction/adduction: 90°/0°/0°, passive flexion/extension: 90°/0°/0°, passive internal/external rotation: 80°/0°/0°; 4th–6th postoperative weeks: active-assisted abduction/adduction: 90°/0°/0°, active assisted flexion/extension: 90°/0°/0°, passive internal rotation/external rotation: free/0°/0°. From the 7th postoperative week free motion.

6.1.7 Tips & Tricks

Precise and strict indication is critical to the success of partial resurfacing. It is contraindicated if there is associated generalized osteoarthritis.

Resurfacing prostheses should be implanted so that it lies a little bit below the surrounding cartilage surface. Protrusion of the implant should be avoided as it can lead to glenoid erosion.

If a Partial Eclipse implant is used in case of a very superiorly located defect, the trans-humeral drill hole must be started so far inferiorly. The axillary nerve should then be protected by making a small incision down to the bone and avoiding uncontrolled blind drilling through the soft tissue.

Before inserting the HemiCAP implant, the joint must be thoroughly irrigated and the inner core of the fixation screw should be cleaned with the enclosed Taper cleaner to allow a secure connection of both components of the implant.

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Miscellaneous

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7.1 Arthrolysis

S. Lorenz, M. Feucht

7.1.1 Indication

Persistent symptomatic motion deficit despite intensive and prolonged conservative treatment (> 6 months) due to adhesive capsulitis after subsidence of symptoms of inflammation.

7.1.2 Operation Principle

Arthroscopic perilabral capsulotomy with preservation of the glenoid labrum, rotator interval release, coracohumeral ligament resection and delineation of the subscapularis tendon.

7.1.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: duration of complaints, trigger (trauma, surgery, immobilization, idiopathic), previous treatment modalities, relevant comorbidities (e. g. diabetes mellitus, hyperthyroidism, autoimmune diseases, Dupuytren contracture)
- Symptom specific examination: range of motion (active and passive, capsular volume and pattern), exclusion of other causes of restriction of motion (e. g. rotator cuff massive tear with pseudo-paralysis or neurological disorders)

Neurovascular Condition

Exclusion of lesions of the brachial plexus, axillary or suprascapular nerves.

Imaging

- X-rays of the shoulder in three views (true AP, y-view, axial) to exclude a secondary frozen shoulder due to mechanical disorders (e. g. dislocated implants, malunited healed fracture or osteophytes)
- MRI (optionally with intraarticular contrast agent) to evaluate assess scarring/hypertrophy of the coracohumeral ligament, the joint capsule and the rotator interval; exclusion of concomitant pathologies (e. g. rotator cuff lesions, pulley lesion, SLAP lesion).
- CT (CT-arthrography if indicated) only in exceptional cases with metal artefacts in the MRI and to eventual mechanical disturbances (e. g. malunited healed fracture, osteophytes, loose bodies)

Patient Information/Consent

Specific operative risks: persistence of complaints, (motion deficit, pain), painful postoperative management with alternating positioning, risk of fracture during manual mobilization under anesthesia, injury of tendons (rotator cuff, long head of the biceps) and ligaments (instability), nerve injuries (axillary nerve, musculocutaneous nerve, brachial plexus), vascular injuries (subclavian and axillary arteries of their branches, risk of humeral head osteonecrosis), recurrence.

7.1.4 Surgical Technique

Positioning and Preparation

- Interscalene catheter is applied
- Beach chair position
- Positioning of the patient arm in an arm holder
- Examination under anesthesia to evaluate and document the range of motion

Arthroscopic Arthrolysis

Diagnostic arthroscopy is performed via the posterior standard portal. An anterosuperior working portal is established in an outside-in technique closely parallel to the anterior glenoid rim. The arthrolysis is performed according to the already diagnosed restricted movement (Fig. 7.1).

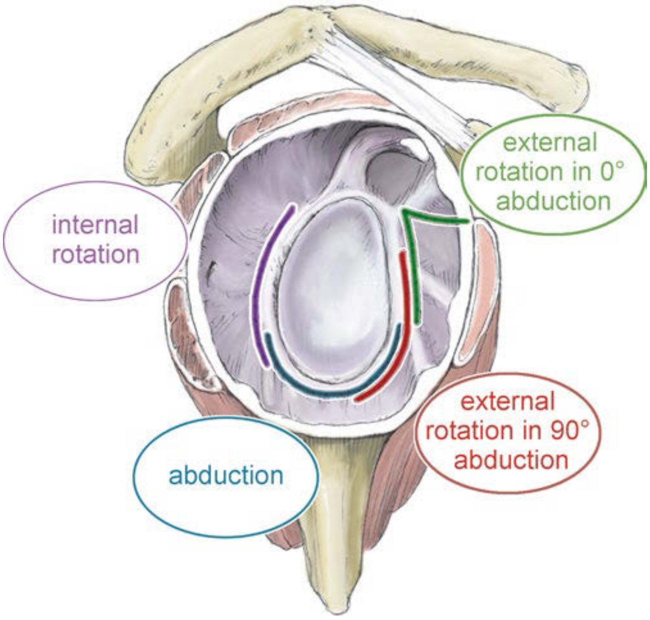
Release/resection of the rotator interval including the superior glenohumeral ligament and the coracohumeral ligament anterior to the subscapularis tendon, approximately 1 cm medial to the glenoid (Fig. 7.4a, b) (caution: the brachial plexus, suprascapular nerve).

Cutting the anterior capsule and the medial glenohumeral ligament (Figs. 7.2 and 7.4c). Release of the adhesions to the posterior aspect of subscapularis tendon. The inferior capsule is then released in successive layers close to the glenoid with the shoulder in neutral position down to the 6:00 o ’clock position, while preserving the labrum. The electrothermal device should always point to the glenoid to protect the axillary nerve, alternatively, an arthroscopic scissor could be used (Fig. 7.4d).

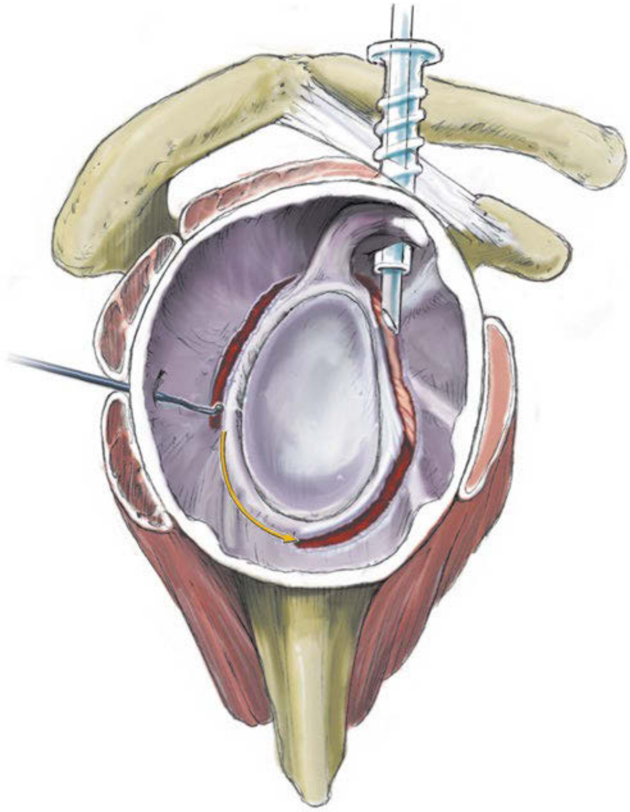
Capsular release is completed posteroinferior after switching the arthroscope into the anterosuperior portal (Figs. 7.3 and 7.4e). The superior capsule is released between the LBT and SSP (Fig. 7.4f). Tenotomy of the LBT is usually indicated. Subacromial bursectomy is performed without decompression.

Passive movement of the arm while fixing the scapula to evaluate and document the range of motion.

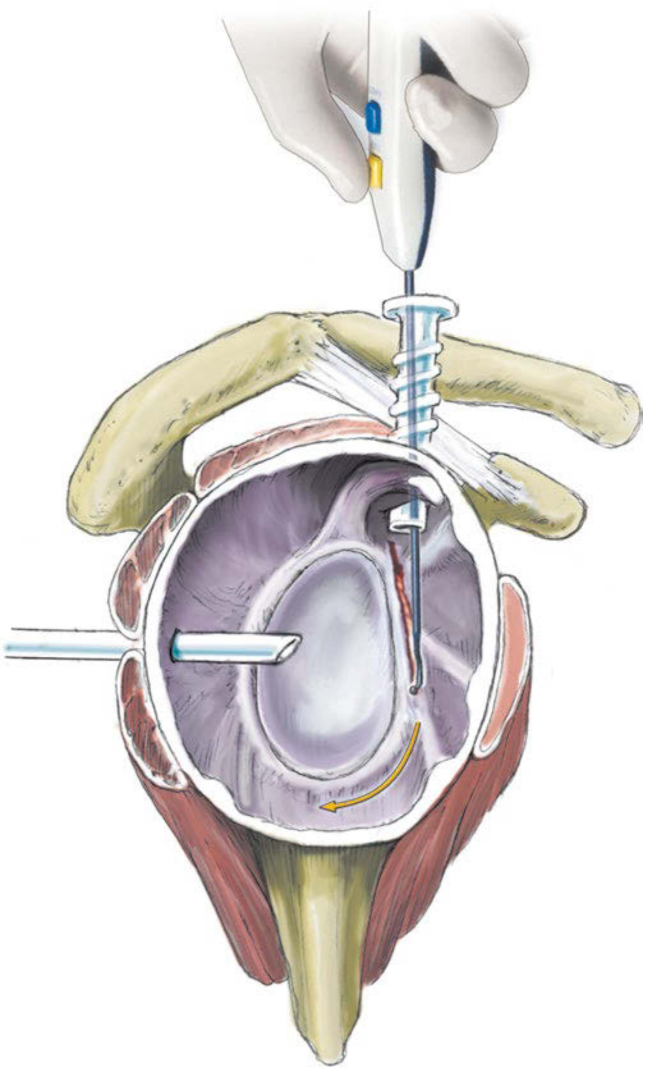
If necessary, mild stretching of residual adhesions. Vigorous mobilization should be avoided (risk of rotator cuff lesions, fracture, brachial plexus lesion).



■ **Fig. 7.1** Scheme of the structures to be released in relation to the corresponding limitation of motion



■ **Fig. 7.3** Release of the posterior capsule with an elctrocautery device after switching the arthroscope to the anterosuperior portal



■ **Fig. 7.2** Release of the anterior capsule and the MGHL with an elctrocautery device

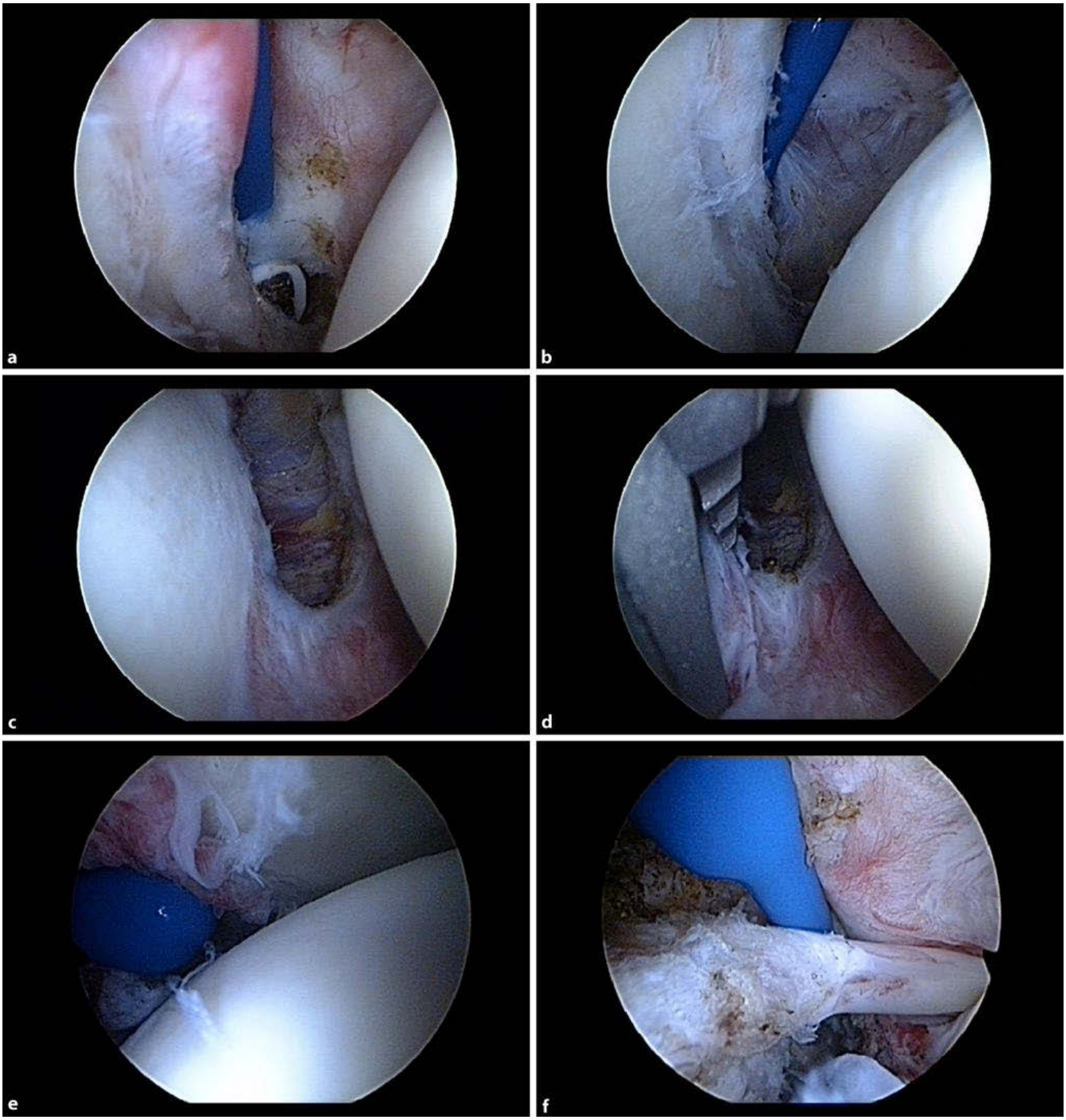


Fig. 7.4a-f Arthroscopic arthrolysis. **a** release of the subscapularis tendon; **b** release of the adhesions up to 1 cm medial to the glenoid rim; **c** release of the anterior capsule including MGHL; **d** release of the inferior capsule using arthroscopic scissors; **e** release of the posterior capsule after switching the arthroscope into the anterosuperior portal; **f** release of the superior capsule between the supraglenoid tubercle and the supraspinatus tendon

7.1.5 Postoperative Management

- Positioning of the arm in a Gilchrist bandage.
- Monitoring of peripheral circulation, motor and sensory innervation (Axillary nerve; sensation over the upper part of the arm).

7.1.6 Follow-Up Management

Alternating internal and external rotation in 90° abduction in a modified Gilchrist bandage during the hospital stay und using scalene catheter (Fig. 7.5). Free range of motion with intensive passive motion exercises to the maximum possible range of motion as well as instructions to self exercises. Physiotherapeutic training 2 times a day during hospital stay, ex-

Fig. 7.5a,b Alternating positioning in a modified Gilchrist bandage in 90° abduction. **a** internal rotation, **b** external rotation

ercises at home at least daily. Discharge from hospital after about 5 days if the pain is tolerable and the exercises could be performed after trial of stopping the scalene catheter.

7.1.7 Tips & Tricks

Entry into the joint is often difficult as the perforation of the thickened posterior joint capsule with the obturator requires more force than usual. Careful palpation of the interval between the humeral head and the glenoid with the obturator before penetration of the capsule to avoid inducing an iatrogenic cartilage injury. Moreover, the extended index finger placed over the obturator prevents uncontrolled slippage into the joint.

Particular attention should be paid during inferior capsular release because of its proximity to the axillary nerve. To avoid nerve injury, the thickened capsule should be released in successive layers and the probe of the elctrocautery should be always held to the glenoid rim, alternatively, an arthroscopic scissor is used.

7.2 Repair of the Pectoralis Major Tendon

T. Kraus, S. Lorenz

7.2.1 Indication

Symptomatic partial and complete ruptures of the pectoralis major tendon in active patients. Conservative treatment is indicated only with intramuscular injuries or partial ruptures in elderly patients with low functional demands.

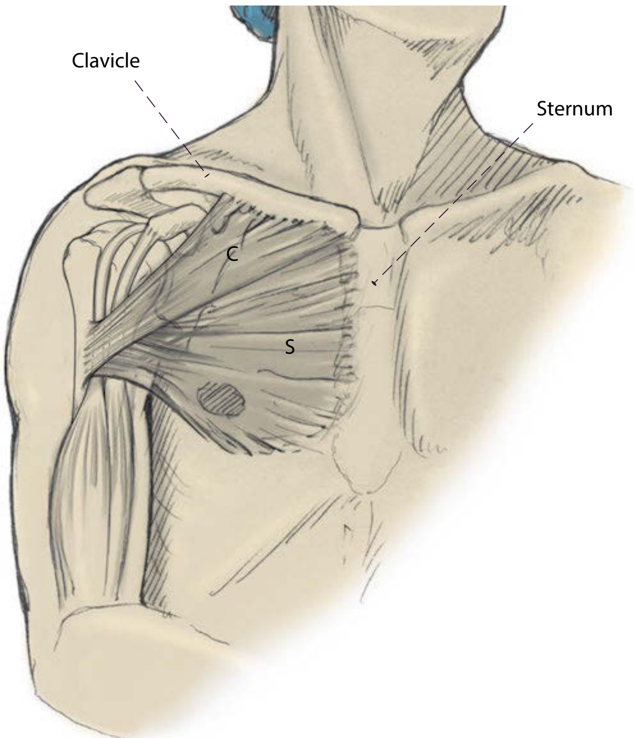


Fig. 7.6 Anatomy of the pectoralis major. C: clavicular head (part), S: sternal head (part)

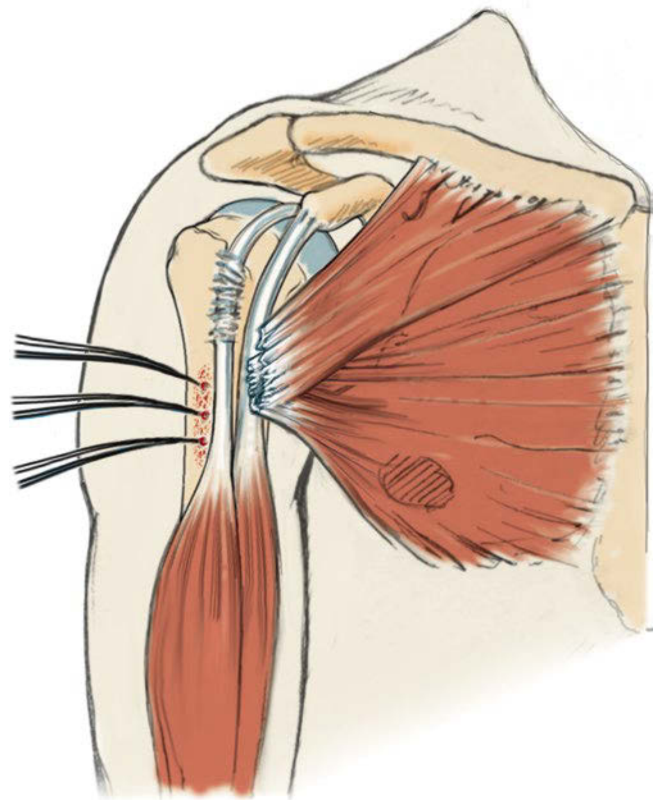


Fig. 7.7 Positioning of the suture anchors at the anatomical site of tendon insertion. Alternatively, the suture anchor may be also inserted medial to the long head of the biceps, thus minimizing the risk of impingement between the pectoralis major tendon and biceps tendon. A potential disadvantage of the latter insertion is a possible weakness of the internal rotation.

7.2.2 Operation Principle

Mobilization of the tendon stump and refixation to the anatomical insertion site at the lateral lip of the bicipital groove using suture anchors.

7.2.3 Preoperative Assessment

Diagnosis

Clinical Symptoms

- Symptom specific history (pain in the chest muscles, subjective weakness of adduction and internal rotation, decreased range of motion), duration of symptoms, etiology (trauma, surgery, immobilization), previous treatment
- Symptom specific examination: swelling and ecchymosis of the chest and upper arm, loss of the anterior axillary fold, muscle atrophy, retraction of the muscle with adduction against resistance, weakness on resisted adduction against resistance, tenderness along the pectoralis major tendon and over the insertion site at the proximal humerus.

Imaging

- X-ray of the shoulder in 2 planes (true AP, axial view) to exclude associated bony lesions as well as bony avulsions.
- MRI to localize the rupture and differentiate between partial and complete tears, to assess the degree of tendon retraction and the muscle condition (advanced atrophy, fatty infiltration); standard MRI of the shoulder is often not enough- axial and coronal sections should be extended to include about 20 cm distal to the glenohumeral joint.

Patient Information/Consent

Specific operative risks: persistent motion or strength deficit, residual cosmetic impairments, neurovascular injury (axillary nerve, musculocutaneous nerve, brachial plexus), injury of the long biceps tendon that requires a tenotomy or tenodesis, material failure, re-rupture.

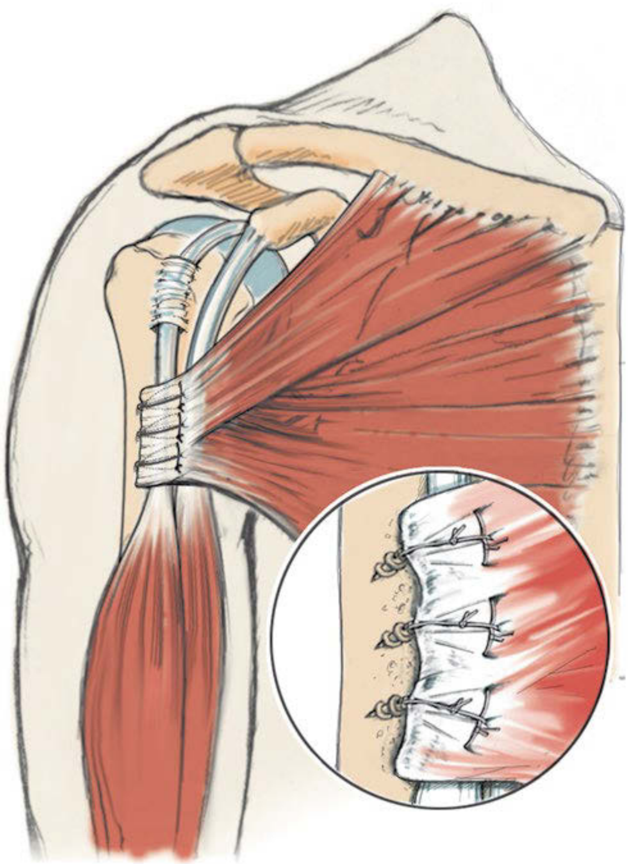
7.2.4 Surgical Technique

Positioning and Preparation

- The patient is positioned in beach chair or supine position
- Positioning of the patient's arm in an arm holder

Repair of the Pectoralis Major Tendon

A curved incision is performed along the inferior border of the pectoralis major muscle to allow access to the mus-



■ Fig. 7.8 The pectoralis tendon is reattached and fixed with Mason-Allen sutures

■ Fig. 7.9 Post-operative radiograph after repair of the pectoralis tendon

culotendinous junction as well as the humeral insertion. Meticulous deep dissection is carried out (to protect the cephalic vein as well as the deltoid muscle) with division of the pectoral fascia. The tendon stump is identified and tied with a strong suture material (e. g. FiberWire, Arthrex). The tendon is mobilized by bluntly and sharply dissecting the adhesions under manual traction of the tied tendon stump. Partial release of the inferomedial parts of the tendon could be performed if there is marked retraction of the tendon to increase its mobility. The insertion area at the lateral lip of the bicipital groove is prepared and freshened (the long biceps tendon should be protected). 2–3 metal suture anchors (e. g. titanium 5.5 mm Corkscrew, Arthrex) are inserted at the freshened insertion area (■ Fig. 7.7) and the tendon is then fixed with mattress or Mason-Allen sutures (■ Fig. 7.8).

7.2.5 Postoperative Management

- The arm is immobilized in a sling
- Monitoring of the peripheral blood circulation, innervation and function
- Postoperative X-ray evaluation (■ Fig. 7.9)

7.2.6 Follow-Up Management

Early functional training with pendulum exercises up to 6 week with passive movement exercises of the glenohumeral joint. Active exercises could start from the 7th week. Exercising is allowed after 3 months.

Anatomy

The pectoralis major muscle is a powerful adductor and internal rotator of the arm. The clavicular head of the muscle originates from the medial two thirds of the clavicle. The sternal head originate from the upper two thirds of the sternum and the second rip (cranial part). The caudal part originate from the lower sternum, the 5th and 6 ribs and the aponeurosis of the external oblique muscle. These 3 parts form the pectoralis tendon that inserts to the lateral lip of the bicipital groove (■ Fig. 7.6). The cranial part is inserted more distally and anteriorly, whereas the caudal part is twisted 180° and inserted craniodorsally (more proximal at the humerus). The innervation is mostly through the lateral pectoral nerve, which originates from C5-C6. The inferior part of the muscle is additionally innervated by the medial pectoral nerve.

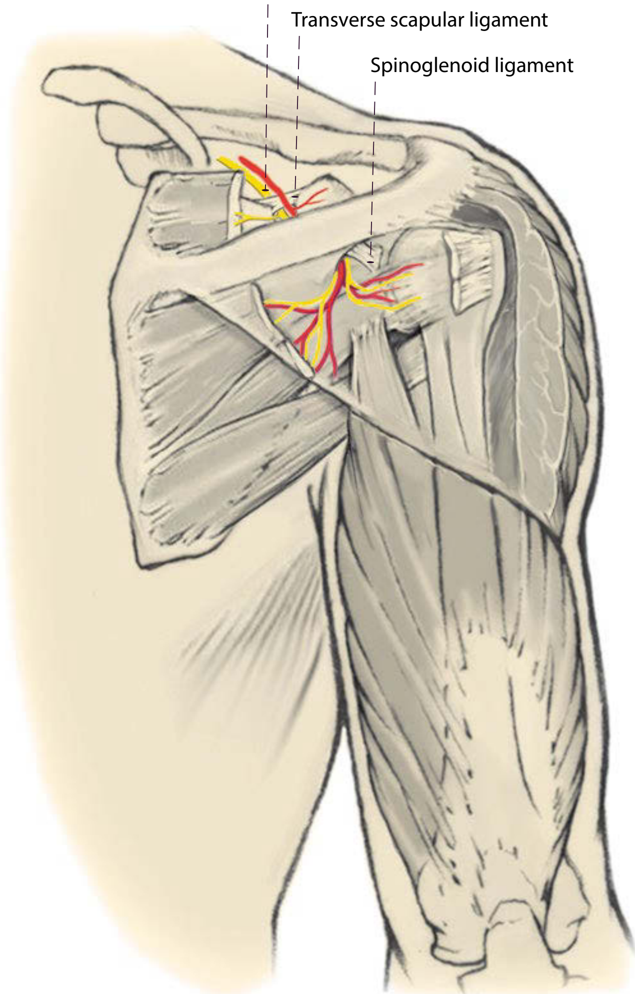


Fig. 7.10 Anatomy of the Suprascapular artery and nerve

Anatomy (Fig. 7.10)

The suprascapular nerve innervates the supra- and infraspinatus muscles. The suprascapular nerve contains in addition to the motor fibers sensory afferents from the subacromial space and the glenohumeral capsule. The nerve arises from the upper trunk of the brachial plexus and then runs through the suprascapular notch under the transverse scapular ligament. The nerve then runs distally through the spinoglenoid notch, the second potential site of entrapment.

7.3 Suprascapular Nerve Release

T. Kraus, S. Lorenz

7.3.1 Indication

Symptomatic compression (entrapment) of the suprascapular nerve either at the suprascapular notch or by cysts at the spinoglenoid notch with deep posterior shoulder pain and/or weakness of the infraspinatus and respectively supraspinatus muscles.

For other causes, such as a malunited scapular fracture, retracted rotator cuff tear or tumor, the treatment is directed primarily to the underlying pathology (e. g. rotator cuff repair, tumor resection)

7.3.2 Operation Principle

Arthroscopic release of the suprascapular nerve by release/resection of the transverse scapular ligament and/or decompression of cysts at the spinoglenoid notch.

7.3.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom-specific history: symptoms (pain, weakness, limitation of movement), duration of symptoms, trigger (trauma, surgery, immobilization, idiopathic), previous treatment
- Symptom-specific examination: atrophy of the infraspinatus and/or supraspinatus muscles (isolated atrophy of the infraspinatus muscle characterizes more entrapment at the area of the spinoglenoid notch, atrophy of both muscles denotes entrapment at the suprascapular notch), range of motion (active and passive), resisted abduction and external rotation in comparison to the opposite side.

Neurological/Vascular Condition

Objective evaluation of the suprascapular nerve lesion by instrumental neurological examination (electromyogram, nerve conduction velocity).

Imaging

- X-rays of the shoulder in three views (true AP, y-view, axial) for identification/exclusion of malunited fracture, or anatomical variations at the suprascapular notch and the scapular spine.
- MRI of the shoulder to identify structural changes at the suprascapular notch, spinoglenoid notch and the joint capsule (glenoid cysts/ganglions); exclusion of concomitant lesions (rotator cuff tear, SLAP lesion).

Patient Information/Consent

Specific operative risks: injury of the suprascapular nerve with subsequent atrophy and weakness of the supra- and infraspinatus muscles.

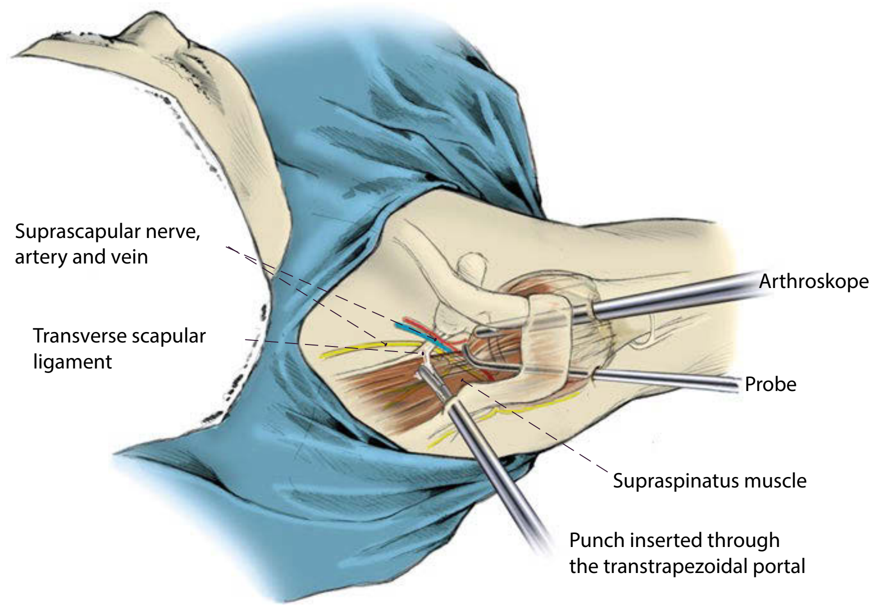


Fig. 7.11 Resection of the transverse scapular ligament via the trans-trapezius portal

7.3.4 Operative Technique

Positioning and Preparation

- Beach chair position
- The patients arm is positioned in an arm holder

Arthroscopic Release of the Suprascapular Nerve at the Suprascapular Notch by Releasing the Transverse Scapular Ligament

Diagnostic arthroscopy is performed via the posterior standard portal. The arthroscope is switched into the subacromial space through a lateral portal. An anterolateral working portal is used for further preparation at the anterior margin of the supraspinatus muscle and towards medial using an electrocautery device.

Anatomical landmarks are the coracohumeral ligament, the coracoacromial ligament, the coracoid process and the anteriorly directed coracoclavicular ligaments. The suprascapular notch and the transverse scapular ligaments, with the suprascapular nerve running through the notch, are located about 1–1.5 cm posteromedial to the coracoclavicular ligaments. The anterior subacromial bursa is resected cautiously to identify the supraspinatus muscle as well as the coracohumeral and coracoacromial ligaments. The medial subacromial bursa, at the anterior margin of the supraspinatus muscle, is opened with the shaver and loose tissue is removed in a medial direction towards the base of the coracoid. The suprascapular notch now can be located posteromedially.

An additional portal is then established through the trapezius muscle, under direct visualization over a needle inserted between the scapular spine and the clavicle, about 6–8 cm medial to the lateral edge of the acromion. A blunt trocar is introduced through this portal. The transverse scapular ligament is visualized and identified. The supraspinatus muscle is retracted posteriorly. The suprascapular nerve lies underneath, while the suprascapular artery and the 2 accompanying veins lie above the transverse ligament. The vessels are gently displaced medially. The suprascapular nerve is identified and exposed as it runs below the ligament through the notch as well as anteriorly and posteriorly to the notch.

After adequate exposure of the nerve and the ligament, the release is performed by dividing the transverse ligament with arthroscopic scissors or punch at the medial wall of the notch (Fig. 7.11). Adhesions between the nerve and the bony wall of the notch are dissected and released until the nerve can slide freely in the notch.

Osseous hypertrophy at the notch or even complete ossification can be removed with a bone cutting shaver or an arthroscopic burr, however this carries a risk of postoperative hematoma and scarring with subsequent compression of the nerve.

Arthroscopic Release of the Suprascapular Nerve by Decompression of Cysts at the Supraglenoid (Spinoglenoid) Notch

Supraglenoid cysts resulting in symptomatic compression of the suprascapular nerve should be decompressed and resected using an electrocautery device. The cysts may be accessed intraarticularly at the superior glenoid rim. The formation of these supraglenoid cysts may be explained through an intraarticular valvular mechanism (similar to a Baker's cyst in the knee) with lesions of the superior or posterosuperior labrum. Therefore, the labral lesion should be treated simultaneously.

A better intraoperative visualization in case of posterosuperior or posterior lesion may be achieved by performing a tenotomy or tenodesis before, or SLAP repair after decompression of the cyst.

7.3.5 Postoperative Management

- The arm is placed in a sling
- Monitoring of peripheral circulation, motor and sensory innervation

7.3.6 Follow-Up Management

Free range of motion with intensive passive motion exercises are allowed. Active movements are allowed after wound healing.

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Elbow

Positioning, Arthroscopic Portals and Diagnostic Arthroscopy

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8.1 Patient Positioning

Basically 3 different positions are possible: supine position, prone position and lateral decubitus position. In all positions both open as well as arthroscopic procedures could be performed. Usually a tourniquet is applied to the proximal upper arm and inflated to a pressure of 250 mmHg.

8.1.1 Supine Position

The supine position is used for open surgical procedures where access to the anterior aspect of the elbow is required. The arm could be positioned on a side table or directly left over the body.

The supine position provides a good access for arthroscopic procedures involving the anterior joint compartment and an easy anatomic orientation, which considerably facilitate the procedure, particularly for the less experienced arthroscopist. For this purpose, the patient's hand lies freely hanging in an arm holder and the shoulder is abducted 90° and the elbow flexed 90°.

The supine position allows free pronation and supination and decreases tension over the anterior neurovascular bundles, which reduced the risk of iatrogenic neurovascular injuries.

8.1.2 Prone Position

The prone position allows a good access for both open and arthroscopic procedures, particularly to the posterior joint aspect. One advantage of this position is the inherent stability of the elbow. Disadvantages includes the complicated anatomical orientation and the need to reposition the patient after intubation.

The arm is positioned in an arm holder or over an arm board, the shoulder is abducted to 90° and the elbow is flexed to 90°. The chest and pelvis must be adequately padded to secure sufficient ventilation.

8.1.3 Lateral Decubitus Position

One advantage of the lateral decubitus position over the prone position is the easier accessibility of the patient during anesthesia. Disadvantages include non-familiar anatomical orientation and the difficulty in positioning and stabilization of the patient. The patient is positioned and stabilized using two side supports against the chest and the back. Alternatively, a vacuum mattress could be used. The arm is freely suspended in front of the body (◘ Fig. 8.1). Shoulders and elbows are flexed 90°. It is very important to securely stabilize the head with straight alignment of the cervical spine.

8.2 Arthroscopic Portals

The standard portals for elbow arthroscopy are illustrated in ◘ Fig. 8.2.

8.2.1 Anterolateral Portal

This standard portal is located 2 cm distal and 2 cm anterior to the lateral epicondyle and allow access into the anterior part of the radiohumeral joint (◘ Fig. 8.3). It perforates the extensor carpi radialis brevis and supinator muscles. A needle is passed intraarticular aiming towards the medial epicondyle, incision of about 6 mm length, blunt dissection of subcutaneous tissues and muscles with a mosquito clamp and a blunt trocar is then inserted in the direction of the medial epicondyle.

The anterolateral portal allows optimal visualization of the ulnar side of the anterior elbow joint (humero-ulnar joint, coronoid process, trochlea and the medial recess). The entire anterior trochlea could be evaluated with flexion and extension. Structures at risk during placement of this portal includes the radial nerve and posterior antebrachial cutaneous nerve. The safety margin to radial nerve is increased and the risk of nerve injury is reduced with a more proximal portal placement.

8.2.2 Anteromedial Portal

This portal is located 2 cm distal and 1 cm anterior to the medial epicondyle (◘ Fig. 8.4) and passes through the flexor carpi radialis, flexor digitorum superficialis and the deep part of the pronator teres. Structures at risk includes the median nerve, medial antebrachial cutaneous nerve, median nerve, ulnar nerve as well as the radial artery, which lies on average 17 mm anteromedial to this portal. This portal can be performed in either an outside-in technique, in which a needle is used to establish the portal aiming for the radiohumeral joint, as well as in an inside-out technique.

The latter is performed by driving the arthroscope directly to the desired portal site on the ulnar side capsule and then replaced with a switching stick that is used to penetrate the capsule bluntly. The skin in then incised and a trocar or an arthroscopic cannula is inserted over the switching stick. This portal is used to visualize the radial side of the joint, particularly the humeroradial joint.

8.2.3 Superoposterior Portal

This portal serves as a viewing portal to visualize the posterior parts of the joint (olecranon, olecranon fossa and posterior recess). It is located 3 cm proximal to the olecranon tip, di-

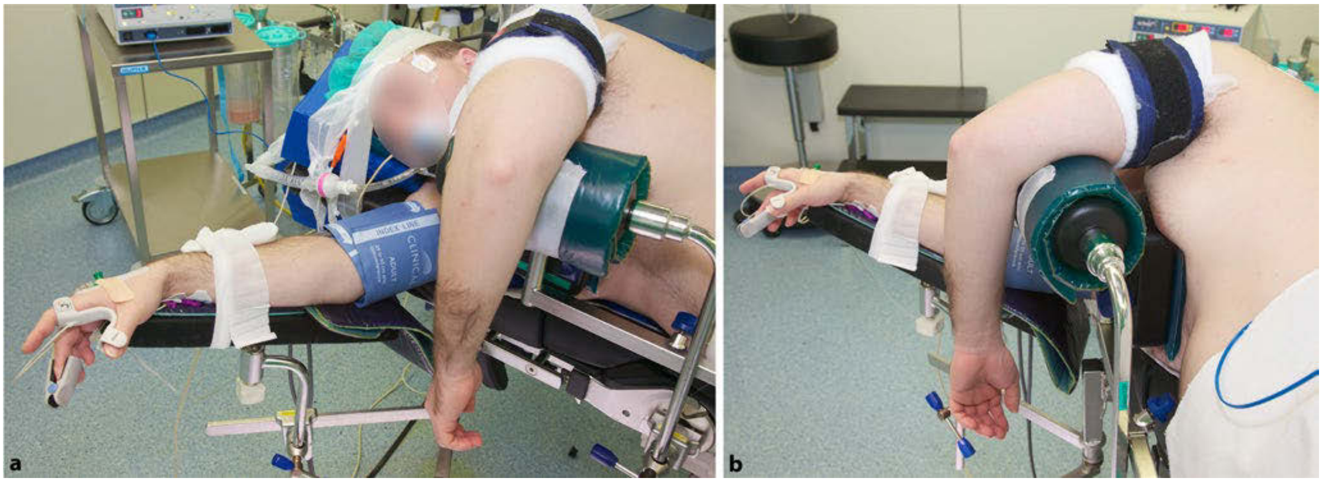

Fig. 8.1a,b Lateral decubitus position. **a** view from the side, **b** inferior view

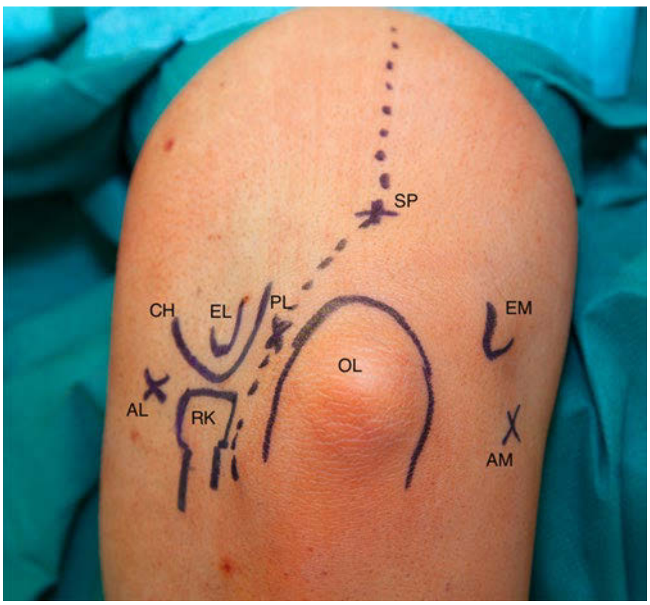

Fig. 8.2 Left elbow in the lateral decubitus position with landmarks and portals drawn. *AL* anterolateral portal; *AM* anteromedial portal; *RK* radial head; *SP* superoposterior portal CH Capitulum humeri; EL Epicondylus lateralis; EM Epicondylus medialis; OL Olekranon; PL posterolateral Portal („soft-spot")

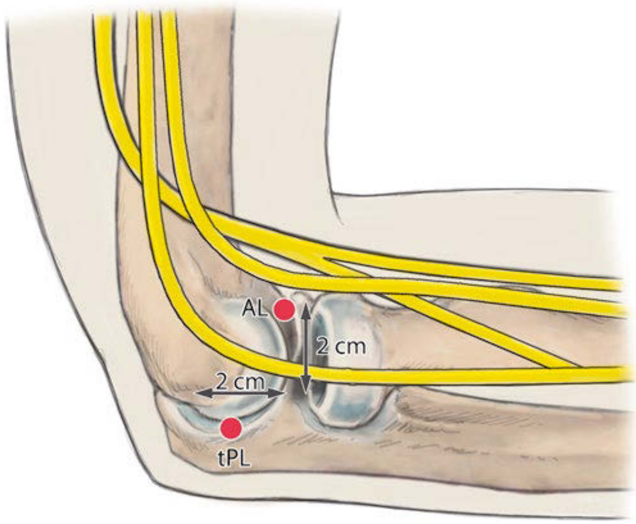

Fig. 8.3 Lateral view of the elbow. *AL* anterolateral portal: 2 cm distal and 2 cm anterior to the lateral epicondyle; deep posterolateral portal: between the radial head, olecranon and lateral epicondyle

rectly through the central part of the triceps brachii tendon (Fig. 8.5).

8.2.4 Posterolateral Portal (Mid-Lateral Portal)

This portal corresponds to the "soft spot" between the radial head, olecranon and lateral epicondyle (Fig. 8.3) and is used primarily for joint distension. The portal is created under arthroscopic visualization after placement of a needle and penetrates the anconeus muscle. This portal visualizes the radiohumeral joint as well as the posterior joint structures (olecranon, olecranon fossa and trochlea).

8.2.5 High Posterolateral Portal

Another posterior portal at the same level of the superoposterior portal, approximately 3 cm proximal to the olecranon tip and directly lateral to the tendon. The portal is created in the direction of the center of the olecranon fossa (Fig. 8.5). It is used also to visualize the posterior part of the joint.

8.3 Diagnostic Arthroscopy

Positioning is done according to surgeon's preference in supine, prone or lateral decubitus position. A tourniquet is placed high to the arm and raised to 280 mmHg. The arm is exsanguinated using an elastic rubber bandage (bloodless). The elbow is visualized using a 30° angle lens under continuous intraarticular fluid infusion at a pressure of 30–50 mmHg.

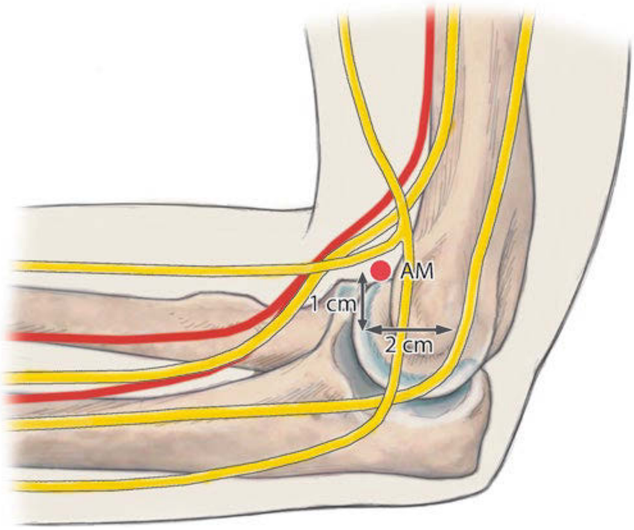

Fig. 8.4 Medial view of the elbow. *AM* anteromedial portal: 2 cm distal and 1 cm anterior to the medial epicondyle

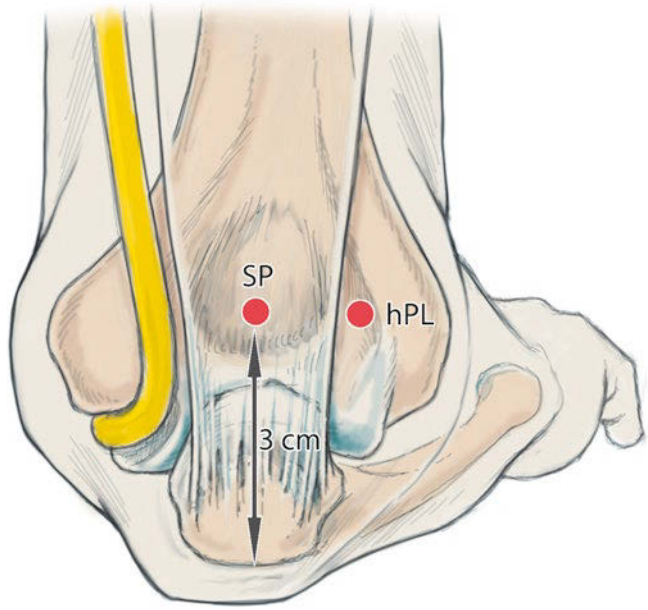

Fig. 8.5 Posterior view of the elbow. SP superoposterior portal: 3 cm proximal to the olecranon tip, *hPL* high posterolateral portal: 3 cm proximal to the olecranon tip and directly lateral to the tendon of the triceps brachii

Fig. 8.6 Distension of the elbow joint with sterile saline solution through a needle in the posterolateral portal ("soft spot")

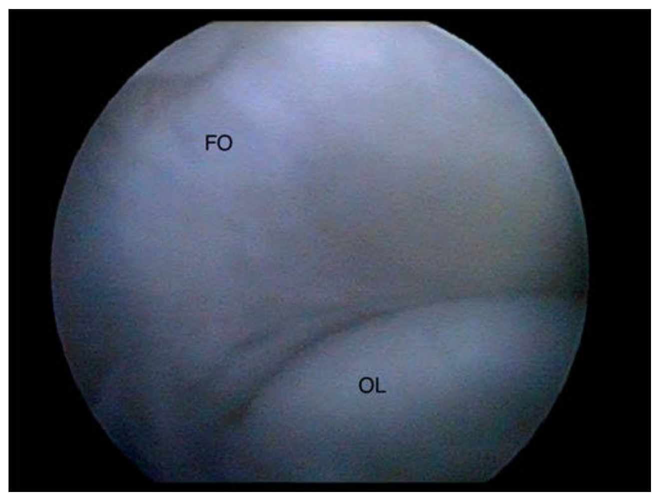

Fig. 8.7 Arthroscopic view from posterior showing the olecranon fossa and olecranon tip. *FO* olecranon fossa; *OL* olecranon

Accurate identification and marking of landmarks and anticipated portals are essential to avoid nerve and vascular complications, due to the close proximity of these important neurovascular structures. The following should be marked: the medial and lateral epicondyles, radial head, capitellum, olecranon, ulnar nerve groove as well as the standard portals (Fig. 8.2).

The patient is lying in prone or lateral decubitus position in the subsequent description of arthroscopy. Before establishing the portals, the elbow joint is initially distended with sterile NaCl solution through a needle inserted into the posterolateral portal (soft spot), to displace the neurovascular structures away from the joint and to reduce the risk of iatrogenic injury (Fig. 8.6). At least 20 ml should be injected into the soft spot, in the triangle between the radial head, olecranon and lateral epicondyle and the intraarticular injection is confirmed by backflow of fluid through the inserted needle. Free backflow of fluid and a slight extension of the elbow confirm the intra-articular injection. Sufficient distension of the joint is indicated by the formation of a horseshoe shaped protrusion of the posterior joint capsule.

The viewing portal should be changed many times to visualize all compartments of the elbow joints. We recommend the following approach with standardized photo documentation:

- Establishing an anterolateral portal, which is primarily used for fluid infusion. Accessing the posterior compartment via the superoposterior portal and visualization of the olecranon fossa and tip of olecranon. The distance between the tip of olecranon and the osteochondral junction at the margin of olecranon fossa should not exceed 7 mm.
- Establishing a deep posterolateral portal (Mid-lateral Portal). Stability testing using a switching stick on both the radial and ulnar sides of the olecranon to evaluate a

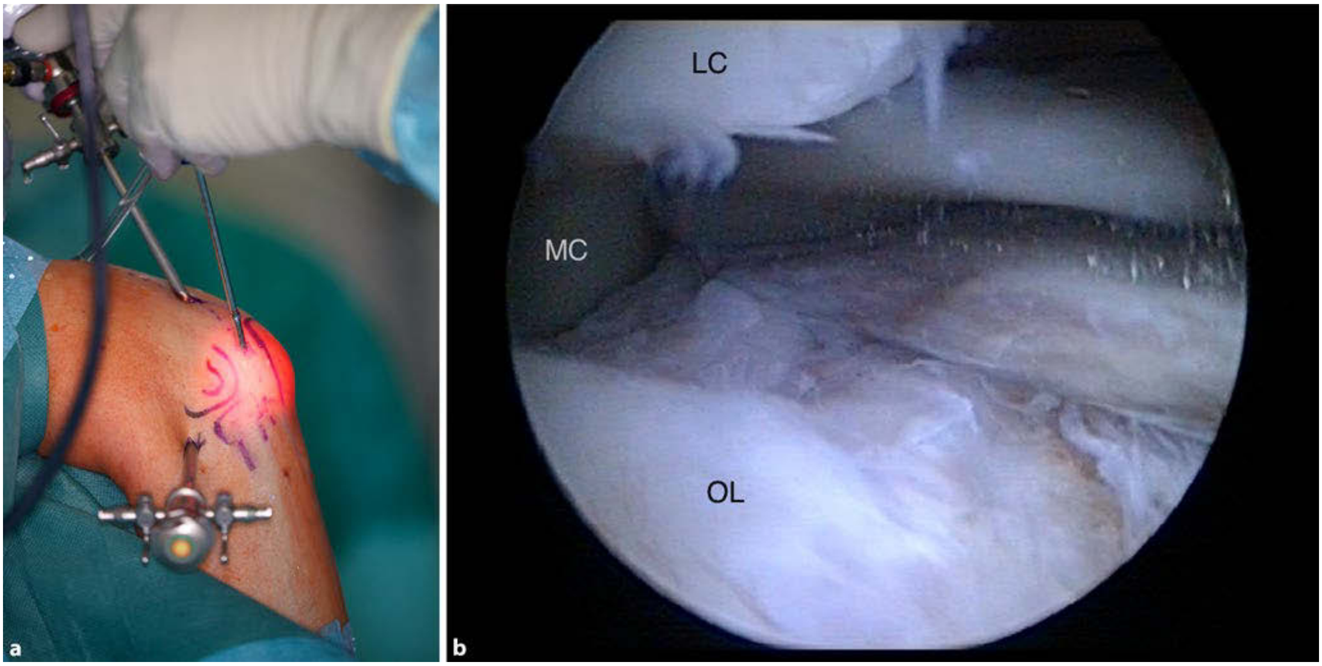

Fig. 8.8a,b Posterior view of the humeroulnar joint showing a switching stick through the joint. **a** extraarticular view; **b** intraarticular view. *LC* lateral condyle, *MC* medial condyle, *OL* olecranon

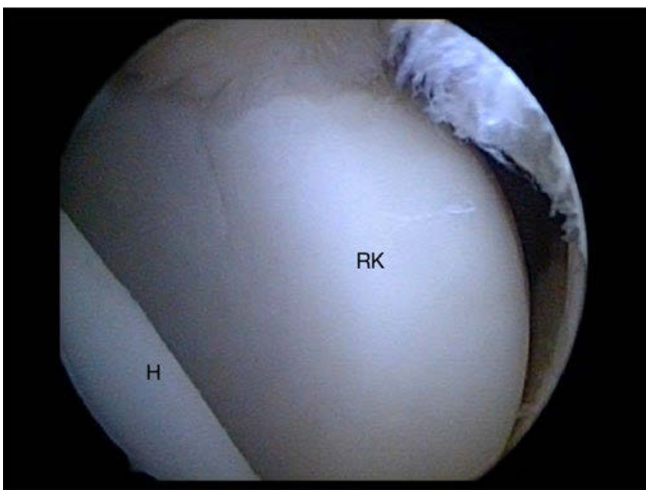

Fig. 8.9 Posterior radioulnar joint. *RK* radial head; *H* humerus

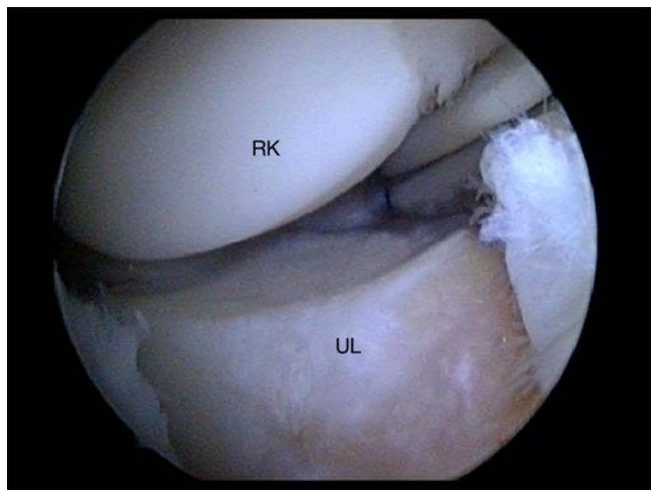

Fig. 8.10 Stability testing of the annular ligament. *RK* radial head, *UL* ulna

lateral or medial ligamentous instability. The arthroscope is next switched to the anterolateral portal for visualization of the anterior compartment (capitellum, coronoid and coronoid fossa).

- Placement of an anteromedial portal in an inside-out technique. The arthroscope is then switched to visualize the coronoid process and radial head. Stability testing of the annular ligament and the humeroradial joint using a switching stick from anterior.

The following photographic documentation should be performed as a standard:

- Photo 1: Posterior view of the olecranon and olecranon fossa (Fig. 8.7).
- Photo 2: Visualization of the humeroulnar joint from posterior with a switching stick inserted through it (Fig. 8.8)
- Photo 3: posterior radioulnar joint (Fig. 8.9)
- Photo 4: Stability testing of the annular ligament (Fig. 8.10)
- Photo 5: Anterior joint compartment (Fig. 8.11)

8.4 Tips & Tricks

Medial portals should be avoided if there is suspicion of ulnar nerve subluxations/dislocation and after ulnar nerve transposition (scars).

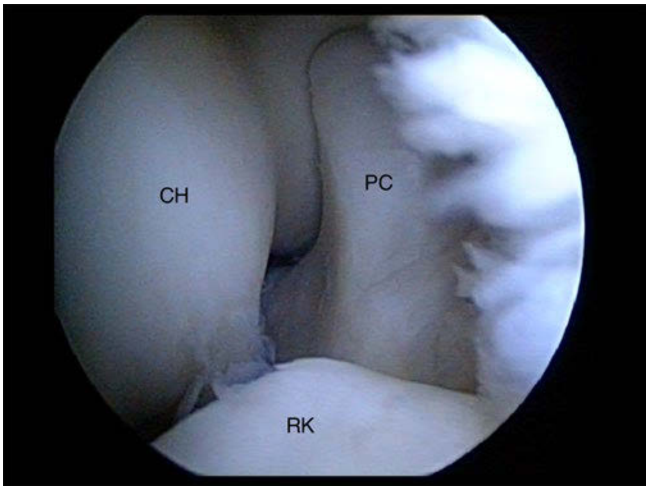

Fig. 8.11 Anterior joint compartment. *CH* capitellum, *PC* coronoid process, *RK* radial head RK

Subcutaneous tissue should be always blunt dissected during portal placement. Stab incisions should be avoided because of the close proximity to the neurovascular structures. Only skin should be incised with the scalpel.

Sufficient distension of the joint is mandatory before establishing the portals to reduce the risk of iatrogenic neurovascular injury.

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Osteochondral Lesion

J. Plath, S. Vogt

A. B. Imhoff, M. J. Feucht (Eds.), *Surgical Atlas of Sports Orthopaedics and Sports Traumatology,*
DOI 10.1007/978-3-662-43776-6_9,

9.1 Autologous Osteochondral Transplantation and Mosaicplasty

J. Plath, S. Vogt

9.1.1 Indication

Focal osteochondral lesions in the load bearing area of the elbow joint (Dipaola grade III/IV), focal osteonecrosis with closed epiphysis.

9.1.2 Operation Principle

Replacement of pathologic tissue with an autologous osteochondral cylinder from a low weight bearing part of the knee, preferably from the proximal lateral trochlea, alternatively from the proximal medial trochlea or the intercondylar notch.

9.1.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: dull pain and swelling more marked laterally, activity related pain, rest pain, locking.
- Symptom Specific examination: swelling, limitation of movements, tenderness over the lesion e. g. capitulum.

Imaging

- Plain X-ray of the elbow AP in 0° and 45°(better visualization of the radiohumeral joint) and lateral views.
- MRI with intravenous contrast agent to assess the extent, stability and vitality of the defect.

Patient Information/Consent

Specific operative risks: rejection of the graft, donor site morbidity, injury to the radial nerve, lateral collateral ligament instability, progression to osteoarthritis or persistence/worsening of the limitation of movement.

9.1.4 Surgical Technique

Positioning and Preparation

- Supine position
- Positioning of the arm to be operated on an arm table with freely movable elbow joint.
- A tourniquet is applied to the arm (200 mmHg)
- A tourniquet is applied to the thigh (280 mmHg) with washing and preparation of donor site (usually ipsilateral knee joint)

Autologous Osteochondral Transplantation

The capitellum is exposed through a lateral approach. Posterior approach is recommended if the lesion is located far posteriorly and anterolateral approach with anteriorly located lesions (Fig. 9.1).

Subcutaneous dissection of the fascia with incision between anconeus and extensor carpi ulnaris. The lateral joint capsule is opened at the level of the radial head with care to preserve the annular ligament (Fig. 9.1). Release of the lateral collateral ligament is sometimes required, depending on location of the lesion.

The size of the defect is determined and the defect is then removed using a special hollow chisel (recipient harvester, OATS instruments, Arthrex; Fig. 9.2). The harvester is driven into the bone, the cylinder is loosened by strong clockwise rotation and then removed with gentle rotatory movements.

Both the defect size and possibility to reconstruct a congruent articular surface are important to be considered during harvesting the osteochondral cylinders. The goal is to completely remove the necrotic areas. Any remaining sclerotic areas should be opened with drilling. This is followed by measuring the depth of the bone socket (Fig. 9.3).

The donor site at the knee (proximo-lateral trochlea) is then exposed through a parapatellar lateral mini-arthrotomy. It is essential during harvesting the donor cylinder, that the surface of the graft could congruently match and reconstruct the articular surface at the defect area. The donor cylinder is harvested using a special harvester (hollow chisel) in the same technique described in (► Sect. 18.3; Fig. 9.4).

The depth of the defect as well as the length of the donor cylinder are measured once again and either the cylinder is shortened to match the defect depth or cancellous bone grafting to compensate and reline the socket. Lastly, the donor cylinder is inserted into the socket with press-fit technique (Fig. 9.5). Prominence of the cylinder or a gap formation between it and the joint surface must be avoided. At the end, dynamic functional examination of the elbow joint and possibly reattachment of the detached collateral ligament.

9.1.5 Postoperative Management

- Rest in a plaster splint
- Monitoring of the peripheral circulation, motor and sensory innervation.
- Postoperative radiographic evaluation

9.1.6 Follow-Up Management

In the first 2 postoperative weeks: free passive mobility of the elbow, particularly maximum flexion and extension.

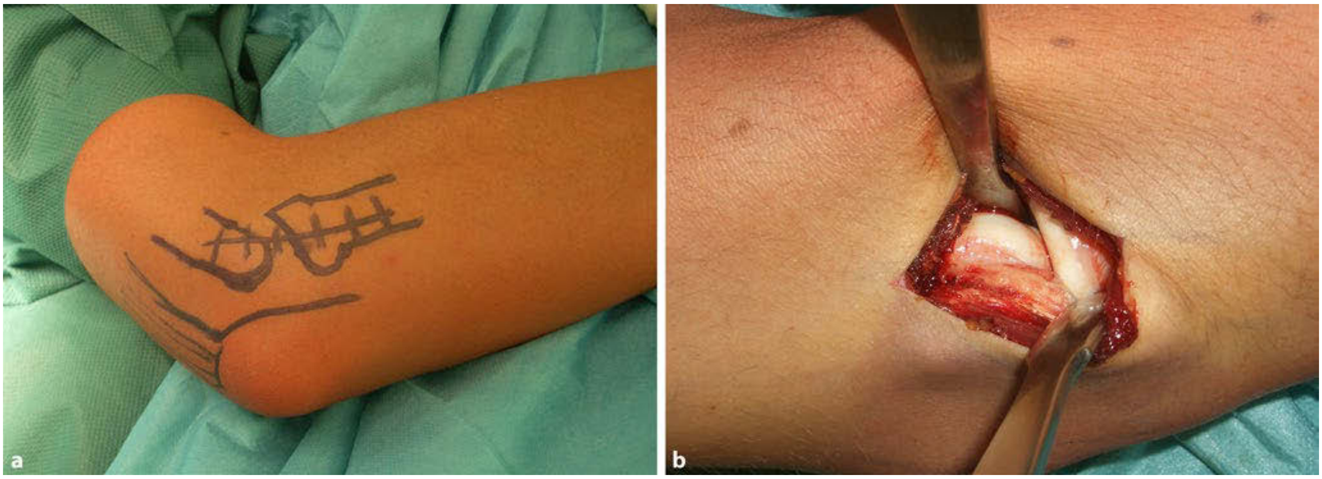

Fig. 9.1a,b Lateral approach. **a** slightly curved incision starting from the lateral humeral epicondyle towards the radial head **b** surgical site after opening the capsule along the interval between anconeus and extensor carpi ulnaris

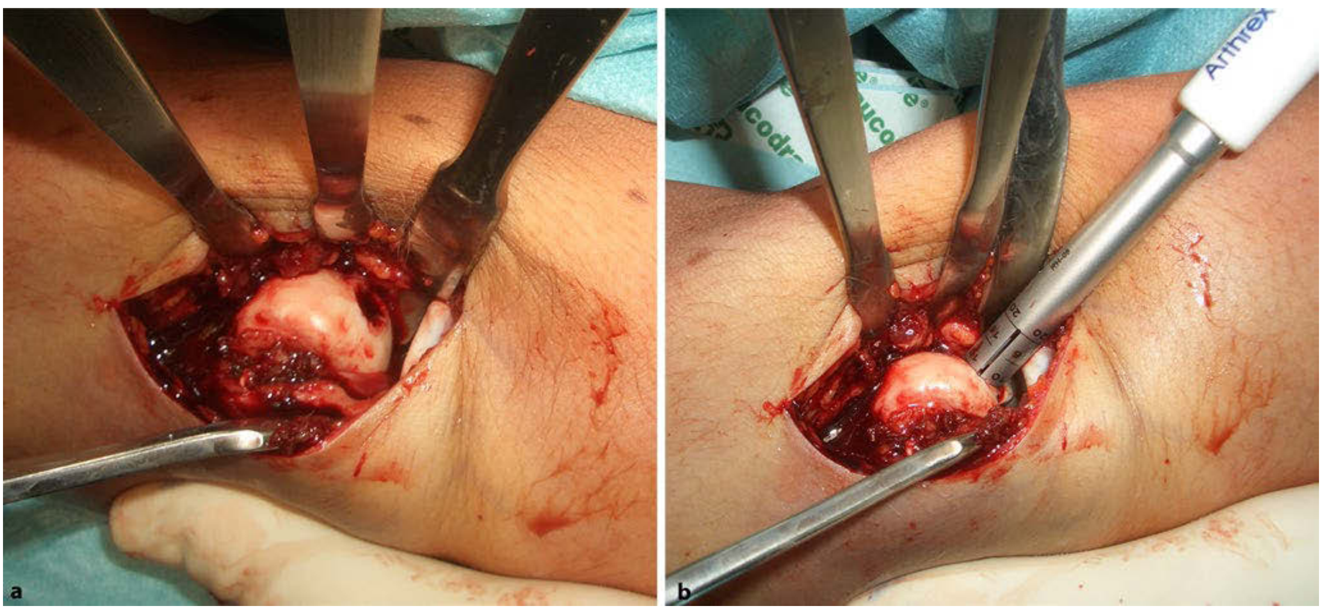

Fig. 9.2a,b Harvesting the defect area at the capitellum with the gouge (recipient harvester) **a** osteochondral lesion on the capitellum **b** driving in the harvester into the defect area

From the 3rd postoperative weeks: free active motion is allowed. Loading of the elbow joint should be avoided for 6 weeks postoperatively.

Starting from 12th weeks complete loading and sport activities are allowed.

Partial weight bearing of the knee joint for 2 weeks postoperatively.

9.1.7 Tips & Tricks

The aim is to manage the defect as possible with only one cylinder, as transplantation of multiple cylinders make it very difficult to restore the articular surface congruity in this region.

See also ► Sect. 18.3.

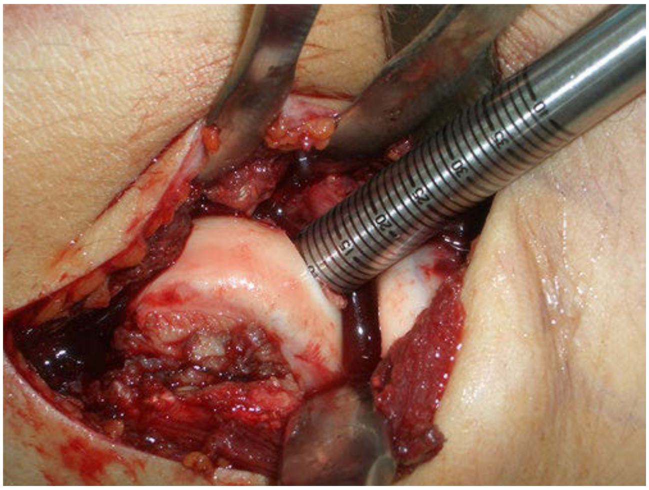

Fig. 9.3 Measuring the depth of the defect socket

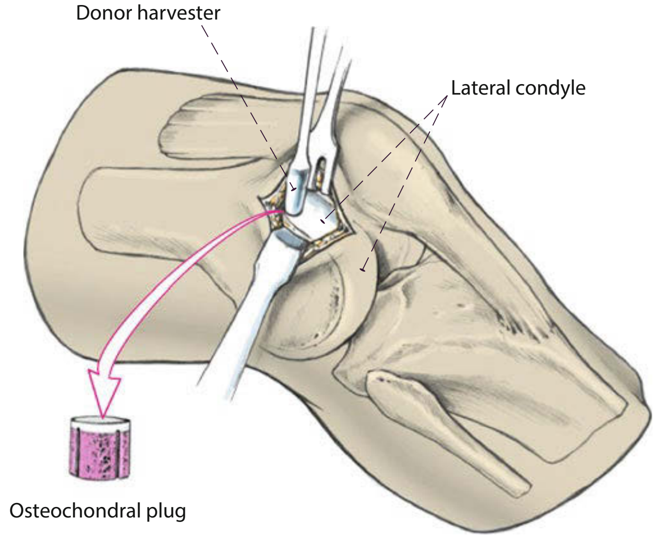

Fig. 9.4 Harvesting the donor cylinder from the proximo-lateral trochlea

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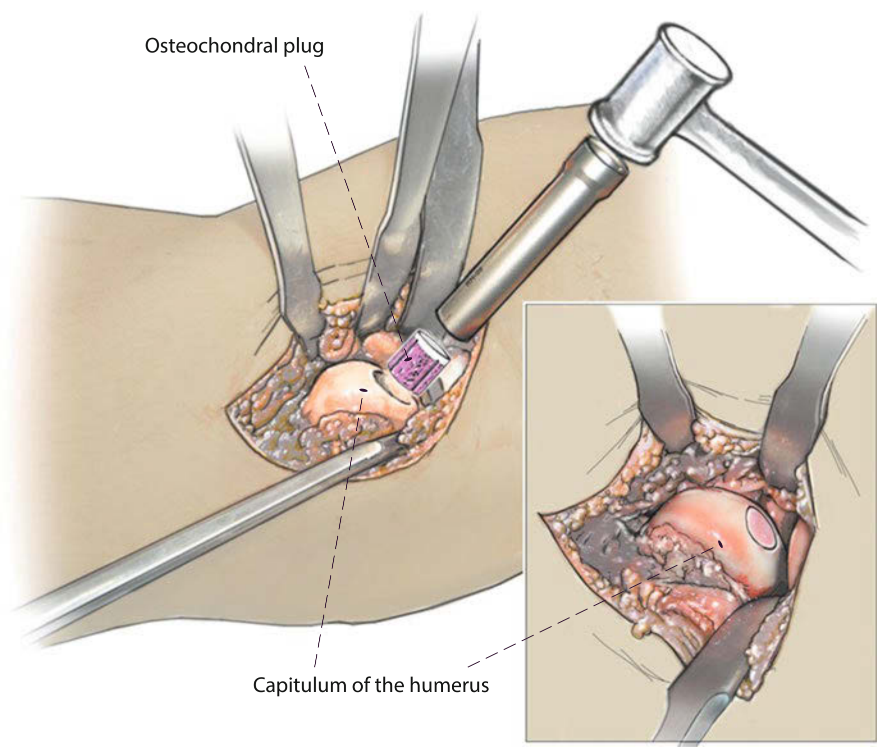

Fig. 9.5a,b **a** insertion of the donor cylinder into the socket created by removal of the lesion at the capitellum, **b** final result

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Tendons

J. Plath, S. Vogt, A. Lenich

A. B. Imhoff, M. J. Feucht (Eds.), *Surgical Atlas of Sports Orthopaedics and Sports Traumatology*,
DOI 10.1007/978-3-662-43776-6_10,

10.1 Repair of the Biceps Tendon

J. Plath, S. Vogt

10.1.1 Indication

Symptomatic rupture of the distal biceps tendon with weakness of the flexion and supination of the elbow joint.

10.1.2 Operation Principle

Open reattachment of the distal biceps tendon to the radial tuberosity using suture anchors or extra- or intramedullary placed buttons.

10.1.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom-specific history: mechanism of injury (sudden maximal eccentric loading of the flexed elbow) symptoms (weakness of flexion and supination of the elbow), previous complaints/operations
- Symptom specific examination: proximal migration of the biceps muscle belly, hematoma in the elbow crease, weakness of flexion and supination in side comparison, positive Hook test.

Imaging

- X-rays of the elbow in two views (a.-p. and lateral) to exclude bony lesions.
- MRI to assess the extent of tendon lesion (complete vs. partial), level of the lesion, tendon quality, retraction of the tendon stump.

Patient Information/Consent

Specific operative risks: heterotopic ossification/radioulnar synostosis, nerve injury (radial, median and musculocutaneous nerves), persistent weakness, loosening, breakage or dislocation of the fixation systems, re-rupture of the tendon.

10.1.4 Surgical Technique

Positioning and Preparation

- Supine position
- The arm to be operated is positioned on a side table with the elbow extended and the forearm supinated.
- A tourniquet is applied to the upper arm (280 mmHg)

Distal Biceps Tendon Repair with Suture Anchors

An s-shaped incision is performed over the antecubital fossa from the radial side proximally to the ulnar side distally (Fig. 10.1). The lateral border of the biceps brachii muscle proximally and the medial border of the brachioradialis muscle distally are used as markers. The musculocutaneous nerve throughout its superficial course over the brachioradialis fascia must be protected and with any doubt, it should be identified and retracted.

The fascia medial to the brachioradialis muscle is incised. Then the radial nerve can be identified and protected proximally between the brachialis and brachioradialis muscles. The proximally retracted torn biceps tendon is then identified and freed of adhesions (Fig. 10.2) and the degenerated segment is resected.

The radial tuberosity is located by palpation in flexion and supination of the elbow. The radial tuberosity is exposed and prepared and the tendon insertion site is freshened. Subsequently, two metallic suture anchor systems (e. g. Corkscrew, Arthrex). An anchor should be inserted in the proximal part and a second anchor in the distal part of the radial tuberosity after predrilling, depending on the anatomical insertion of the tendon (Fig. 10.3a).

The distal tendon stump is whipstitched with one suture end of each anchor for at least 2 cm length in a locking manner (Krakow stitch). The tendon is then repositioned by pulling the other free end of the sutures and then the corresponding suture ends are tied together successively (Figs. 10.3b and 10.4).

Distal Biceps Tendon Repair with Extra- or intramedullary Buttons

Approach and preparation of the tendon stump and the radial tuberosity is performed as described above.

The tendon end is whipstitched with a strong, nonabsorbable suture material (e. g. FiberWire, Arthrex) in Krackow technique, in which stitching is started at the distal end of the tendon in an ascending manner along one edge of the tendon and then continued backwards on the opposite edge of the tendon, so that both suture ends exits from the distal end of the tendon.

The thickness of the tendon is measured using sizing block. The free ends of the sutures are then passed respectively through the two central holes of the button and then tied to the opposite side of the tendon end facing the button. A sufficient distance between the button and the tendon end should be maintained to allow flipping (tilting) of the button on the far cortex. An additional separate suture is passed through each of the button lateral holes (e. g. FiberWire, Arthrex), one is used to pull and the other is used to flip the button. The next step to drill a bicortical hole at the tendon insertion over the radial tuberosity. The forearm is positioned in maximal supination and a guide wire with eyelet is drilled in the center of the radial tuberosity and brought through the far cortex and the skin of the posterior forearm. A cannulated reamer is used

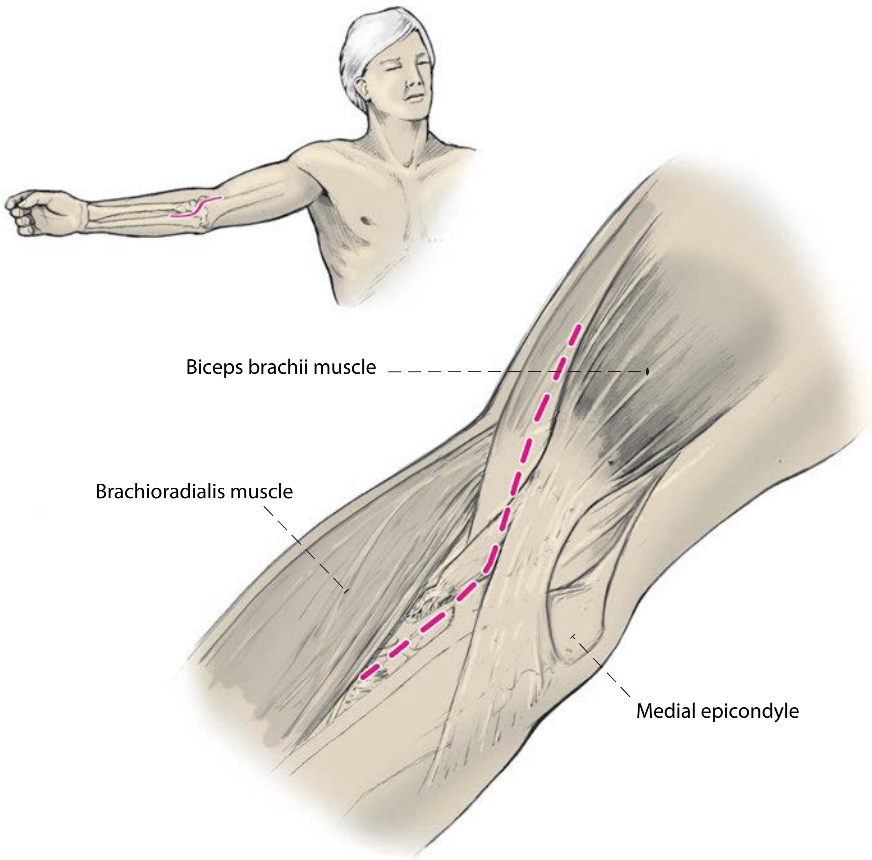


Fig. 10.1 S-shaped skin incision along the lateral border of the biceps brachii and the medial border of the brachioradialis muscles

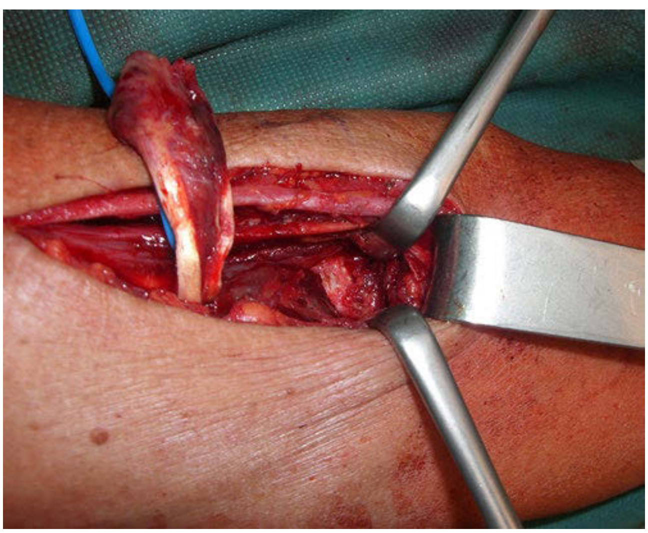


Fig. 10.2 exposure of the biceps tendon stump

to overdrill the guide wire according to the tendon thickness down to far cortex without penetrating it.

The pulling and flipping sutures are pulled through the eyelet of the guide wire (Fig. 10.5a). With the elbow flexed to 90°, the button is pulled through the far cortex using the traction suture and then flipped by pulling the second suture (Fig. 10.5b). Finally, the correct position of the button should be radiologically checked. The traction and flipping sutures can be now carefully pulled through the skin.

10.1.5 Postoperative Management

- A long arm plaster splint or special elbow brace (e.g. Epico ROM, medi) in neutral position is applied
- Checking the peripheral circulation, sensory and motor innervation.
- Postoperative radiograph

10.1.6 Follow-Up Management

Long arm plaster splint or special elbow brace (e.g. Epico ROM, medi) in 90° of flexion is used for 6 weeks. Early functional rehabilitation is started with free passive mobilization and active assisted exercises. Active biceps activity is avoided for 6 weeks. Office activity can be started from the 6th postoperative week, light physical activities from the 12th Week and severe physical activities maximal loads with sport after 14–16 weeks.

Fig. 10.5a,b **a** After drilling of a unicortical hole, the traction and flipping sutures of the button are pulled through the far cortex and the skin of the posterior forearm. **b** final result after pulling the tendon into the hole and flipping the button

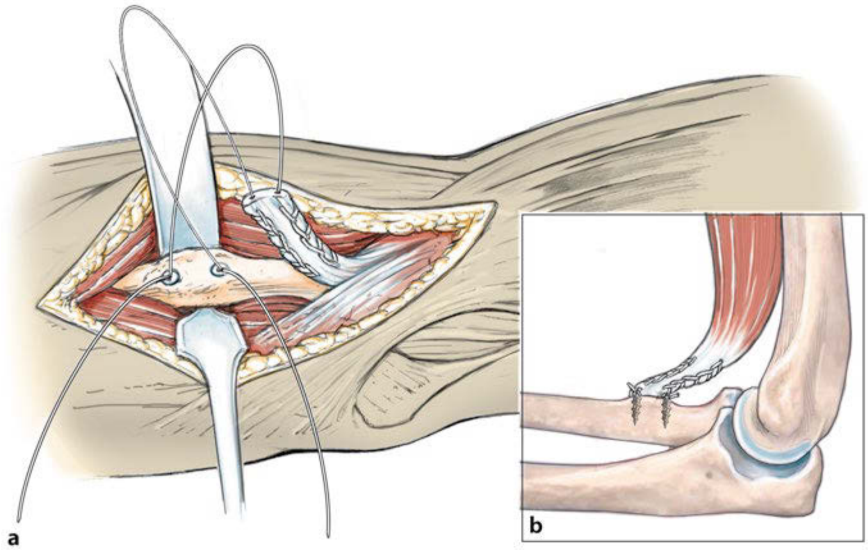
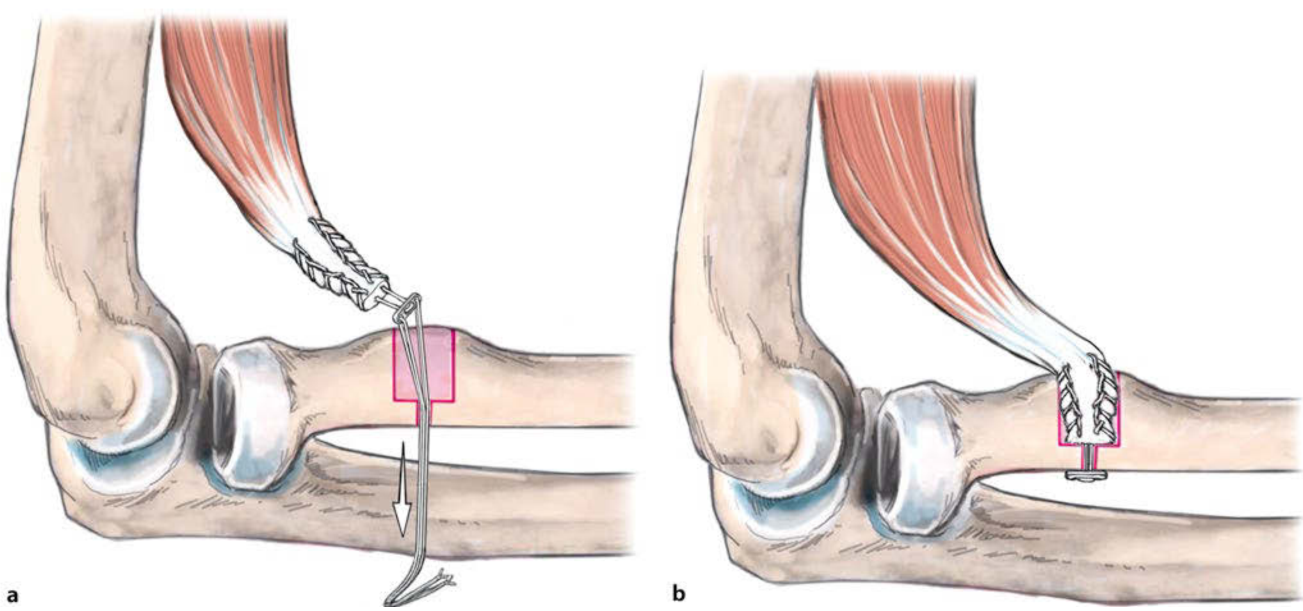


Fig. 10.3a,b **a** Insertion of two suture anchors at the radial tuberosity and whipstitching the tendon **b** Repaired biceps tendon after tying the corresponding pairs of sutures together

Fig. 10.4a,b Postoperative radiographs after biceps tendon repair using 2 suture anchors. **a** a.-p. and **b** lateral views



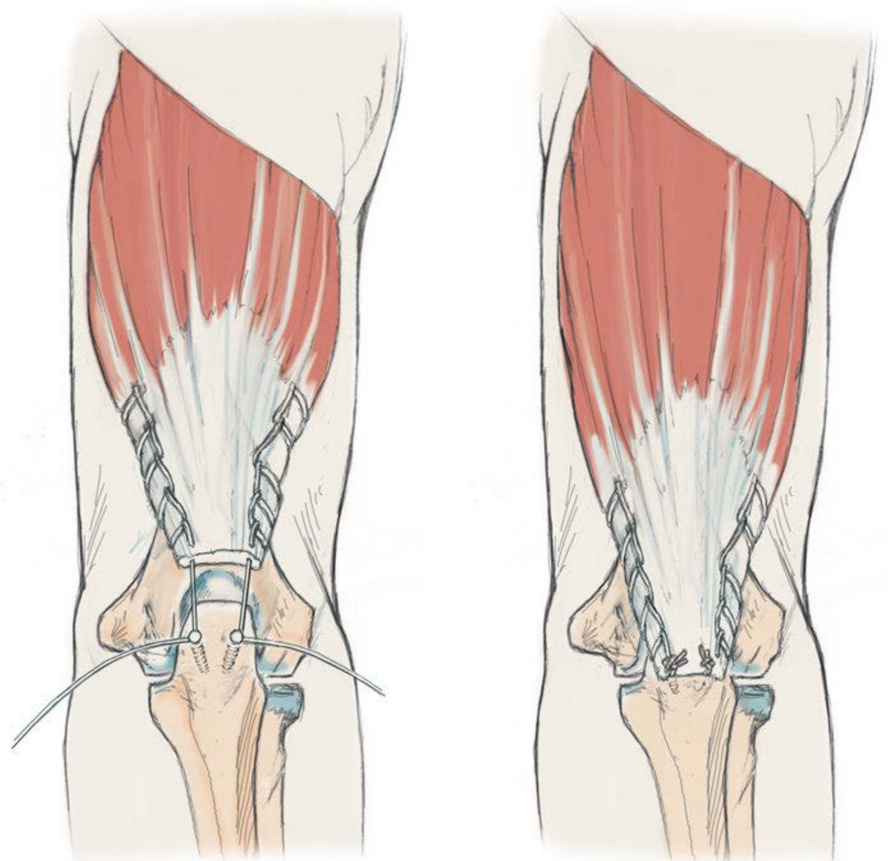


Fig. 10.6 Repair of the triceps tendon to the olecranon using suture anchors

10

10.1.7 Tips & Tricks

Maximal supination of the forearm is necessary during deep dissection and passage of the guide wire to reduce the risk of injury to posterior interosseous nerve (radial nerve).

The branches of the recurrent radial artery should be carefully ligated, to reduce the risk of postoperative bleeding and heterotopic ossification.

Extensive debridement of the near cortex must be avoided when using suture anchors for fixation to avoid reducing the pullout strength of the anchors.

10.2 Repair of the Triceps Tendon

J. Plath, S. Vogt

10.2.1 Indication

Principally, operative reattachment of complete ruptures of the triceps tendon. Primary surgical treatment for partial ruptures > 50 %.

10.2.2 Operation Principle

Open reattachment of the triceps brachii tendon to the olecranon using suture anchors (Fig. 10.6).

10.2.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom-specific history: mechanism of the accident (weight lifting, fall on the outstretched arm with maximal eccentric loading of the extended elbow), steroid abuse, systemic diseases (secondary hyperparathyroidism with chronic renal insufficiency, rheumatoid arthritis, ontogenesis imperfecta, diabetes mellitus), previous complaints (olecranon bursitis) or surgery (elbow fracture).
- Symptom specific examination: hematoma, palpable defect and hematoma over the olecranon; weakness of the elbow extension (residual function with preserved lateral insertion to the fascia of the extensor carpi ulnaris and anconeus)

Imaging

- X-rays of the elbow in two views (a.-p. and lateral) to exclude bony lesions.

- MRI to assess the extent of tendon lesion (complete vs. partial), level of the lesion (avulsion, Intratendinous, musculotendinous junction), tendon quality and retraction of the tendon stump.

Patient Information/Consent

Specific operative risks: nerve injury (ulnar and posterior antebrachial cutaneous nerves), persistent weakness, limited motion particularly the terminal active extension and passive flexion, loosening, breakage or dislocation of the fixation systems, re-rupture of the tendon and soft tissue irritation through the anchors.

10.2.4 Surgical Technique

Positioning and Preparation

- Lateral decubitus or supine position
- Arm is placed in an arm holder and hanged freely in front of the body or with lateral position, the elbow is flexed to 90°
- Tourniquet is not used to avoid restriction during intraoperative triceps mobilization.

Distal Triceps Tendon Repair with Suture Anchors

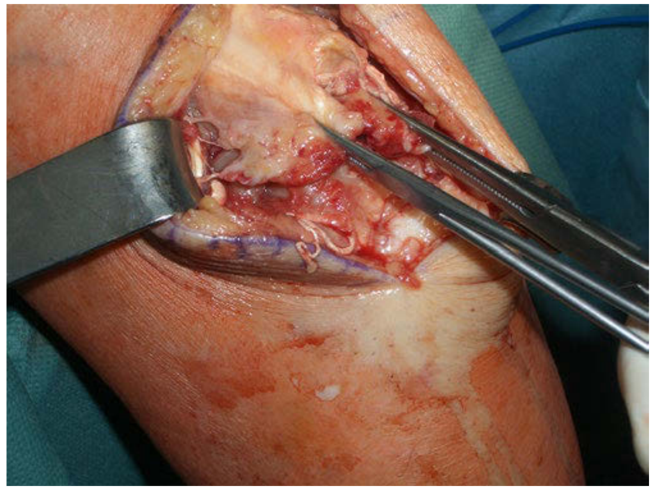
The olecranon is exposed via a posterolateral approach. Skin incision along the lateral border of the triceps brachii muscle extending distally to about 2 cm distal to the tip of the olecranon. The incision can be extended proximally for adequate exposure of the tendon stump (◘ Fig. 10.7).

The triceps foot print on the olecranon is exposed and freshened with a bur or a chisel. Suture anchors are then inserted. Two double loaded metal anchors are used (e.g. Corkscrew loaded with FiberWire, Arthrex), respectively, one medial and the other lateral at the tendon insertion site with a slight inclination distally (◘ Fig. 10.8a). Pre-drilling and tapping before insertion of the anchors are necessary. Anchors should be distally oriented to avoid penetration and breakage into the humeroulnar joint.

The distal tendon stump is then mobilized, the degenerated segment is resected and the tendon stump is whipstitched with continuous locked stitches for a length of at least 3 cm with one limb of each suture anchor (◘ Fig. 10.8b). The tendon is then repositioned by pulling on the free ends of the sutures which are then successively tied together (◘ Fig. 10.9).

10.2.5 Postoperative Management

- An elbow brace (e.g. Epico ROM, medi) fixed in 45° flexion is applied
- Checking the peripheral circulation, sensory and motor innervation.



◘ **Fig. 10.7** Exposure of the tendon stump

- Postoperative radiograph (◘ Fig. 10.10)

10.2.6 Follow-Up Management

An elbow brace (e.g. Epico ROM, medi) is used for 6 weeks. In the 1–2. Week passive exercises outside the brace to avoid elbow stiffness. Starting from the 3rd week, free passive and active -assisted physiotherapeutic exercises are allowed, active triceps contraction is not allowed for 6 weeks, gradual strengthening of the triceps brachii is allowed after 6 weeks postoperatively. Office activity is allowed after about 6 weeks postoperatively, slight physical activities after 12 weeks, heavy physical work and maximal loading with sport (weight lifting) after 4–6 months.

10.2.7 Tips & Tricks

The skin incision should be carried out lateral to the olecranon and not central to ensure adequate soft tissue coverage and avoid endangering the wound healing.

Extensive debridement of the near cortex must be avoided when using suture anchors for fixation to avoid reducing the pullout strength and stability of the anchors.

10.3 Surgical Treatment of Lateral Epicondylitis (Hohmann Technique)

J. Plath, S. Vogt

10.3.1 Indication

Lateral epicondylitis resistant to treatment despite intensive conservative measures for more than 6 months.

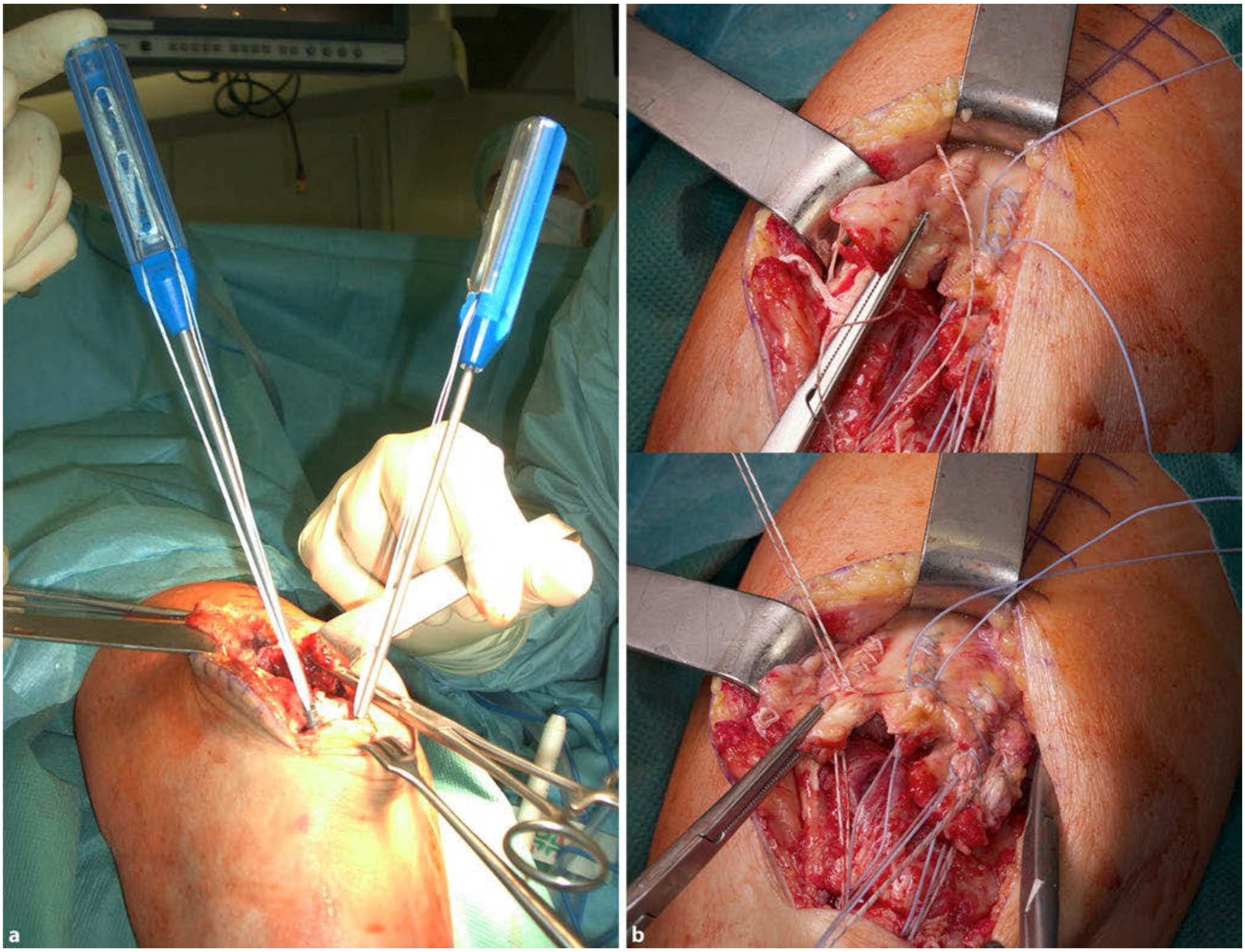


Fig. 10.8a,b **a** Insertion of two suture anchors at the insertion of the triceps tendon on the olecranon; **b** whipstitching the tendon stump

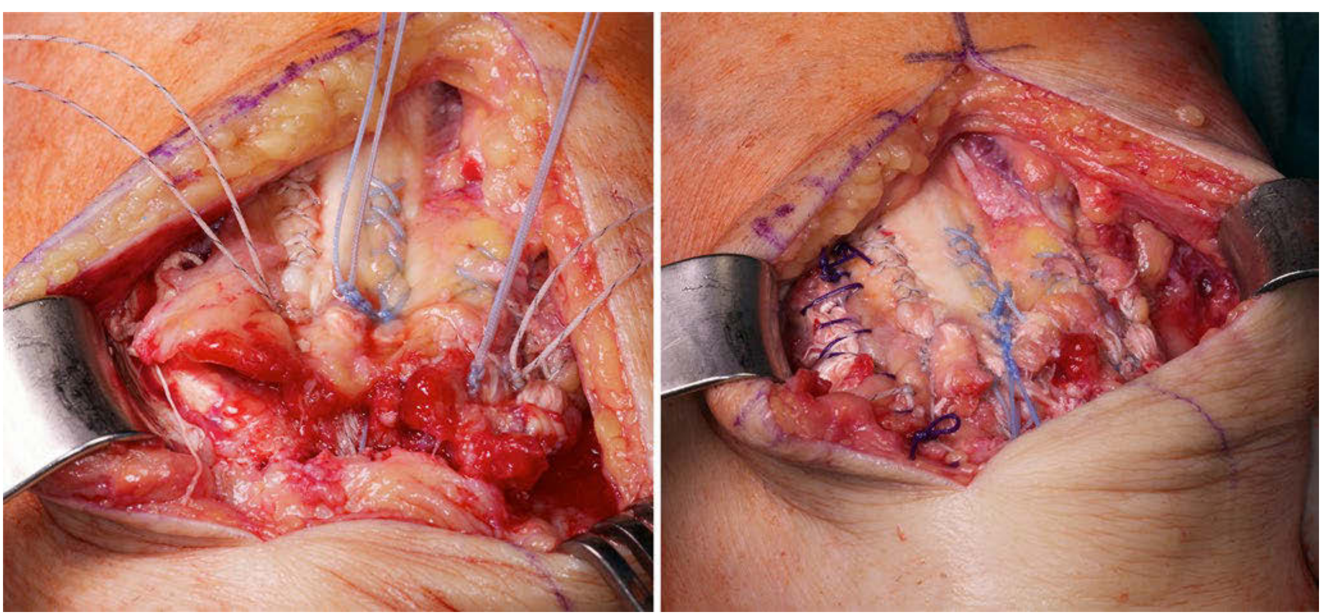


Fig. 10.9 Repositioning of the tendon after tying the sutures together

■ **Fig. 10.10a,b** Postoperative radiographs after triceps tendon repair using 2 suture anchors. **a** a.-p. view; **b** lateral view

10.3.2 Operation Principle

Excision of the pathological tendon tissue, denervation, desinsertion of the inflamed tendons and healing with elongated fibrous tissue.

10.3.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom-specific history: symptoms and its duration, previous conservative measures, recent cortisone injections, job circumstances
- Symptom specific examination: tenderness over the lateral humeral epicondyle, Mill test (pain induced with passive stretching of the tendons), Cozen test (Pain induced with dorsiflexion against resistance), middle finger pain provocation (pain at the lateral epicondyle induced with dorsiflexion of the middle finger against resistance)

Imaging

- X-rays of the elbow in two views (a.-p. and lateral) to exclude bony lesions.
- An MRI is not generally necessary for diagnosis, only to confirm the diagnosis or with suspected intra-articular pathologies

Patient Information/Consent

Specific operative risks: injury to the lateral collateral ligament, formation of joint fistulas with joint penetration or recurrence with inadequate debridement.

10.3.4 Surgical Technique

Positioning and Preparation

- Supine position
- The arm to be operated is positioned on a side table with the elbow flexed , forearm pronated and sterile roll below the hand.
- A tourniquet is applied to the upper arm (280 mmHg)

Release of the Extensor Carpi Radialis Brevis Muscle (Hohmann Technique)

Curved skin incision for about 4 cm anterior to the lateral epicondyle (■ Fig. 10.11), and exposure of the extensor aponeurosis. The insertion of the extensor carpi radialis brevis (ECRB) lies beneath the muscle belly of the extensor carpi radialis longus (ECRL) anteriorly and covered posteriorly by the fascia of the extensor digitorum muscle (ED) (■ Fig. 10.12). The extensor aponeurosis is sharply incised at its anterior edge, in the area of the palpable groove at the margin of the muscle belly of the ECRL.

The ECRL muscle belly is detached from the ECRB insertion and retracted medially with a Langenbeck retractor. The ECRB fibers can be recognized from its degenerative thickened appearance. Sharp subperiosteal detachment and removal of the ECRB fibers from the epicondyle (■ Fig. 10.13). Debridement here is performed strictly anterior to the lateral epicondyle in order not to compromise the lateral collateral ligament.

After resection of the degenerated tendon segment, decortication of the exposed lateral epicondyle with a bone nibbler or a sharp spoon curette to obtain local bleeding into the defect (■ Fig. 10.14).

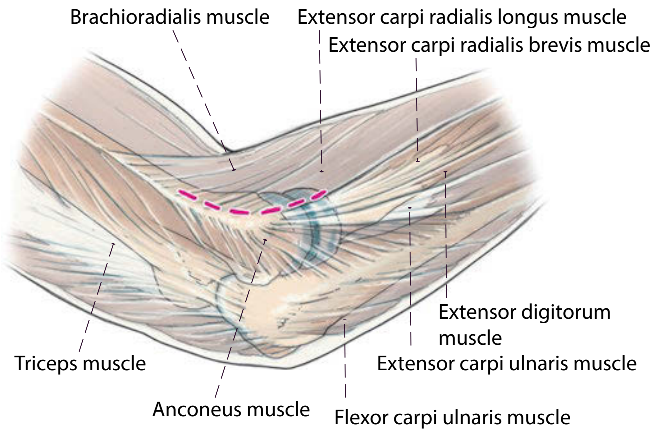


Fig. 10.11 About 4 cm long curved incision anterior to the lateral epicondyle

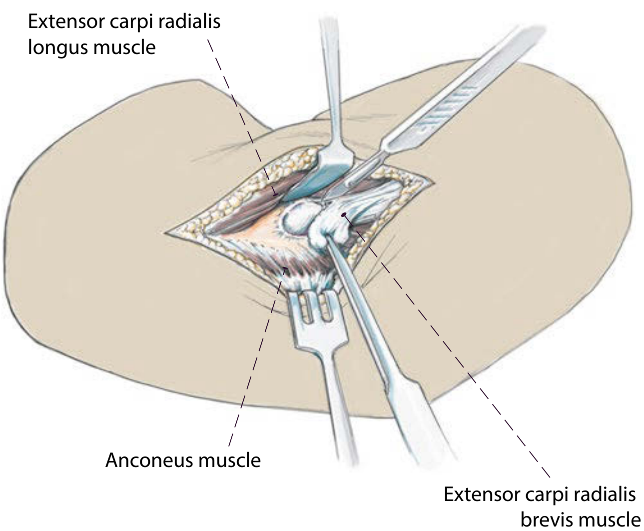


Fig. 10.13 Subperiosteal release of ECRB

10.3.5 Postoperative Management

- The arm is immobilized in a sling
- Checking the peripheral circulation, sensory and motor innervation.
- Postoperative radiograph

10.3.6 Follow-Up Management

The arm is immobilized in a sling for 2 weeks. In the 1st–6th postoperative weeks: free movement of the elbow and adjacent joints is allowed, passive stretching of the extensor origin without excessive load of the elbow allowed. From the 6th week: muscle strengthening and active stretching and from the 12th week return to the sport are allowed.

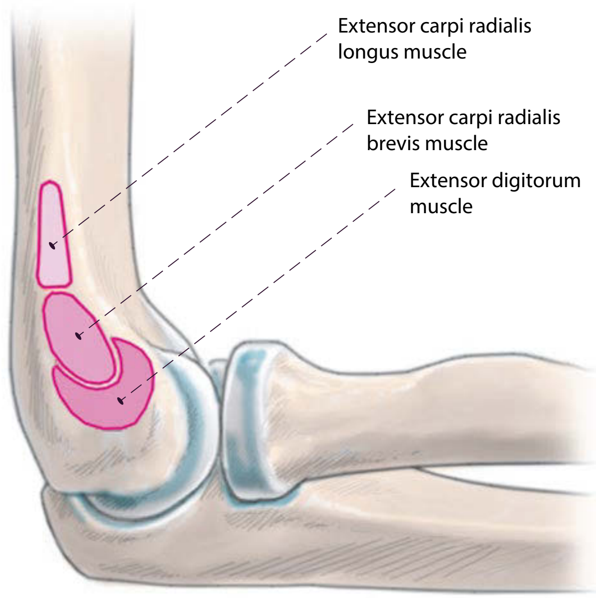


Fig. 10.12 Insertion area of the extensor tendons

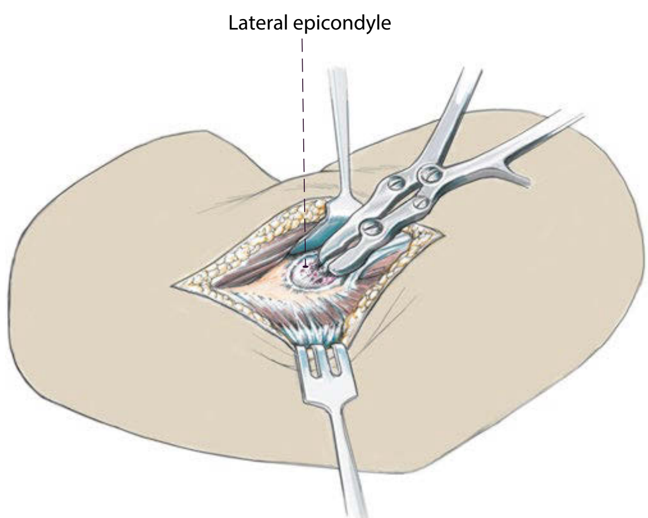


Fig. 10.14 Decortication of the exposed epicondyle with a bone nibbler

10.3.7 Tips & Tricks

Careful exposure of the ECRB insertion is necessary to identify the degenerated part of the tendon.

Excessive debridement posteriorly is not allowed to protect the lateral collateral ligament.

In some cases, the lateral joint capsule is opened during debridement. This should be thoroughly sealed be to prevent formation of a fistula.

10.4 Radial Stabilization

A. Lenich, J. Plath

10.4.1 Indication

Chronic posterolateral elbow instability.

10.4.2 Operation Principle

Restitution of posterolateral elbow stability by reconstructing the lateral ulnar collateral ligament (LUCL) with an autologous triceps flap.

10.4.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom-specific history: Elbow dislocation (number, mechanism of injury, type), subjective instability, limitation of the daily life activities, work and leisure activities, elbow pain more marked laterally, underlying diseases (rheumatoid arthritis), side dominance, previous surgeries (especially desinsertion of the extensor origin)
- Symptom Specific examination: tenderness at the lateral epicondyle or the olecranon, pivot shift test of the elbow (posterior subluxation of the radial head under valgus stress and axial loading in maximal supination with spontaneous reduction in flexion), pain and instability with resistive movements with the arm in supination, improved with pronation, signs of generalized hyperlaxity.

Imaging

- X-rays of the elbow in two views (a.-p. and lateral) to exclude a bony avulsion, assess the degree of osteoarthritis and to exclude open growth plates -.
- Dynamic examination of the lateral elbow stability using an image intensifier (under anesthesia)
- MRI to assess the extent of LUCL lesion (complete vs. partial) and accompanying ligamentous and cartilage injuries

Patient Information/Consent

Specific operative risks: persistent instability, loosening, breakage or dislocation of the fixation systems, postoperative limitation of movement due to tunnel misplacement.

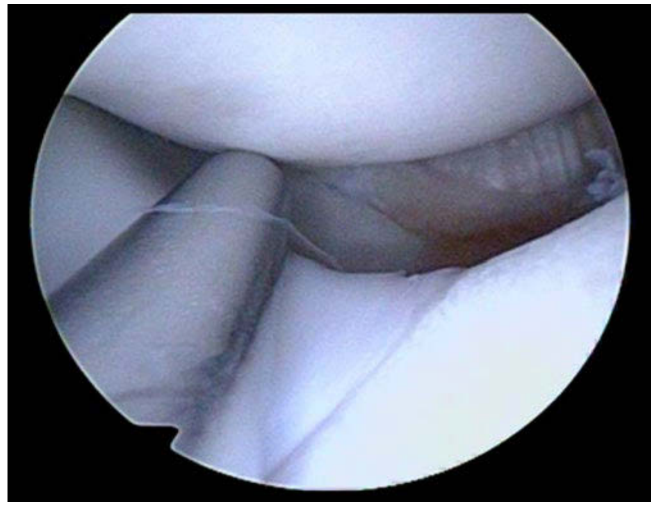


Fig. 10.15 Arthroscopic examination of the stability of the radiohumeral joint using a switching stick

10.4.4 Surgical Technique

Positioning and Preparation

- Lateral decubitus
- Arm is placed over a roll and can be flexed to at least 110°, the arm should remain sterile after being removed from the half-shell and the roll should be removable to allow ligamentous reconstruction or dealing with the radial head after performing the arthroscopy.
- Re-evaluation of elbow stability under anesthesia
- An arm tourniquet is applied with 240 mmHg

LUCL Replacement Ligament Reconstruction with Autologous Triceps Flap

A diagnostic arthroscopic is performed at the beginning with photo documentation. Evaluation of the stability with a switching stick should be given a special consideration (Fig. 10.15). A distance between the tip of the olecranon and the osteochondral margin of the fossa in 90° flexed elbow of > 7 mm is indicative of radio-humeral instability. If the clinical diagnosis is confirmed, the arthroscopy is finished and the arm is positioned sterile on a movable side table in the lateral position.

The posterior transtendon portal is extended laterally over the mid-lateral portal (skin incision of approximately 10 cm length). The triceps tendon is exposed. On the ulnar side, the thickened triceps aponeurosis is palpated and a flap of about 7–8 cm length and 0.5–1 cm width is isolated (Fig. 10.16a). After harvesting the tendon flap, the resultant defect in the triceps aponeurosis is closed with continuous Vicryl sutures. The graft is then whipstitched with FiberWire No. 2 sutures at both ends and the thickness is measured (Fig. 10.16b).

The lateral condyle and epicondyle are exposed after subperiosteal dissection of the extensor muscles anteriorly and the insertion of the LUCL is identified (Fig. 10.17a).

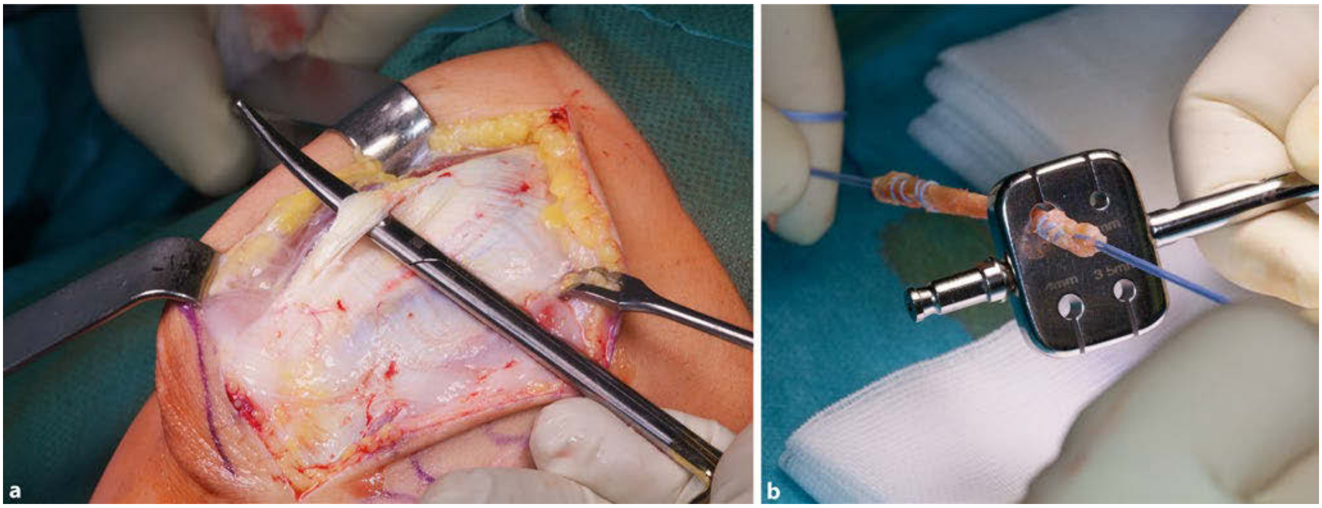


Fig. 10.16a,b Graft harvesting and preparation. **a** Harvesting the ulnar part of the triceps aponeurosis (7–8 cm long) **b** Assessing the graft thickness after whipstitching both ends

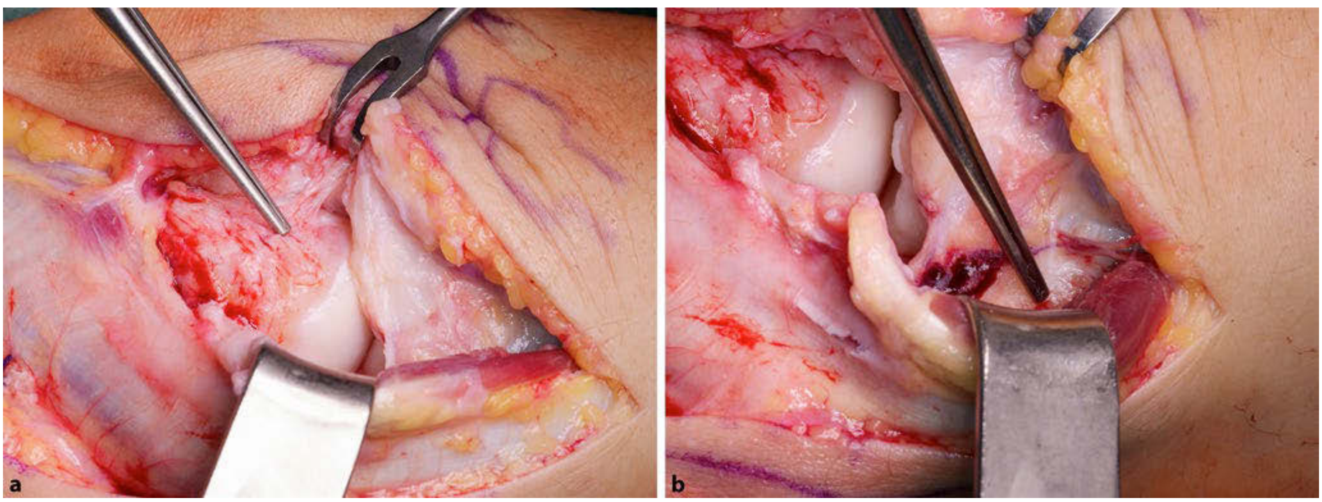


Fig. 10.17a,b Exposure of the points of insertion of the LUCL. **a** humeral insertion **b** ulnar insertion

The proximal ulna is exposed down to the distal insertion of the LUCL (Fig. 10.17b). Guide wires are inserted at the isometric center of the humeral insertion as well as the center of the ligament insertion on the proximal ulna and directed toward the olecranon fossa. Isometricity is tested using a suture loop (Fig. 10.18). Bicortical overdrilling on the humeral side and unicortical drilling on the ulnar side over the guide wires with a 4-mm spiral cannulated drill bit. The graft is fixed first to the ulnar side using either an intramedullary biceps button (Arthrex. Fig. 10.19), or a suture anchor (e. g. 3.5 mm Bio-Corkscrew, Arthrex). One suture end from the humeral side of the graft is shuttled through the humeral drill hole and the graft is fixed proximally using a tenodesis screw (Fig. 10.20a,b). Additionally, both suture ends are tied together over the isometric center. The knot should come to rest within the drill hole (Fig. 10.20c). Free elbow flexion and-extension is then checked. A uniform graft tension throughout the entire range of motion indicates correct positioning of the graft.

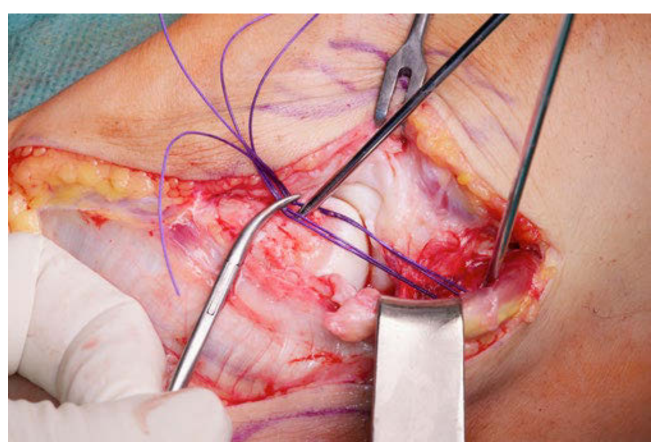


Fig. 10.18 Testing for the Isometricity with a suture loo after placement of guide wires at the center of the proximal and distal ligament insertion

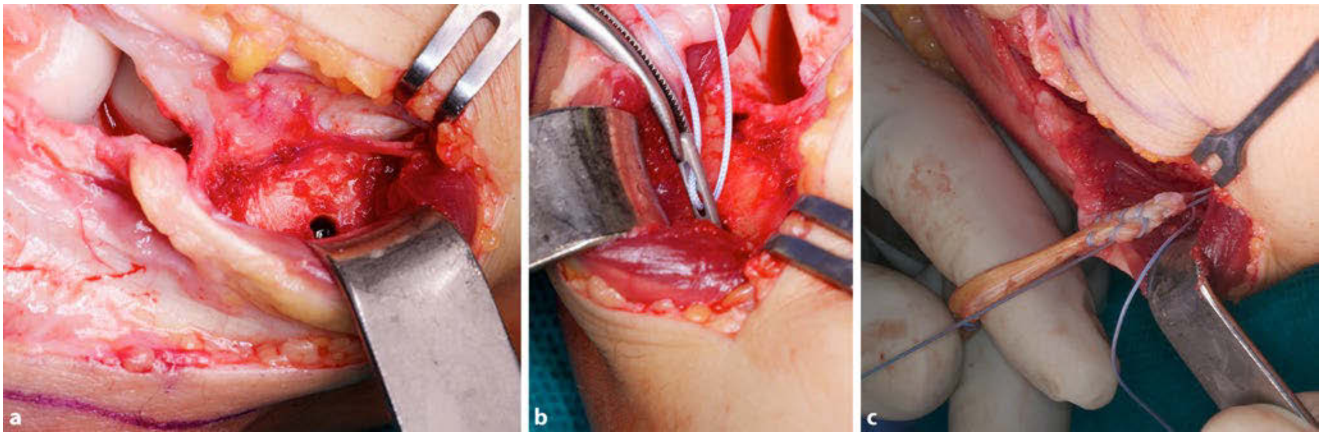


Fig. 10.19a–c Fixation of the graft on the ulnar side. **a** unicortical tunnel at the ulnar ligament insertion **b** intramedullary insertion of the biceps button **c** pulling the graft into the tunnel

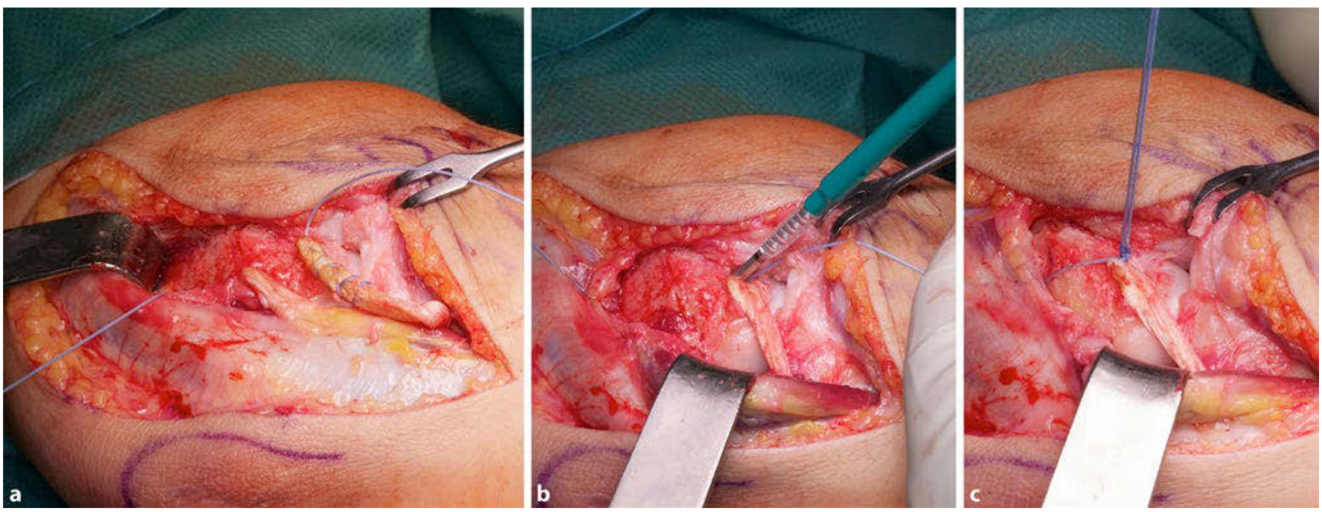


Fig. 10.20a–c Fixation of the graft on the humeral side. **a** Shuttling one suture end of the proximal end of the graft through the humeral tunnel **b** graft fixation with a tenodesis screw **c** tying both ends of the pulling sutures over the isometric center

The extensor muscles are then reattached using a double loaded 3,0-mm Bio-FASTak anchor (Arthrex) anterior to the humeral tenodesis screw (Fig. 10.20a), a second row using the available FiberWire sutures is added over the isometric center and a third reinforcement with transosseous sutures posterior and proximal (Fig. 10.21b). The sutures of the first and second rows are fixed posteriorly to the lateral condyle using a PushLock anchor (Arthrex) (Fig. 10.21c).

10.4.5 Postoperative Management

- Checking the peripheral circulation, sensory and motor innervation.
- An Epico ROM hinged elbow brace (Medi).
- Postoperative radiograph

10.4.6 Follow-Up Management

An Epico ROM hinged elbow brace is used with limitation of the extension/flexion to 0°/20°/90° for 2 weeks without pro-/supination, then two weeks 0°/10°/100° and 2 weeks 0°/0°/120°. From the 7^{th} postoperative week free range of motion is allowed with full load after 12 weeks.

10.4.7 Tips & Tricks

The pivot-shift test is very difficult to be performed in the awake patient because of the muscular counter contraction. A clinical examination or radiological confirmation short acting anesthesia is recommended when there is still clinical suspicion.

If the isometric center of the humeral LUCL insertion can't be identified from the ligament remnants, it could be identified by palpating the lateral condyle and if necessary using an image intensifier to localize it with K-wire. The iso-

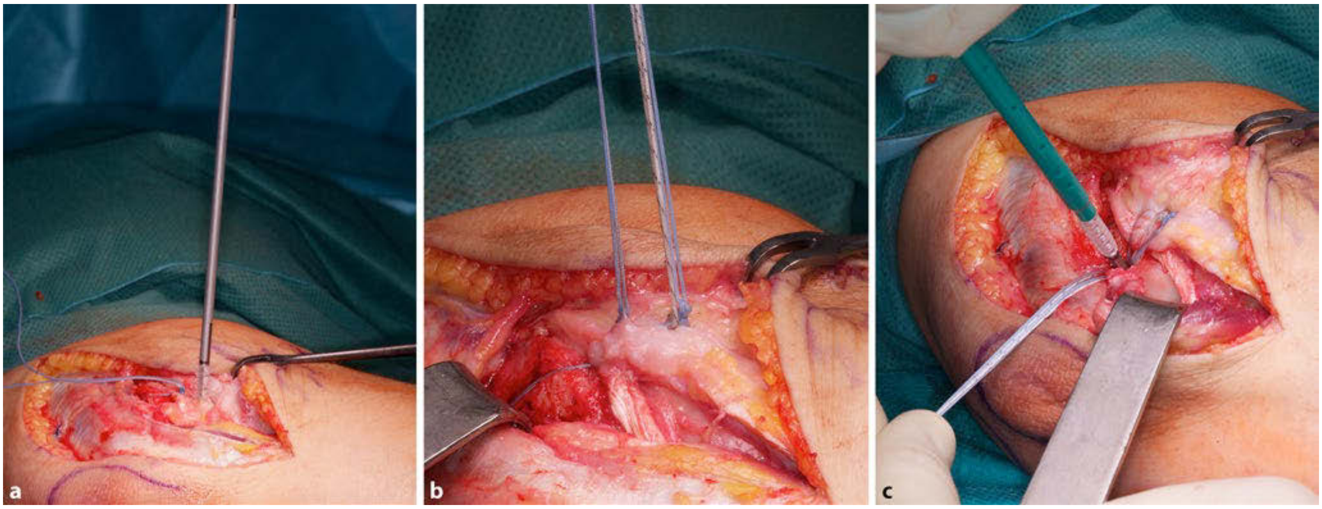


Fig. 10.21a–c Reattachment of the extensor muscles. **a** 3.0-mm Bio-FASTak anchor is inserted anterior to the humeral tenodesis screw; **b** Sutures are then passed through the extensors and the belonging suture ends are tied together; **c** Final fixation of the suture ends with a PushLock anchor posterior in the lateral condyle

metric center represents the midpoint of the lateral condyle circle. A perpendicular placement to both condyle is important here.

10.5 Arthrolysis

J. Plath, S. Vogt

10.5.1 Indication

Loss of the functional range of motion resistant to treatment for more than 6 months; extension/flexion 0°/30°/130° or pronation/supination 50°/0°/50° ("functional arc" by Morrey).

Conditions in which with conservative therapy no gain can be expected (blocking osteophytes, heterotopic ossification, non-or malunion, blocking implants, ulnar neuropathy).

- Arthroscopic arthrolysis: in mild loss of ROM < 30°, intra-articular pathology or capsular contracture.
- Open arthrolysis ("lateral column procedure"): pronounced findings with > 30° loss of ROM due to extra-, intra-articular or combined causes
- Open arthrolysis ("Outerbridge-Kashiwagi procedure"): In arthritic elbow with bony blocking due to osteophytes or loosed bodies.

10.5.2 Operation Principle

Release and resection of all pathological segments of the capsule, removal of osteophytes or loose bodies blocking the movements particularly in the region of the olecranon, coronoid process as well as the olecranon and coronoid fossae (Figs. 10.22 and 10.23).

10.5.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: course and duration of symptoms, side dominance, restriction (activities of daily life, work, leisure), previous treatments, previous surgery, implants, complications.
- Symptom specific examination: accurate documentation of the flexion, extension, pronation and supination range of motion, hard/soft limitation of movement, inspection for scars/previous surgery, pain on motion, condition of the elbow muscles.

Neurological/Vascular Condition

Preoperative neurological evaluation of the peripheral sensory function, particularly the ulnar nerve, assessing the peripheral perfusion.

Imaging

- X-rays of the elbow in two views (a.-p. and lateral) to assess the bony condition (osteophytes, malalignment, loose bodies, heterotopic ossification); additional special views to assess the individual compartments are possible.
- MRI to assess the soft tissues e. g. scarring, neurovascular bundles (ulnar tunnel syndrome), size and location of loose bodies, depth of the olecranon and coronoid fossae, chondropathies.
- CT for the precise localization of osteophytes, loose bodies and heterotopic ossification as well as to evaluate fracture healing, joint congruency and malalignment.

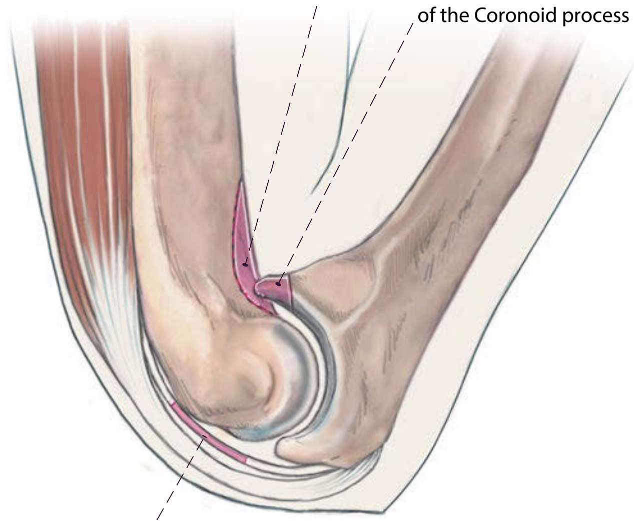


Fig. 10.22 Therapeutic options for flexion deficit: release of the triceps tendon from the distal humerus, partial resection of the posterior capsule, partial resection of the coronoid process, debridement of coronoid fossa

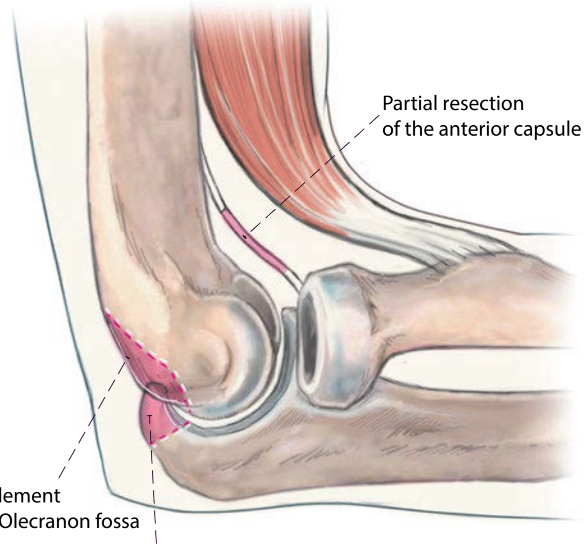


Fig. 10.23 Therapeutic options for extension deficit: partial resection of the anterior capsule, partial resection of the olecranon, debridement of the olecranon fossa

Patient Information/Consent

Specific operative risks: Usually only limited improvement in the range of motion can be achieved, long and intensive postoperative rehabilitation (requires high compliance), fracture, nerve damage esp. the ulnar nerve, recurrence, collateral ligament injury and elbow instability.

10.5.4 Surgical Technique

Positioning and Preparation

Arthroscopic Arthrolysis

- Lateral decubitus
- Re-evaluation of elbow motion under anesthesia
- An arm tourniquet is applied (280 mmHg)

Open Arthrolysis

- Supine position
- The arm is placed over a side table
- An arm tourniquet is applied (280 mmHg – Creating a upper arm tourniquet (280 mmHg)

Arthroscopic Arthrolysis

Landmarks and portals are precisely identified and marked. This is markedly difficult due to the intra-articular adhesions and thus increases the risk of neurovascular complications. The elbow joint is distended using the mid-lateral posterolateral portal. Often only 15–20 ml or less can be injected due to the tight capsule. The standard anterolateral portal is established to perform a diagnostic arthroscopy of the anterior compartment. Adhesions between the capsule and the anterior humerus can released by gentle sweeping motion of the trocar increasing the initial space for the diagnostic arthroscopy. The anteromedial working portal is then established in outside-in technique and a working cannula is inserted. Loose bodies and scar tissue are removed with the motorized shaver. Fibrous strands can be cut using a hooked electrocautery. Osteophytes blocking movements are resected with the burr or osteotome.

Viewing and working portals could be variably used as required to reach all parts of the anterior elbow joint. Furthermore, it can be very helpful to establish an accessory portal for the insertion of a soft tissue retractor. The mid-lateral portal can be used for this purpose. Anterior capsular release is then performed where the capsule is released from medial to lateral. A punch (basket or duckbill) is used to perform capsulotomy of the dorsal lateral parts where the radial nerve lies directly anterior to the capsule.

After completion of the anterior arthrolysis, a superior posterolateral portal is established for visualization of the posterior joint compartment. Adhesions here can be also released using a trocar directed towards the olecranon fossa with gentle sweeping motion

For visualization, an additional transtendinous superoposterior portal is established. Adhesions are released and osteophyte blocking the motion are resected similar to the anterior joint. Loose bodies are more commonly found in the posteromedial or the lateral gutters and are removed with the shaver or a grasper.

Subsequently, posterior capsular release is performed. The posterior capsule is sharply released from the distal humerus. Great care must be taken on the medial side where the ulnar nerve lies. The posterior radiohumeral joint can now be visualized via the posterolateral portal and the fibrous tissue can

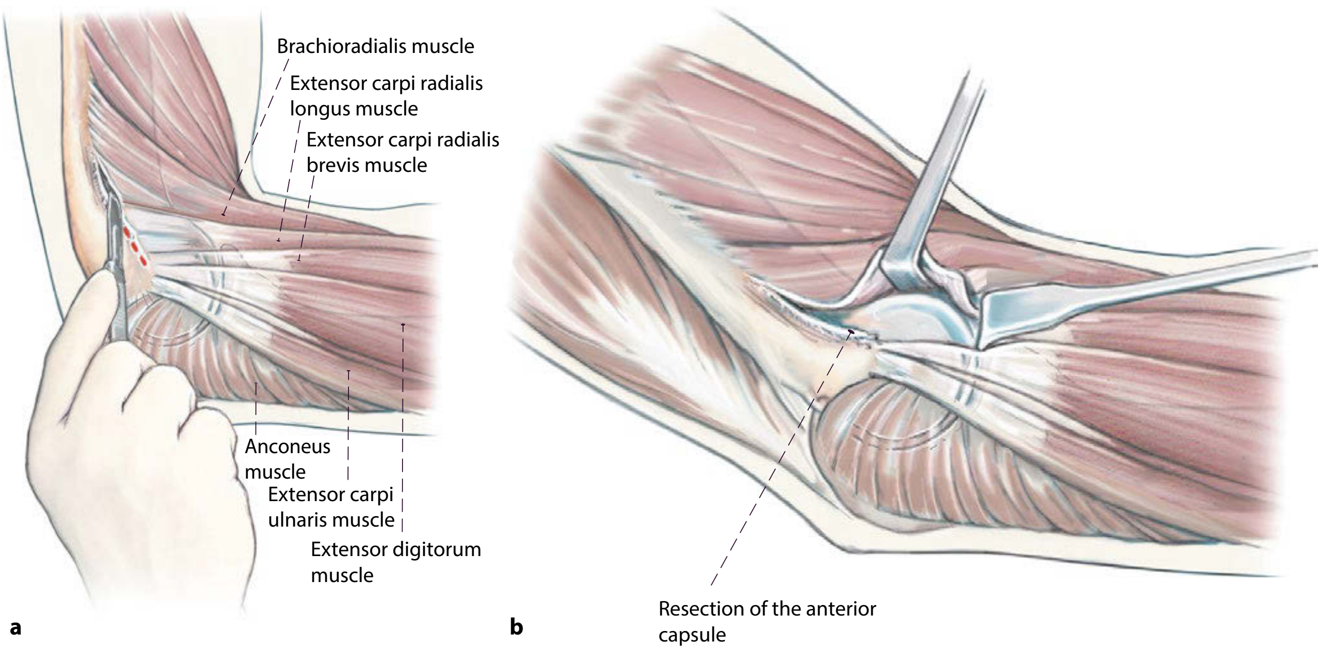


Fig. 10.24 Releasing the distal part of the origin of the brachioradialis, extensor carpi radialis longus and if needed also the extensor carpi radialis brevis and excision of the underlying anterior capsule

be removed through the mid-lateral portal. At the end, the elbow is mobilized und under arthroscopic visualization to exclude any remaining mechanical limitation to movement.

Open Arthrolysis ("Lateral Column Procedure")

The lateral part of the joint is exposed via a lateral approach. A curved skin incision starting just proximal to the lateral epicondyle and extending for about 6 cm and extending distally to end about 3 cm distal to the epicondyle.

Release starts anteriorly with extension deficits. This begins with sharp release of the origins of the distal brachioradialis, extensor carpi radialis longus and if necessary the extensor carpi radialis brevis (Fig. 10.24). The released muscle origins are elevated together with the brachialis muscle from the anterior elbow capsule and retracted medially together with radial artery and nerve. The anterior capsule is incised above the radiohumeral joint and the capsule is excised down to the level of the coronoid process (Fig. 10.24). The lateral collateral ligament must be here protected. The non-visualized medial part of the joint capsule are palpated and released to complete the anterior release.

In the presence of flexion deficit one must check for the presence of mechanical causes in the coronoid and radial fossae as well as the coronoid process.

Soft tissues or loose bodies in the fossae are removed with a sharp spoon curette and osteophytes of the coronoid process are removed with the osteotome (Fig. 10.22).

Extension and flexion are then assessed. If there is extension deficit of > 10° with limited flexion of < 130° an additional posterior release is then needed. In such case the triceps tendon is released from the distal humerus and the posterior elbow capsule. The interval between the anconeus and extensor carpi ulnaris is developed and the anconeus is released from the humerus (Fig. 10.25). The posterior capsule is detached from the distal humerus with a sharp periosteal elevator. Care should be taken by releasing medially to avoid ulnar nerve injury and if there is any doubt, the ulnar nerve may be exposed and protected via an additional medial approach.

With persistent extension deficit despite anterior release, the olecranon and olecranon fossa should be inspected for mechanical causes and loose bodies, soft tissues or osteophytes blocking the extension must be removed (Fig. 10.23).

Open Arthrolysis ("Outerbridge-Kashiwagi Procedure")

Posterior approach to the elbow joint. The skin incision runs on the central posterior aspect of the arm extending from the tip of the olecranon proximally for approx. 6 cm. The triceps muscle is split in line of its fibers to expose the posterior joint compartment.

Osteophytes over the olecranon and in the olecranon fossa are removed with the osteotome and loos bodies are removed. A widow is made through the olecranon fossa with a chisel or drill pit bit (Fig. 10.26). This allows the resection of loose bodies in the anterior compartment as well as removal of osteophytes from the coronoid process.

10.5.5 Postoperative Management

- Two plaster cast splits are made, in the position of maximal attainable flexion and extension

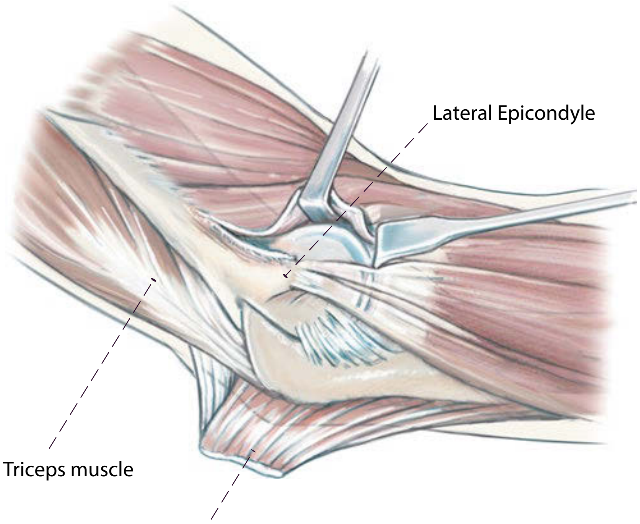


Fig. 10.25 Releasing the anconeus from the humerus

- Checking the peripheral circulation, motor and sensory innervation.
- Postoperative radiograph

10.5.6 Follow-Up Management

4- to 6-hourly alternation of the elbow position in flexion-extension splints for 48 h, followed by the use of a CPM machine. Brachial plexus block for at least 3 days, then adequate pain control (PCA). NSAIDs (indomethacin) for prophylaxis against heterotopic ossification as well as muscle relaxant. Multiple daily exercise and physiotherapy settings.

10.5.7 Tips & Tricks

Arthroscopic arthrolysis is technically demanding and associated with a high risk of iatrogenic neurovascular injuries and therefore should be only done by an experienced arthroscopic surgeon. A complete medical history regarding the previous surgery (implants, ulnar nerve transposition) must be preoperatively documented.

With reduced range of flexion to < 100°, or pre-existing ulnar nerve neuropathy an accompanying ulnar nerve decompression should be performed. Capsular release is performed only after completion of the debridement to avoid inappropriate reduction of the intra-capsular pressure and thus reduction of the quality of the arthroscopic view. For the same reason, removal of large loose bodies that requires capsulotomy are postponed towards the end of the procedure.

Portal placement into the anterior compartment is very difficult due to the close relationship to the course of the important neurovascular structures. For this reason, anterior arthrolysis is performed at the beginning of the procedure as the portal placement would be more difficult after starting the arthroscopy due to soft tissue swelling.

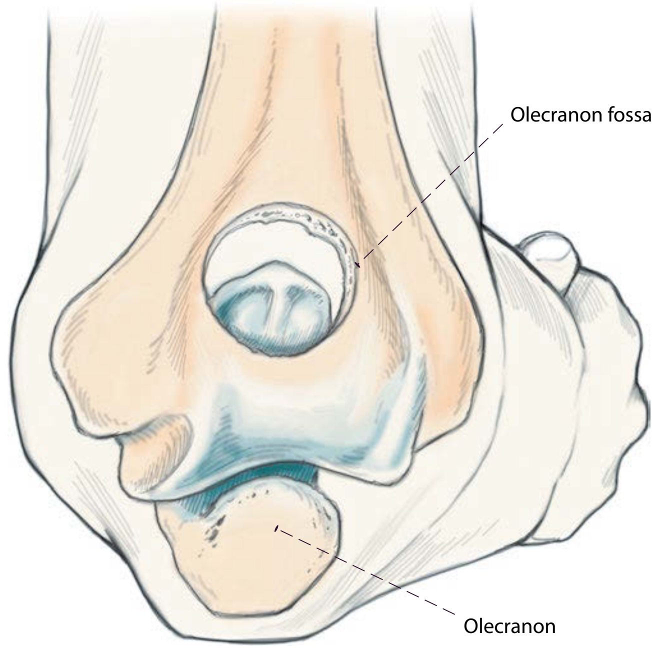


Fig. 10.26 A cortical window through the olecranon fossa

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Hip and Pelvis

Patient Positioning, Portals, and Impingement

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11.1 Patient Positioning, Arthroscopic Portals, Diagnostic Arthroscopy

C. Mella

11.1.1 Indication

The most common indication for hip arthroscopy currently is the treatment of femoroacetabular impingement (FAI) with secondary injury to the cartilage and the acetabular labrum. Other indications include synovial diseases (chondromatosis, localized pigmented villonodular synovitis [PVNS] and septic arthritis), post-traumatic conditions (loose bodies, labral tears, ligamentum teres injuries). The spectrum of hip arthroscopy has expanded in the last few years to involve management of periarticular disorders, e.g. coxa saltans (snapping hip), psoas tendinitis, injuries of gluteus medius tendon, etc.

Osteoarthritis of the hip is not an indication for arthroscopy, however in some selected cases it may be used to temporarily alleviate the symptoms.

11.1.2 Patient Positioning and Preparation

Fracture table is essential for performing hip arthroscopy to allow distraction and opening of the central compartment of the joint (Fig. 11.1). The patient could be positioned in either supine or lateral position (surgeon's preference). Padding and fixation of the foot to the distraction device should be done very carefully to avoid loosening of the foot during the surgery or injuries resulting from excessive pressure with strong distraction. The perineal post should be also padded with a cushion to prevent pressure injuries to the skin and decrease the risk of pudendal nerve injury. The leg is positioned in slight abduction, 20° flexion and internal rotation (to relax the anterior joint capsule).

Distraction

After positioning a trial distraction is done to check the stability of the positioning and the distractibility and opening of the joint. The contralateral leg is mildly distracted (manually) to avoid tilting of the pelvis with traction. The leg to be operated on is then gradually distracted and the degree of distraction is confirmed with an image intensifier introduced from the contralateral side (adequate opening of the joint space > 10 mm). The stability of the distraction construct is confirmed once again and the traction is then released completely, the skin is disinfected and the surgical field is fully prepared. This approach is advisable to minimize the duration of traction. The total duration of intraoperative distraction should not exceed 120 minutes.

11.1.3 Arthroscopic Portals

Relevant skin landmarks for portal placement are marked after beginning the operation and distracting the hip. (Fig. 11.2) These landmarks include greater trochanter (GT), iliac crest and anterior superior iliac spine (ASIS). An imaginary line between the middle of the Patella and ASIS is also marked. Several portals have been described by many authors (Byrd, Dienst Philippon) for performing hip arthroscopy. The first to be marked are the anterolateral (ALP) and posterolateral portals (PLP), each about 1 cm proximal to the greater trochanter. The anterior portal (AP) is marked at the intersection of a transverse line at the level of the greater trochanter ant the previously anteriorly marked line between the patella and ASIS. Additional distal portal (DP) about 8–10 cm distal and 3–4 cm anterior to the ALP to access the peripheral compartment could be established. The mid-anterior portal (MaP) between the AP and DP is personally preferred as it can be used to visualize both the peripheral and central compartments and allows a better angle of approach in case of labral fixation with anchor sutures. The anterolateral portal is established first. The guide needle is slightly introduced aiming proximal and posterior into the joint, penetrating the distal third of the joint capsule and passing into the distracted joint space. The correct position of the guide needle should be checked with image intensifier (Fig. 11.3). After successful placement, the needle is advanced more into the joint space. The sharp tip of the needle should be oriented proximally to prevent labral injury (Fig. 11.3). A nitinol wire is passed through the needle, which should reach the deep part of the acetabular fossa without resistance. The needle is removed and soft tissue dilators, of increasing diameters are passed over the nitinol wire and through a small skin incision to allow placement of the 70° arthroscope. The next portal is placed under direct arthroscopic visualization (outside-in). The so-called "safe triangle" between the labrum and femoral head over the anterior joint aspect should be identified (Fig. 11.4). Personally, the mid distal portal (MDP) is preferred. The needle is then advanced till it reaches the safe triangle and penetrates the joint capsule (Fig. 11.4). This is followed by dilatation of the portal using specific dilators and an anterior working cannula is introduced (Fig. 11.5a,b). Most hip arthroscopies could be performed utilizing these two portals. Placement of a third posterolateral portal is helpful in cases of extensive synovectomy, posteriorly lying loose bodies or if it is necessary to reach better the acetabular fossa. Hip arthroscopy is performed using an infusion pump an average pressure of 45–60 mmHg is recommended. In some cases or with intra-articular bleeding, this could be increased temporarily to 90–120 mmHg.

Fig. 11.1 Supine positioning of the patient on a fracture table. The foot is adequately padded and fixed to the table with bandages. The perineal post is padded with a broad cushion of at least 15 cm diameter. The leg to be operated is slightly flexed, internally rotated and abducted. The image intensifier is introduced from the opposite side

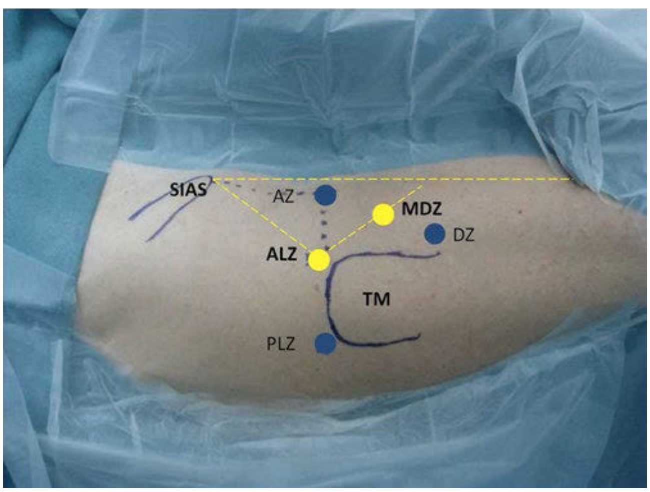


Fig. 11.2 After distraction, the anatomical skin landmarks are marked: greater trochanter (GT instead of TM), iliac crest and anterior superior iliac spine (ASIS instead of SIAS). Likewise, the transverse line at the level of the greater trochanter and a line between ASIS and midline of the patella are marked. In our own approach we prefer to perform arthroscopy through 2 portals: the anterolateral portal (ALP instead of ALZ) and the mid-anterior portal (MAP instead of MDZ). The anterior portal (AP instead of AZ), the posterolateral portal (PLP instead of PLZ), and the distal portal (DP instead of DZ)

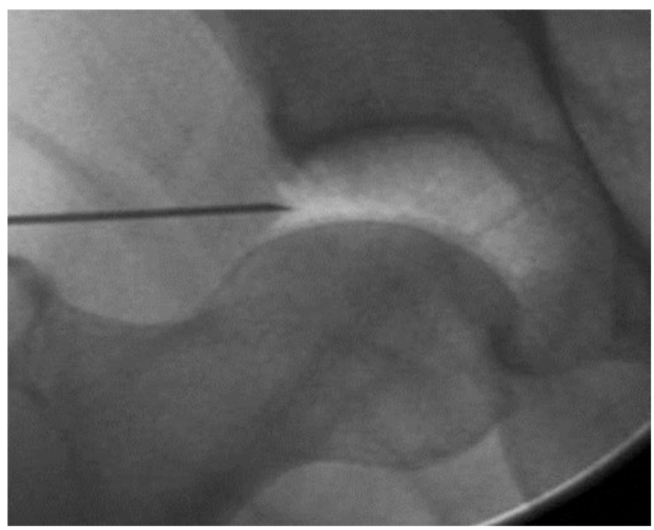


Fig. 11.3 The resultant gap between the femoral head and acetabulum after distraction should be well recognized and measures about 10–15 mm. A needle is introduced through the anterolateral portal under fluoroscopic control. The distal cutting edge of the needle tip should be oriented proximally and the needle is introduced into the distal third of the joint space (between labrum and femoral head)

Capsulotomy

Capsulotomy needs to be performed after portal placement as it helps to decrease the resistance of the joint capsule and facilitate the insertion of large instruments. It is done with an arthroscopic scalpel introduced through the mid-anterior portal under direct visualization via the anterolateral portal (Fig. 11.5c). The capsule is then opened (through very light movements with lateral compression) along the labral attachment as well as towards anterior and lateral (towards the arthroscope) (Fig. 11.5d). The arthroscope is switched from lateral to anterior after performing the anterior capsulotomy. A second arthroscope could be used to ensure switching of the portals without loss of access to the joint and without damaging the cartilage. This second arthroscope could be inserted under direct visualization along an already placed switching stick. The lateral capsulotomy is then performed while viewing from the mid-anterior portal. The extent of the lateral capsulotomy is dependent on the underlying pathology. At the end of the arthroscopy, the capsule could be repaired with arthroscopic sutures.

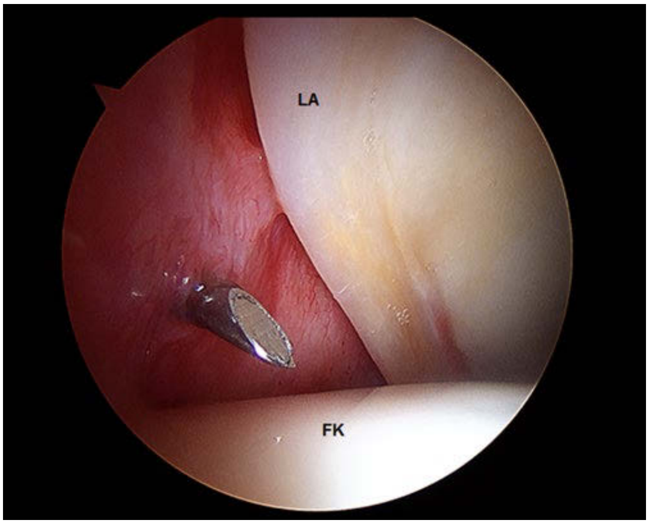


Fig. 11.4 After insertion of the 70° arthroscope through the anterolateral portal, the so-called safe triangle should be identified in the anterior joint aspect, between the labrum (LA) and the femoral head (FH instead of FK). The needle is then further introduced under direct arthroscopic visualization and the mid-anterior portal is established

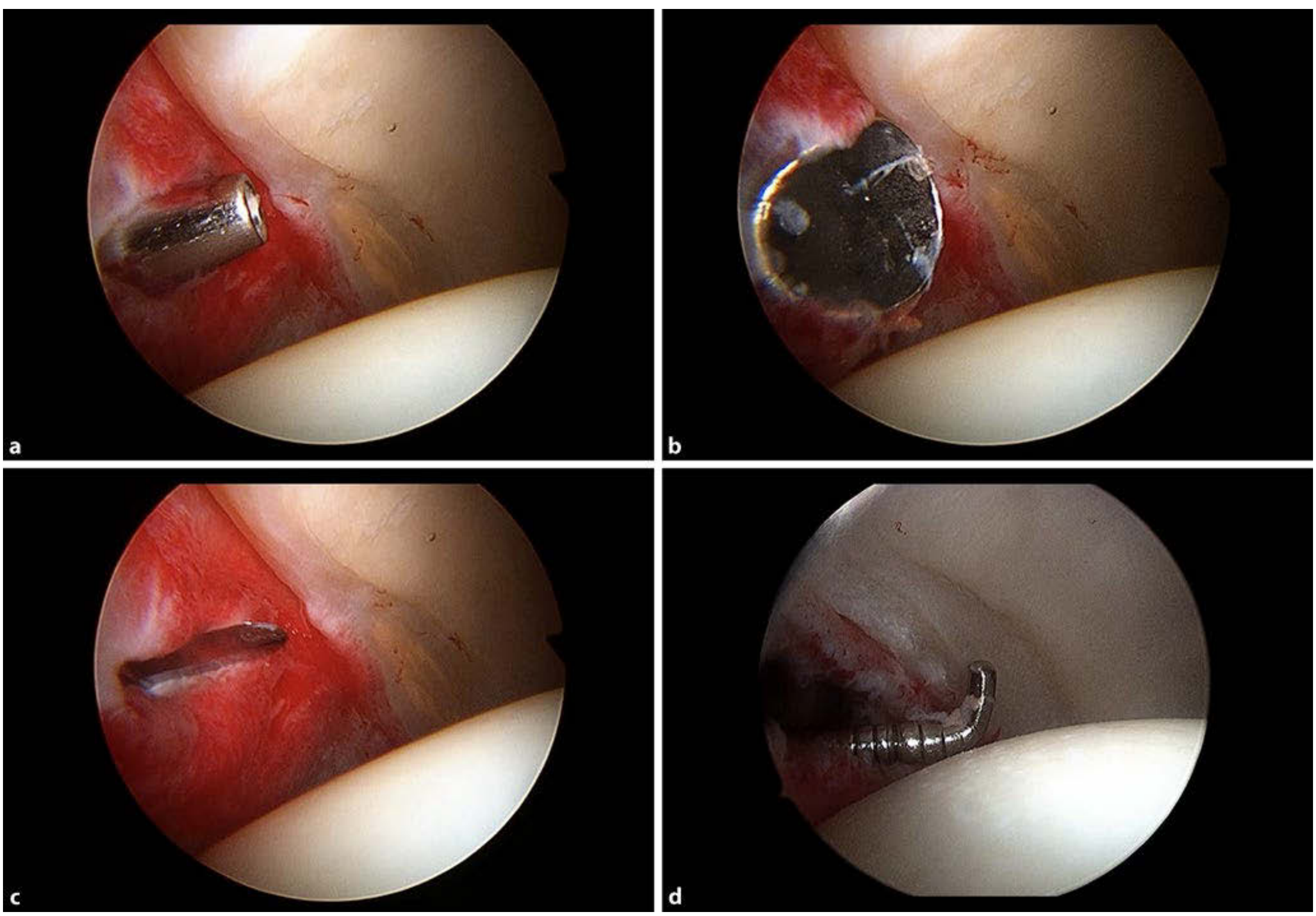


Fig. 11.5a–d Capsulotomy is performed in the portal region to allow free increased mobility of the instruments. After insertion of the tissue dilators (**a**) and a working cannula (**b**) an arthroscopic knife is inserted (**c**). The joint capsule is incised through lateral pressure in both directions. This allows easier switching of instruments through the portal, as well as improved mobility in the narrow joint space (**d**)

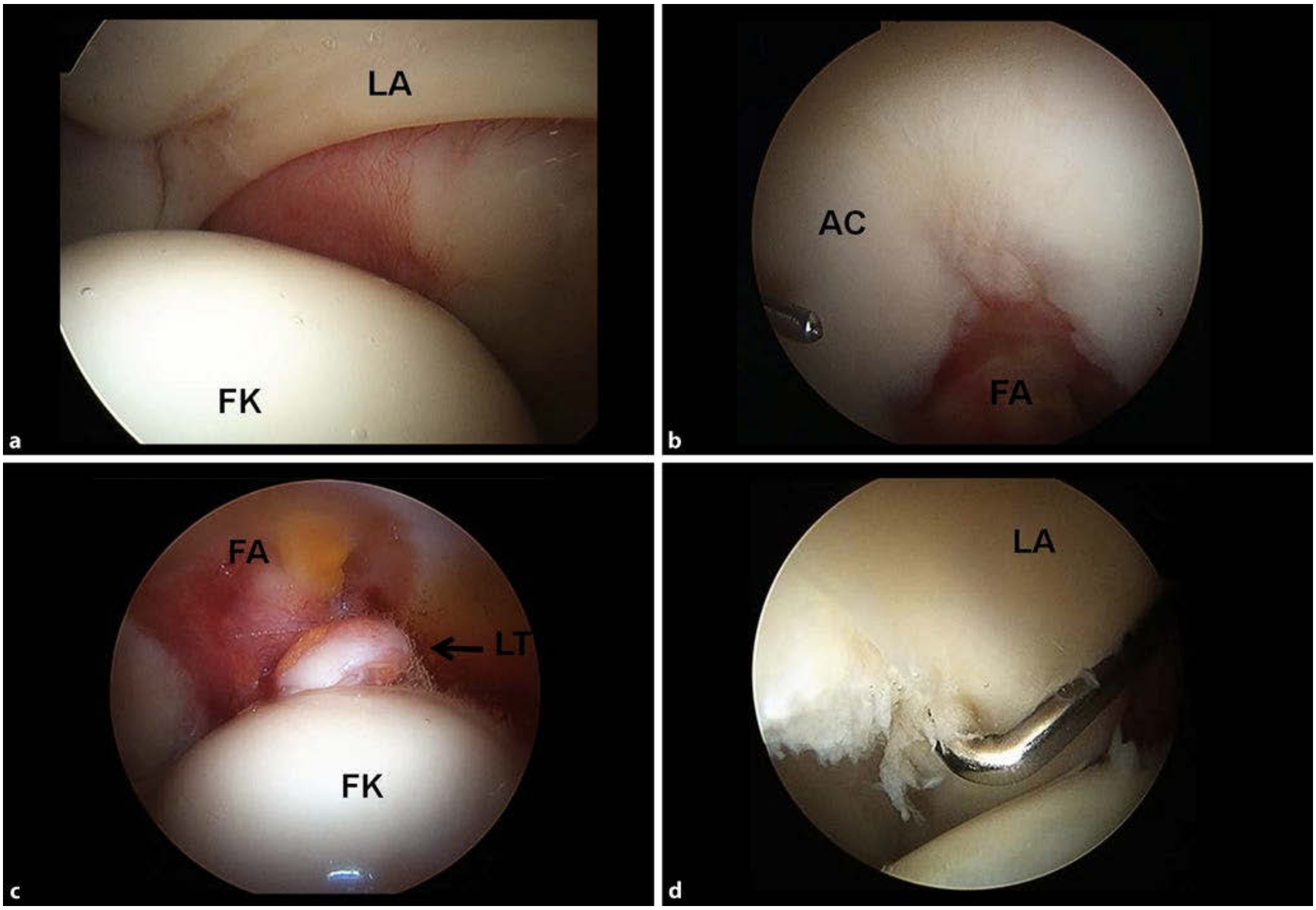


Fig. 11.6 a–d Complete inspection of the central joint compartment using a 70° arthroscope after establishing the two portals (**a**, **b**). The labrum (*LA*), the cartilage of the femoral head (FH instead of FK) and the acetabulum (*AC*) must be assessed. The arthroscope is then rotated towards the acetabular fossa (*FA*) (**c**). Here, the synovial tissue, pulvinar and ligamentum teres (*LT*) could be seen. Palpation is performed with an arthroscopic probe in all the mentioned places. With the probe the diagnosis of the most frequently occurring labral basal tears at the chondrolabral junctions could be made (**d**)

11.1.4 Diagnostic Arthroscopy/Arthroscopic Examination

Central Compartment

Portal placement and capsulotomy is followed by complete arthroscopic Inspection of the central compartment of the hip (Fig. 11.6). This is performed by rotating the light cable of the 70° Scope in all directions to reduce extensive unnecessary movements of the arthroscope in the already tight joint space to the minimum. Diagnostic arthroscopy is performed always by viewing through both portals to obtain a general impression about the joint. A systematic approach is recommended, starting with evaluation of the entire articular surface of the acetabulum and femoral head (direct visualization as well palpation with an arthroscopic hook (Fig. 11.6a, b). Subsequently, the arthroscope is turned towards the acetabular fossa to evaluate the synovial tissue and ligamentum teres (Fig. 11.6c). Loose bodies as well as early marginal osteophytes could be detected here in the fossa. The next step is the evaluation of the whole extent of the labrum, mostly up to the level of the transverse ligament. Evaluation of the consistency and stability of the labrum with arthroscopic hook is a decisive factor especially at the chondrolabral junction, which represents the most common site of labral injuries (Fig. 11.6d).

Peripheral Compartment

Arthroscopic evaluation of the peripheral compartment takes place after evaluation of the central compartment. Synovial disorders, cartilage lesions as well as femoral bony deformation ("femoral bump") in FAI could be here detected and managed. Joint distraction is gradually released with the 70° Arthroscope in the anterolateral portal and a shaver in the mid-anterior portal (Fig. 11.7). After complete release of joint distraction, free flexion and rotation is allowed and the leg is then held in 45° flexion. Capsulotomy is then enlarged to allow access to the entire peripheral compartment (Fig. 11.7d) as well as identification of the anatomical landmarks (Fig. 11.8.):

- Central: labrum from a peripheral viewing angle
- Medial: medial synovial plica
- Lateral: lateral synovial plica and retinacular vessels
- Peripheral: femoral neck

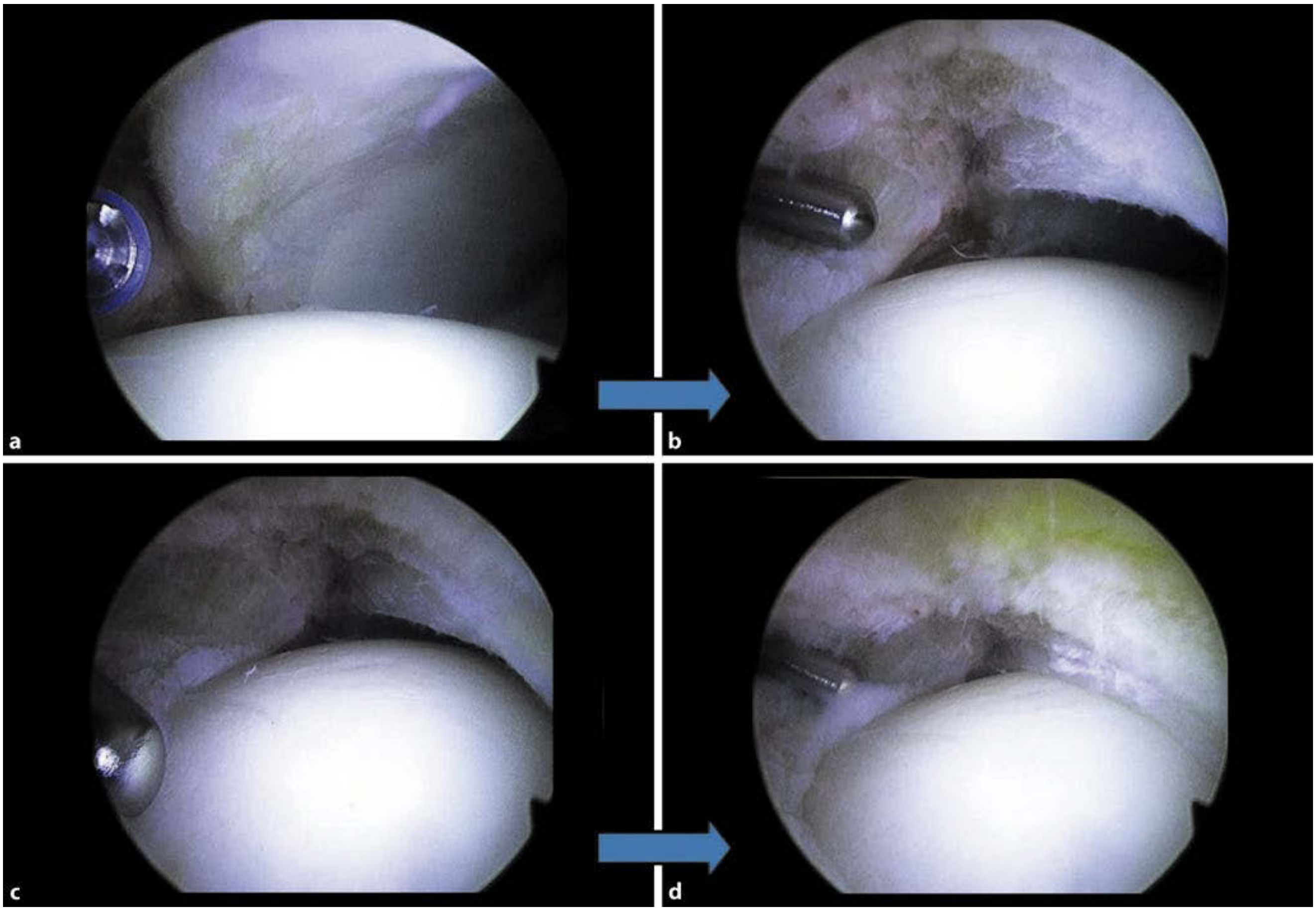


Fig. 11.7a–d After finishing arthroscopy of the central compartment (**a**) the distraction is progressively released (**b**, **c**) to be able to access the peripheral compartment (**d**). Instruments (70° arthroscope and Shaver) are maintained through the anterolateral and the mid-anterior portal

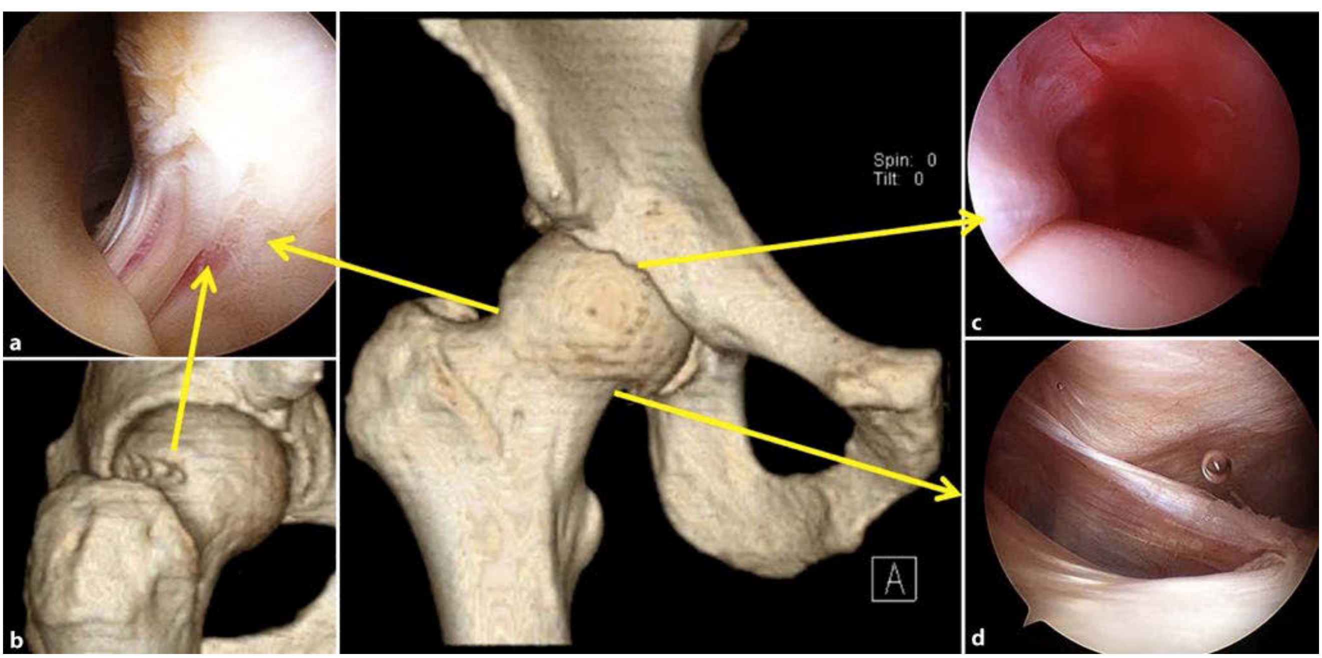


Fig. 11.8a–d The entire anterior aspect of the peripheral compartment could be easily reached through extending the capsulotomy and free mobility of the limb. Better orientation could be easier with identification of the reference structures: the laterally synovial fold with the retinacular Vessels (**a**, **b**), centrally the acetabular labrum from a peripheral viewing angle (**c** limit to the medial compartment) and medially the medial synovial fold (**d**)

The leg is then brought into flexion and external rotation to be able to reach the medial aspect. The lateral region with the sinovial folds including the retinacular vessels could be reached easily with the leg held in extension and internal rotation. By medially extending the capsulotomy, the nearby psoas tendon could be attainable and tenotomy could be done through the same portal (if needed). At the end of the procedure, the skin is sutured after possible closure of the capsulotomy.

11.1.5 Postoperative Management

Passive mobilization should be started immediately after hip arthroscopy using a continuous passive motion (CPM) machine up to 70° of hip flexion. Flexion over 90° and forceful rotatory movements should be avoided in the first 4 weeks. Weight bearing using a crutch is allowed from the day of surgery and is recommended for about 1 week. Depending on the procedure pattern (e. g. microfracture) a longer period of non-weight bearing using 2 crutches may be necessary.

11.1.6 Tips & Tricks

It is advisable to give a sufficient time to ensure an optimal positioning and distraction as these steps are crucial factors to avoid possible intra- and post-operative complications (Excessive distraction: skin and nerve injuries; too little distraction: labrum and Cartilage injuries). The sense of resistance of the joint capsule as well as its penetration with the needle and dilators should be learnt and recognized. Working against hard resistance is avoided (this resistance can be labrum, cartilage or bone). A good intraarticular visualization could be achieved primarily by rotating the light cable of the 70° arthroscope and not through moving the arthroscope itself in the narrow joint space. Adequate capsulotomy facilitates switching and movement of the instruments. Systematic evaluation (direct visualization and palpation with arthroscopic hook) of all intraarticular structures in both compartments should be performed in every hip arthroscopy. Switching to the peripheral compartment is achieved after slowly releasing the distraction without changing the portals. Loosening of rotation and flexion with freely mobile leg facilitates accessing the lateral and medial regions.

The anatomical landmarks in the peripheral compartment should be well known, particularly the lateral synovial fold (site of retinacular vessels) to avoid their injury when femoroplasty and resection are performed in case of a CAM-Impingement.

Early mobilization of the joint (using CPM machine, bicycle ergometer without resistance) must be ensured. These measures reduce postoperative pain and risk of adhesions.

11.2 Femoroacetabular Impingement

11.2.1 Indications

Patients with femoroacetabular impingement (FAI) have abnormal bony morphology of the acetabulum (Pincer-FAI) or at the anterior part of the femoral head-neck-junction (Cam-FAI). Abutment of the proximal end of the femur against acetabular rim occurs with excessive flexion and rotation. This can results in progressive injury of the labrum and the adjacent cartilage with the risk of progressive hip osteoarthritis. The pincer type of FAI could be caused by either over coverage (coxa profunda, Protrusio acetabuli) or mal-orientation (retroversion) of the acetabulum. The Cam type of FAI is caused by an anterolateral abnormal bone morphology (femoral "bump") associated with loss of the offset of the femoral head-neck junction anteriorly. There is a combination of both deformities (Pincer and Cam) in most cases.

Indication for surgical treatment includes young patients with relevant pain, reduced range of motion and radiologically confirmed Cam- or Pincer- deformity.

In advanced cartilage damage (osteoarthritis of the hip) or asymptomatic patients (incidental finding) without significant bony deformity, alternative treatment options, other than arthroscopy are recommended.

11.2.2 Operation Principle

The treatment of FAI consists of correction of the bony deformity as well as management of secondary labral and chondral injuries. This includes resection of the abnormal bony acetabular rim in a Pincer deformity and in cam deformity, resection and correction of the bony bumps on the anterior aspect of the femoral head-neck junction in the peripheral compartment.

11.2.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: Mostly younger and physically active/athletic patients with movement related pain with flexion and rotation. Pain is localized mainly to the anterior and lateral hip regions, occasionally radiating down to the thigh and knee.
- Symptom specific examination: Groin pain, limited ROM of the hip with positive impingement test (limitation of flexion, adduction and internal rotation) as well as limitation of external rotation and abduction (Faber test).

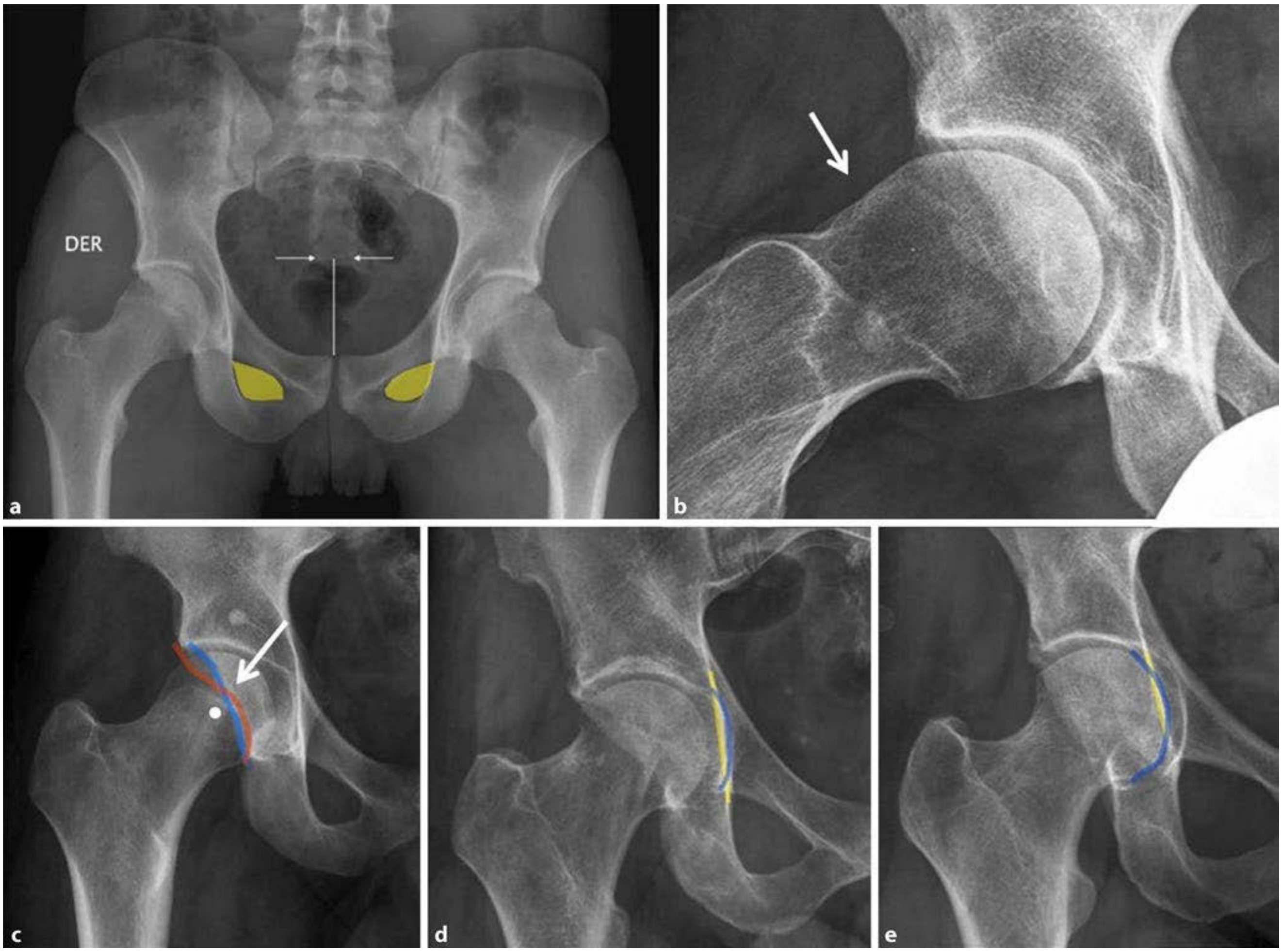


Fig. 11.9a–e Radiological diagnosis of FAI. A perfectly centered A.P view of the pelvis is very important. The symmetry of the obturator foramina should be here respected. The tip of the coccyx should be centered and 2 cm above the symphysis pubis (**a**). The cam deformity could be best visualized with an axial view of the hip and femoral head. (**b**). A bony prominence or loss of the anterior offset of the femoral head-neck junction could be recognized (*arrow*). With acetabular retroversion (**c**) the anterior acetabular rim (*red line*) crosses the posterior acetabular rim (*blue line*) from medial to lateral ("Crossover"-Sign, *arrow*). The center of the femoral head is located lateral to the posterior acetabular rim. In a coxa profunda (**d**) the acetabular fossa (*blue line*) crosses medially over the ilioischial line (*yellow line*), in cases of protrusio acetabuli (**e**) the femoral head (*blue line*) also crosses the ilioischial line (*yellow line*) medially

Imaging

A well centered symmetrical anteroposterior (AP) pelvis radiograph is very essential to allow accurate tracing of different lines representing the acetabular rim and depth and through which a pincer deformity could be diagnosed. To evaluate a cam deformity a "cross-table" -side view (or Dunn view) is required (Fig. 11.9).

A better illustration of the bony deformity and subsequently better planning of the required bony resection could be obtained through CT with 3D reconstruction (Fig. 11.17).

MRI is essential to diagnose intra-articular labral and cartilage Injuries, as well as to exclude other pathological lesions before hip arthroscopy (e. g. tumors, osteonecrosis).

Planning

Pincer-FAI: Planning the extent of the acetabular rim resection is based on the preoperative X-ray radiographs. If there is acetabular retroversion with overhanging bone at the anterior acetabular wall ("Cross-over" sign), resection of this anterolateral acetabular rim is performed until this "cross-over" – sign is corrected. In case of coxa profunda or protrusio acetabuli, resection continues till normalization of the center edge (CE) angle of Wiberg (approx. 25°).

Cam FAI: The required amount of bone resection at the femoral head-neck junction could be planned based on the preoperative axial hip radiographs. In certain cases and with marked lateral deformation a hip CT with 3D reconstruction is helpful to plan the extent of resection, particularly the proximity of the deformation site to the retinacular vessels (indicated by the nutrient foramen).

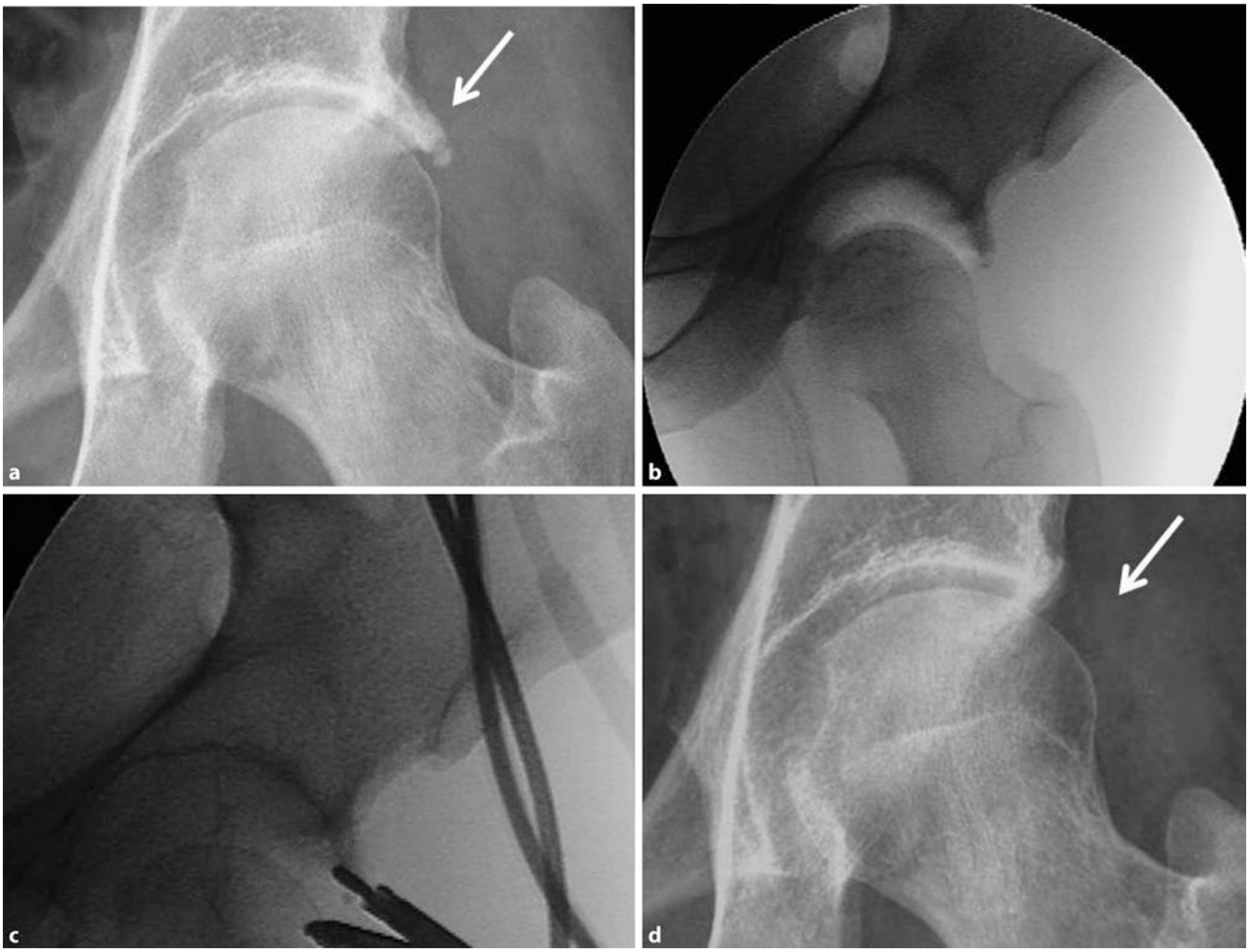


Fig. 11.10a–d Pincer FAI. X-ray image of a pincer deformity (**a**) with bony apposition at the acetabular rim (ossified labrum, *arrow*). The deformity is better visualized after hip distraction. (**b**). Ossified labrum and prominent acetabular rim are resected using an arthroscopic burr (**c**). Postoperative radiograph (**d**) verifying an adequate correction of the pincer deformity (*arrow*)

11.2.4 Surgical Technique

Positioning and Preoperative Preparation

Lateral or supine position on a fracture table. Evaluation of the range of motion under general anesthesia. An axial/lateral view of the femoral neck with the image intensifier is helpful for planning the cam resection. Distraction and establishment of portals followed by capsulotomy. Diagnostic intra-articular arthroscopy is performed followed by management of labral and chondral lesions.

Arthroscopic Acetabular Rim Resection (Acetabuloplasty) in Pincer-FAI

After performing a diagnostic arthroscopy of the central hip compartment, a decision should be made about the ideal management of existing labral lesions. Degenerative changes or ossification of the labrum are common findings in pincer impingement that don't allow labral preservation in all the cases and necessitate partial resection (Figs. 11.10 and 11.11).

If the labrum could be preserved, it is detached according to the technique described in ► Sect. 11.3. After complete labral detachment, the bony acetabular rim is debrided and the synovial tissue remnants are released using a shaver or radiofrequency ablation (RFA) (Fig. 11.12). An intraoperative fluoroscopic evaluation should be performed when there is doubt about the correct site of the acetabular rim to be resected (Fig. 11.13). Bone is resected from the acetabular rim using motorized Burr via the mid anterior portal (Fig. 11.12). Best visualization could be obtained with the arthroscope in the anterolaterallateral portal. A systematic resection, from anterior towards lateral, without leaving irregularities or step formation, is recommended. The depth of resection is guided by the preoperative planning, this is approx. about 5–8 mm. The peripherally located chondral lesions could be excised together with the bony acetabular rim resection. The more centrally extending chondral lesions must then be specifically and separately treated (with either abrasion arthroplasty or microfracture according to the type of the lesion).

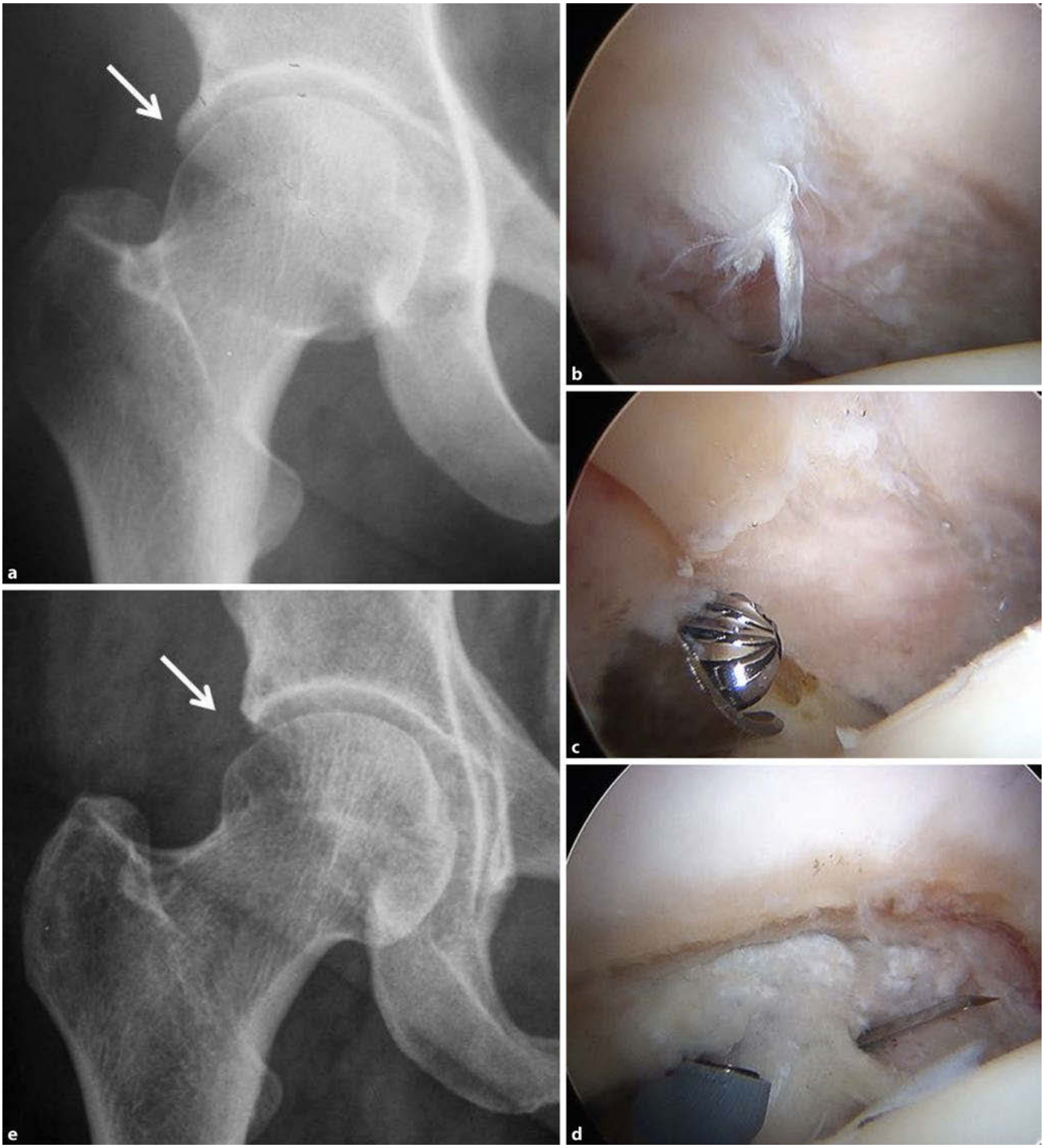


Fig. 11.11a–f Pincer FAI. X-ray image of a pincer deformity (**a**) exhibiting a prominent posterior wall of the acetabulum (*arrow*). An ossified labrum without acetabular chondral injury is confirmed intraoperatively (**b**). The ossified labrum is resected with the burr, also the prominent posterior acetabular wall (**c**). Placement of a third posterolateral portal is required to complete resection posteriorly (**d**). Intraoperative arthroscopic image (**d**) and postoperative radiograph (**e**) provide information about the resultant correction of the pincer deformity

Portals are switched after complete resection of the anterior acetabular rim to perform the lateral acetabular rim resection (Fig. 11.12). A posterolateral portal is established if it is necessary to resect the also the most posterior acetabular rim (Coxa profunda, protrusio acetabuli) (Fig. 11.11). The bone surface is smoothened after complete resection with an arthroscopic burr. Cartilage remnants at the osteochondral junction could be removed with an arthroscopic grasper and stabilized with RF-Ablation (Fig. 11.13). The previously detached labrum can be repaired after complete acetabular rim resection (Fig. 11.13).

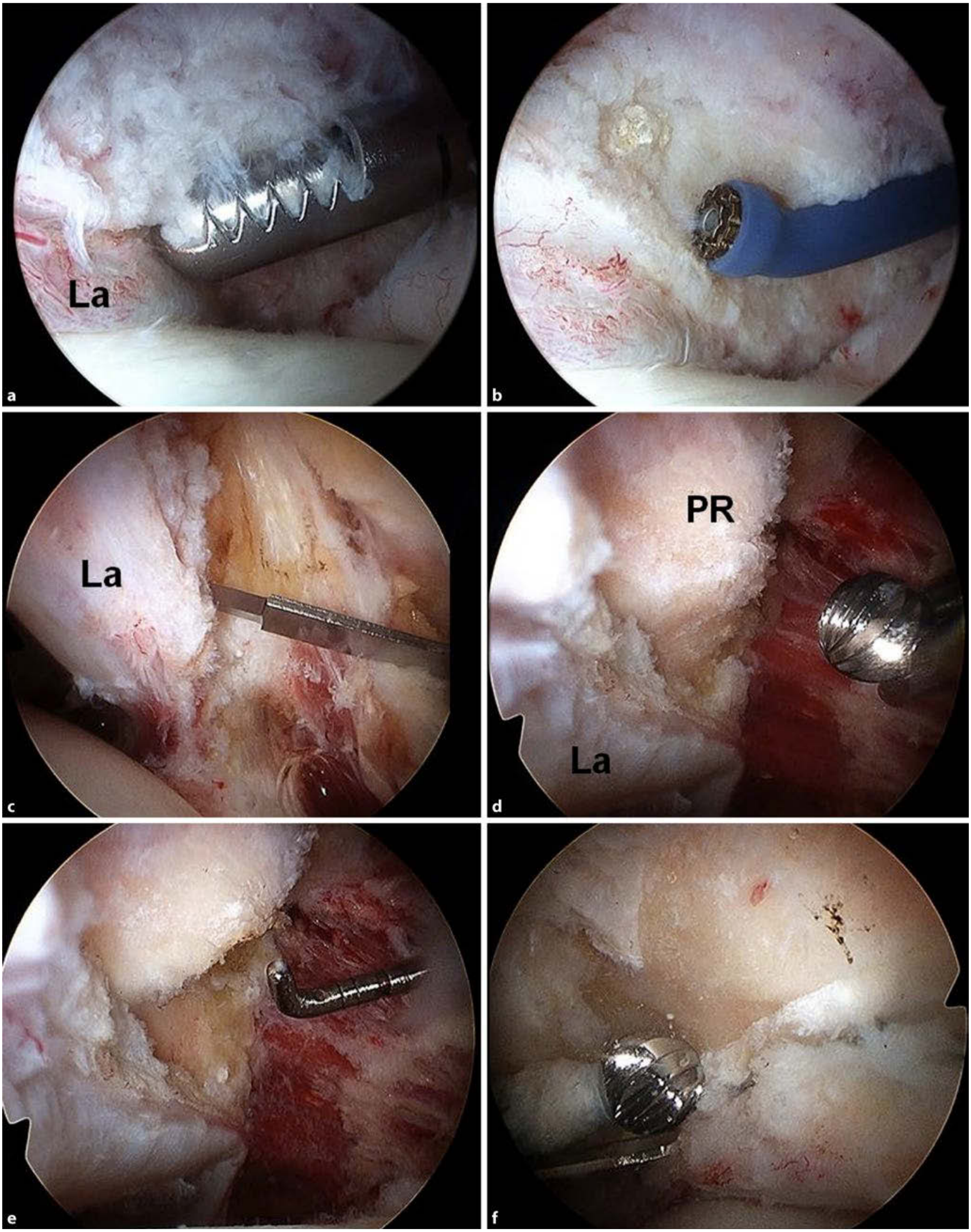


Fig. 11.12a–f Pincer FAI with labral refixation (Part 1). A shaver (**a**) or radiofrequency electrode (**b**), are used initially to resect the synovial tissue at the peripheral labral margins. The labrum is then released from the bone using an arthroscopic knife (**c**) the detached labrum (*La*) now falls distally exposing the bony acetabular rim (*PR*) for resection (**d**). Resection is performed with an arthroscopic burr (**d**) in the anterior region (**e**). Resection of the lateral part is performed after switching the 70° arthroscope anteriorly and the burr laterally to complete resection of the acetabular rim (**f**)

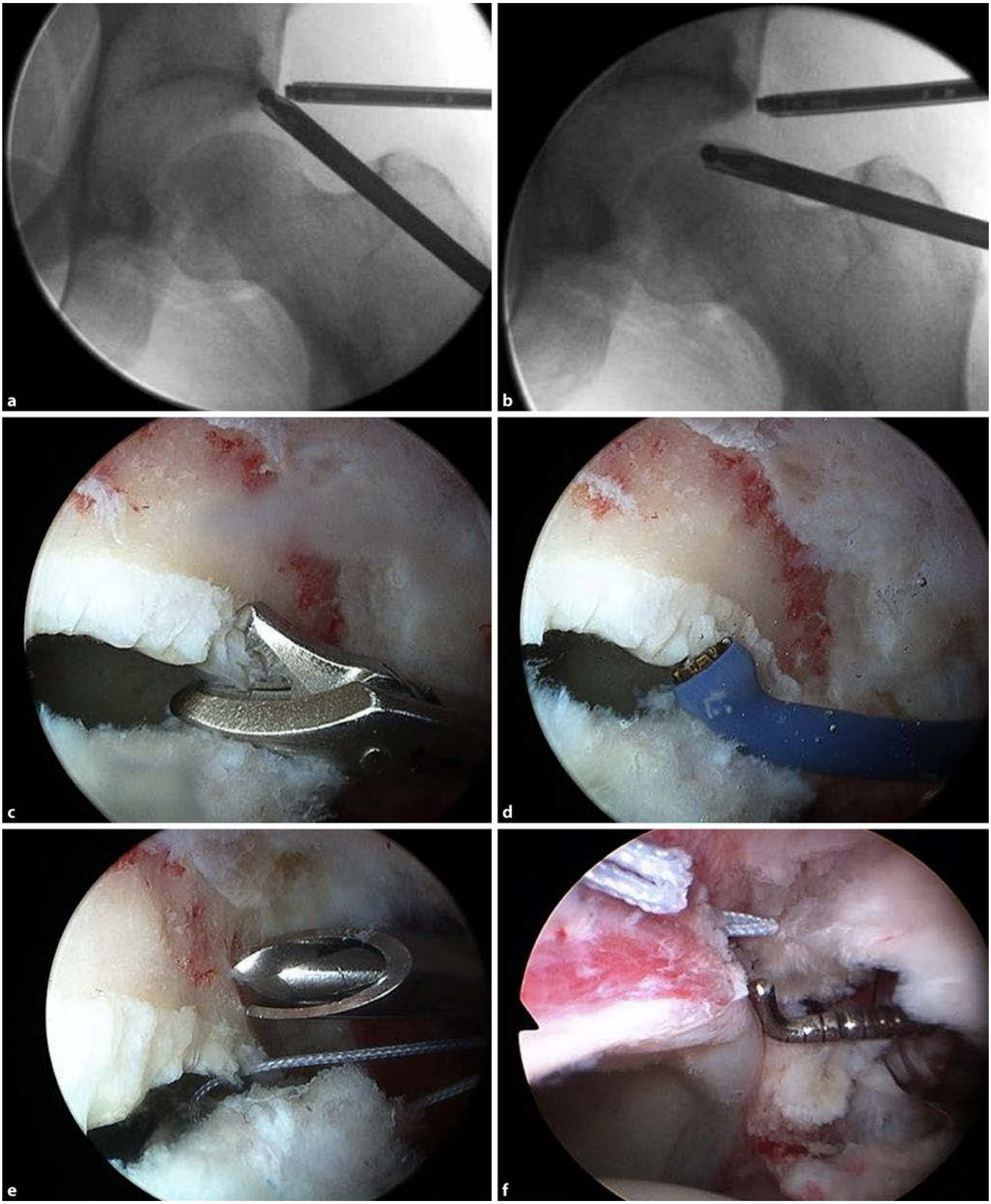


Fig. 11.13a–f Pincer FAI with labral refixation (Part 2). The extent of acetabular rim resection could be intraoperatively controlled using fluoroscopy. The lateral (**a**) and anterior (**b**) resection margins are identified by holding the burr against them. The cartilage remnants are removed after bony resection (**c**). The osteochondral junction could be stabilized using a radio frequency electrode (**d**). Subsequently, the labrum is fixed using suture anchors, which are placed directly at the osteochondral margin (**e**) to achieve an anatomical labral refixation (**f**)

Depending on the pre-operative planning and intraoperative findings, if the chondrolabral junction is intact and in an adequate condition, the chondrolabral union can be preserved intact and not disrupted. A careful trimming of the acetabular rim is performed (< 5 mm). Chondrolabral repair with suture anchors is recommended if bony resection results in instability of the chondrolabral junction. (▶ Sect. 11.3).

Arthroscopic Femoral Resection (Femoroplasty) in Cam-FAI

In patients with Cam-FAI, labral and chondral lesions of the central compartment should be first managed. Lesions of the chondrolabral junction with detachment of the adjacent cartilage is typically seen in patients with Cam-FAI (◘ Fig. 11.17c). The substance of the labrum itself is affected only in later stages of the disease. Depending on the extent and depth of the injury, cartilage lesions could be treated with microfracture or abrasion chondroplasty (◘ Fig. 11.17d). The peripheral compartment is then visualized after complete treatment of chondral and labral lesions. The distraction of the hip is released, the foot is laid free at the fracture table allowing free flexion and rotation of the leg. The 70° arthroscope is placed in the anterolateral portal, the shaver in the mid anterior portal, then the capsulotomy is extended allowing visualization of the anatomical landmarks in the 4 areas of the peripheral compartment. The margins of the bony deformity in the lateral region as well as the distance to the retinacular vessels should be identified to avoid iatrogenic injuries during bone resection.

A systematic resection of the femoral bony bump is performed after adequate capsulotomy and identification of anatomical landmarks. Resection should begin centrally with the leg in neutral rotation position and about 30° flexion (◘ Fig. 11.14). It is recommended to start resection with an arthroscopic burr at the central limit. The junction with the cartilage should be slanting and smoothened without any steps. The resection should begin centrally and extends towards the femoral neck until the normal concavity as well as the contour of the femoral head is restored. Access to the lateral aspect is facilitated by increasing extension and internal rotation of the leg allowing resection of the remaining lateral part of the femoral bump (◘ Fig. 11.15). After performing lateral resection, the leg is held in flexion and external rotation to allow access to the medial region (◘ Fig. 11.14). The junction with the femoral neck is better visualized with increased flexion, also here a smooth junction at the end of bony resection should be ensured. The entire bony surface should be smoothened after completing resection. This could be achieved using a burr with the shaver rotating anticlockwise. Soft tissue remnants are resected with a shaver or RF-Ablation. Arthroscopic capsular closure with simple arthroscopic sutures is recommended if extensive capsulotomy has been done.

Evaluation of Resection

Dynamic testing of the correction of femoral impingement against acetabular rim should be intraoperatively performed. This is accomplished by gradual internal rotation of the fully flexed hip and should reveal that the femoral head no longer abuts against the acetabular rim or the labrum (◘ Fig. 11.16). Successful resection can be documented intraoperatively with an axial X-ray view of the neck that could be compared with the immediate preoperative one (◘ Fig. 11.16). Postoperative evaluation of resection in individualized cases is also possible using computed tomography (◘ Fig. 11.17).

11.2.5 Postoperative Management

- Cooling and elevation of the extremity
- Use of elastic compression bandage.
- Monitoring of peripheral circulation, motor and sensory innervation
- Postoperative radiographic evaluation in selected cases

11.2.6 Follow-Up Management

Early passive mobilization with CPM machine to achieve 75° flexion. Flexion more than 90° as well as internal rotation should be avoided in the first four weeks. Use of a crutch in the first two weeks is also recommended.

11.2.7 Tips & Tricks

In the pincer deformity, precise planning of the depth and extent of acetabular rim resection should be based on the preoperative radiographs. The CE (Wiberg) angle should be restored to about 25° postoperatively. Every 1 mm bone resected reduces this angle about 2°. Intraoperatively, the arthroscopic burr (5 mm) or arthroscopic probe with millimeter scale could be used as measuring tool.

The free mobility of the leg should be well utilized to allow access and resection of the entire femoral cam deformity in the peripheral compartment.

Recognizing the anatomical landmarks in the 4 areas of the peripheral compartment should be well learnt. This is particularly important in the lateral region, where the lateral synovial fold with the retinacular vessels should be identified before bone resection.

Restoration of the anatomical contour and curvature at the junction with the femoral head cartilage should be performed with avoidance of deep, sharp resection and step formation.

The labrum should remain intact to the area of resection in flexion and the joint space sealed. It is highly recommended to perform a dynamic test after resection of the femoral Cam

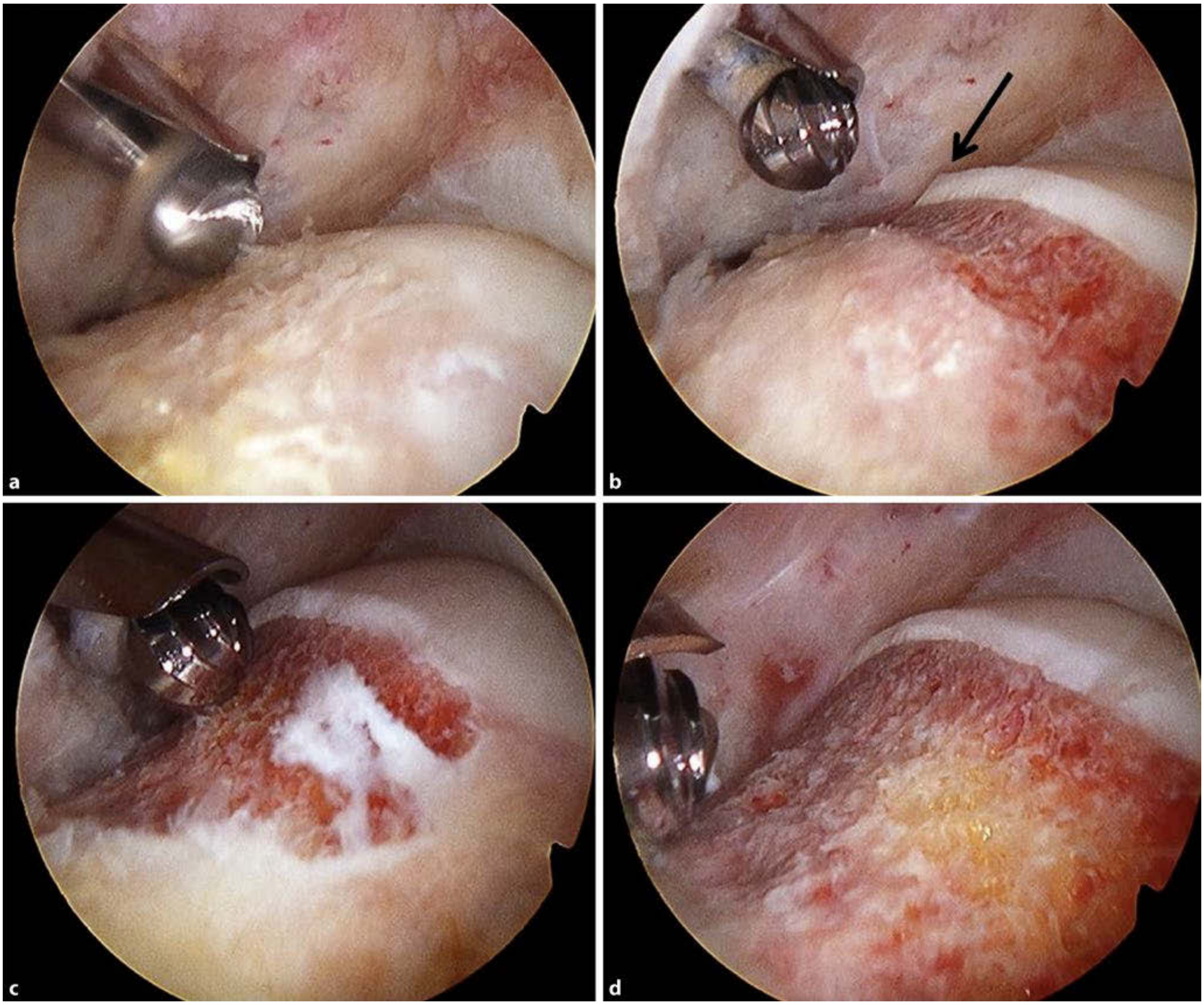


Fig. 11.14a–d Femoral resection (Femoroplasty) in Cam FAI. The bony prominence (femoral bump) of the cam deformity is visualized in the peripheral compartment along the anterior femoral head-neck junction (**a**). Degenerative cartilage changes and loss of the femoral offset should be detected (**a**). Resection begins centrally at 30° flexion and neutral rotation position (**b**). Then the margin of the femoral head is trimmed with a burr, taking into account that the adjacent cartilage of the femoral head should be smoothly and upward slanting towards the joint (*arrow*). This can be achieved applying only mild pressure with the burr over the cartilage margins. The lateral aspect could be accessed and resected through extension and internal rotation of the limb (**c**). The medial side resection is performed in flexion and external rotation (**d**). Finally, the resected bone surface is smoothened using a burr rotating in anticlockwise followed by dynamic motion evaluation

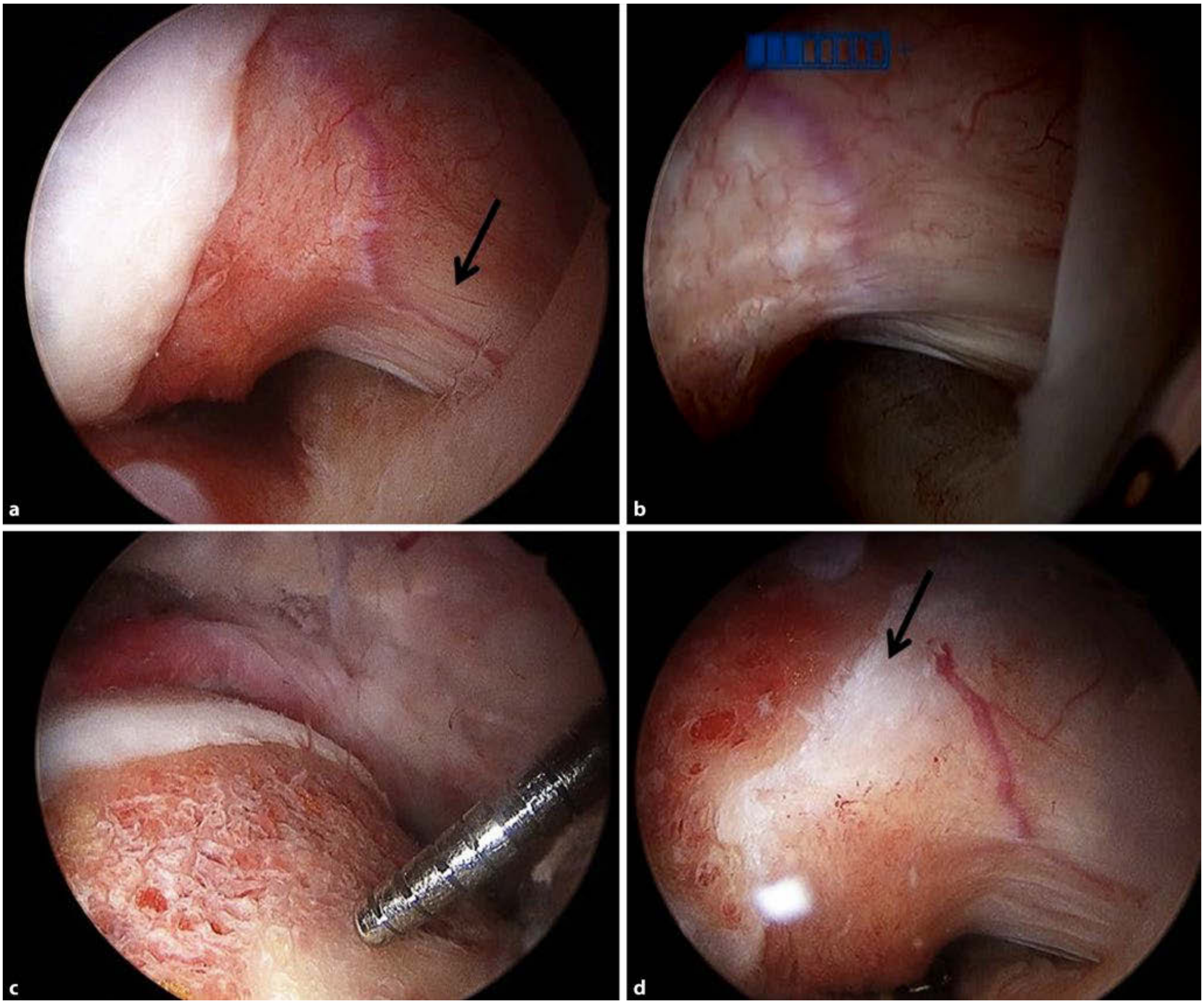


Fig. 11.15a–d Resection of the lateral aspect with cam FAI. The femoral bony prominence (femoral bump) is often large enough to reach the lateral synovial folds (**a**), which contain the retinacular vessels (*arrow*). It is recommended to visualize the synovial folds and these vessels before resection (**a**, **b**), to avoid their injury during bone resection (**c**) (risk of osteonecrosis). This is achieved by rotating the 70° arthroscope laterally. Occasionally, the pulsation of these folds could be even detected. After clearly identifying the location of these vessels, the bone resection could be carried out close to or even more posterior to the retinacular vessels (**d**, *arrow*)

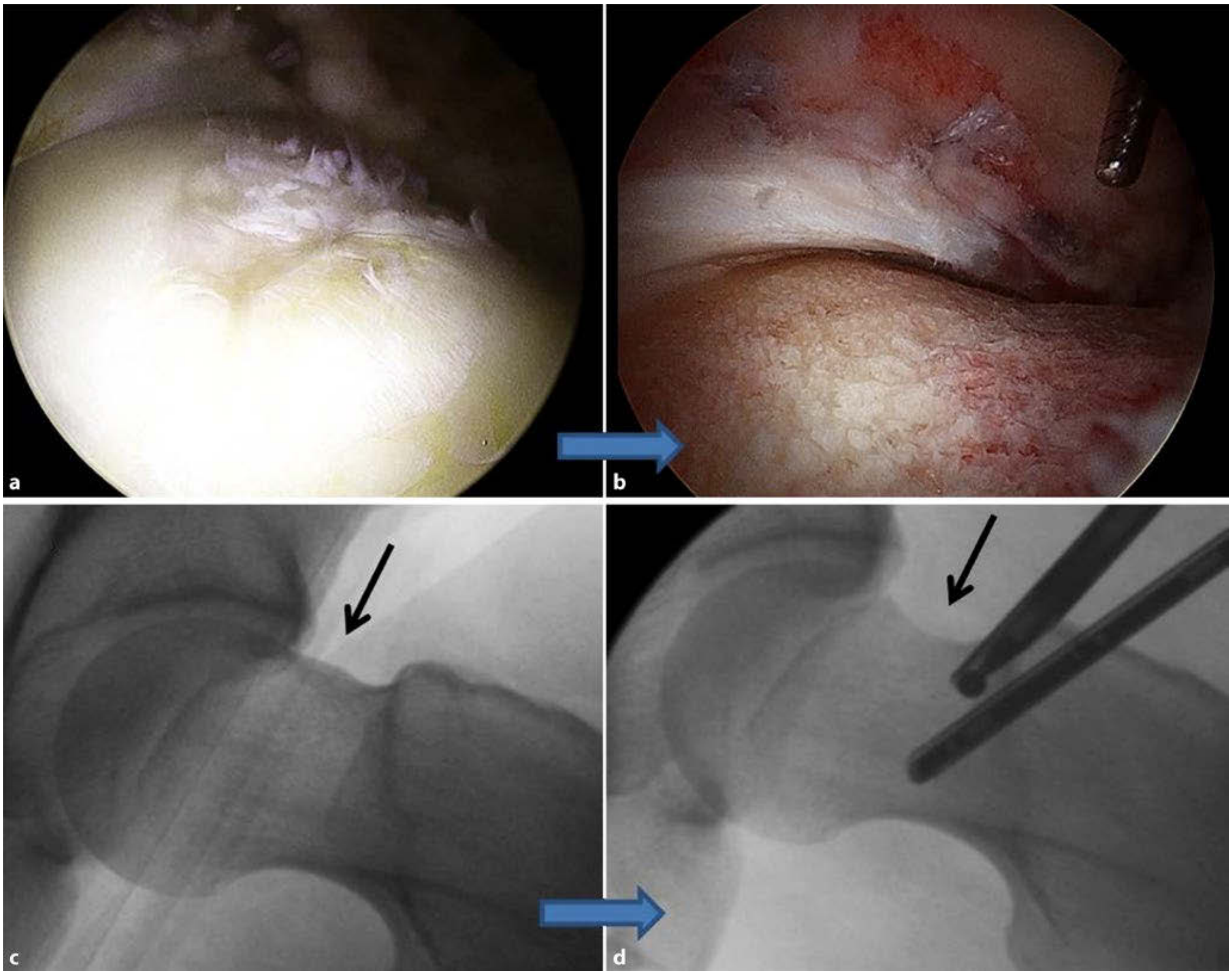


Fig. 11.16a–d Evaluation of bone resection in Cam FAI. Dynamic evaluation of the ROM is essential to evaluate the adequacy of bone resection in cam FAI (**a**). This is performed by bringing the hip into maximal flexion, adduction and internal rotation. There should be no further abutment of the femur against the labrum or the acetabular rim (**b**). During surgery, adequacy of resection could be also assessed using fluoroscopy. This could be compared with the immediate preoperatively performed axial radiograph of the femoral neck (**c**), in which the cam deformity and bony protrusion is clearly visible (*arrow*). The restoration of the anterior offset of the femoral head-neck junction is clearly visible after resection is performed (**d**, *arrow*)

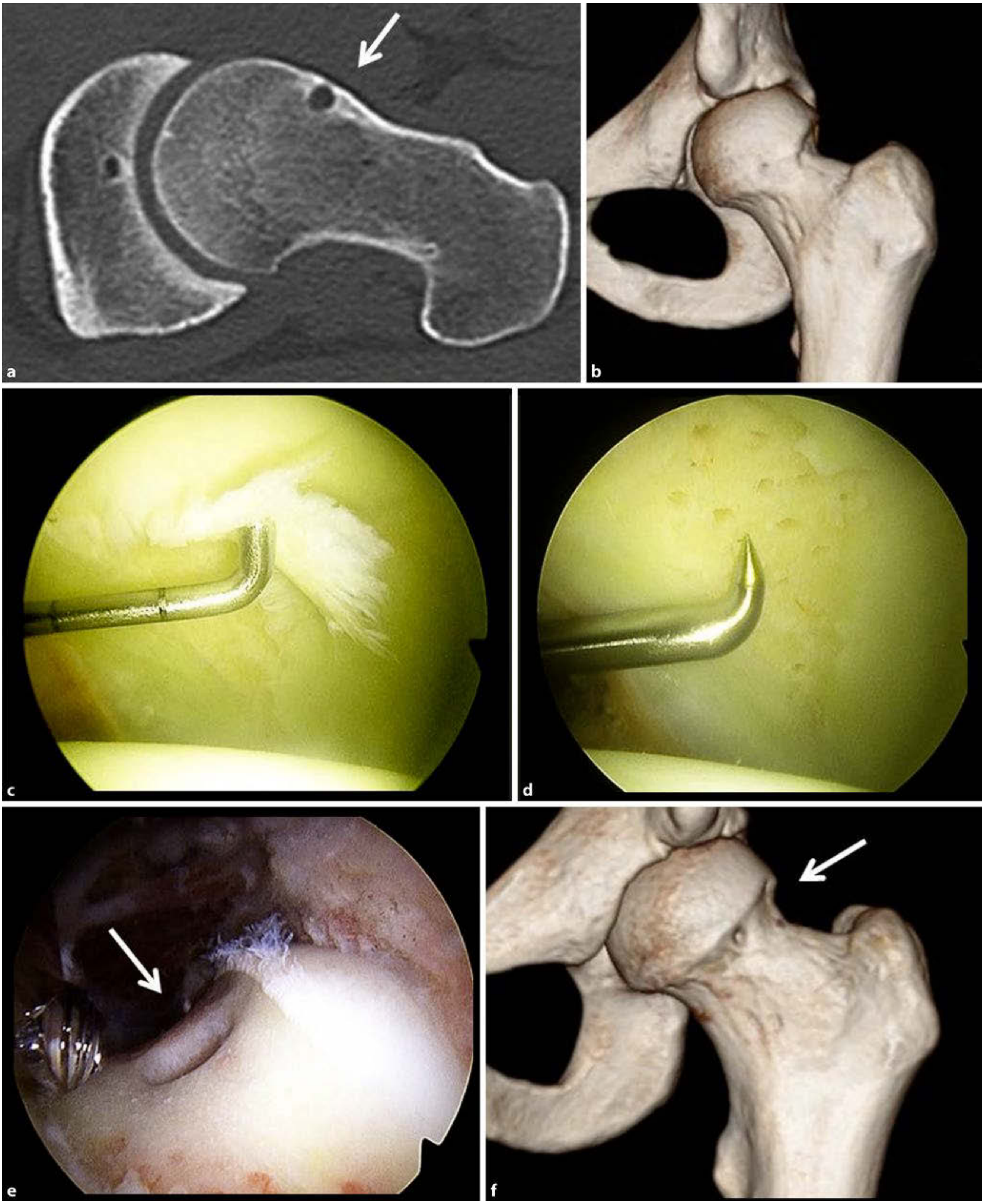


Fig. 11.17a–f Clinical case of a Cam FAI. The femoral bone prominence with a cam-type impingement could be also well delineated in CT. The axial views (**a**) and 3D reconstruction (**b**) confirm the loss of offset at the femoral head-neck junction. A secondary Impingement cyst is well recognized (*arrow*). A typical pattern of chondral injury for cam FAI with focal cartilage detachment close to the chondrolabral junction is confirmed intraoperatively (**c**). Microfracture is recommended in cases with complete focal detachment of cartilage resulting in exposed bone (**d**). The Impingement cyst is visible after bony resection at the femoral head-neck junction (**e**, *arrow*). Postoperative CT confirms restoration of the physiological contour of the femoral head as well as restoration of the femoral offset (**f**)

deformity. Any remaining prominent protrusions that abuts against the labrum should be subsequently resected. The gap between the labrum and resection area should be about 1–2 mm.

At the end of the cam resection, sufficient time should be taken to smoothen the resected bony surface using motorized burr rotating anticlockwise to achieve a slanting junction to the cartilage as well as to remove soft tissue remnants along the medial margin of resection area.

Care should be taken to encourage early mobilization of the hip to reduce the risk of adhesions. Non weight bearing after bony resection is not generally required.

11.3 Labral Reconstruction/Repair/Refixation

11.3.1 Indication

Lesions of the acetabular labrum arise mostly as a result of bony deformities of the hip joint, most commonly femoroacetabular impingement (FAI). With a cam-(FAI) deformity, there is an abutment of the non-spherical femoral head against the acetabular chondrolabral junction. This leads to avulsion of the basal part of the labrum, mostly in the anterolateral region. In the pincer type of FAI, there is a direct impact of the femoral neck against the acetabular rim, resulting mainly in degenerative intra-substance labral injuries.

Hip dysplasia is another cause of labral injury, which results in avulsion of the most basal part of the mostly hypertrophied labrum. Purely traumatic labral injuries are less common (e. g. hip dislocation).

Due to the protective function of the labrum to the joint (including stabilization, vacuum and sealing effect of the central compartment), labral refixation is always preferred to resection.

Labral resection is indicated if there is significant degenerative changes to the labrum, in such cases the possibility of labral reconstruction (e. g. with gracilis tendon or fascia lata) should be taken into consideration, particularly in young patients. It is crucial in addition to labral repair or reconstruction to correct the underlying bony deformity (FAI, dysplasia) in order to prevent labral re-injury and progression to osteoarthritis.

Labrum refixation is indicated in symptomatic patients after failure of conservative therapy.

11.3.2 Operation Principle

The election of the optimal procedure for labral repair is dependent on the type of injury as well as the existing bony deformity. Direct labral refixation with suture anchors to the acetabular rim is indicated if there is a labral tear close to the base in the absence of lesions requiring acetabular rim resection (◘ Figs. 11.18 and 11.23). If the labral injury is associated with pincer-FAI, an acetabuloplasty must be additionally performed (◘ Figs. 11.22 and 11.24). In such cases, the labrum base must be detached from the acetabular rim, acetabuloplasty is performed (resecting the bony acetabular rim with burr) and subsequently the labrum is re-fixed with suture anchors using either knotted and knotless anchors. The sutures could be passed through (◘ Fig. 11.21) or around (◘ Fig. 11.25) the labrum, depending on the size of the labrum and the type of injury. It is very important to pass suture and perform the refixation close to the acetabular rim avoiding labral deformation or a high, non anatomic refixation in order to preserve as possible the sealing function of the labrum.

11.3.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: The main symptom of labral injury is motion-dependent pain in the anterior, lateral or posterior aspects of the hip joint (groin or gluteal region), occurring mainly with flexion and rotatory movements
- Symptom-specific examination: pain with flexion, internal rotation and adduction (anterior impingement test)

Imaging

The priority in diagnostic imaging is to obtain a well centered anteroposterior X-ray view of the pelvis as well as an axial view of the hip to best identify probable FAI or dysplasia and exclude hip osteoarthritis.

MRI with high resolution (> 1.5 T) can confirm the labral injury and moreover helps in diagnosing possible cartilage injuries as well excluding other diseases before performing hip arthroscopy (osteonecrosis, tumors, etc.).

11.3.4 Surgical Technique

Positioning and Preparation

The patient can be positioned in supine or lateral position on a fracture table. Positioning, distraction, diagnostic arthroscopy is performed in the same technique described in ▶ Sect. 11.1.

Evaluation of the Labral Injury

After placing both portals, the entire labrum (including the junction to the transverse ligament) is assessed through rotating the 70° arthroscope. The majority of labral injuries could be detected mainly in the anterolateral region. It is also crucial

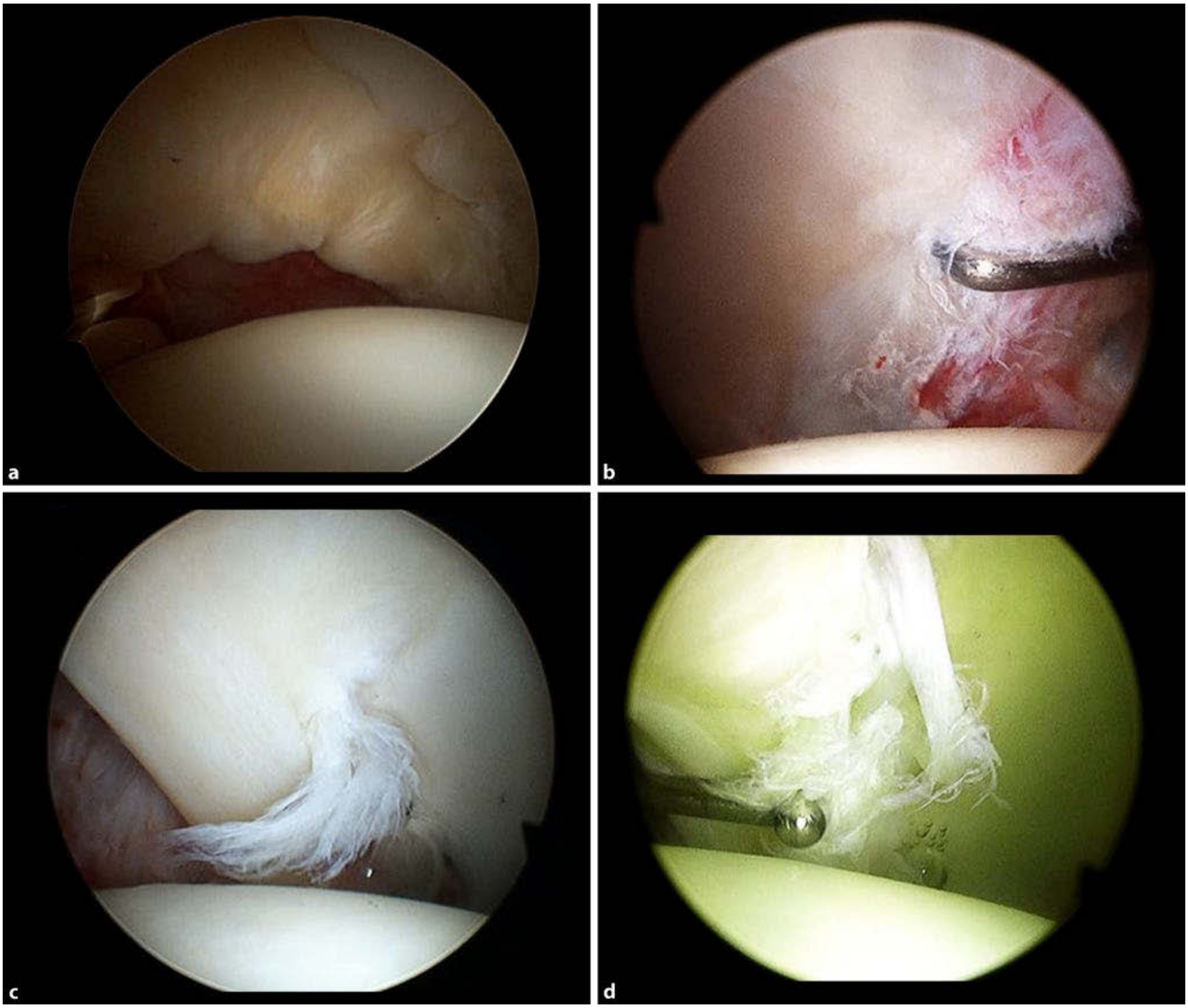


Fig. 11.18a–d Types of labral injuries: The acetabular labrum can present a yellow coloration (as a sign of early degenerative changes), intralabral cysts or tearing of the labrum substance (**a**, **b**). In addition, labral ossifications could be palpated with an arthroscopic probe (**b**). Labral base tears(**c**) are often the result of cam deformity not showing significant lesions of the labrum substance itself. Labral instability resulting from such lesions could be confirmed with an arthroscopic probe (**d**)

to evaluate the labrum using an arthroscopic probe (to pull and palpate) which allows a better evaluation of basal labral tears at the chondrolabral junction as well as concomitant adjacent chondral injuries. Different pathological conditions could be found: Degenerative changes, basal tears, intralabral ruptures, chondro-labral instability or intralabral ossification (Fig. 11.18). Many options for arthroscopic management exist depending on the type of lesion as well as the possible acetabular bony deformity (e.g. pincer deformity). Options are:: Partial labral resection, detachment and reattachment, acetabuloplasty and chondrolabral refixation.

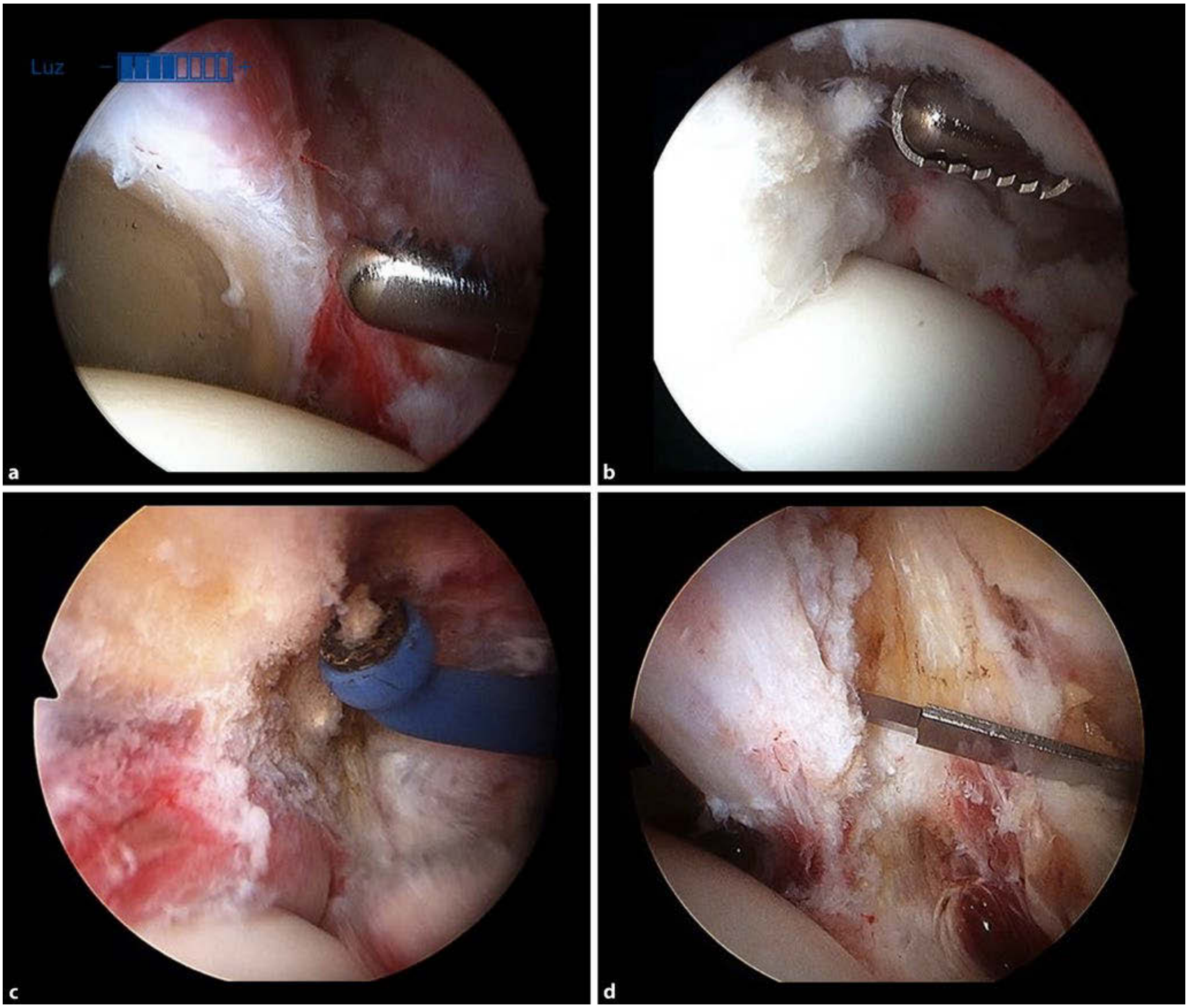
Partial Labral Resection

Partial labral resection is indicated if significant degenerative changes are present (e.g. extensive ossification, intralabral cysts, yellowish softening of the labrum). After performing capsulotomy and diagnostic arthroscopy, the injured labrum is resected with a punch or motorized shaver. Only the injured parts should be resected.

Important to prevent a re-rupture is to leave at the edge of the resected area a stable transition to the intact labrum. This is achieved through an oblique resection edge using the radiofrequency ablation.

Labral Base Tear

Refixation of the labrum is indicated if there is a detachment or basal rupture in absence of degenerative changes. Refixation is achieved by releasing the labrum at the injured area, debridement and decortication of the adjacent bone and then refixation with suture anchors. Additional acetabular rim re-



◘ **Fig. 11.19a–d** Labral detachment. Before detaching the labrum, the peripheral perilabral sulcus should be freed from synovial tissues with the shaver (**a**). This area could be easily accessed if the distraction is temporarily released. Residual tissues at the junction of the labrum to the bony acetabular rim could be removed using the RF ablation to allow a better visualization (**b**, **c**). The peripheral part of the labrum is then detached from the acetabular rim using an arthroscopic knife (**d**). Depending on the underlying pathology, the labrum could be detached partially or completely. The detachment must always be made directly at the bone without injuring the substance of the labrum itself

sectionis performed in case of of pincer deformity. Synovial tissue should be removed from the peripheral perilabral sulcus using a shaver or radiofrequency ablator before detaching the labrum to allow identification of the labral margin with the underlying bone. Temporary release of distraction is optional in this step of surgery to allow an easier access to this bone edge as well as to reduce the overall distraction time (◘ Fig. 11.19).

The labrum is then detached and averted from the bone using an arthroscopic knife along the outer basal aspect close to the bone to preserve the entire labrum (◘ Fig. 11.19d). The labrum is then detached at the injured area along the chondrolabral junction under direct visualization (◘ Fig. 11.20a). Labral detachment and release should take place only in the injured area. In cases of a pincer deformity the labrum must be released more extensive to allow an adequate resection of the acetabular rim.

The remaining tissues after labral detachment are debrided and removed away from the bone using an arthroscopic curette of shaver followed by bone resection with the burr (◘ Fig. 11.20). Bony resection of the acetabular rim is performed until the entire extent of the pincer deformity is corrected (▶ Sect. 11.2). If acetabuloplasty is not necessary, bone is resected only under the injured labrum to obtain a smooth surface with a stable chondrolabral junction. The labrum is then reattached to the free bone surface using suture anchors (◘ Fig. 11.23).

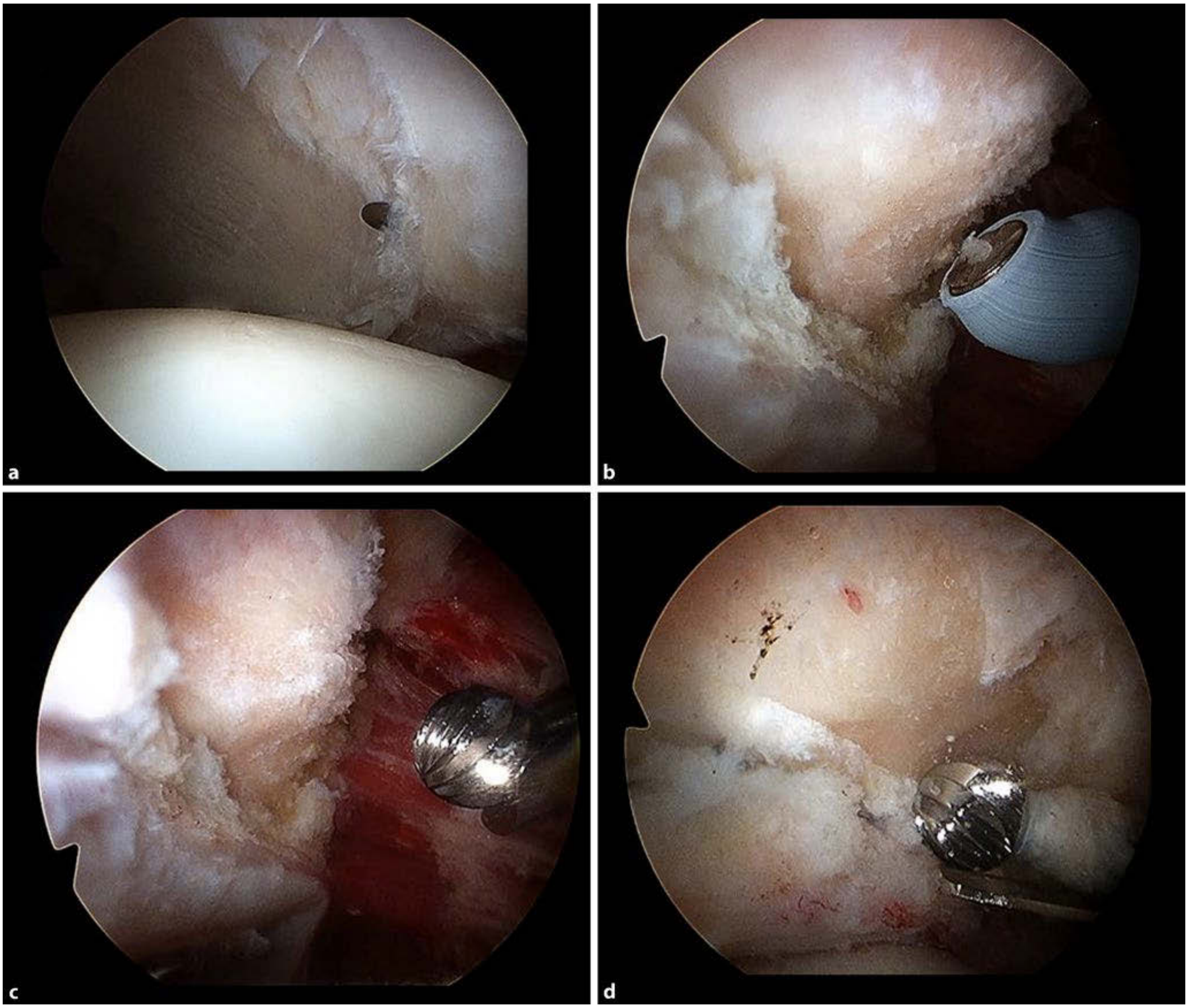


Fig. 11.20a–d Labral detachment. If the labrum should be completely detached from the acetabular rim (e.g. basal labral tear), this is done using an arthroscopic knife through the chondrolabral junction (**a**). This is done along the part of the acetabular rim to be detached, leaving the anterior and lateral parts of the labrum intact (this creates a so-called bucket handle tear). The labrum after detachment could be distally held using the 70° arthroscope to allow better visualization of the bony acetabular rim (**b**). The acetabular rim is then resected using a burr. The extent of resection depends on the underlying pincer deformity and the existing adjacent chondral changes (**c**). It is very important to create a stable osteochondral junction and a smooth bony edge to allow a stable fixation of the labrum (**d**)

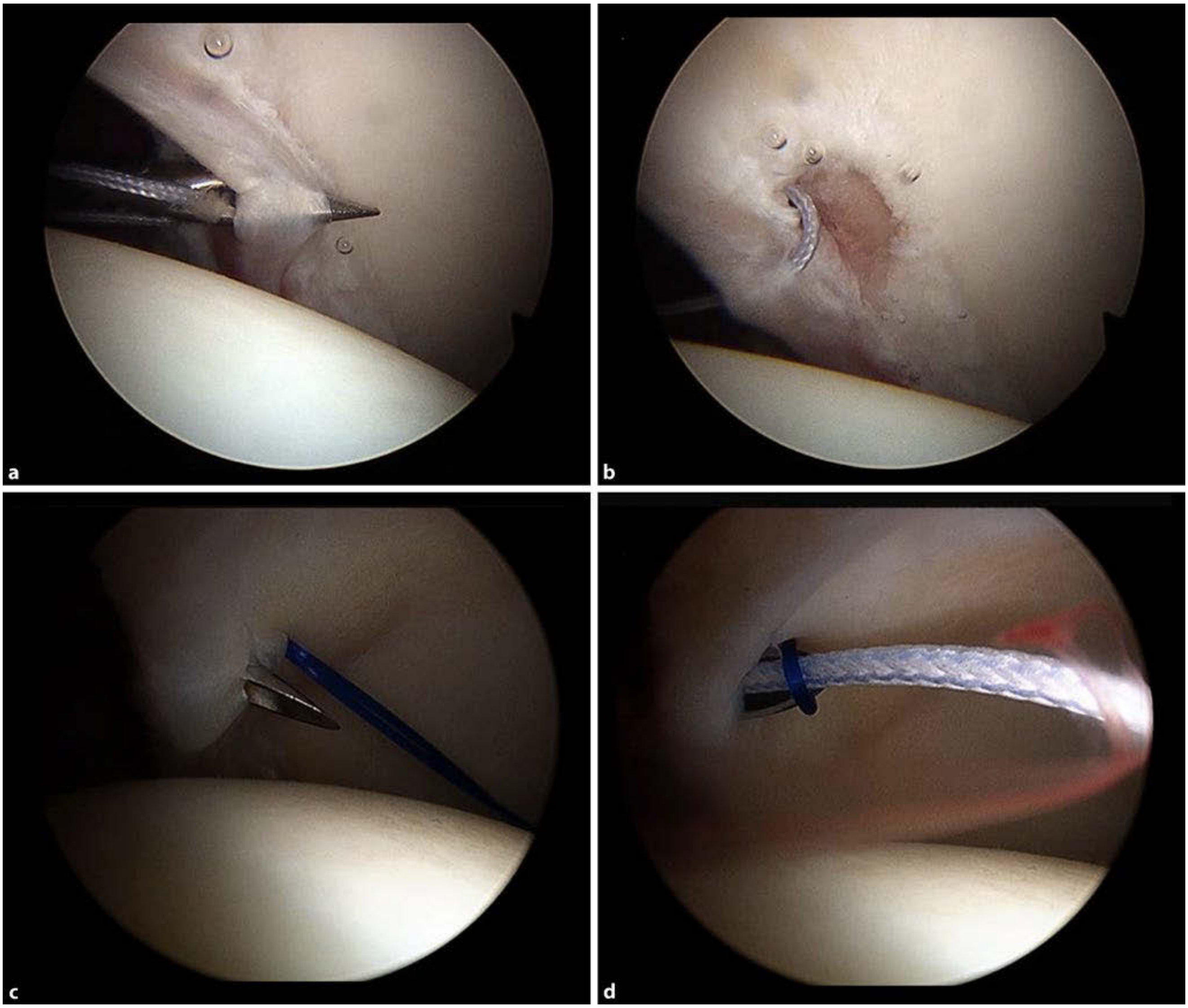


Fig. 11.21a–d Passing translabral suture. If the labrum is sufficiently large (> 5 mm) and without degenerative changes, it is possible to perform a translabral repair. The suture is passed through the labrum using a "Bird beak- suture passer" (Arthrex) (**a**, **b**). Another less traumatic option is to use a "Suture Lasso" (**c**, **d**)

Labrum Refixation

The use of arthroscopic cannulas is recommended during this phase of arthroscopy to allow an easier passage and management of sutures and to minimize the risk of soft tissue bridges. Labrum refixation could be achieved by passing sutures around the labrum in a looped manner (perilabral suture), which is indicated in cases of a thin labrum labrum (< 5 mm) or with degenerative changes. This is technically easier, but has the disadvantage that the labrum is partially deformed and the suture material remains between the labrum and femoral head (Fig. 11.25). If the labrum is large enough (> 5 mm) and with no degenerative changes, the sutures could be passed through the labrum itself (translabral suture). This technique has the advantage of less labral deformation, and no remaining suture material between labrum and femoral head. A variant of this translabral repair is the so-called labral base repair in which the translabral sutures are passed through the base of the labrum (Figs. 11.22 and 11.23). Additional advantages of this technique includes that no suture threads remain in the central joint compartment as well as achieving an anatomical reconstruction of the chondrolabral junction.

A so-called "Birdbeak suture passer" (Arthrex) helps to pass the sutures through the labrum. Optionally, a less traumatic "Suture Lasso" could also be used (personal preference) (Fig. 11.21).

The labrum is fixed using suture anchors being crucial the correct placement and orientation of the anchors. Predrilling for anchor is done directly at the margin of resected bone adjacent to the joint surface to allow anatomical labral fixation (Figs. 11.22c and 11.24a).Drilling should be always directed proximally far away from the acetabular articular surface to avoid its penetration. The 70° arthroscope should be always facing the acetabulum during drilling to visualize any probable perforation of the articular surface. The surgeon should

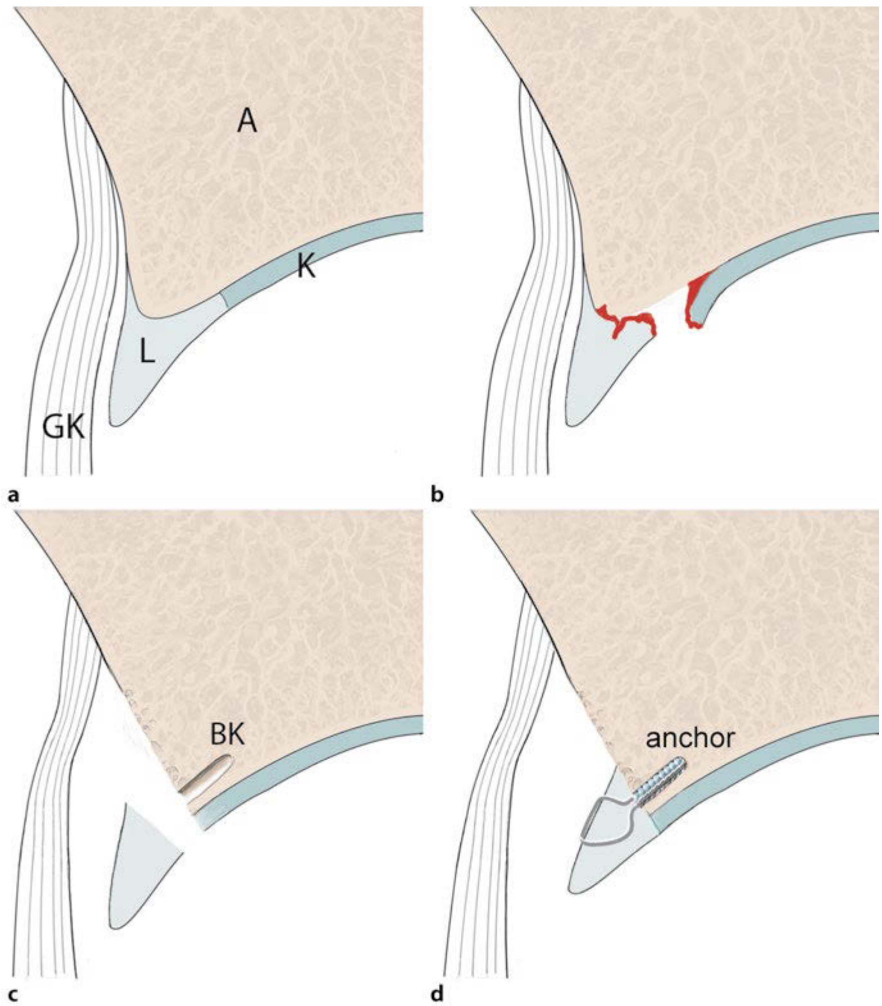


Fig. 11.22a–d Repair of labral basal tear. Schematic representation of the chondrolabral complex (**a**) with basal labral avulsion tear (**b**). This results classically from abutment of the of the cam deformity (bump) against the chondrolabral junction (**a**, *arrow*). This results in a basal labral avulsion and detachment of the adjacent cartilage from the acetabulum (**b**). The management includes detaching the labrum from the acetabular rim which is then resected (**c**). Subsequently, the Labral repair with suture anchors is performed (**d**). To achieve that, the drill hole must be placed close to the osteochondral junction and directed proximally in an oblique orientation. Penetration of the joint with the drill must be strictly avoided (**c**, *arrow*). Lastly the basal labral repair is performed, in which the sutures are passed through the base of the labrum. This allows anatomic labral repair without leaving suture material over the joint surface (*A*: acetabulum, *L*: labrum; *K*: Cartilage; *GK*: joint capsule; *BK*: drill hole)

have the hand sense of drilling through cancellous bone; a resistance may correspond to the acetabular subchondral bone or a prior placed anchor. In those cases, a new more proximally directed socket should be drilled. Next step is to fix the labrum with suture anchors ensuring an anatomical position and proper tensioning of the sutures. Individualized adjustment of both suture limbs prevents rotation, deformation or inversion of the labrum (Fig. 11.24).

The number of the required anchors depends on the extent of labral detachment. The distance between the anchors should be about 8–10 mm. It is v essential to achieve a stable fixation of the labrum, this is checked after fixation with an arthroscopic hooked probe. The hip distraction is released after completing the labral fixation to evaluate the correct repositioning of the labrum over the femoral head as well as the stability of the repaired labrum in flexion and rotation (Figs. 11.24e, f and 11.25).

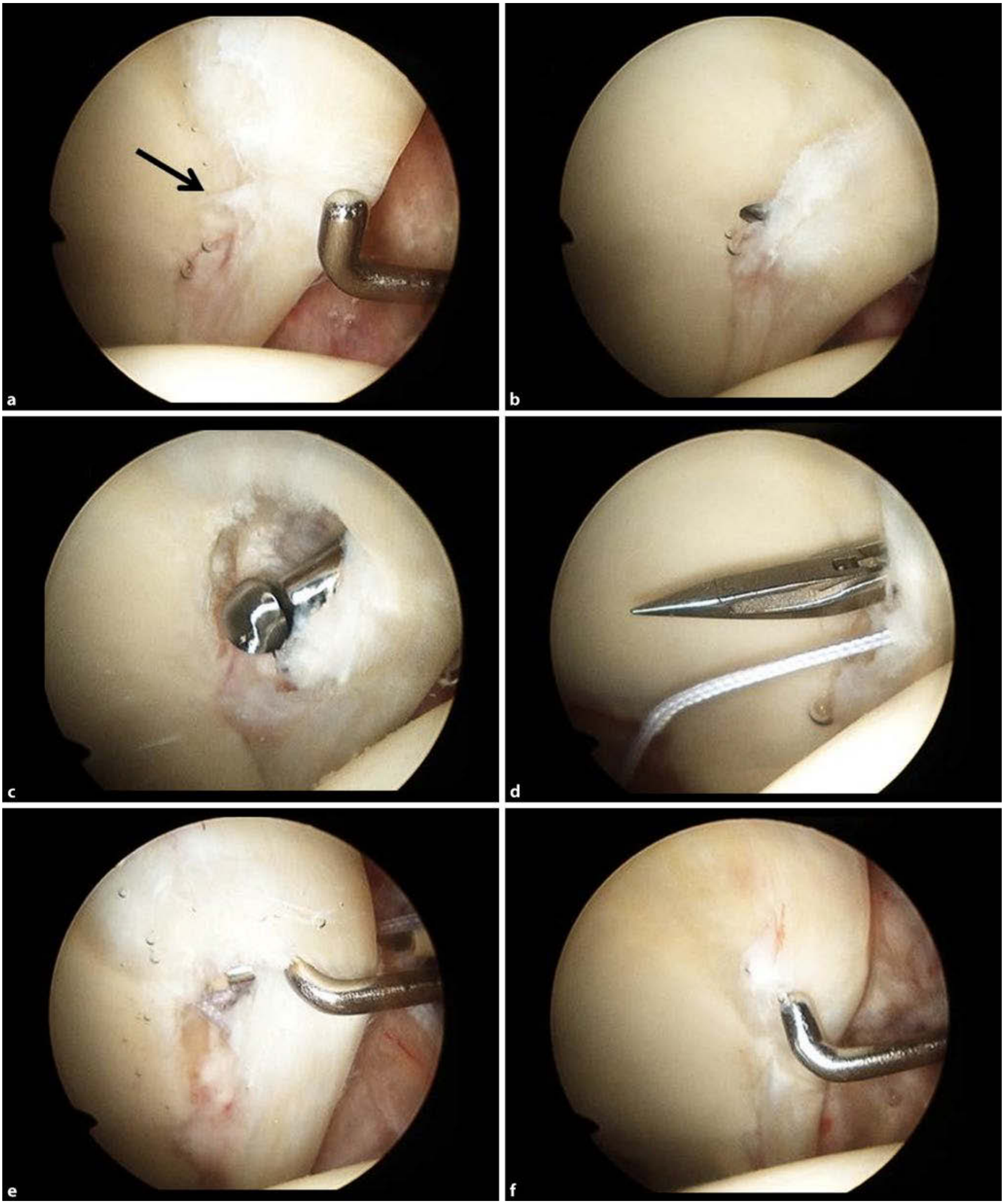


Fig. 11.23a–f Labrum refixation with labral base repair. Labral injury with a basal labral tear secondary to a cam deformity (**a**, *arrow*). The Labrum is completely released with the arthroscopic knife (**b**). The bone adjacent to the inured area is resected with a bur (**c**). Translabral passage of the suture is then performed, the sutures of the anchor are passed directly through the base of the labrum (**d**). The suture is retrieved with a forceps between the labrum and acetabular rim (**d**). After drilling through the debrided bone near to the joint surface, the labrum is fixed by tying the sutures (**e**). With this translabral basal repair, the labrum could be anatomically reconstructed (**f**) without remaining residual sutures in the central joint region or between labrum and femoral head

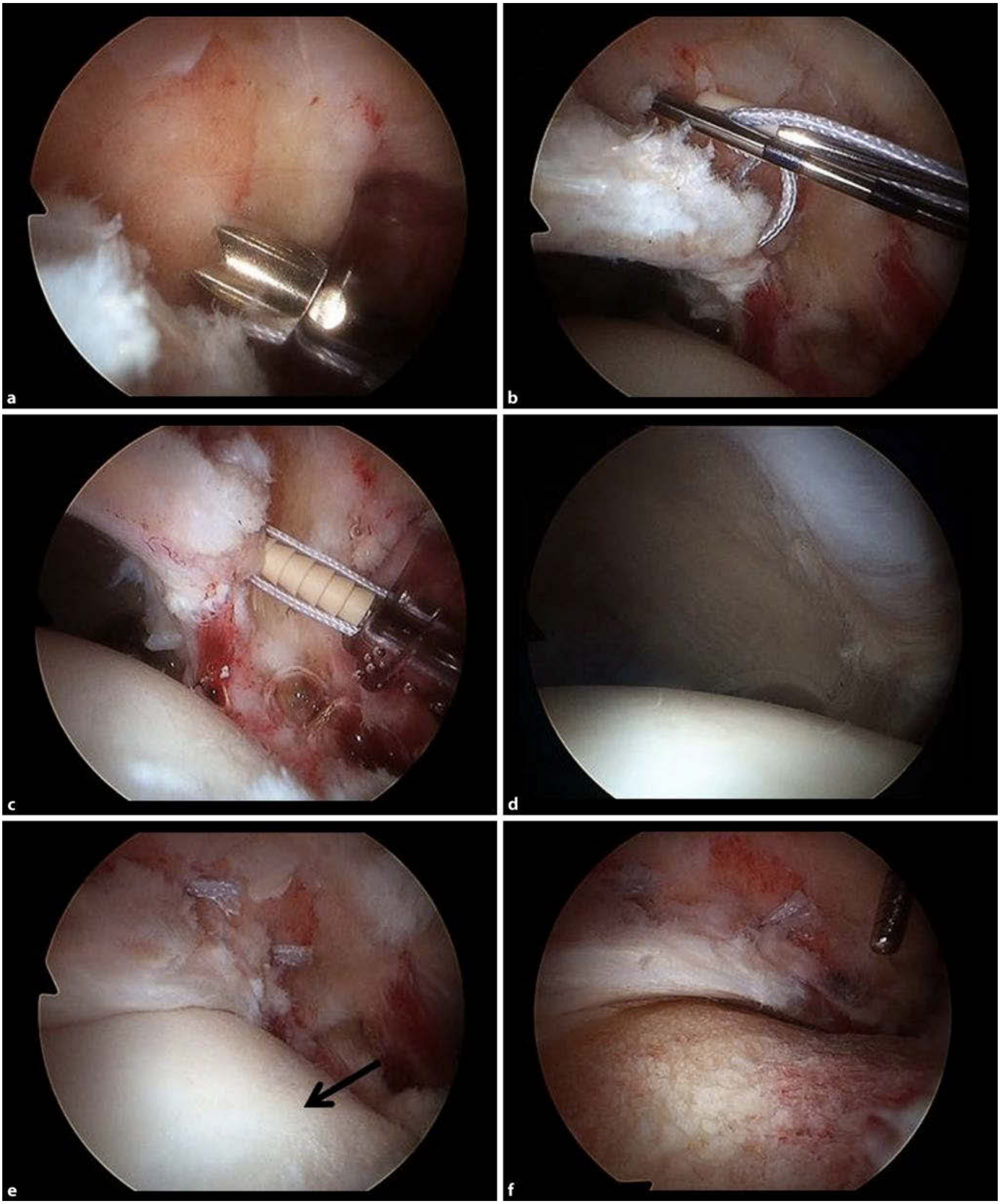


Fig. 11.24a–f Labrum refixation after acetabular rim resection. After acetabular rim resection in a pincer deformity, the detached labrum should be repaired using suture anchors. The drill hole is placed directly at the osteochondral junction of the acetabular rim to allow an anatomical placement of the reattached labrum (**a**). The direction of the drilling should be oriented obliquely proximal to avoid penetration of the joint surface. Marking of the drilling hole with a nitinol wire is recommended before placing the knotless anchor (**b**). Bony resistance confirms a correct intraosseous location of the drill hole. The labrum could be now reattached to the acetabular rim (preferably with a translabral basal repair **b**). Tension as well as eversion and inversion of the labrum could be controlled tensioning each suture thread individually (**c**). After fixation with suture anchors, the anatomical refixation of the labrum could be achieved without visible sutures in the joint area (**d**). Successful reattachment (with 2 anchors) could be confirmed if the correct relation of the labrum to the femoral head remains after releasing the distraction (**e**). The now visible cam deformity at the femoral head (**e**, arrow) is then resected with a burr, until there is no more impingement in internal rotation and flexion as proved with dynamic movement testing (**f**)

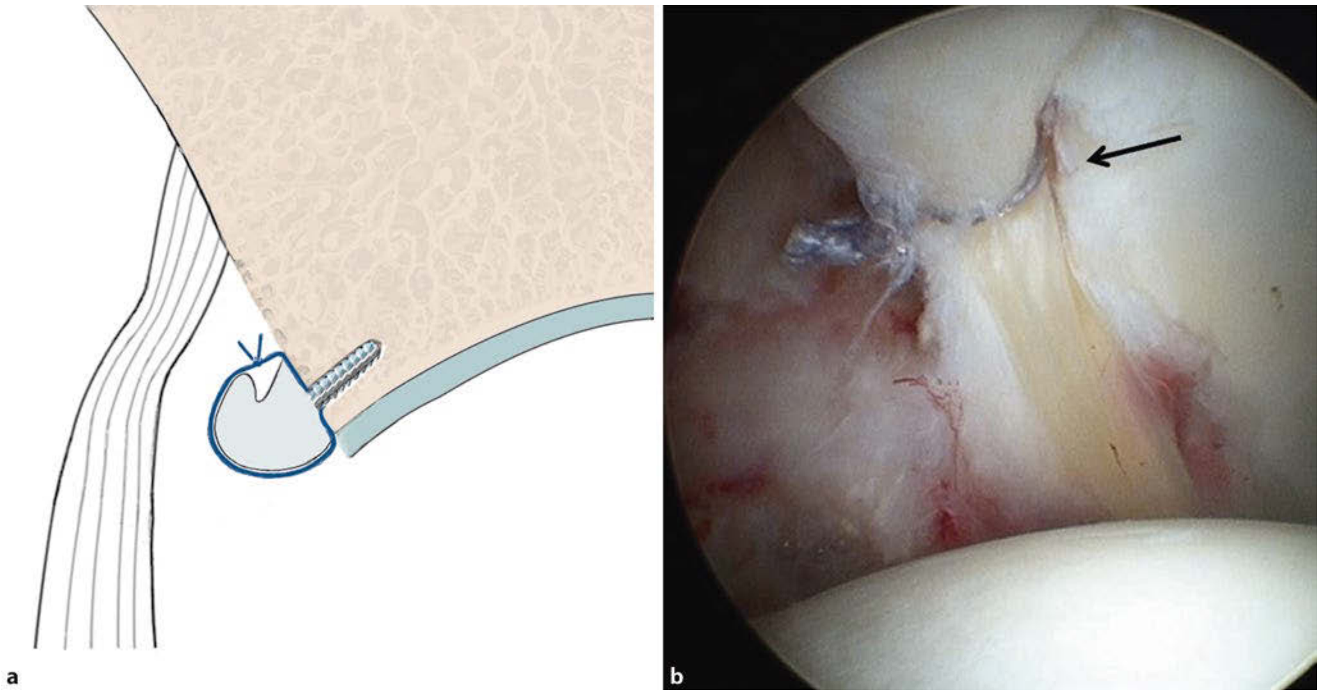
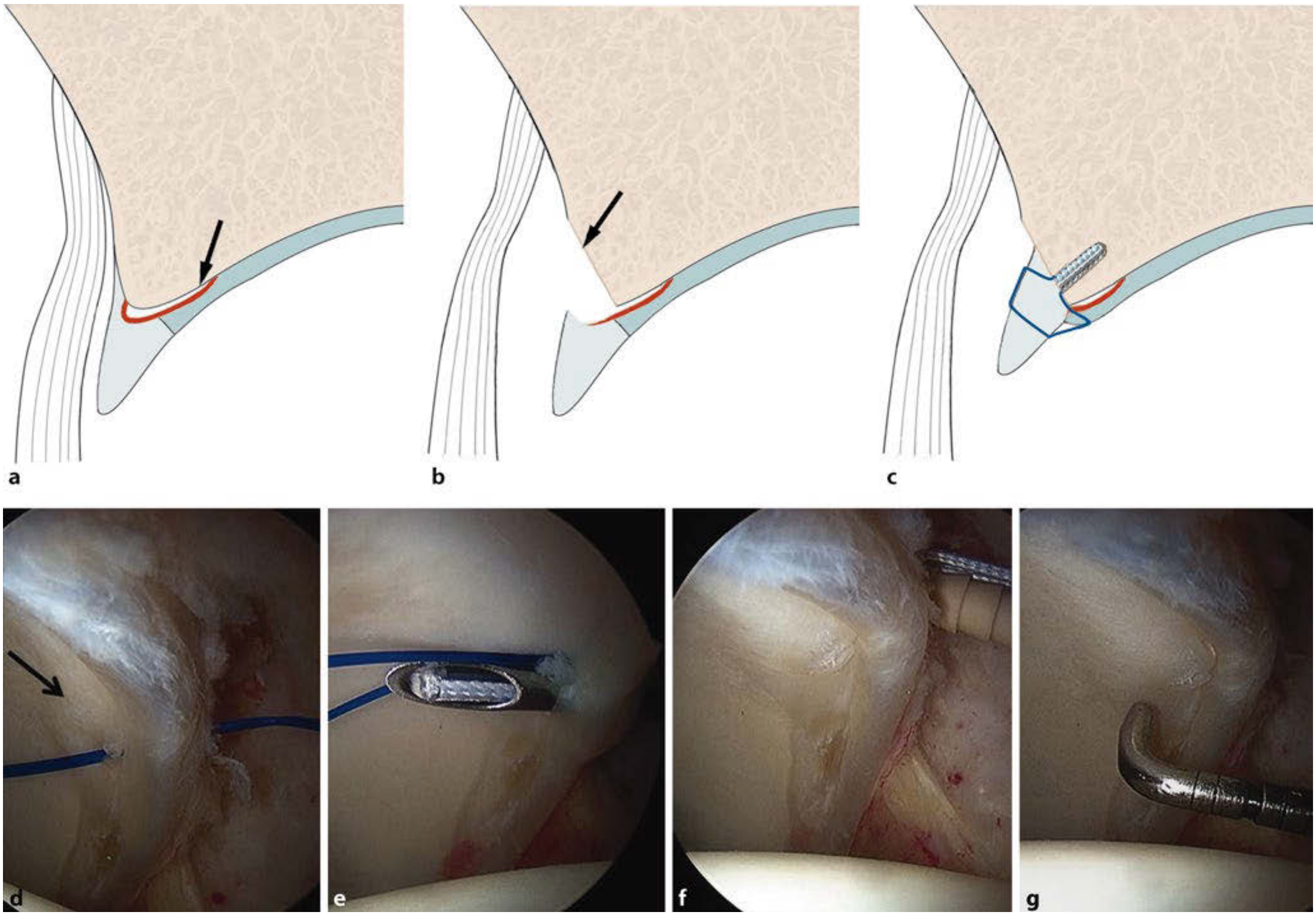


Fig. 11.25a, b Labral repair with perilabral suture-technique. If the labrum shows degenerative changes or has a very small size(< 5 mm), there will be an increased risk of suture cut through and failure if translabral technique is used. In such cases, the suture should be passed around the labrum (**a**, **b**). This often results in deformation of the labrum (**a**) and limits the option of an anatomical reconstruction of the chondrolabral junction (**b**, *arrow*)



■ **Fig. 11.26a–g** Chondrolabral refixation. The FAI is often associated with chondrolabral injuries. The cartilage and labrum are detached from the adjacent bone without interruption of the chondrolabral junction. The cartilage appears softened and with increased mobility on examination with a probe (**a**, *arrow*, called "wave sign"), the labrum also shows instability with traction and pressure using the probe. In such cases, the labrum is detached at its periphery without cutting through the chondrolabral junction (**b**). Exposed acetabular bone is freshened with a curette after resection of the acetabular rim. The refixation using suture anchors involves passing suture threads through both the cartilage as well as the base of the labrum (**c**). It is recommended here to penetrate the cartilage with a "Suture Lasso" (**d**). The translabral suture is then passed through the base of the labrum (**e**) ensuring that it passes around the chondrolabral junction (**f**). After refixation with suture anchor (**e**), the stability of the labrum is evaluated with the arthroscopic probe (**g**). The stability of the repaired cartilage could be confirmed mostly in the same way

Chondrolabral Refixation

Unstable labral tears are often associated with lesions of the adjacent cartilage (chondromalacia Grade 2–3) without interruption of the chondrolabral junction (■ Fig. 11.26). In those cases the refixation of the labral lesion is indicated maintaining the chondrolabral junction intact. The procedure begins with releasing the labrum peripherally with a scalpel followed by passing the arthroscopic knife between the cartilage and acetabulum without penetrating or damaging the intact chondrolabral junction (the tip of the scalpel shouldn't be seen from the articular surface). This is followed by selective bone resection using an arthroscopic burr. The resultant chondrolabral flap is then fixed using a special repair technique in which the stitch of the suture anchor is passed directly through the cartilage as well as through the base of the labrum (■ Fig. 11.26).

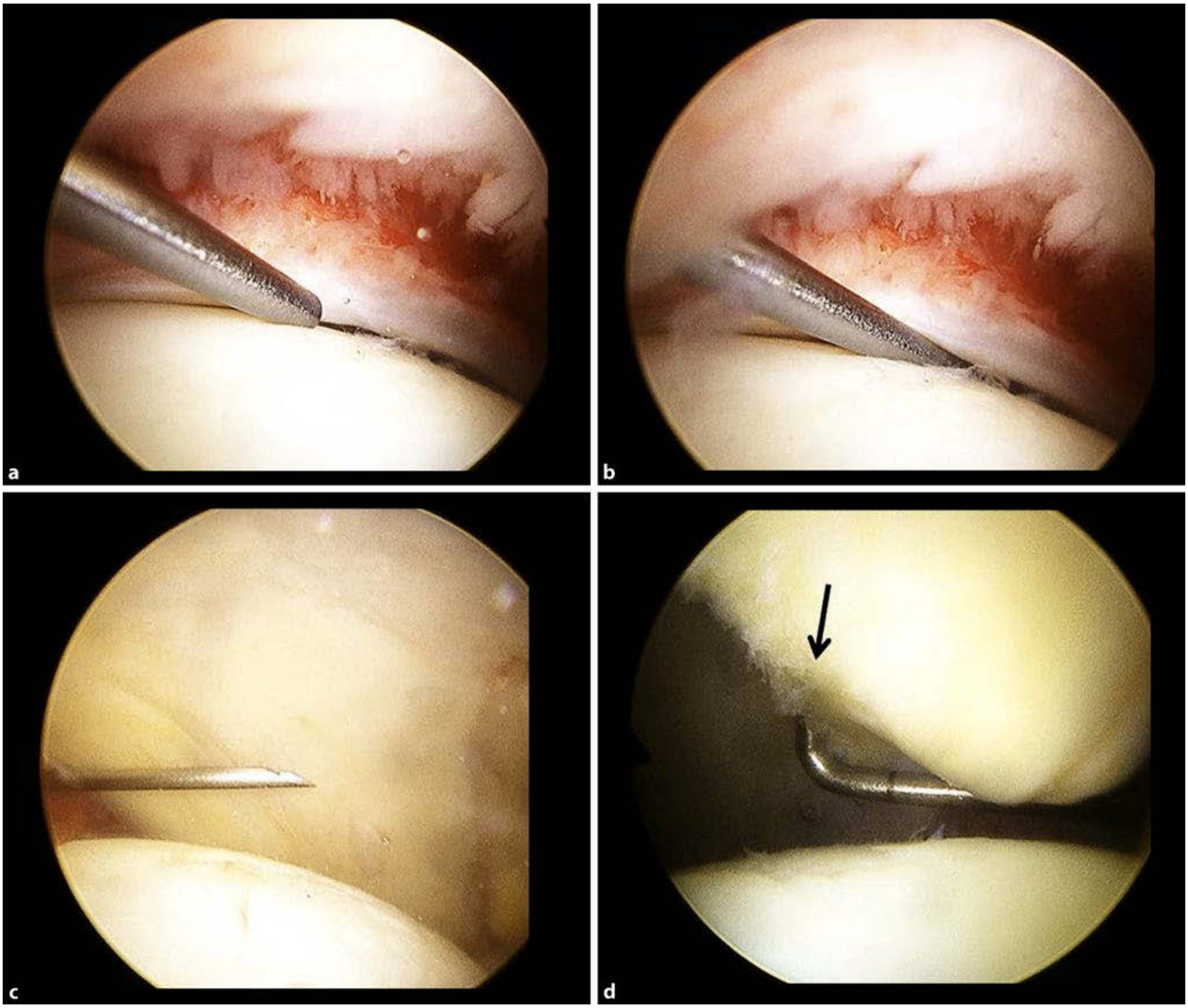


Fig. 11.27a–d Labrum in hip dysplasia. Patients with hip dysplasia shows mostly a hypertrophied labrum which increases the risk of labral injury during the portal placement. To avoid that, it is recommended to start hip arthroscopy in the peripheral compartment. After introducing the arthroscope (through the portal recommended by Dienst), a nitinol wire is introduced through the anterolateral portal between labrum and femoral head (**a**). The distraction is increased allowing introduction of the guide wire, cannula and arthroscope under direct visualization without injuring the labrum (**b**). With the 70° arthroscope in the central compartment, the safe triangle is sought in the anterior part of the joint (**c**) allowing a safe placement of the second portal under direct vision paying particular attention also for the hypertrophied labrum (**c**). The intraoperative diagnosis confirms a hypertrophied labrum (> 12 mm) and a basal labral avulsion (**d**, *arrow*). Labral resection in patients with dysplasia should be avoided as possible

Special Situations of the Labrum

Hip Dysplasia

Patients with hip dysplasia usually have a hypertrophied labrum, which contributes significantly to joint stability. Labral resection shouldn't be performed in these patients to avoid inducing more instability. On the other side, there is an increased risk of injury during portal placement. The technique described by M. Dienst is recommended in these patients and involves the visualization of the peripheral compartment first and, after them, approaching the central compartment under direct visualization and monitoring of the labrum (Fig. 11.27).

Ossification and Calcinosis

Intralabral ossification or a focal calcinosis could exist as part of a FAI. These lesions could be locally removed ("enucleation") without necessity for labral resection (Fig. 11.28). Reconstruction of the labrum is often required after removal of these ossification or calcinosis through perilabral suture repair.

Chondrolabral Sulcus

A deep sulcus frequently exists at the chondrolabral junction and shouldn't be considered as a labral tear (basal avulsion) (Fig. 11.29). This sulcus could resemble a basal labral injury in the MRI. This sulcus, in contrast to the labral tear, doesn't

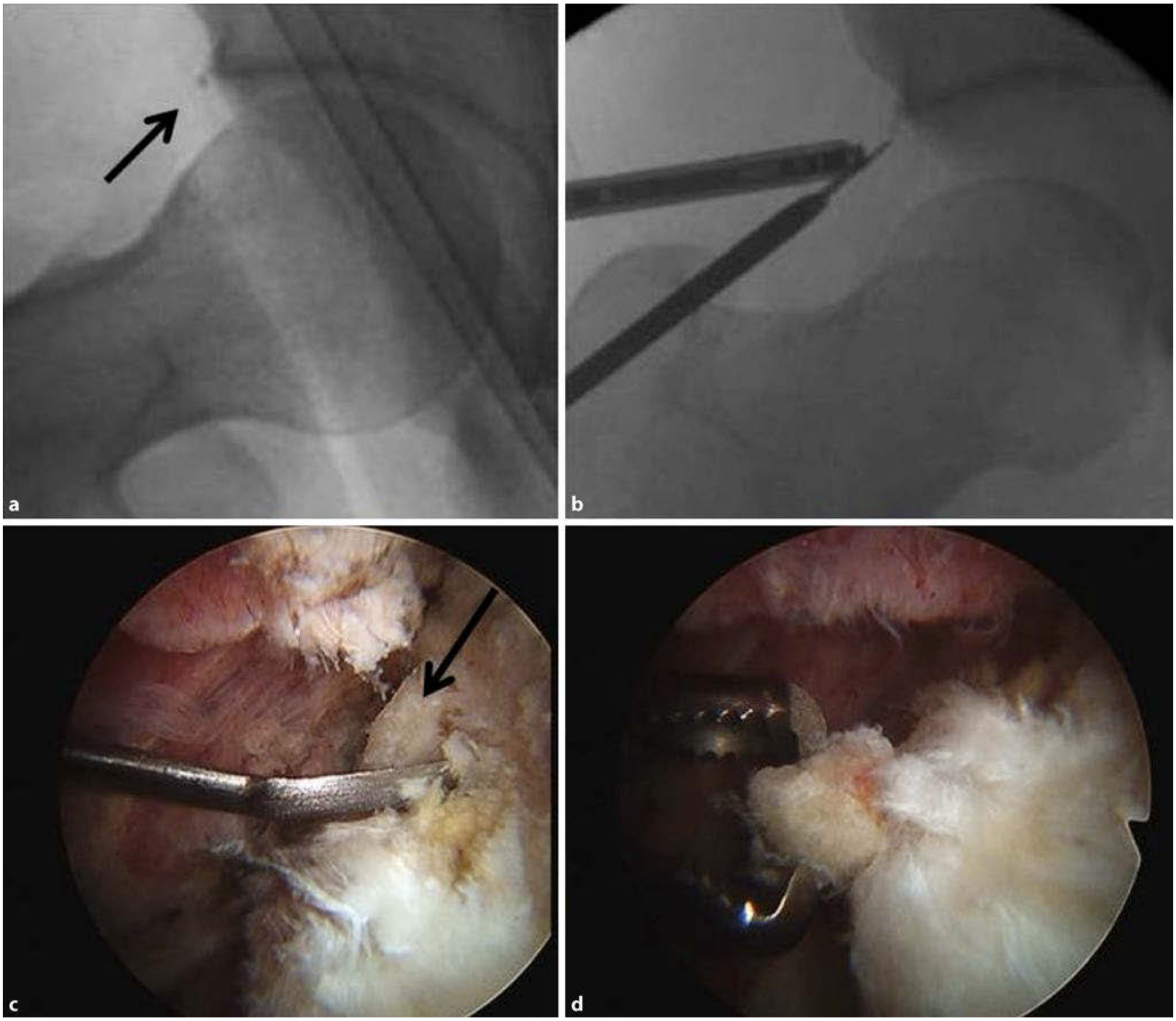


Fig. 11.28a–d Intralabral ossification and calcinosis. Intralabral ossifications or calcinosis could occur as a result of degenerative changes. This can be seen in x-rays directly adjacent to the acetabular rim (**a**, *arrow*). The ossification could be directly dissected from the labrum with the arthroscopic knife (**b**) and subsequently freed from the remaining soft tissues (**c**, *arrow*) and removed with a grasper (**d**). Intralabral calcinosis could be occasionally seen. These are not bony lesions, but consist of soft, chalky substance resembling the calcific tendinitis of the shoulder. These lesions are also released using an arthroscopic knife, the debrided tissues are removed with the shaver

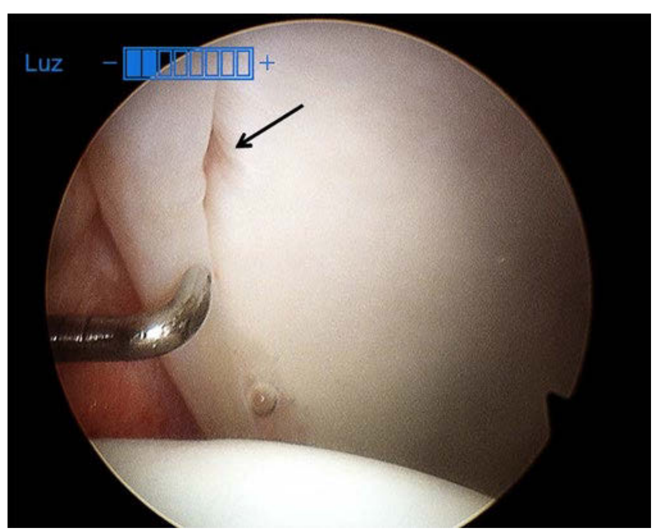


Fig. 11.29 Chondrolabral sulcus. A sulcus of varying depth is often seen at the chondrolabral junction (*arrow*). In contrast to basal labral tears, the surface and substance of the labrum remains intact. The cartilage directly adjacent to the chondrolabral sulcus is also intact

show tissue abnormality, unstable structures or an adjacent chondral lesion. Labral refixation is usually not necessary in these cases.

11.3.5 Postoperative Management

- Cooling and elevation of the extremity
- Elastic compressive bandage
- Monitoring of peripheral circulation, motor and sensory innervation

11.3.6 Follow-Up Management

Passive mobilization using a CPM machine up to 70° flexion of the hip. Flexion beyond 90° and forceful rotation should be avoided in the first 4 weeks. Walking supported with one crutch is encouraged from the day of surgery and for about one week.

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Tendons

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A. B. Imhoff, M. J. Feucht (Eds.), *Surgical Atlas of Sports Orthopaedics and Sports Traumatology,*
DOI 10.1007/978-3-662-43776-6_12,

12.1 Proximal Hamstring Tendons Repair

T. Saier, P. Brucker

12.1.1 Indication

Acute (≤ 6 weeks) and symptomatic chronic complete rupture or bony avulsion (adolescence) of one or more of the ischiocrural muscles (long head of the biceps femoris, semimembranosus and semitendinosus; "Hamstrings") with decreased strength of Knee flexion/internal rotation and increased functional demands.

Relative indications: partial rupture, complete rupture with low functional demands in the elderly; obviously retracted chronic rupture with (≥ 6 weeks) with moderate degree of fatty infiltration or atrophy.

Contraindications: irreducible chronic rupture with extensive fatty infiltration and atrophy of the muscles.

12.1.2 Operation Principle

Reattachment of the distal tendon stump or the bony avulsion to the ischial tuberosity using suture anchors.

12.1.3 Preoperative Assessment

Diagnosis

Clinical

Symptom specific history: timing and mechanism of the injury (typical patho-mechanism is an indirect force during sprinting or jumping (take-off phase) through a forced eccentric contraction of the ischiocrural muscles with extended knee and flexed hip joints resulting in distortion, rupture or bony avulsion of the proximal hamstring tendons. Pain (mostly in sitting), swelling and hematoma in the gluteal region as well as the proximal posterior thigh, instability or weakness during walking. An audible pop in the gluteal region during the trauma is often describe. Risk factors: smoking, chronic systemic diseases, steroid intake and chronic deficiency disorders.

Symptom specific examination: limping, hematoma in the posterior aspect of the proximal femur. The posterior thigh muscles retract distally with absent tension during active contraction in comparison to the other side. Tenderness by deep palpation over the gluteal fold (ischial tuberosity). A gap is palpable over the hamstrings origin (ischial tuberosity) in comparison to other side. Pain over the ischial tuberosity with passive elevation of the extended leg. Weakness of knee flexion (against resistance in prone position) as well as weakness of the hip extension against resistance. In comparison to the other side, a significant reduction of the tone of the distal hamstrings with active knee flexion. Decreased active internal rotation of the knee with rupture of the semitendinosus and semimembranosus. Decreased active external rotation of the knee with rupture of the biceps femoris.

Imaging

- X-ray: pelvic AP or hip AP and lateral views to assess the bony status and exclude apophyseal avulsion.
- MRI of the pelvis and thigh in 3 planes to differentiate between partial and complete ruptures and to assess the hematoma, the involved tendons (often limited injury), retraction, atrophy and fatty infiltration (Fig. 12.1).

Patient Information/Consent

Specific operative risks: prolonged and a very exhausting and restricted postoperative recovery with consequent use of a hip-knee hinged brace (especially in chronic ruptures or with marked retraction), mobilization using crutches and prophylaxis against DVT for at least 8–10 weeks after surgery, a minimum of 4–6 months of restricted motion; increased risk of infection (proximity of the operative field to the anus), re-rupture, suture and knot insufficiency, anchor dislocation, heterotopic ossification; loss of muscle strength or limitation of the knee or hip flexion; sensorimotor deficit of the affected limb (injury of the posterior cutaneous nerve of the thigh, sciatic or inferior gluteal nerves); pain or discomfort with prolonged sitting; compartment syndrome of the posterior thigh compartment.

12.1.4 Surgical Technique

Positioning and Preparation

- Prone position with 20° of hip flexion
- Marking the skin incision at the gluteal fold or femoral (Fig. 12.2)
- Application of an Iodine-impregnated adhesive incision drape to the surgical field.

Proximal Hamstring Tendon Refixation Using Suture Anchors

Transverse skin incision along the gluteal fold (Fig. 12.2). After transversely incising the fascia, the inferior margin of the gluteus maximus muscle is mobilized and superiorly retracted. When placing retractor under the gluteus maximus, care must be taken that the maximum depth shouldn't exceed 4 cm (Inferior gluteal nerve).

The ischiocrural fascia incised with great care for the course of the sciatic nerve which could be located and palpate 1–1.5 cm lateral to the ischial tuberosity. In chronic ruptures, scarring could result in marked tissue adhesions that necessitates neurolysis of the sciatic nerve.

The biceps femoris and semitendinosus muscles have a common origin at the ischial tuberosity, immediately medial

Fig. 12.1 Proximal hamstring rupture on MRI

Fig. 12.2 Positioning and skin incision

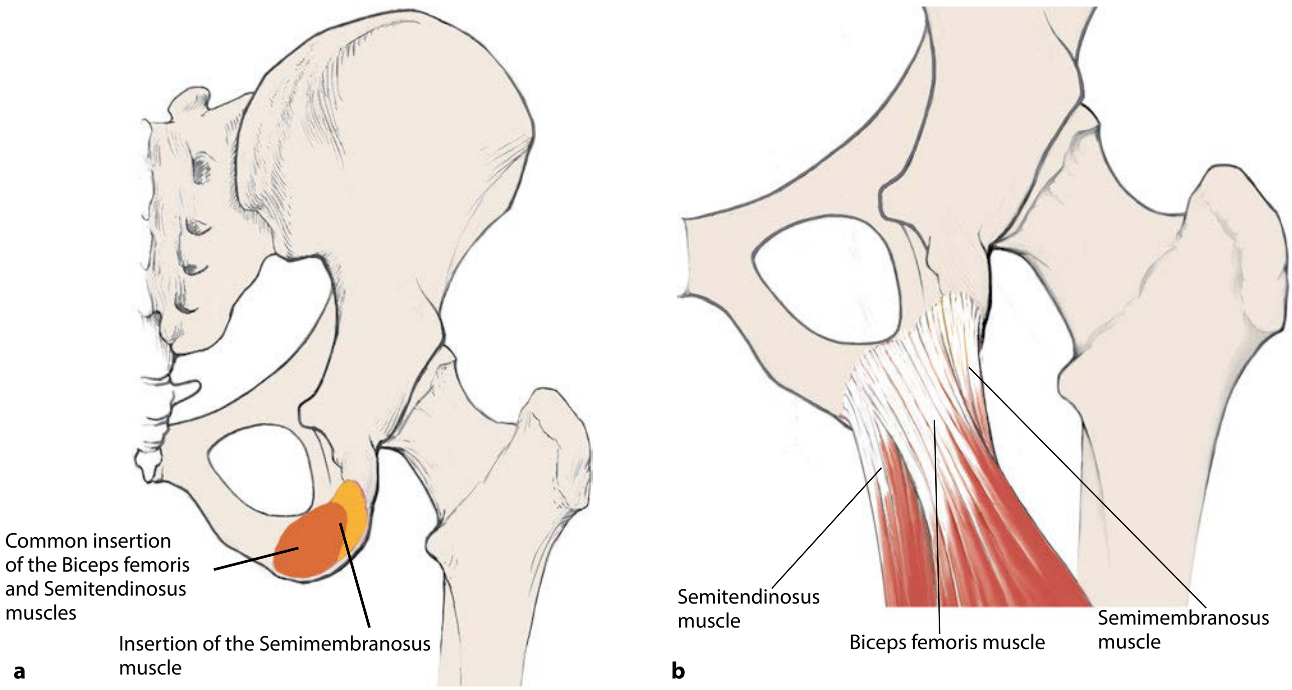


Fig. 12.3a,b Zone of insertion of semitendinosus-/biceps femoris and semimembranosus tendons

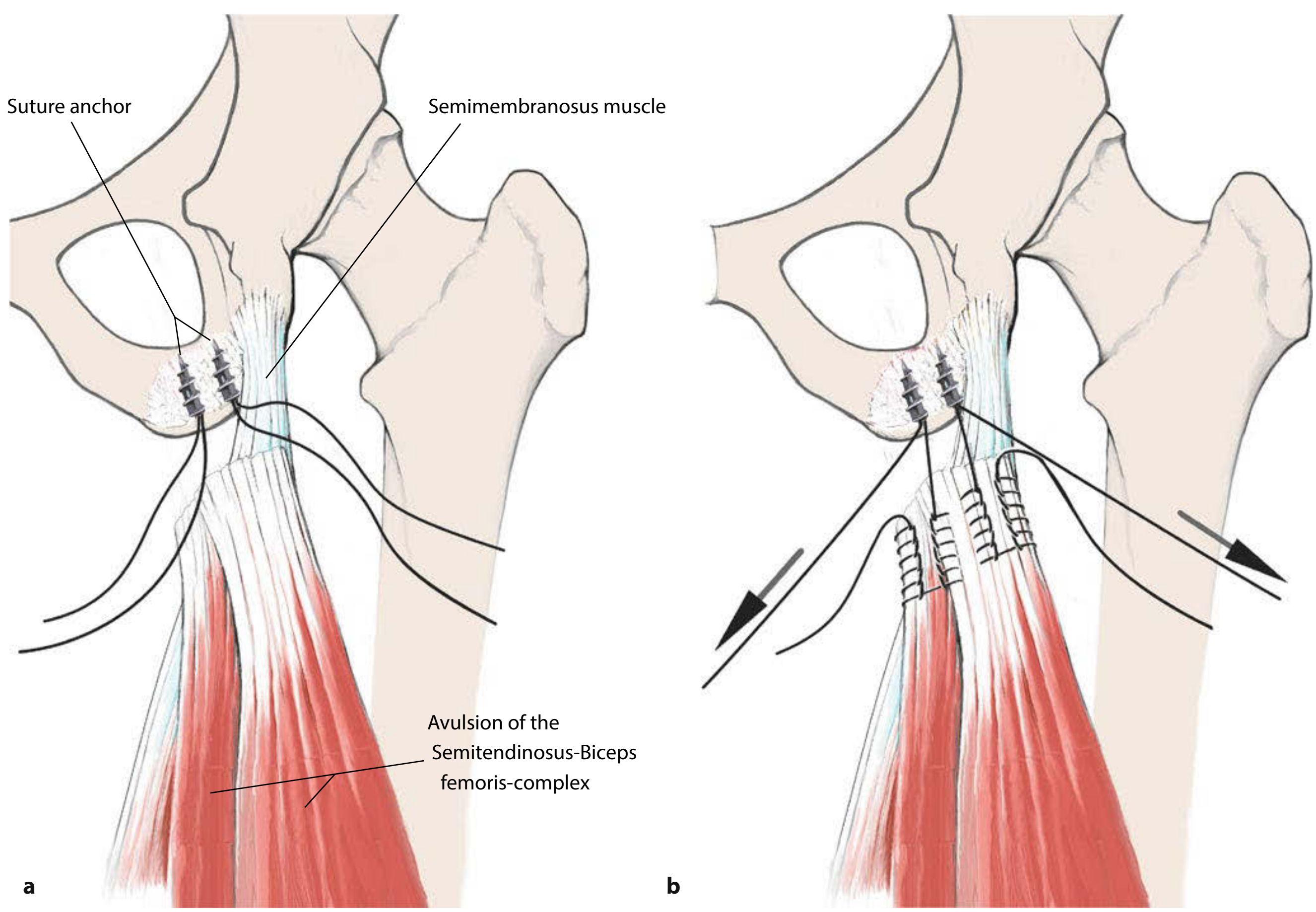


Fig. 12.4a,b **a** Stitching the hamstring tendons with one suture limb from each anchor; **b** Repositioning of the tendons by pulling the other free suture end (pulley principle)

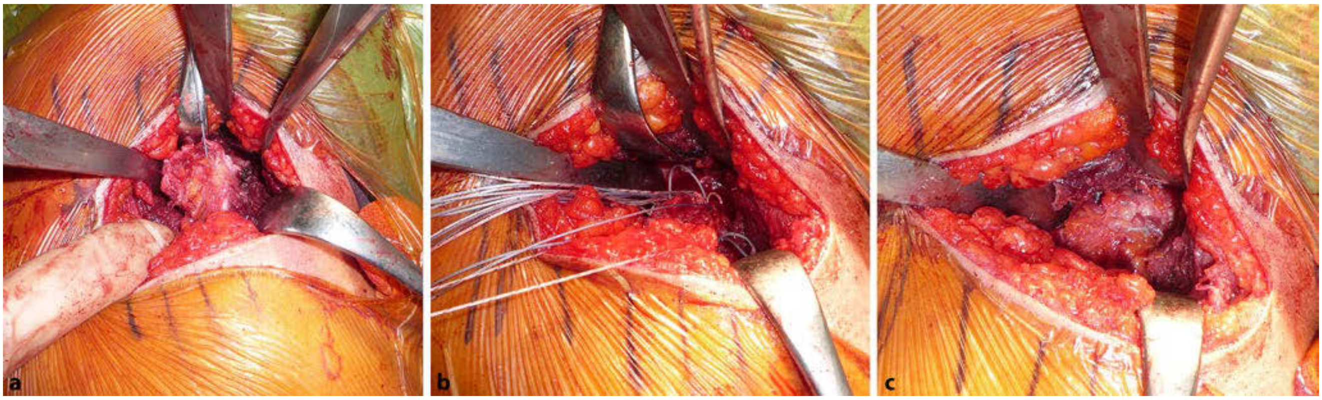


Fig. 12.5a–c Intraoperative view. **a** Mobilization of the proximal hamstring tendons complex; **b** Stitching the tendon complex; **c** Reattached tendon complex

Fig. 12.6a,b Postoperative radiograph after hamstring tendon refixation using 3 suture anchors. **a** AP view; **b** axial view

to the origin of the semimembranosus tendon (Fig. 12.3). With complete avulsion of all tendons and to restore the anatomy, it is recommended to insert one of the anchors more laterally for reattachment of semimembranosus tendon, which anatomically crosses under common tendon of the semitendinosus and biceps femoris muscles.

After identifying the ruptured hamstring tendons, they are stitched and the bony insertion zone at the ischial tuberosity is freshened with a bone nibbler or a chisel. Titanium suture anchors preloaded with non-absorbable sutures (e.g. 5.5 mm Corkscrew, FiberWire, Arthrex) are used for reattachment.

Bone sockets for the anchors are predrilled and tapped at the ischial tuberosity (with a 3.2-mm drill bit). Reattachment is performed routinely using 3–4 suture anchors. The tendon end is stitched securely with one suture limb in an ascending and descending pattern. The tendon stump is then repositioned through pulling the other free suture limb (Figs. 12.4 and 12.5). The final knot is tied at 30° knee flexion. The target should be a tension-free construct when the knee is extended. A hip-knee hinged brace (e.g. Newport orthosis) is recommended to be applied before extubation.

12.1.5 Postoperative Management

- Monitoring of peripheral circulation, motor and sensory innervation
- A hip-knee hinged brace (e.g. Newport orthosis) is recommended
- Cooling of the extremity
- Postoperative radiographs (hip anteroposterior hip and axial; Fig. 12.6)

12.1.6 Follow-Up Management

In acute cases with an easy non-complicated refixation without tension, 6 weeks of only sole contact without orthosis are sufficient. In chronic cases with refixation of the tendons under tension, non-weight bearing mobilization on crutches with consequent use (24 h/day) of a rigid hip-knee hinged brace. The orthosis here is fixed in hip extension and 90° knee flexion. From the 7th week physiotherapeutic rehabilitation program is started with a concentrated stretching program of the postoperatively shortened ischiocrural muscles.

Fig. 12.7 Approach: starting about 2–3 cm distal to the anterior superior iliac spine and extending inferiorly for about 8–10 cm

Gradual weight bearing is then allowed at a rate of 15–20 kg/week. An accompanying targeted muscle strengthening of the atrophied hamstrings as well as exercises to improve proprioception should be performed. The target should be a free hip and knee mobility between 12–16 weeks after the procedure. Ergometer training is started between 8–10 weeks after surgery. Treadmill training is started at 4 months. Resumption of the specific sport training at 6–8 months postoperatively. Competitive and contact sports could be resumed between 10–12 months postoperatively.

12

12.1.7 Tips & Tricks

After incision of the ischiocrural fascia, evacuation of the hematoma evacuation guides the way to localize the rupture zone.

To avoid sciatic nerve injury during lysis of adhesions or scarring in chronic ruptures, it is recommended to identify the nerve distal to the rupture zone and trace it proximally.

When drilling or tapping bone sockets for suture anchors at the ischial tuberosity, penetration into the pelvis must be avoided (vascular/nerve injuries).

To avoid postoperative discomfort during sitting, the anchors must be introduced to just below the bone surface.

In chronic hamstring tendon refixation, intraoperative injection of platelet rich plasma (e. g. ACP Arthrex) could be helpful as an adjuvant to support tendon healing.

In chronic ruptures or with large hematoma, a drain should be left in the posterior compartment.

12.2 Rectus Femoris Tendon Refixation

T. Saier, P. Brucker

12.2.1 Indication

Complete rupture or displaced bony avulsion (young patients) of the proximal tendon of the rectus femoris in active and athletic patients with high functional demands.

Alternatively: conservative treatment with partial ruptures.

12.2.2 Operation Principle

Refixation of ruptured tendon or the avulsed bone fragment to the tendon origin using suture anchors.

12.2.3 Preoperative Assessment

Diagnosis

Clinical

Symptom specific history: timing and mechanism of the causative injury (typical patho-mechanism is a forceful contraction of the quadriceps against resistance as e. g. with forceful football shooting or landing after a jump); acute stabbing motion-dependent groin pain, swelling in the groin or the proximal thigh area; athletic history: activity, performance level, demands.

Symptom specific examination: the anterior thigh muscles are retracted distally with decreased muscle tone during active contraction of the quadriceps (with knee extension against resistance or hip flexion), tenderness over the anterior inferior iliac spine. Sometimes a gap could be palpable at the origin of the rectus femoris. Increased range of knee flexion compared to other side. In some cases the retracted muscle could form what is called a pseudo-tumor that could compress the proximal part of the thigh.

Imaging

- X-ray: pelvic AP view to exclude bony avulsions and to evaluate the ossification centers of the anterior inferior iliac spine in side comparison. With bony avulsions, an additional axial view of the hip joint is mandatory to evaluate the degree of distal displacement.
- MRI of the pelvis and thigh in 3 planes to confirm diagnosis and evaluate the lesion: localization, differentiate between partial and complete ruptures as well as the degree of retraction.

Patient Information/Consent

Specific operative risks: prolonged recovery with restricted mobility (at least 3 months); rerupture, loosening or avulsion

Fig. 12.8a–c Refixation of ruptured of the straight head tendon. **a** Identification of a tendon stump **b** Stitching the tendon stump with sutures **c** Reattached tendon

of the suture anchors or the knots; sensory deficits in the groin or the upper thigh regions; sexual or conceptual dysfunctions; weakness of the hip flexion.

12.2.4 Surgical Technique

Positioning and Preparation

- Supine position
- Freely mobile the lower extremity
- Application of an Iodine-impregnated adhesive incision drape to the surgical field.

Rectus Femoris Tendon Refixation Using Suture Anchors

Anterior vertical incision, beginning about 2–3 cm distal to the anterior superior iliac spine and extending inferiorly for about 8–10 cm distance. (Fig. 12.7).

Dissection performed down to the origin of the rectus femoris tendon (at the anterior inferior iliac spine or the supra-acetabular sulcus just cranial to the superior acetabular rim). Identification of the tendon stump (Pars recta and Pars reflecta, possibly with a bone chip), hematoma is evacuated and soft tissue adhesions are released and lysed. Careful debridement with passing a stay suture at the distal tendon stump. Freshening of the proximal tendon origin zone down to the bone level. 2–3 titanium suture anchors (e. g. Corkscrew 5.5 mm, Arthrex) are then introduced at the already prepared tendon bed. The tendon stump is then stitched with one suture limb from each anchor in an ascending and descending technique ("baseball stitches"). In case of a bony avulsion, the bone chip is integrated into the repair (transosseous) or drilled to pass the sutures through it. The tendon is repositioned by pulling the free suture ends from the other side and the sutures are then tied (Fig. 12.8).

If the tendon rupture is more distally located, tendon is directly repaired (e. g. Krackow tendon suture) using non-absorbable suture material (e. g. FiberWire, Arthrex). The stability of tendon repair is then checked under forced mobilization of the knee joint.

Fig. 12.9 Postoperative radiograph after refixation of the rectus femoris tendon using 2 suture anchors

12.2.5 Postoperative Management

- Cooling and elevation of the extremity
- Monitoring of peripheral circulation, motor and sensory innervation
- Postoperative radiographs (pelvis anteroposterior view, Fig. 12.9)

12.2.6 Follow-Up Management

Mobilization using crutches with partial weight bearing (20 kg) for 6 weeks, avoiding active extension of the knee joint. Limitation of the range of motion in the 1.–2. postoperative weeks to: passive flexion/extension: free/0°/0° of the hip and 60°/0°/0° of the knee (with the hip flexed). In the 3.–4. postoperative weeks: passive flexion/extension: free/0°/10° of the hip (with extended knee) and 90°/0°/0° of the knee (with the hip flexed). In the 5.–6. postoperative weeks: passive flexion/extension: free/0°/20° of the hip (with extended knee) and 120°/0°/0° of the knee (with the hip flexed). Gradually increasing weight bearing is allowed from the 7. weeks as tolerated.

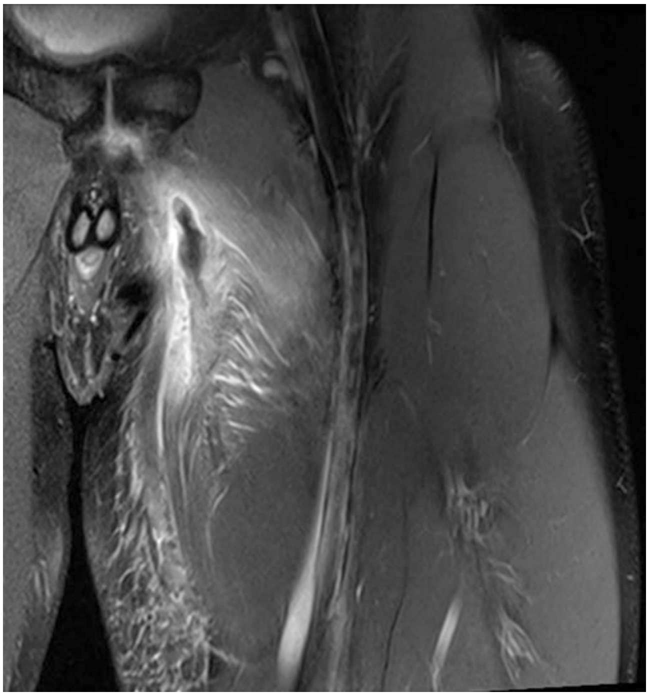


Fig. 12.10 Avulsion of the adductor longus on MRI

If the repair is under marked tension, non-weight bearing for 6 weeks postoperatively and a hinged hip-knee brace (Newport Orthosis) could be used, with restriction of the range of motion to: hip flexion/extension free/30°/0° and knee flexion/extension 90°/0°/0° postoperatively (with the hip flexed) for to 6 weeks. This is flowed by gradual weight bearing as tolerated.

Ergometer training is started after 6 weeks with mild resistance. Resumption of treadmill training not before 10–12 weeks after surgery, and the sport-specific training after 3–4 months. Return to competitive sport after 6–8 months.

12.2.7 Tips & Tricks

Attention to the "internervous plane": After splitting the fascia lata, dissection is continued between the tensor fascia lata (superior gluteal nerve) and sartorius (femoral nerve) down to the superior edge of the acetabulum. The ascending branch of the circumflex artery may be ligated and the lateral femoral cutaneous nerve should be explored and protected during dissection between the muscle bellies.

The anatomy should be respected during tendon repair: the straight head originates directly from the anterior inferior iliac spine. This part constitutes the superficial part of the rectus femoris tendon which radiates into the proximal third of the muscle belly. The tendon of the indirect or reflected head originates from the supra-acetabular margin and passes into the depth of the muscle down to appear at the level of the distal third.

Closer of the fascia should be without tension to avoid compression of the lateral femoral cutaneous nerve with meralgia paresthetica.

In chronic rectus femoris tendon refixation, intraoperative injection of platelet rich plasma (e.g. ACP Arthrex) could be helpful as an adjuvant to support tendon healing.

12.3 Refixation of the Adductor Tendons

K. Müller-Wohlfahrt, P. Brucker

12.3.1 Indication

Treatment is usually conservative, and surgery is rarely indicated in case of rupture of the adductors, even for high level athletes, as these ruptures are mostly localized to the muscular part. Exceptions are proximally located complete ruptures with tendon retraction, where a surgical reattachment may be considered.

12.3.2 Operation Principle

The tendon stump is stitched with sutures, adhesions are released and the tendon is then reattached to the bone origin with suture anchors.

12.3.3 Preoperative Assessment

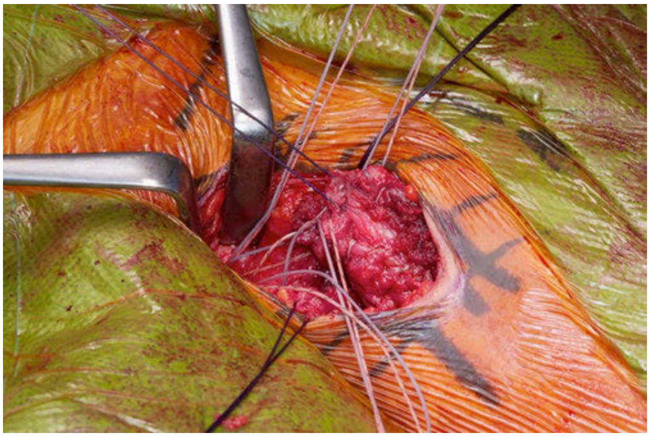
Diagnosis

Clinical

- Symptom specific history: the triggering event or trauma. Typical mechanism of injury is a forced abduction of the thigh during maximum contraction of the adductor muscles. Especially the m. adductor longus is injury relevant. Symptoms (pain, weakness), duration of symptoms, patient's functional demands.
- Symptom specific examination: Tenderness, swelling over the origin as well as along the course of the affected muscles with hematoma formation, painful passive adduction as well as active abduction and adduction of the leg, isolated isometric contraction of the adductors is painful or even not possible due to pain, one-legged standing (on the affected side) may not be possible.

Imaging

- X-ray: pelvis AP view to exclude osseous avulsions.
- MRI of the pelvis and thigh (Fig. 12.10) for Localization of the lesion, assessment of the degree of retraction and condition of the muscle (atrophy, fatty infiltration) and exclusion of associated lesions



■ **Fig. 12.11** Stitched and prepared adductor longus tendon for reattachment

■ **Fig. 12.12** Reattached adductor longus tendon

Patient Information/Consent

Specific operative risks: Rerupture, loosening or avulsion of the suture anchors; sensory deficits in the groin or the upper thigh regions; sexual or conceptual dysfunctions; weakness of the hip abduction.

12.3.4 Surgical Technique

Positioning and Preparation

- Supine position
- The knee is padded with a roll in 20° of flexion
- Optionally, the hip joint is positioned in 60° of abduction

Refixation of Adductor Tendons Using Suture Anchors

The skin is incised just distal and parallel to the groin over the site of rupture and below the inguinal ligament, with significant retraction a longitudinal incision along the course of the muscle is performed.

Fasciotomy is then performed followed by identification of the following three muscles: pectineus, adductor longus, and gracilis muscles. The ruptured tendon stump is exposed, adhesions are released and the hematoma is evacuated.

The osseous insertion zone is freshened followed by insertion of 1–2 suture anchors (e.g. Corkscrew, Arthrex) at the anatomical tendon origin. The tendon stump is then stitched continuously in an ascending and descending manner with one limb of the suture (e.g. FiberWire, Arthrex) (■ Fig. 12.11).

The hip abduction is reduced to 20° and the sutures are tied after repositioning the tendon stump to the anatomical origin (■ Fig. 12.12). With more distally located ruptures, the ruptured tendon ends should be directly repaired with non-absorbable suture material (e.g. FiberWire, Arthrex).

The tendon repair is checked through forceful abduction of the hip.

■ **Fig. 12.13** Postoperative radiograph after reattachment of the adductor longus tendon using 2 suture anchors

12.3.5 Postoperative Management

- Monitoring of peripheral circulation, motor and sensory innervation
- Use of elastic compressive bandages
- Cooling and positioning of the operated leg in 20–30° hip flexion and 0° abduction
- Postoperative radiograph (■ Fig. 12.13)

12.3.6 Follow-Up Management

Mobilization using crutches with partial weight bearing (20 kg) for 6 weeks postoperatively with passive flexion and abduction allowed. Gradually increasing weight bearing is allowed from the 7. week as tolerated (determined by the degree of pain, swelling and achieved range of motion). Full weight bearing is allowed between ca. 10–12 weeks. Running could be allowed after ca. 3 months and specific sports training after ca. 4 months.

12.3.7 Tips & Tricks

Cave: The inguinal canal is located just proximal to the incision and the femoral neurovascular structures are laterally located, which requires particular attention should be paid for a careful dissection. The spermatic cord runs along the proximal side of the incision and should be protected with a Langenbeck retractor.

If the adductor brevis or adductor magnus tendons are injured, a deep blunt dissection is mandatory. The adductor brevis lies between the anterior and posterior branches of the obturator nerve. The muscle is innervated by the anterior branch while the posterior branch innervates the adductor magnus. The anterior branch of the obturator nerve that lies anterior to the adductor brevis should then be exposed and protected.

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Knee

Patient Positioning, Arthroscopic Portals, Diagnostic Arthroscopy, and Tendon (Graft) Harvesting

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13.1 Patient Positioning

All arthroscopic and open procedures of the knee joint described in this book are performed through the authors in the supine position: the patient is positioned on the operating table with the legs extended and the feet at the end of the operating table. The thigh is well padded with a cotton bandage and the cuff of the tourniquet is then applied. A circular adhesive drape is placed distal to the tourniquet cuff to prevent soaking of the cotton bandage with arthroscopy fluid.

A foot support and a lateral post are attached to the operating table so that the leg to be operated could be positioned and fixed in 90° of flexion without assistance (◘ Fig. 13.1). The lateral post acts as a supporting fulcrum during arthroscopic surgery while exerting valgus stress to open the medial compartment and therefore should be installed by the surgeon itself. An abdominal belt is used to secure the patient to the operating table. The leg is draped in a manner allowing free movement and the foot is wrapped with a stockinette to the middle of the leg.

13.2 Arthroscopic Portals

Important landmarks are marked before establishing the portals and include: patella, tibial tubercle, patellar tendon, medial and lateral femoral condyle, and the upper margins of the medial and lateral tibial plateaus and joint line. A vertical or horizontal stich incision down to the joint capsule is made with a no. 11 Scalpel blade (about 8 mm in length). The joint capsule could be further dissected with a scissor, if needed. After establishing the viewing portal (see below), all other portals are created in outside-in technique: this is performed under arthroscopic visualization, using a needle to determine the optimal position of the portal before an incision is made (◘ Fig. 13.2).

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13.2.1 Anterolateral Portal

Standard portal for diagnostic arthroscopy. The knee is flexed to 90° and the entry point corresponds to the soft spot between inferolateral patellar border, lateral margin of the patellar tendon and the medial margin of the lateral femoral condyle. A stab incision is made at the level of the inferior patellar border, 0.5–1 cm lateral to the patellar tendon (◘ Fig. 13.3). The blade is advanced towards the intercondylar notch until the joint capsule is incised.

13.2.2 Anteromedial Portal

Standard working portal (for instruments). It is established under direct arthroscopic visualization medial to the patellar tendon after preliminary localization with a needle (◘ Figs. 13.2 and 13.3). The intraarticular entry point is dependent on the pathology to be treated. The site of pathology must be easily accessible with the needle without any obstacle.

13.2.3 Central (Transpatellar) Portal

Could be alternatively used as a viewing portal. A vertical skin incision between the two femoral condyles, about 1 cm distal to the inferior patellar border with the knee in 90° flexion. A trocar is then passed bluntly through the Patellar tendon. This approach, however, should be used with great caution (risk of injury to the patellar tendon and Hoffa's fat pad).

13.2.4 Accessory Medial and Lateral Portals

Additional anteromedial/medial or anterolateral/lateral portals could be used according to the operative procedure to be done (e. g. deep anterolateral portal for drilling the femoral tunnel in PCL reconstruction, the high anteromedial portal for an easier access to the lateral meniscus in the figure-four position and the accessory medial portal system for placement of the femoral tunnel of the posterolateral bundle in double bundle ACL reconstruction ◘ Fig. 13.3). The portals are established in outside-in technique after identification of the proper site with a needle.

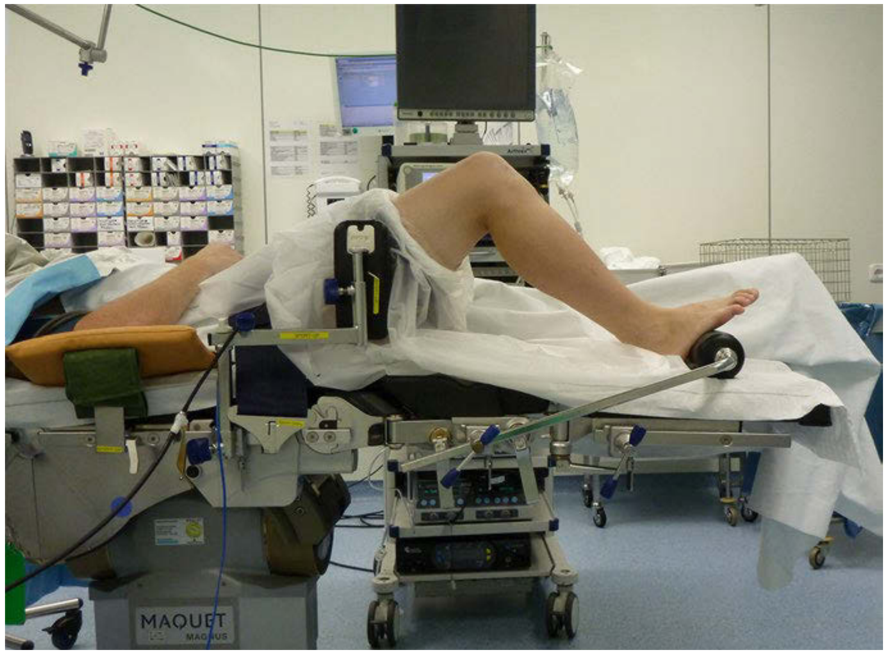
13.2.5 Posteromedial Portal

With the knee in 90 degrees flexion, the arthroscope is introduced via the anterolateral portal through the notch (medial to the ACL) into the posterior compartment to visualize the medial femoral condyle, the posterior horn of the medial meniscus and the posteromedial capsule. A needle is introduced under arthroscopic visualization approximately 1 cm above the joint line and 2 cm posterior to the medial condyle (◘ Fig. 13.4). The skin is incised and then a switching stick is used to create the portal (tissues could spread out with a scissor).

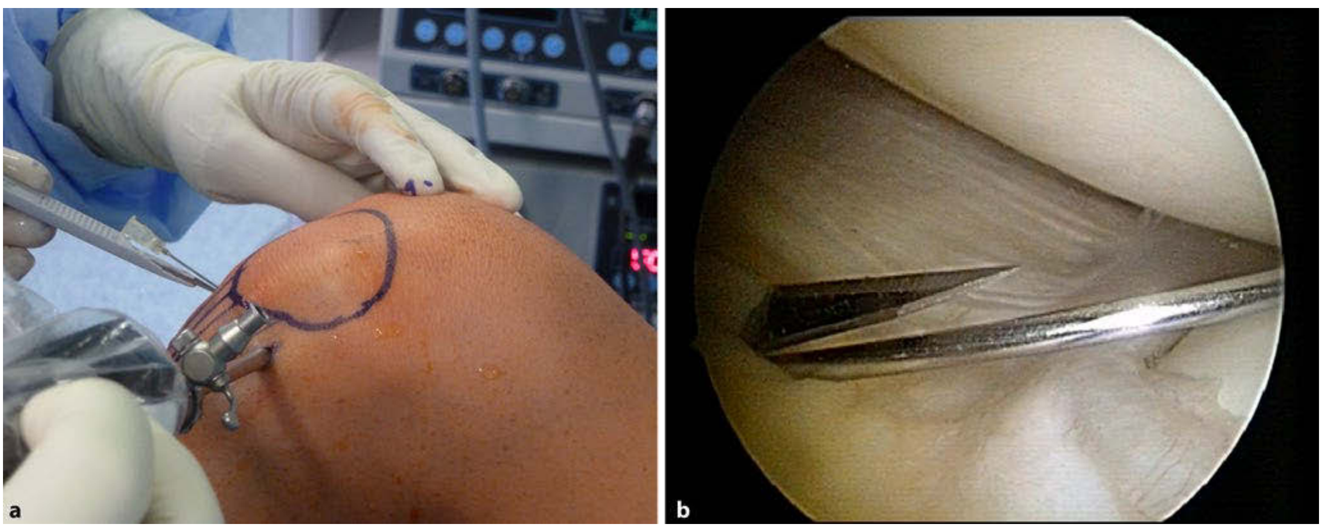
Caution: If this portals is placed so far anteriorly, instruments will be diverted by the medial femoral condyle; and if the portal is created to far posteriorly, there will be an increased risk of iatrogenic injury to the posterior neurovascular structures (◘ Fig. 13.4).

13.2.6 Posterolateral Portal

This portal is created as the posteromedial portal in 90° knee flexion and anterior to the biceps femoris tendon.



■ **Fig. 13.1** Supine position. A foot support and lateral post are mounted to the operating table to allow positioning of the leg to be operated on in 90° flexion



■ **Fig. 13.2a,b** Establishing portals in outside-in technique. **a** stab incision after identification of the optimal portal location with a needle **b** arthroscopic view

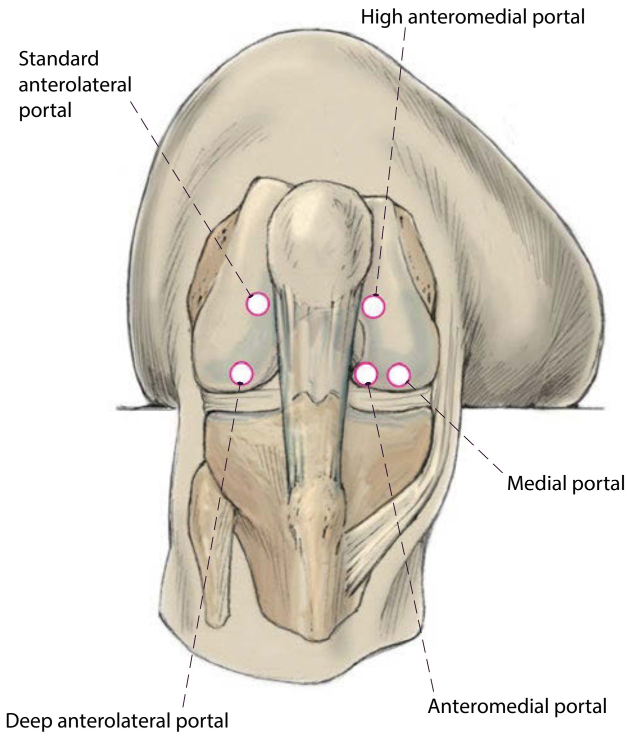


Fig. 13.3 Commonly used arthroscopic portals for the knee

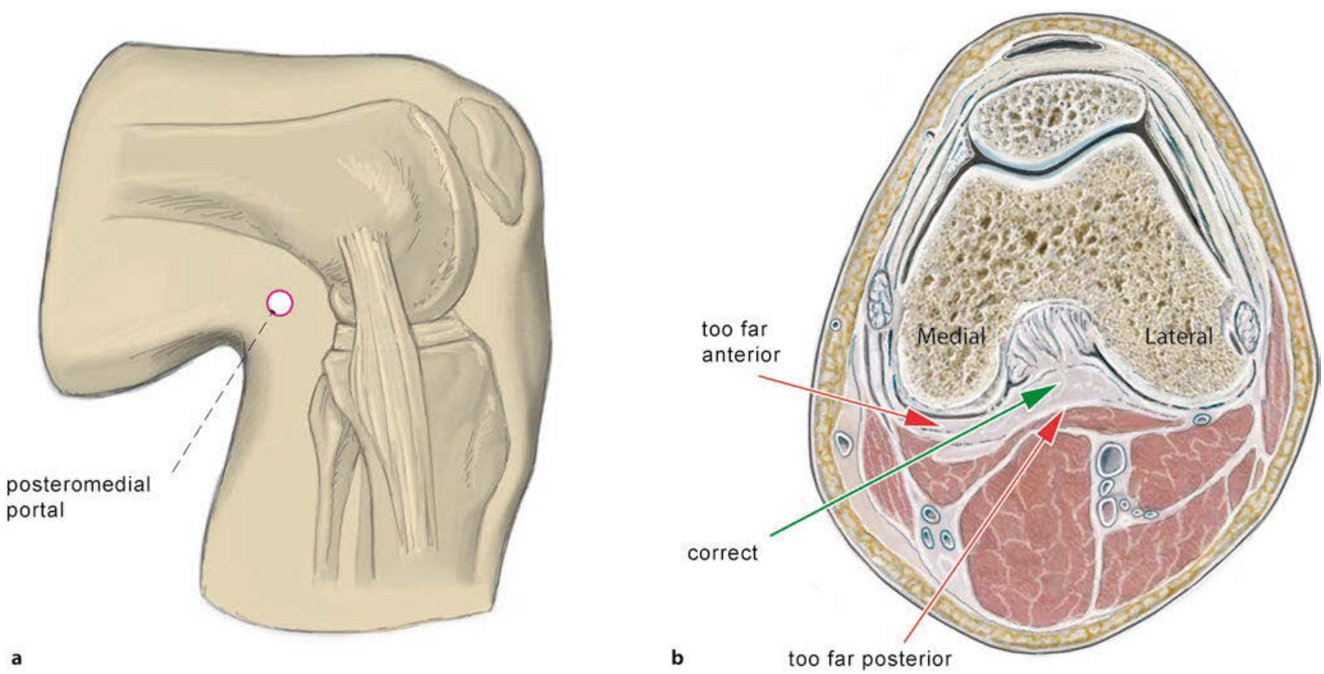


Fig. 13.4a,b Establishing the posteromedial portal. **a** lateral view, **b** axial view

13.2.7 Lateral and Medial Suprapatellar Portals

Each is located about 1 cm proximal to the superolateral/superomedial edge of the patella and established in outside-in technique with the knee in extension. These are not standard portals, and are only necessary with few indications (e.g. complete synovectomy).

13.3 Diagnostic Arthroscopy

As part of the diagnostic arthroscopy, the following should be evaluated: synovium (for increased injections, adhesions, abnormal growths and large plicae), the quality of patellofemoral and tibiofemoral articular cartilage, the integrity of the menisci and the capsuloligamentous structures and the presence of loose bodies should be excluded.

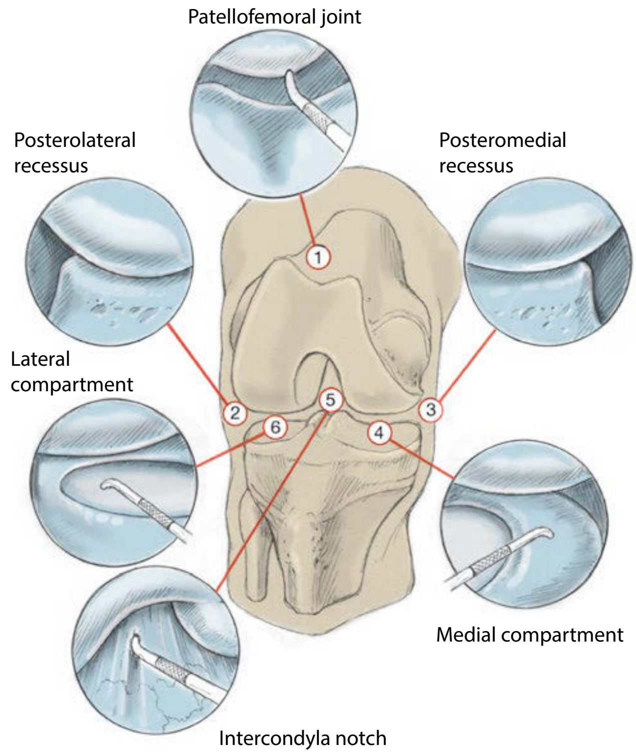
Arthroscopy is performed using a 30° arthroscope under a constant inflow pressure of 50 mmHg. The diagnostic arthroscopy should be always according to a standardized systematic approach. A recommended "diagnostic tour" (◘ Fig. 13.5) is described below:

A Standard anterolateral portal is established and a trocar is inserted towards the intercondylar notch in 90° of knee flexion. The knee joint is then slowly extended after assuring intraarticular location of the trocar which is advanced into the medial part of the suprapatellar pouch at the same time. The Arthroscope is then introduced and the joint is distended with fluid.

The arthroscope is then withdrawn until the patellar cartilage is visualized. Further withdrawal of the arthroscope until the trochlear cartilage also appears (◘ Fig. 13.5, detail 1). The arthroscope is then advanced into the suprapatellar pouch and then across the femoral condyles to visualize the lateral gutter (◘ Fig. 13.5, detail 2) and then into the medial gutter until the base of the medial meniscus could be visualized (◘ Fig. 13.5, detail 3).

The medial compartment is entered with the knee in 20–30° flexion and under valgus stress. The anteromedial portal is then established. An arthroscopic probe is then introduced to assess the tibiofemoral articular cartilage, and the medial meniscus (◘ Fig. 13.5, detail 4). The knee is flexed to 90° to visualize the anterior and posterior cruciate ligaments and then evaluate their integrity with an arthroscopic probe (◘ Fig. 13.5, detail 5).

The anterior horn of the lateral meniscus is visualized and the leg then brought into figure-four position. The Arthroscope and the probe are then advanced into the lateral compartment to assess the articular cartilage and the lateral meniscus (◘ Fig. 13.5, detail 6). The posterolateral part of the lateral meniscus is pushed inferiorly to visualize the popliteus tendon. Finally, the knee could be extended to assess and probe the patellofemoral cartilage. All sections should be photo documented.



◘ **Fig. 13.5** Diagnostic arthroscopy **tour**: Patellofemoral joint, Posterolateral gutter, Posteromedial gutter, Medial joint space, Intercondylar notch, Lateral Joint space

13.4 Tendon (Graft) Harvesting

13.4.1 Harvesting the Semitendinosus and Gracilis

About 3 cm long oblique incision is made over the pes anserinus (1–2 cm medial and distal to the tibial tuberosity). A longitudinal incision could be alternatively used. Dissecting and incising the sartorius fascia in line of its fibers along the upper margin of the gracilis (the gracilis is superior to the semitendinosus) (◘ Fig. 13.6a). If only the semitendinosus to be removed, the fascia is split along its upper border.

A right angle clamp (Overholt) is passed under each tendon to pass a suture loop around it (◘ Fig. 13.6b). The distal tendon insertion is lifted off the bone with sharp dissection subperiosteally together with the attached periosteum and all the facial or vincular attachments are cut up to the popliteal fossa (◘ Fig. 13.6c).

The distal end of each tendon is loaded into a closed tendon stripper, which is then advanced over the tendon (parallel to the thigh axis) to strip it from its muscle belly (◘ Fig. 13.6d).

Tendons are then prepared on a back table using a special preparation board. Excess fatty tissues and attached muscle are carefully and bluntly trimmed with a periosteal elevator (or with scalpel). The vincular remnants as well as frayed parts of the tendon are then sharply excised. The broadened

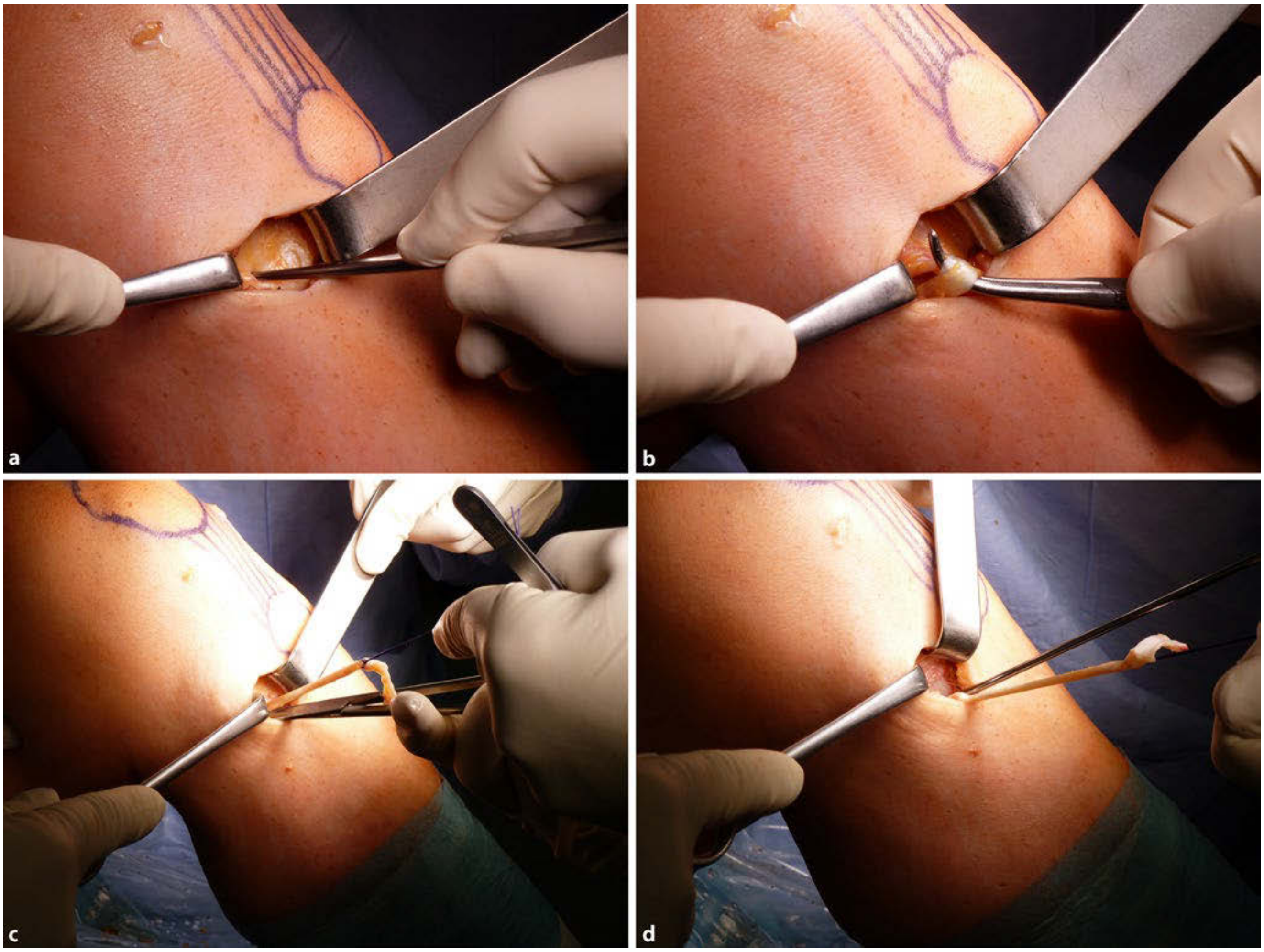


Fig. 13.6a–d Harvesting of the semitendinosus. **a** palpation of the superior edge of the tendon and incision of Sartorius fascia; **b** right angle (Overholt) clamp is passed under the tendon to pass a suture loop around it **c** Trimming of all vincular and facial attachment after lifting off the distal end of the tendon; **d** harvesting the tendon with tendon stripper

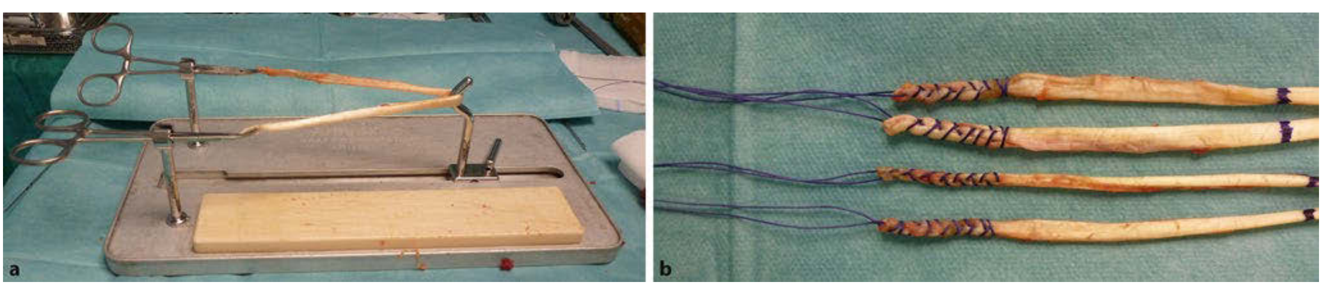


Fig. 13.7a,b Preparation of the semitendinosus and gracilis tendons. **a** Tensioning the tendons on a special preparation station (board) after stripping of fat and muscle tissues **b** final prepared grafts for ACL reconstruction in double bundle technique

proximal part of the tendon is folded longitudinally, so that a uniform tendon width is obtained.

The graft is clamped and tensioned using the holding posts of the preparation board (Fig. 13.7a) and both tendon ends are whip-stitched for about 2 cm (Fig. 13.7b). According to the intended use, the graft could be doubled or folded several times and its diameter is then measured using a sizing template (block).

13.4.2 Harvesting of the Quadriceps Tendon

A central, 8–12 mm wide strip of the quadriceps tendon together with an attached patellar bone block (using a trapezoidal bone block sawing template) are harvested.

Median skin incision of about 6 cm, beginning just below the superior pole of the patella. Subcutaneous tissue is incised down to the fascia lata. The fascia is opened and bluntly dis-

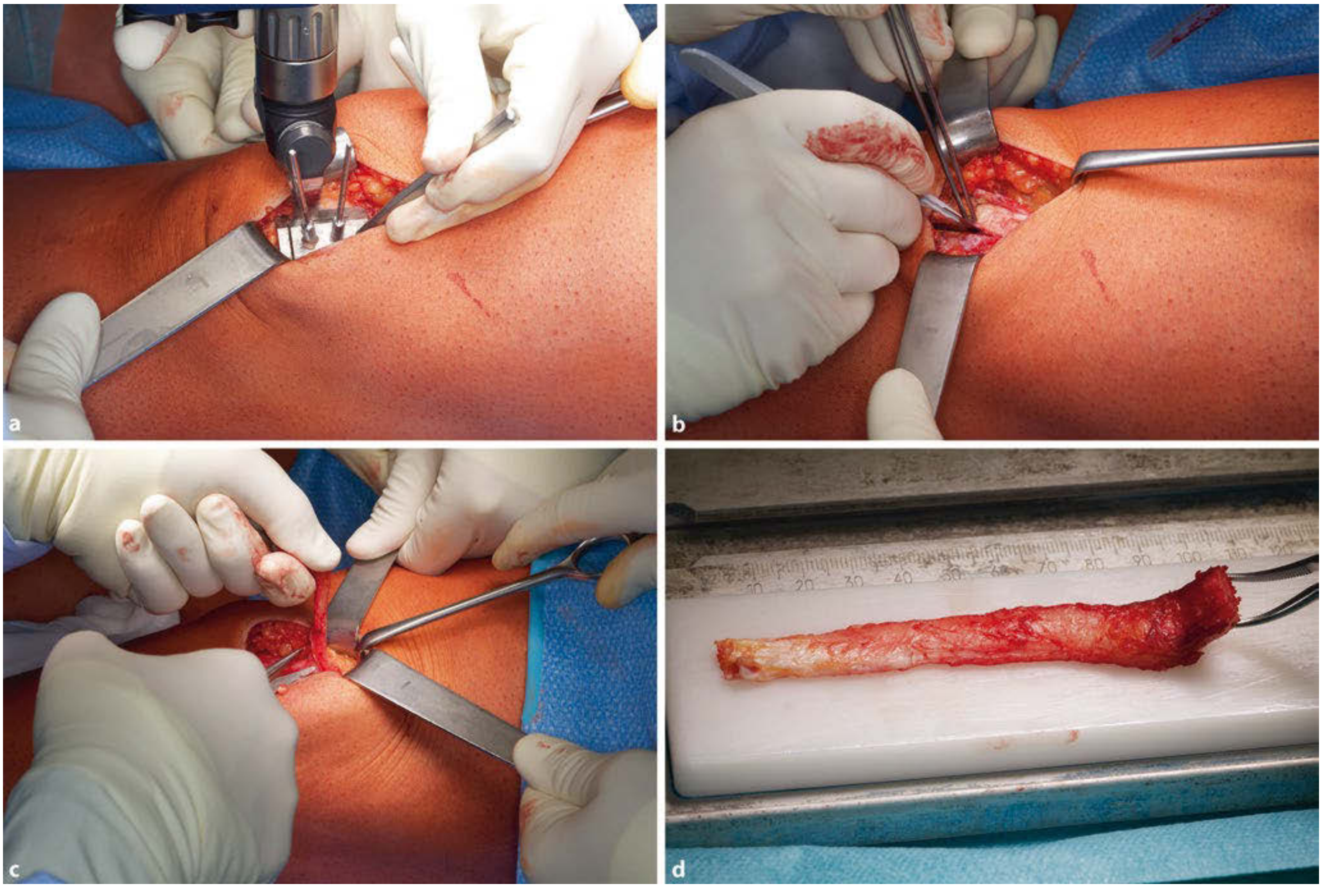


Fig. 13.8a–d Harvesting of the quadriceps tendon with patellar bone block. **a** sawing of the bone block using a sawing template; **b** incising the tendon strip in line with the tendon fibers; **c** dissection and elevation of the graft **d** Quadriceps tendon graft after harvesting

sected from the tendon to expose the anterior aspect of the patella and the tendon insertion. The sawing template is fixed to the bone using 2 guide wires so that a bone block of about 1.5–2 cm length could be sawed from the superior central part of the patella. The bone block is then elevated using a chisel.

A strip of quadriceps tendon is incised with a scalpel parallel to its fibers along the extension of the medial and lateral borders of the bone block and dissected from posterior remaining part of the tendon and synovial tissues (Fig. 13.8c, d).

The graft is then prepared using a specific preparation board (workstation). Attached fatty tissue is dissected and the bone block is further prepared and contoured with a bone nibbler until it could be easily passed through the desired diameter of the sizing template.

A strong suture (e.g. FiberWire, Arthrex) is passed through the two holes in the bone block (that were drilled during sawing of the bone block for temporary fixation). The other end of the graft is whip-stitched for about 2 cm.

13.5 Tips & Tricks

The tourniquet should be placed proximally to the thigh as possible, particularly in procedures involving drilling of bone sockets in the femur (e.g. cruciate ligament reconstruction).

The level of the patella should be evaluated on the lateral radiographs before establishing the anterolateral portal. The inferior border of the patella couldn't be used as a landmark for portal placement if there is patella alta or baja.

Working (instruments) portals are always established after probing with a needle and are dependent on the planned operative procedure.

The cutting blade of the scalpel should be always directed away from the important structures during portal placement (e.g. patellar tendon, meniscus).

Establishing portals under trans-illumination minimizes the risk of injury to the subcutaneous veins and nerve branches.

Trocar is introduced at the beginning of the arthroscopy always towards the intercondylar notch to minimize the risk of iatrogenic cartilage injury.

The arthroscopic probe should be kept always intra-articular after its insertion during diagnostic arthroscopy to avoid difficulty in re-insertion with changing position of the soft tissue if the leg position is changed.

It is very important during harvesting the semitendinosus tendon to cut the vincular attachments to the gastrocnemius muscle to avoid early and incomplete stripping of the tendon if these attachments are left.

The semitendinosus and gracilis tendons should both be clearly identified before final removal.

The suprapatellar pouch should not be opened during harvesting the quadriceps tendon to avoid excessive outflow of arthroscopy fluid.

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Meniscus

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14.1 Meniscectomy

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14.1.1 Indication

Symptomatic traumatic or degenerative irreparable meniscal lesions: radial tears larger than one third of the meniscus diameter, longitudinal tears, bucket handle tears or flap tears in the avascular (white- white) zone. Symptomatic discoid meniscus.

14.1.2 Operation Principle

Restoration of a stable meniscal contour by removing the most minimal amount of the unstable meniscus.

Discoid meniscus: Arthroscopic re-contouring of the meniscus by removing the central part and eventually fixing the peripheral part to the capsule, if unstable.

14.1.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: triggering event (etiology), symptomatology (pain, locking, limitation of motion, subjective instability), duration of the complaint.
- Symptom specific examination: range of motion (extension or flexion deficit with springy resistance), meniscal signs, exclusion of concomitant instability.

Imaging

- X-ray of the knee in 3 views (AP, lateral and tangential patella) to exclude osseous lesions and to evaluate the degree of osteoarthritis.
- MRI to assess the meniscal lesion and the other knee intraarticular lesions.

Patient Information/Consent

Specific operative risks: residual symptoms, iatrogenic cartilage injury, intra-articular breakage of instruments, resulting instability, symptomatic postoperative bone marrow edema up to osteonecrosis (post meniscectomy syndrome), progression of osteoarthritis

14.1.4 Surgical Technique

Positioning and Preparation

- Supine position
- A thigh tourniquet is applied

Arthroscopic Partial Meniscectomy

Diagnostic arthroscopy is performed via the anterolateral portal. The operative indication is confirmed and possible concomitant lesions are assessed.

A needle is used to determine the optimal angle of inclination towards the lesion before establishing the working portal. It is recommended to establish the working portal according to the location of the lesion: posterior horn lesions can be addressed through portals placed about 2 cm medial or lateral to the midline, portal to address lesions of the pars intermedia are placed about 4 cm medial or lateral to the midline. High anteromedial or anterolateral portal are needed to access lesions of the anterior horns.

The meniscal tear is assessed by inspection and palpation with an arthroscopic probe. Resection of meniscal tissue is then performed depending on the shape, size and location of the lesion (Fig. 14.1). Unstable meniscal tissue is sparingly resected so as to preserve the largest possible amount of intact meniscus tissue. All free-floating meniscal tissue parts must be completely irrigated and sucked out after resection.

- Radial tear: restoration of a stable contour of the meniscus by stepwise resection of the tear using meniscal biters/baskets and shaver (Figs. 14.2 and 14.3)
- Longitudinal tear: resection of the unstable central part using meniscal biters/baskets and contouring of the tear edges (Fig. 14.4)
- Flap/oblique tear: resection of the flap from its base and restoration of the stable meniscal contour by smoothing the edges of the tear after resection (Fig. 14.5)
- Horizontal tear: resection of the upper or lower leaf, located in the avascular zone according to the tissue quality (Fig. 14.6)
- Bucket handle tears: resection of the central bucket handle fragment (located in the white-white zone), smoothing the rims and restoration of a stable contour of the meniscus (Figs. 14.7 and 14.8)
- Discoid meniscus: creation of a "normal" meniscus contour by resecting the central part, additional repair of the peripheral part to the capsule with sutures is needed if it is unstable.

14.1.5 Postoperative Management

- Monitoring of peripheral circulation, motor and sensory innervation.
- Use of elastic compressive bandages
- Cooling and elevation of the extremity.

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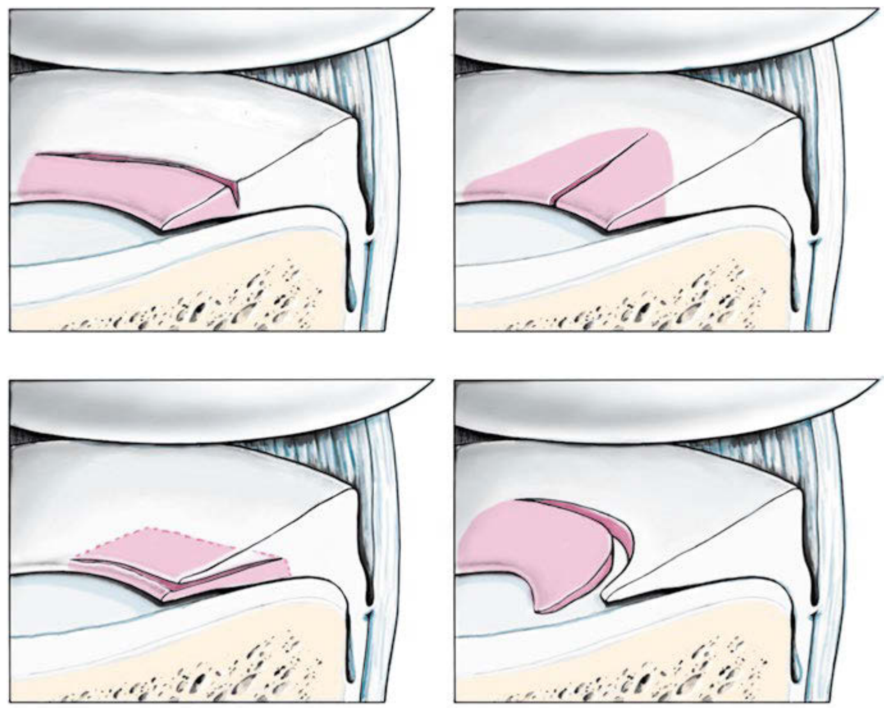


Fig. 14.1 Partial meniscectomy according to the type of the lesion

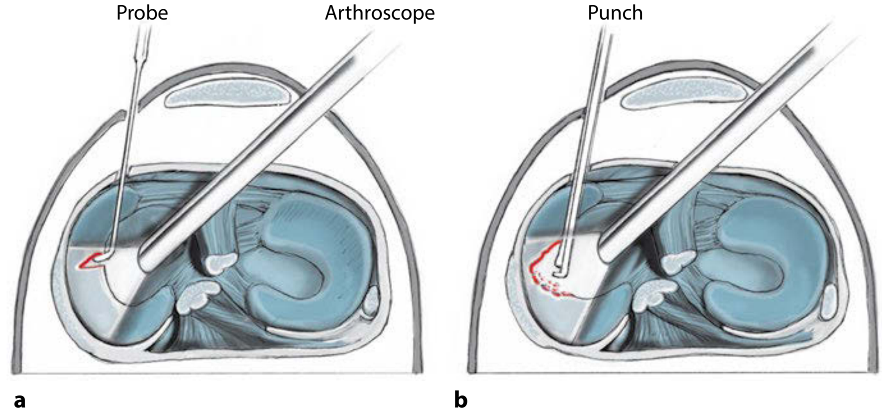


Fig. 14.2 Partial meniscectomy of the radial tear. **a** assessment of the radial tear using a probe **b** restoration of a stable contour of the meniscus by gradual resection using a meniscal biter

14.1.6 Follow-up Management

Functional treatment without immobilization. Full weight bearing as pain and swelling permit.

14.1.7 Tips & Tricks

Incorrect placement of the portal, particularly if the medial portal is too superior, there is an increased risk of instrumental cartilage injury. Therefore, prior to establishing the portal, a needle is always used to assess the accessibility of the lesion as well as the distance to the corresponding femoral condyle.

The medial compartment is often very tight, particularly with degenerative lesions of the posterior horn of the medial meniscus. In such case the posteromedial capsule can be carefully released with a special arthroscopic knife so that the meniscus can be easily reached and the risk of injury to the adjacent cartilage is reduced (POL release: release of the posterior oblique ligament) or alternatively the longitudinal fibers of the medial collateral ligament can be percutaneous released using a needle. Both techniques lead to a widening of the medial compartment.

To avoid post-operative complications (progression of osteoarthritis, instability) the following rule must be considered with partial meniscectomy: as much as necessary, as little as possible!

Extensive resection of the meniscus posterior horn and interruption of meniscus margins should be avoided.

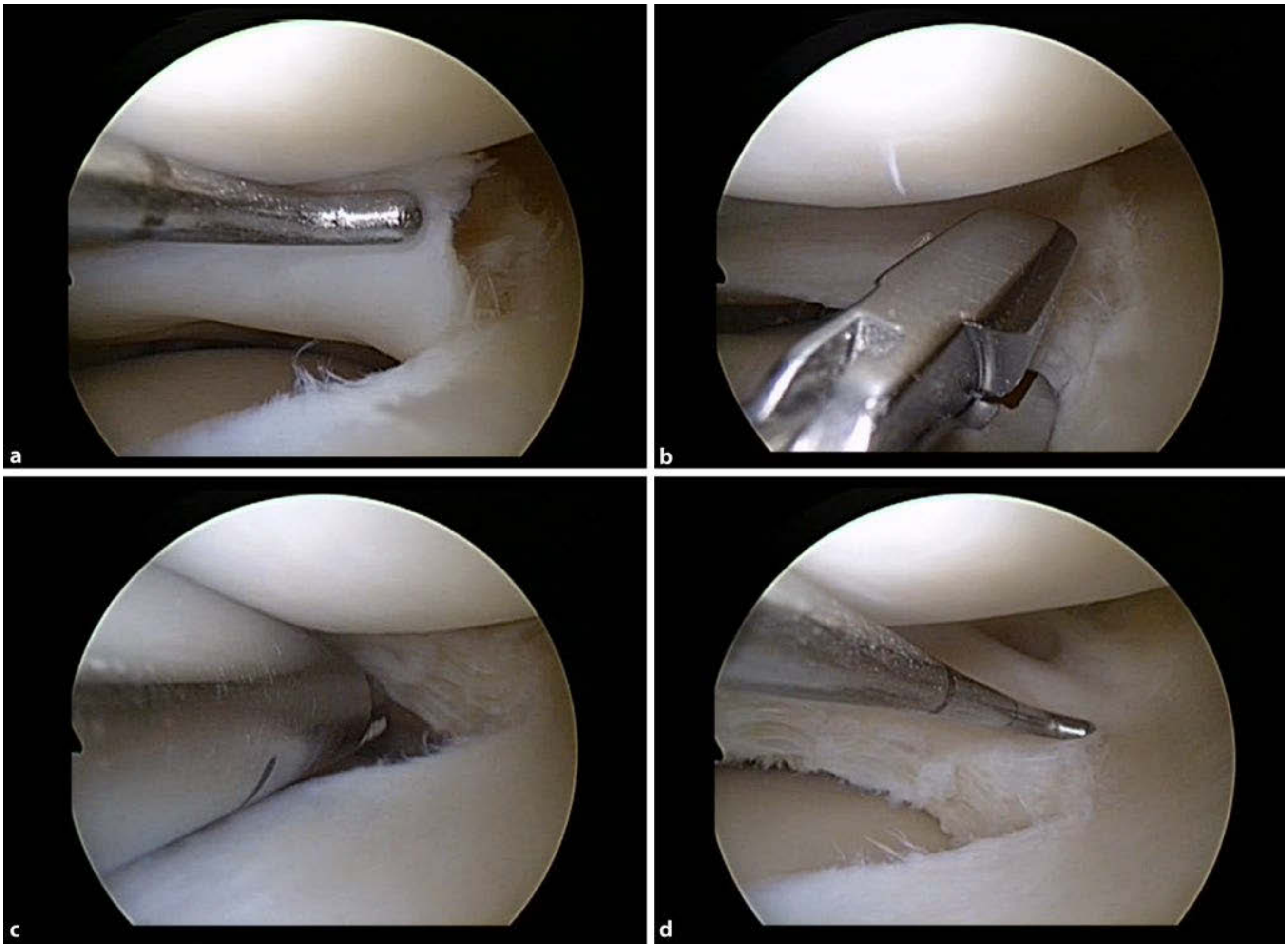


Fig. 14.3a–d Partial meniscectomy of the radial tear. **a** radial tear of the medial meniscus; **b** resection of the unstable fragments with a meniscal biter **c** smoothing of the resected margins with the shaver **d** final result

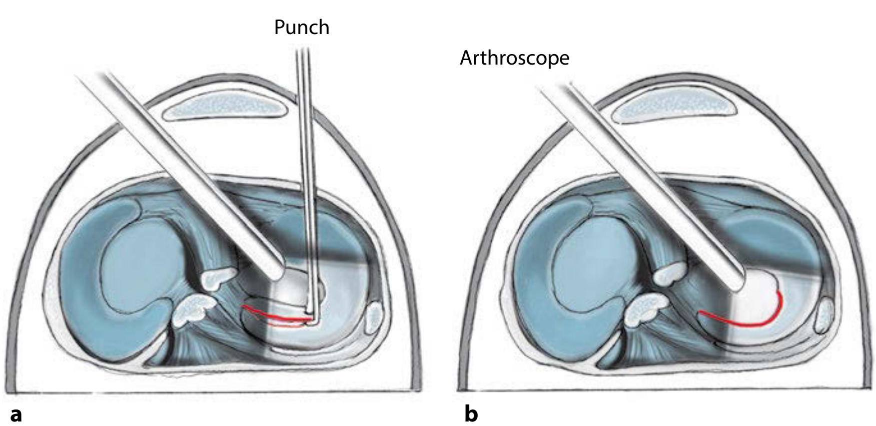


Fig. 14.4a,b Partial meniscectomy of longitudinal tears. **a** resection of the central part with meniscal biter **b** final result

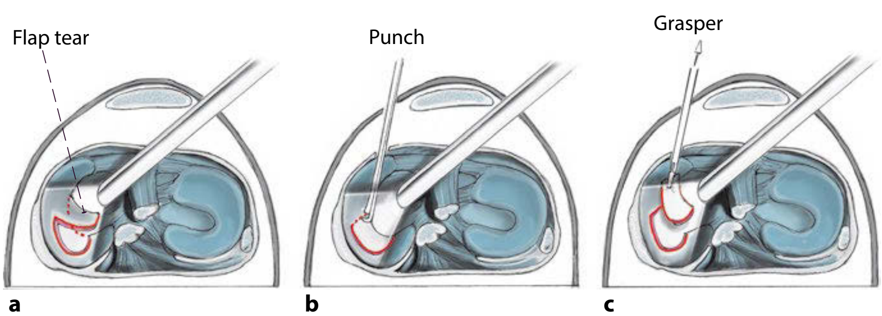


Fig. 14.5a–c Partial meniscectomy of flap/oblique tears. **a** exposure of the flap tear; **b** resection of the base of the flap; **c** remove the resected flap with a grasper

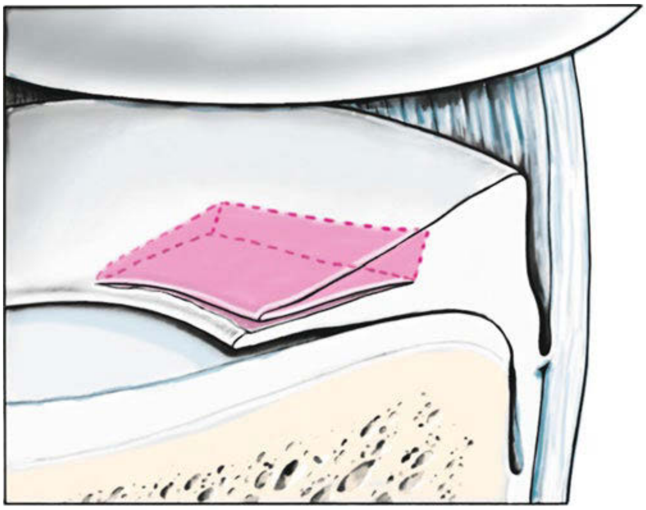


Fig. 14.6 Partial meniscectomy of horizontal tears. Selective resection of the upper or the lower leaves depending on the tissue quality

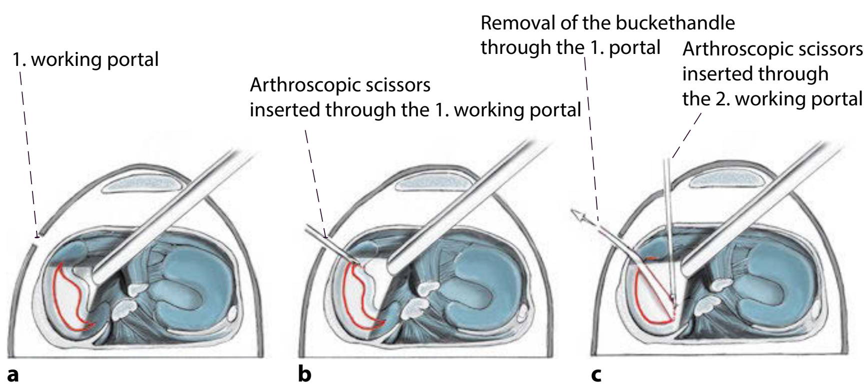


Fig. 14.7a–c Partial meniscectomy of bucket handle tear. Here two working portals are needed, but alternatively, only one working portal may be used. **a** Exposure of the bucket handle tear; **b** resection of the central part of the bucket handle at its anterior attachment; **c** resection of the posterior attachment and removal of the bucket handle

Fig. 14.8a–c Partial meniscectomy of present bucket handle tear. **a** bucket handle tear in the white-white zone of the medial meniscus; **b** resection of the central part using a high frequency electrode; **c** final result

14.2 Meniscal Repair and Meniscal Root Fixation

S. Döbele, S. Hinterwimmer

14.2.1 Indication

Symptomatic meniscal tears in the red-red or red-white zone (Fig. 14.9).

Relative indication in tears extending into the white-white zone.

14.2.2 Operation Principle

Arthroscopic repair of meniscal tears using absorbable or non-absorbable suture. There are 4 different principles that can be distinguished:

- Outside-in technique: The meniscus is penetrated with two needle cannulas from the outside to inside the joint. A suture is then passed through the hollow needle to inside the joint and then shuttled outside the joint using the second needle. Both suture limbs are then tied to the capsule.

- Inside-out technique: The meniscus is penetrated twice from the intra-articular side with a special suture needles. The extra-articular suture limbs are then tied to the outer surface of the capsule.
- All-inside technique: The fixation is carried out exclusively intra-articular with suturing instruments that includes the sutures, the knots as well as supporting plates for the sutures on the base of the meniscus.
- Meniscal root repair: The torn meniscus root is stitched and the sutures are then passed outside through a tibial tunnel and tied on the cortex.

14.2.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: time and mechanism of injury, symptomatology: pain (with rotatory movements or extreme flexion), locking and limitation of motion.
- Symptom specific examination: range of motion (extension or flexion deficit with springy resistance), tenderness over the medial or lateral joint line, meniscal signs, exclusion of concomitant instability.

Neurological/vascular status

Examination and documentation of peripheral neurological condition (saphenous and common peroneal nerves).

Imaging

- X-ray of the knee in 3 views (AP, lateral and tangential patella) to exclude osseous lesions and to evaluate the degree of osteoarthritis.
- MRI to assess the meniscal lesion and the other knee intraarticular lesions.

Patient Information/Consent

Specific operative risks: injury to the saphenous or common peroneal nerves, injury of the neurovascular branches in the popliteal region, iatrogenic cartilage damage, suture-induced cartilage damage, intra-articular fracture of instruments, implants dislocation, foreign body reaction with effusion, recurrent tear.

14.2.4 Surgical Technique

Positioning and Preparation

- Supine position
- A thigh tourniquet is applied
- Examination under anesthesia (exclusion of concomitant instability)

Arthroscopic Meniscal Repair

Diagnostic arthroscopy is performed via the anterolateral portal to confirm the surgical indication and assess possible concomitant lesions. The optimal angle of inclination to the lesion that ensures sufficient distance from the adjacent femoral condyle should be first assessed using a needle before establishing the working portal. The meniscal tear is inspected and assessed with an arthroscopic probe. The tear margins are debrided and freshened with a shaver or meniscus rasp.

Outside-In Technique

This repair technique is particularly suitable for lesions of the anterior horn. Skin is vertically incised opposite the site of the tear and dissection is carried out down to the capsule. A cannulated needle is passed under arthroscopic visualization from outside to inside through the base of the meniscus and the centrally displaced torn part. A PDS suture is passed through the needle into the joint (◘ Figs. 14.10 and 14.12a).

A shuttle suture is passed to inside the joint through a second cannulated needle inserted through the meniscus base superior to the first needle (◘ Fig. 14.12b, c), the previously inserted PDS suture is passed through the loop of the shuttle with the aid of an arthroscopic grasper (◘ Fig. 14.12d), and then shuttled through the meniscus to outside the joint (◘ Figs. 14.10 and 14.11). The suture passing through the meniscus represents now a vertical suture. If a horizontal suture is preferred, both needles should be inserted side by side.

According to the tear size, additional sutures are passed, until the tear is completely obliterated when pulling on the extra-articular suture ends. Corresponding suture ends are tied together over the carefully dissected capsule (◘ Fig. 14.12e, f).

Inside- Out Technique

This repair technique is particularly suitable for lesions in the middle zone. A special repair instrument, consisting of a guide cannula (e.g. Meniscal Repair Joystick system, Arthrex) and a suture armed with 2 flexible meniscus needles (e.g. 2-0 FiberWire Meniscus Repair Needles, Arthrex, Inc.) is required.

Skin is vertically incised opposite the site of the tear and dissection is carried out down to the capsule. The cannula is passed inside the joint through the working portal with the meniscus needle retracted. The cannula is placed ca. 2–3 mm from the tear and the needle is then advanced through the base of the meniscus to outside the joint (◘ Figs. 14.13 and 14.15a,b). The cannula is then moved ca. 4–5 mm anteriorly or posteriorly (horizontal mattress suture) or just superiorly or inferiorly (vertical mattress suture). The second meniscus needle is passed through the meniscus to outside the joint (◘ Figs. 14.14 and 14.15c,d).

Additional sutures are added, until the tear is completely stabilized with external traction of the suture ends

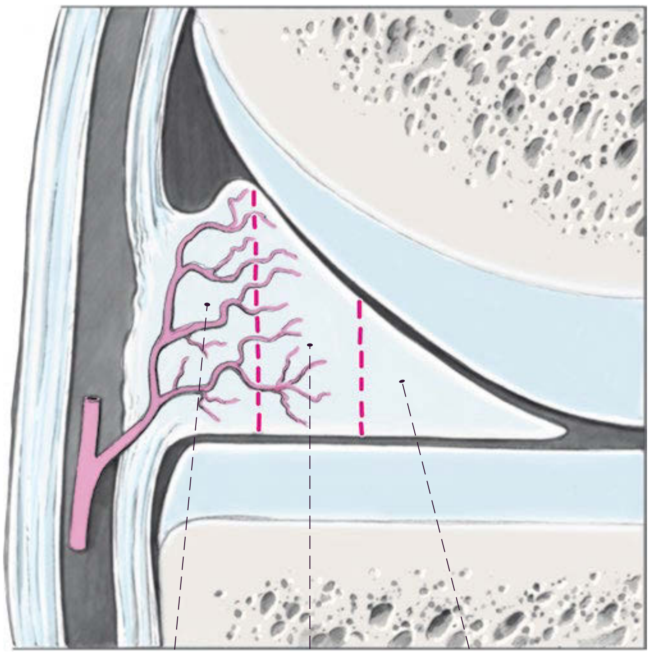


Fig. 14.9 Vascular zones of the meniscus (red-red zone, red-white zone, white-white zone) according to its vascularization

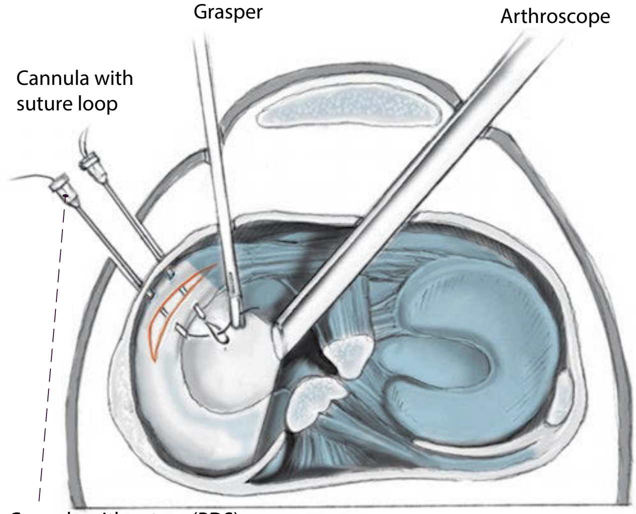


Fig. 14.10 Passing a suture (PDS) through the cannula and passing this suture end through a shuttle loop passed similarly through a second cannula

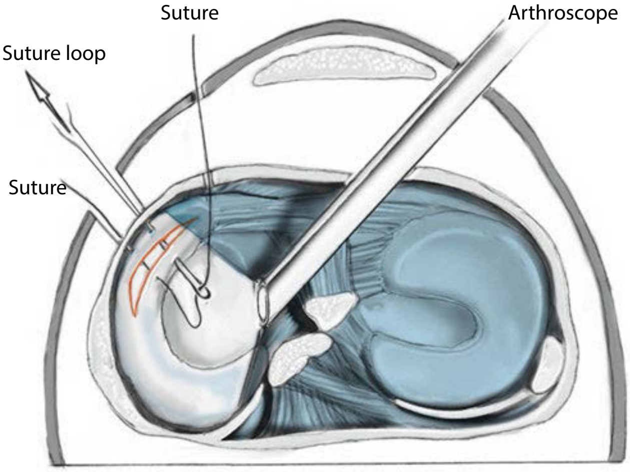
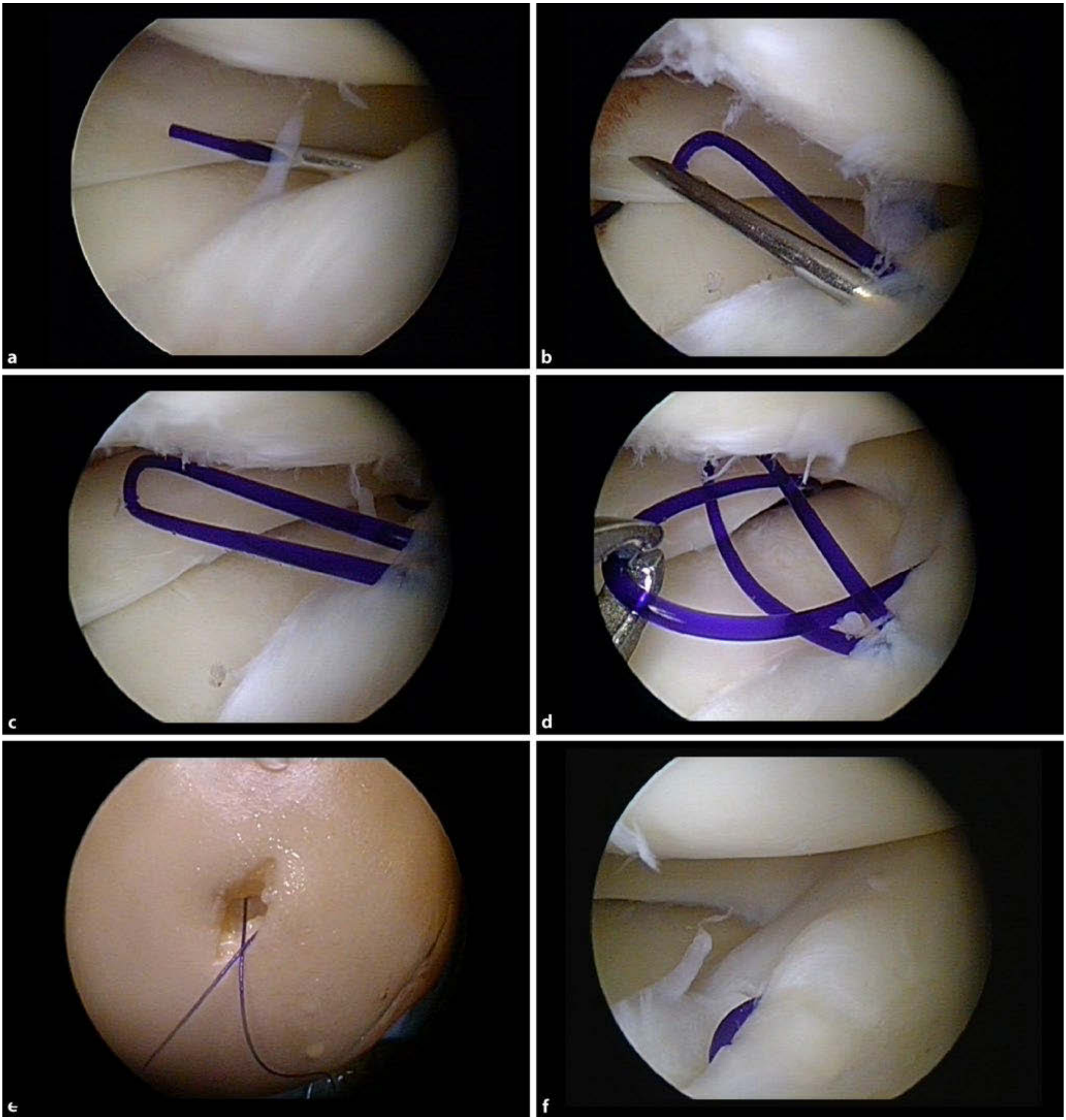
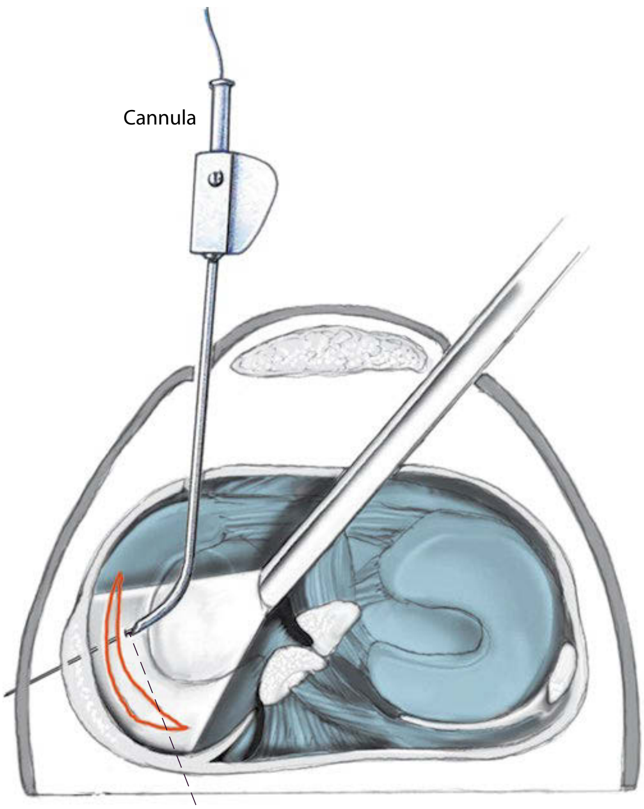


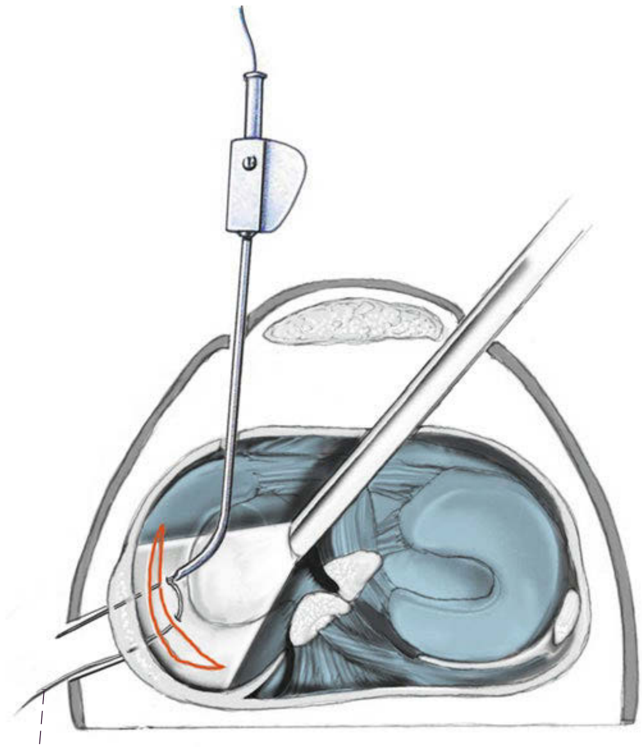
Fig. 14.11 Shuttling the suture (PDS) to outside the joint with the suture loop. Finally, the two free suture ends are tied on the outer surface of the capsule



■ **Fig. 14.12a–f** Arthroscopic outside-in suturing technique. **a** piercing the meniscus with a hollow needle and insertion of a PDS suture **b** passing a suture loop through a second hollow needle; **c** suture loop after removal of the hollow needle; **d** passing the PDS suture through the loop and shuttling of the PDS suture outside the joint; **e** knotting the two suture ends on the capsule; **f** resultant horizontal mattress suture



■ **Fig. 14.13** Piercing of the meniscus with the first meniscal needle passed through the guide cannula



■ **Fig. 14.14** Piercing the meniscus with the second meniscal needle after placement of the guide cannula. Finally, the two free suture ends are tied over the joint capsule

(■ Fig. 14.15e, f). Corresponding suture ends are tied together over the carefully dissected capsule.

All-Inside Technique with Anchor System

This technique is particularly suitable for lesions of the posterior horns. The anchor system (e.g. Meniscal Cinch, Arthrex) contains 2 plastic plates, which are connected to each other by a non-absorbable suture with a pretied sliding knot.

The plates are passed as previously described with the inside-out technique via an applicator through the meniscus and the joint capsule so that the plates are flipped behind the joint capsule to act as an anchor (■ Fig. 14.16).

The suture with the pretied sliding knot is then pulled to close the meniscal tear (■ Fig. 14.17). The knot is tightened with a knot pusher and the suture is cut with an arthroscopic suture scissors leaving only about 3 mm.

Meniscal Root Fixation (Repair)

The torn meniscus root is pierced twice with a shuttle instrument and armed with a non-absorbable suture (e.g. FiberWire, Arthrex, ■ Fig. 14.18a–e).

The bony bed of the meniscus root is freshened with a shaver. Trans-tibial drilling of a guide wire using the ACL guide placed at the freshened bony bed of the meniscus root (■ Fig. 14.18f). Overdrilling the guide wire with a 4.0 mm drill while securing the wire tip with a spoon curette to protect the adjacent femoral cartilage as well as the anterior and posterior cruciate ligament (■ Fig. 14.18g).

A suture lasso or shuttle suture is then passed through the drilled tunnel to inside the joint and used to shuttle the two limbs of the suture pulling the meniscus root to outside the joint (■ Fig. 14.18h,i). The meniscus root is repositioned by pulling the sutures under arthroscopic visualization. Finally, these are tied over a fixation button on the tibial cortex (■ Fig. 14.19).

14.2.5 Postoperative Management

- Monitoring of peripheral circulation, motor and sensory innervation.
- Use of elastic compressive bandages
- Cooling and elevation of the extremity.

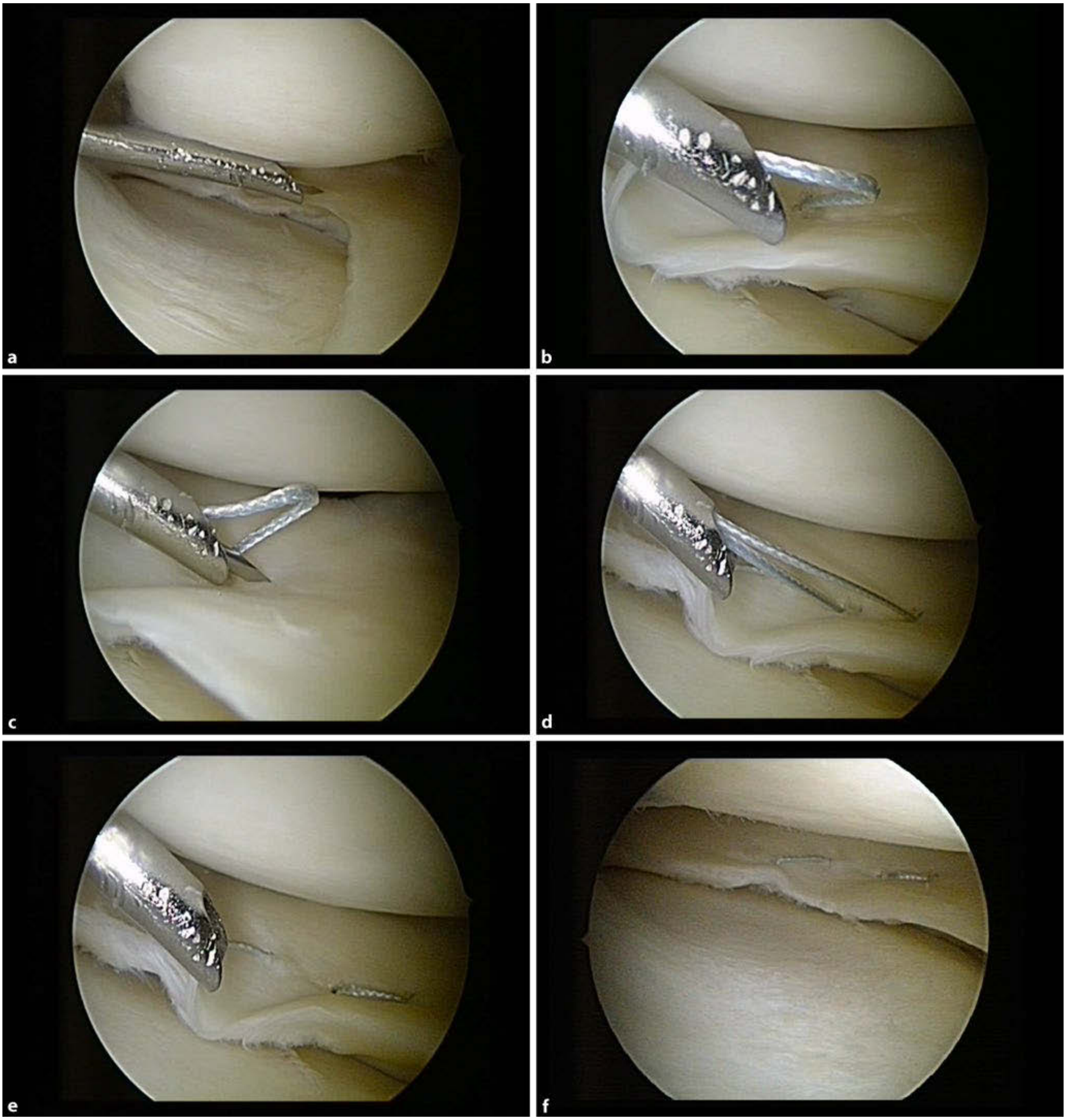


Fig. 14.15a–f Arthroscopic inside-out suturing technique. **a** insertion of the guide cannula and piercing the meniscus with the first meniscal needle; **b** retraction of the guide cannula; **c** piercing the meniscus with the second meniscal needle; **d** removing the guide cannula, **e** knotting of the corresponding suture ends over the joint capsule; **f** end result after performing 2 horizontal sutures

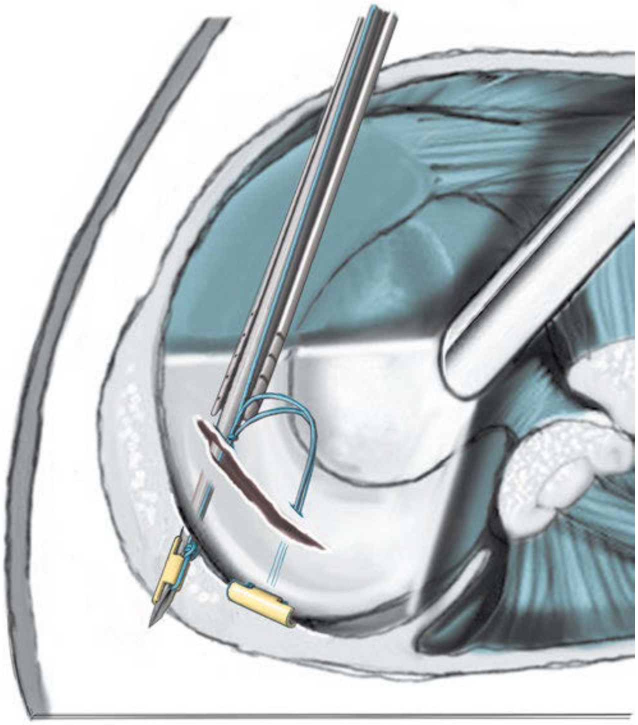


Fig. 14.16 All-inside suturing technique with anchor system

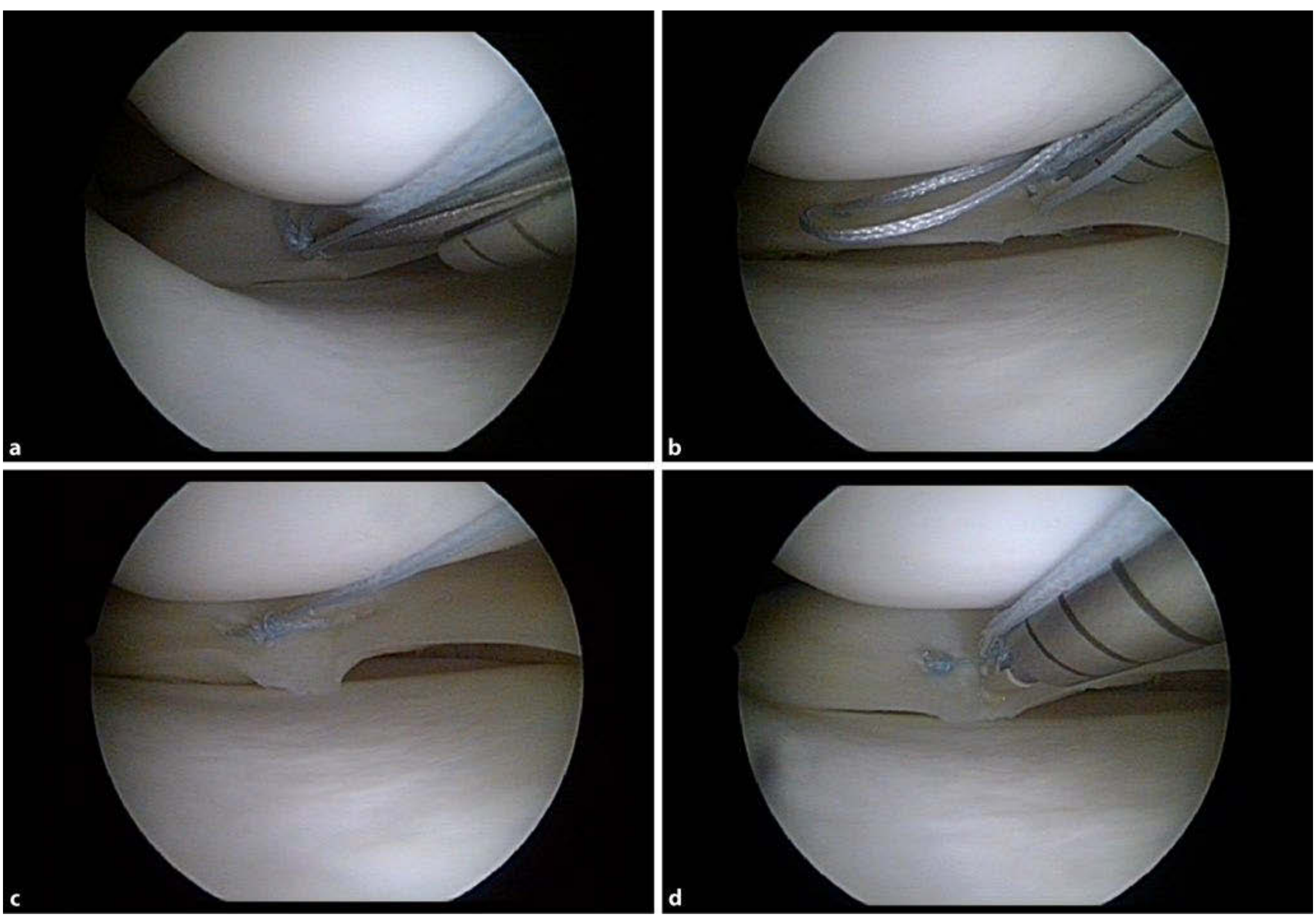


Fig. 14.17a–f Arthroscopic all-inside suturing technique. **a** piercing the meniscus and joint capsule with the first anchor plate using the applicator; **b** piercing with the second plate; **c** tightening the sliding knot; **d** Performing another suture in the same way (in this case, crossing horizontal and vertical sutures are performed)

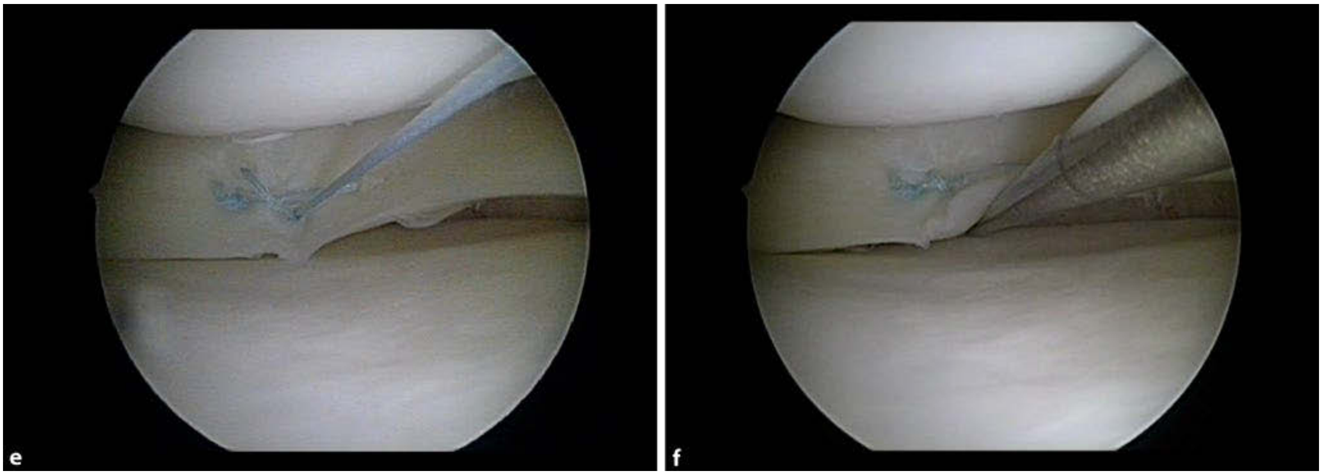


Fig. 14.17a–f (continued) Arthroscopic all-inside suture. **e** tightening the sliding knot; **f** stability testing with the arthroscopic probe

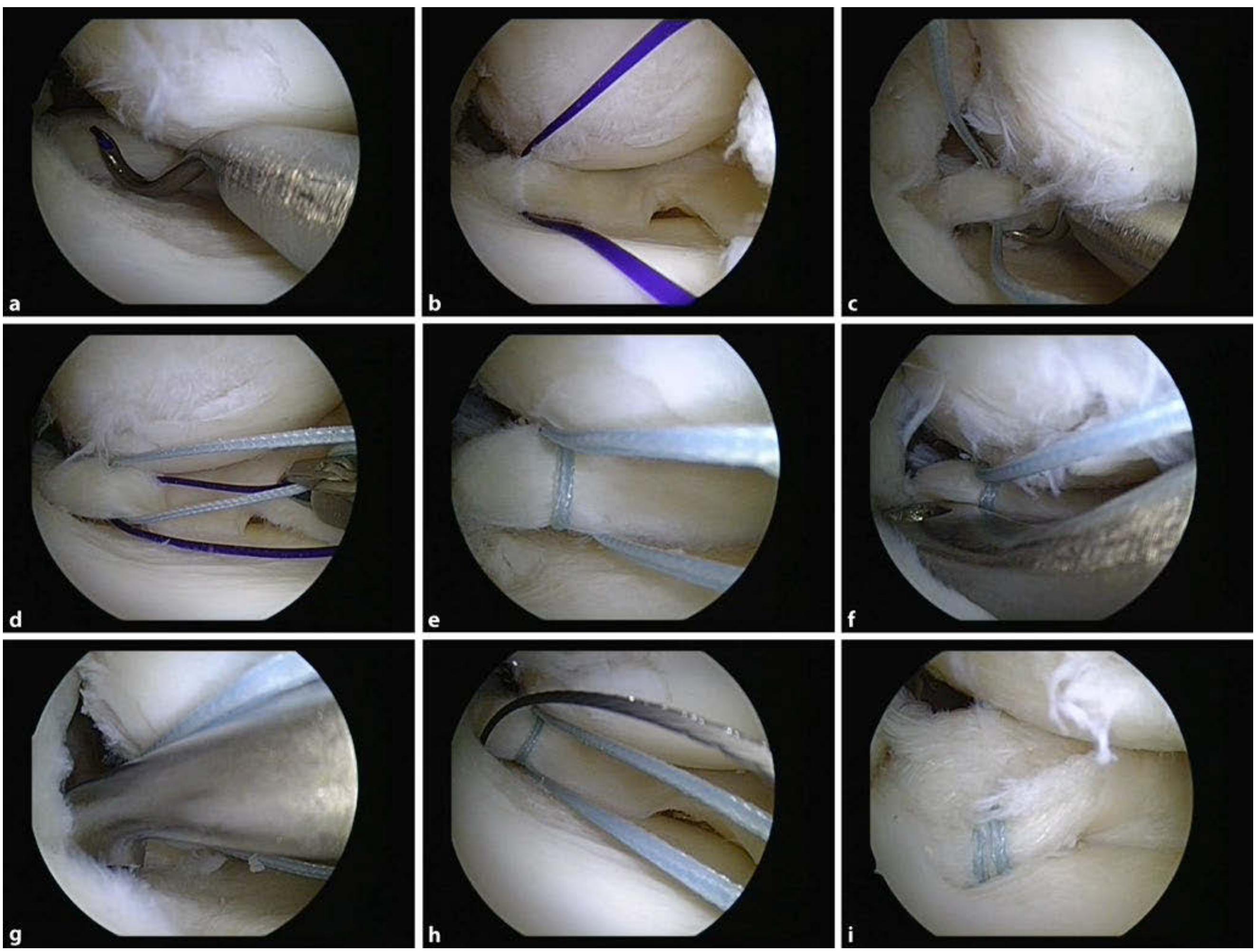


Fig. 14.18a–i Arthroscopic meniscal root fixation. **a** the meniscus root is pierced with a shuttle instrument; **b** passing a shuttle loop; **c** re-piercing the root after pulling in a FiberWire suture; **d** shuttling both ends of the FibreWire suture exiting the upper and lower surfaces of the meniscus root to outside the joint; **e** The meniscus root pulled with the FiberWire suture after the second shuttling; **f** An ACL tibial guide is inserted and a guide wire is inserted into the center of the meniscal root bed; **g** over-drilling the guide wire with a cannulated drill bit with protection using a spoon curette; **h** A suture lasso is inserted to shuttle the two FiberWire ends through the tibial drill hole; **i** end result after knotting the two ends of the FiberWire over a plate on the anterior tibial cortex

■ **Fig. 14.19** Schematic representation of meniscal root fixation

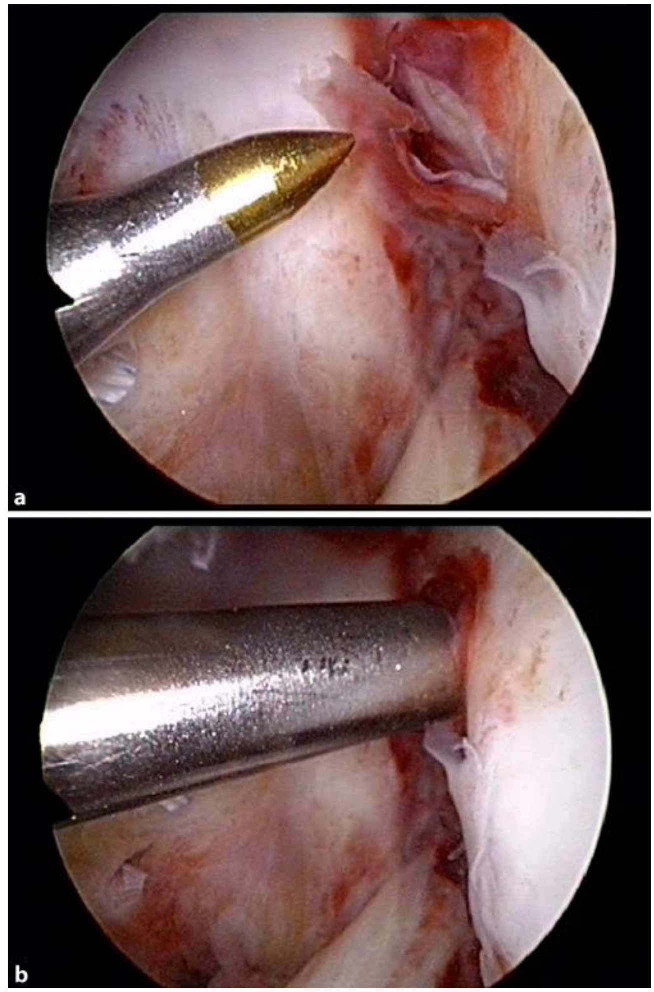
14.2.6 Follow-up Management

Medial Meniscus

Partial weight-bearing with 20 kg for 2 weeks, followed by gradual transition to full weight-bearing. Wearing a knee extension brace for 6 weeks (24 hours/day), accompanying physiotherapeutic training with restriction of the range of motion to flexion/extension: 90°/0°/0°. Then free range of motion is allowed and sensorimotor training can be started.

Lateral Meniscus

Partial weight-bearing in the first 6 weeks with 20 kg load then gradually increased weight-bearing as tolerated. A 4-point hard frame knee brace is used for 6 weeks with restriction of the range of motion to flexion/extension 60°/0°/0°. From the 7th week active flexion/extension are freely allowed avoiding loading the knee at more than 90° of flexion (squatting, leg press) during the first 3 postoperative months.



■ **Fig. 14.20a,b** Microfracture above the ACL insertion to promote healing

14.2.7 Tips & Tricks

The vertical mattress suture has a higher strength compared to the horizontal mattress suture as the majority of the collagen fibers within the menisci run in a circular manner.

To avoid nerve or vascular injury or even skin injury, the depth of penetration for the all-inside suture instruments should not exceed 16 mm.

With inside-out and outside-in techniques in the medial compartment, the capsule must be freely and cautiously dissected before passing the sutures and in any case before tying the knots to avoid injury to the saphenous nerve.

If the repaired meniscus is pulled upward by the vertical mattress sutures placed on the femoral side of the meniscus, additional vertical or horizontal mattress sutures placed entirely on the tibial side of the meniscus could be performed to balance the meniscus.

Microfracture of the intercondylar region improves healing of the repaired meniscus by providing influx of bone marrow elements into the joint (■ Fig. 14.20).

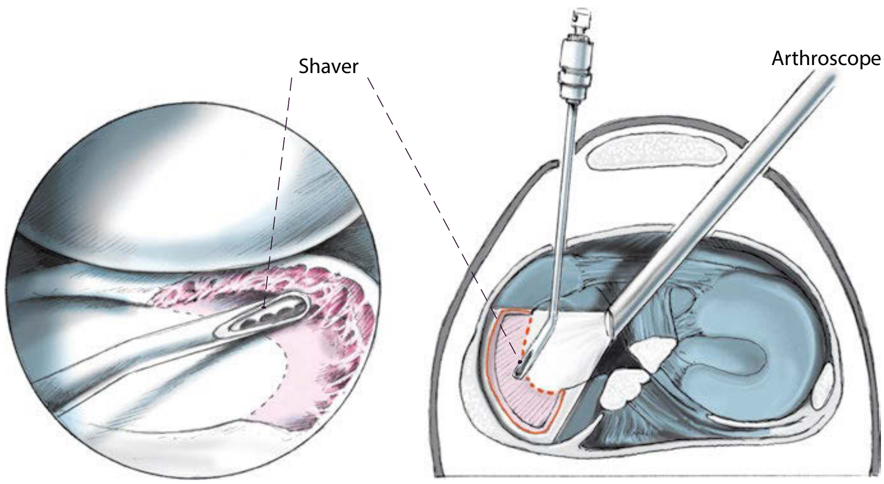


Fig. 14.21 Creation of a stable meniscus rim

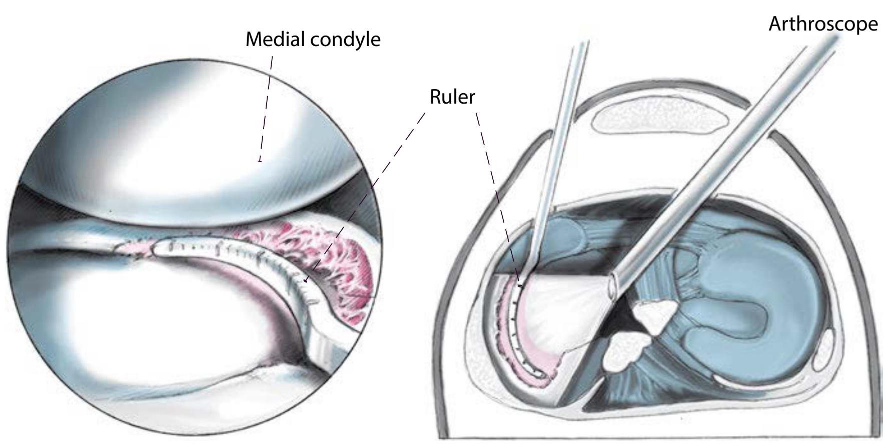


Fig. 14.22 Measuring the arc length of the defect with a special measuring device

14.3 Meniscus Replacement

G. Meidinger, S. Hinterwimmer

14.3.1 Indication

Symptomatic knee joint compartments after subtotal medial or lateral meniscectomy with still intact anterior and posterior meniscus roots as well as intact meniscal rim.

Specific contraindications: higher grade cartilage damage (> Grade 2), osteoarthritis, malalignment (> 5° varus/valgus), ligamentous instability, obesity (BMI > 30 kg/m2), allergy to components of the meniscal replacement.

14.3.2 Operation Principle

Replacement of a subtotally resected medial or lateral meniscus with a collagen meniscus implant (CMI) or a polyurethane implant (Actifit) to restore the meniscus function and to delay the development of degenerative changes and osteoarthritis .

14.3.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: activity related pain at the medial or lateral joint line, previous operations. – Symptom specific examination: inspection of the leg alignment, tenderness at the medial or lateral joint lines, exclusion of concomitant ligamentous instability.

Imaging

- X-ray of the knee in 3 views (AP, lateral and tangential patella) to assess the degree of osteoarthritis.
- long leg standing radiographs AP with suspected leg malalignment
- MRI to assess the remaining meniscal tissue, particularly a still intact meniscal rim, exclusion of high grade cartilage lesions and ligamentous lesions.

Patient Information/Consent

Specific operative risks: injury to the saphenous or common peroneal nerves during fixation of the synthetic meniscus with sutures, overreaction to components of the synthetic meniscus, arthrofibrosis, rupture or displacement of the synthetic meniscus, dislocation or absorption (CMI), failure of

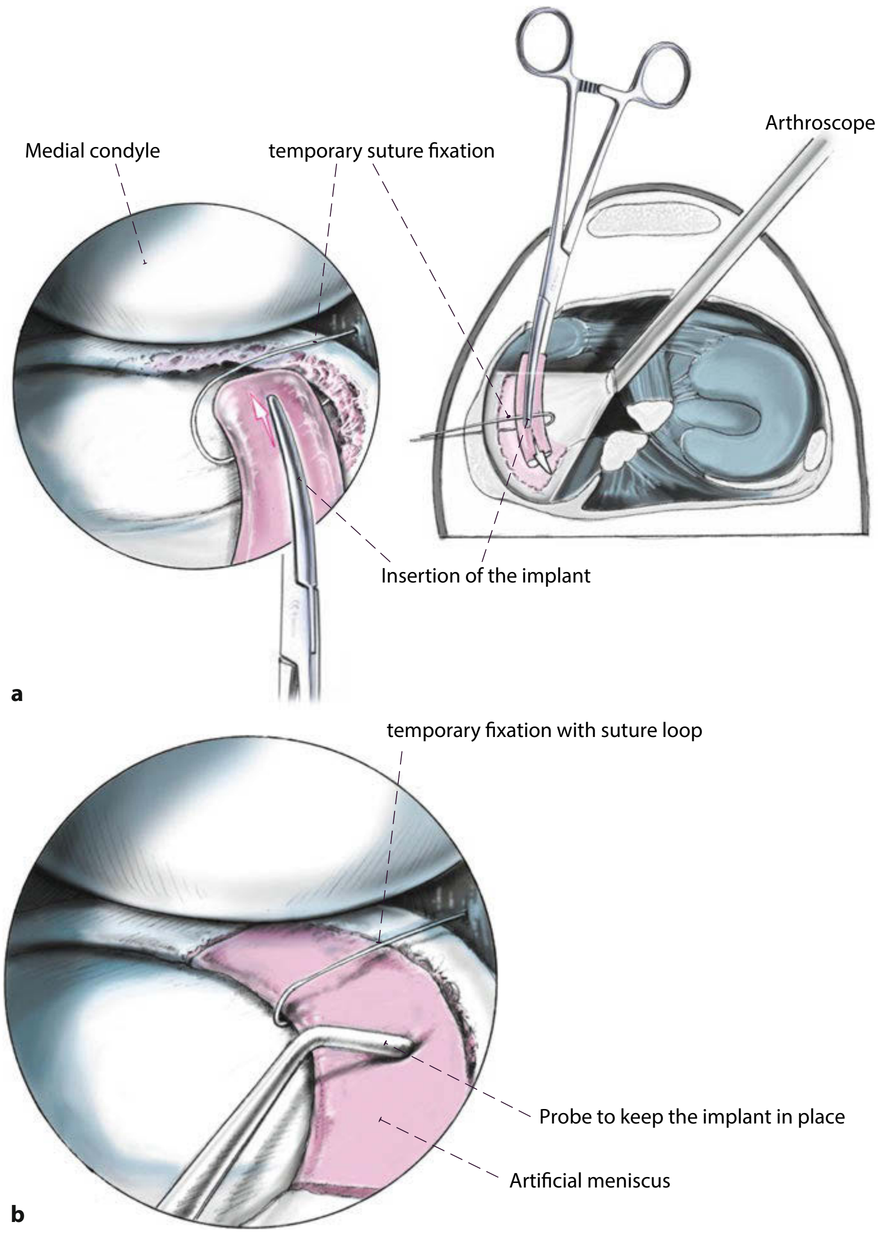


Fig. 14.23a,b **a** The artificial meniscus is introduced with a clamp and temporarily fixed with a suture loop; **b** fine adjustment of the artificial

the meniscal repair, cartilage damage, progression of degenerative changes.

14.3.4 Surgical Technique

Positioning and Preparation

- Supine position
- A thigh tourniquet is applied

Artificial Meniscus Replacement

Diagnostic arthroscopy is performed via the standard portals to verify the correct indication, assess the articular cartilage and exclude associated injuries. If a CMI is to be implanted, the graft must be simultaneously immersed in sterile whole blood withdrawn from the patient.

The affected meniscus is trimmed or partially resected until having a stable peripheral rim of the meniscus in the red-white or red-red zone (Fig. 14.21). A right angle or a slightly oblique cut of the anterior and posterior edges of the defect are better to fit the artificial meniscus.

Debridement/needling is performed either arthroscopically using a special instrument "morning star" or from outside with a cannulated needle until it bleeds slightly at the base of the meniscus (checked by temporary reducing the pump pressure). The measuring device is inserted to measure the arc length of the defect (Figs. 14.22 and 14.25a). The artificial meniscus is cut to the corresponding required size and inserted with the specialized application clamp (Fig. 14.25b) and positioned with the arthroscopic probe.

The artificial meniscus in then positioned by slightly pulling on suture loops that are already passed through its

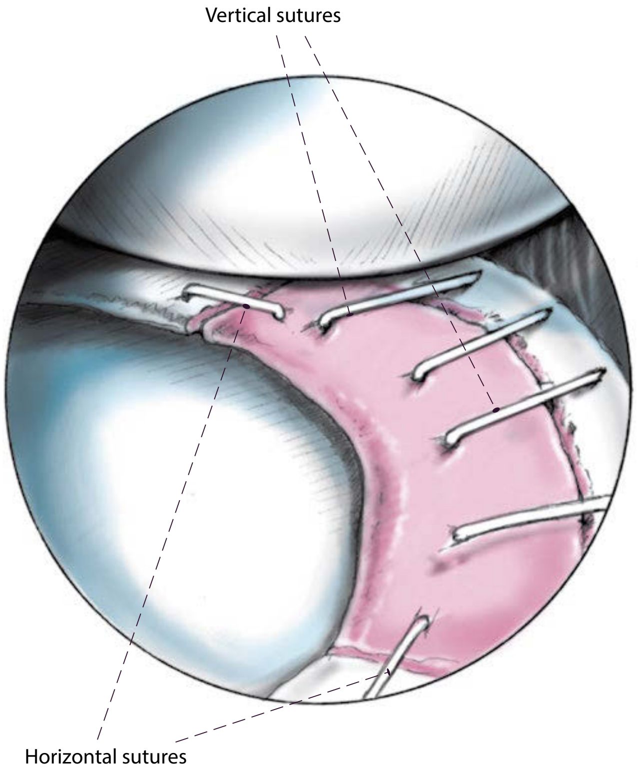


Fig. 14.24 Artificial meniscus fixed with horizontal and vertical sutures

center and completed to outside in inside-out technique (Fig. 14.23). Final fixation of the artificial meniscus is carried out with non-absorbable sutures passed in the inside-out, outside-in or all-inside technique (▶ Sects. 14.2). Horizontal mattress sutures are used at the junction of the artificial meniscus and the meniscal rim both anterior and posterior with vertical mattress sutures at about 5 mm intervals distance in between them (Figs. 14.24 and 14.25c–f).

After fixation of the artificial meniscus about 3–4 microfracture holes are made just above the ACL insertion in the intercondylar fossa to allow passage of marrow blood and thus stem cells to stimulate the healing (Fig. 14.26).

14.3.5 Postoperative Management

- Monitoring of peripheral circulation, motor and sensory innervation, irritation of the saphenous or the common peroneal nerves are manifested with electrical pain on touching the skin distal to medial or lateral incision used for the inside-out suturing.
- Use of elastic compressive bandages
- Cooling and elevation of the extremity.

14.3.6 Follow-up Management

A knee extension brace is used with non-weight bearing for 6 weeks. Limitation of range of motion in the 1st–4th postoperative weeks to active-assisted flexion/extension: 60°/0°/0°. In the 5th–6th postoperative weeks active-assisted flexion/extension: 90°/0°/0° (outside the brace). From the 7th postoperative week free active range of motion of the knee with gradually increased weight bearing are allowed.

Loading the knee beyond about 90° flexion is prohibited (squatting, leg press) in the first 3 postoperative months. Cycling, crawl swimming and treadmill can be started at about 3 months postoperatively, full sports ability at about 6 months postoperatively.

14.3.7 Tips & Tricks

The CMI is braided and supported with absorbable Vicryl suture prior to introduction into the joint which make the intraarticular alignment and positioning easier because after soaking with blood it turn to be softer in consistency.

A suture loop is passed in the inside-out technique before inserting the artificial meniscus allows temporary correct positioning. Over-tightening of the temporarily inserted suture loop or the definitive fixation sutures can damage the artificial meniscus.

The popliteus tendon must not be involved during fixation of a lateral artificial meniscus.

To allow seedling the artificial meniscus with autologous cells, it should be fixed as possible to the red zone and the meniscal rim should be sufficiently freshened and debrided.

A fibrin clot may be sutured to the base of the artificial meniscus to promote healing.

In case of concomitant ligamentous instability, operative stabilization of the joint should be performed simultaneously or in a preceding procedure. If the knee joint is unstable, the expected survival of the meniscus transplant is low.

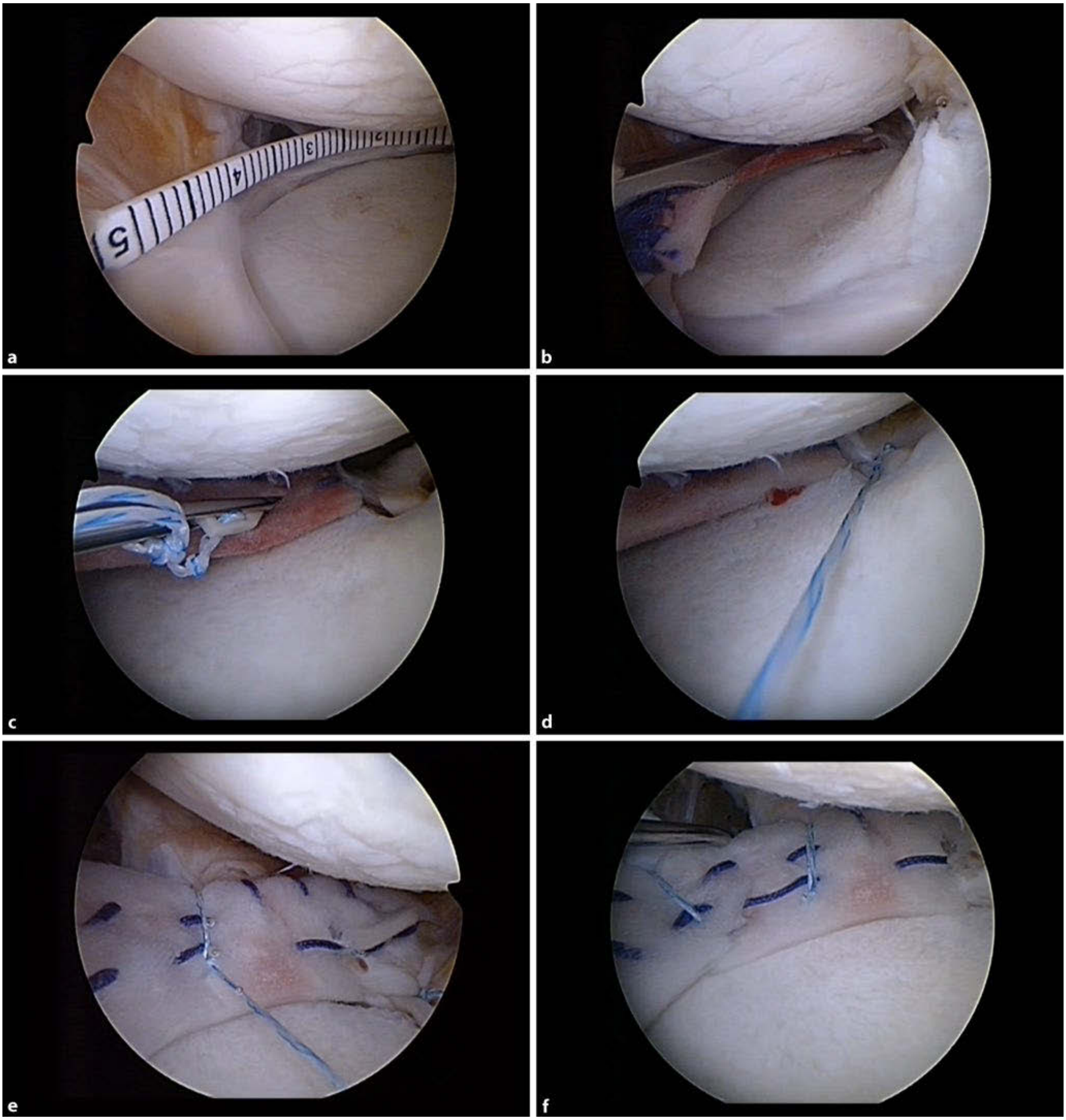


Fig. 14.25a–f CMI implantation (medial compartment). **a** measurement of the arc length of the defect, **b** insertion of the implant with a clamp; **c** fixation of the implant to the medial meniscus posterior horn with an all-inside horizontal suture; **d** pulling the pretied sliding knot; **e** further fixation of the implant to the rim with all-inside vertical sutures; **f** checking the stability of the implant after complete fixation with an arthroscopic probe

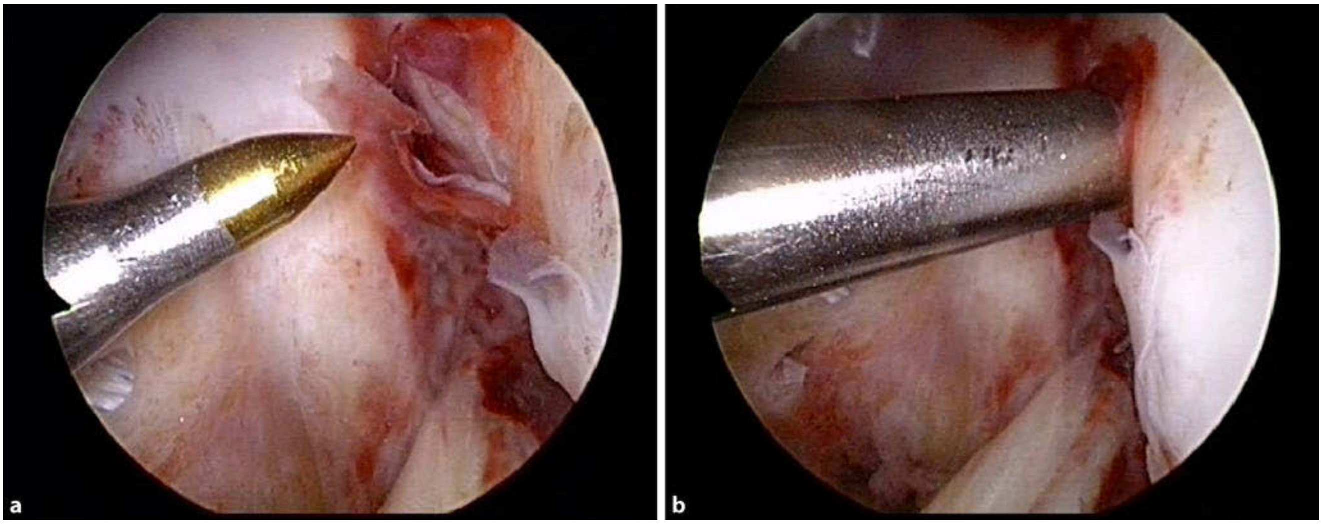


Fig. 14.26a,b Microfracture above the ACL to promote the healing

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14

Ligaments

M. Feucht, S. Hinterwimmer, S. Döbele, G. Meidinger

A. B. Imhoff, M. J. Feucht (Eds.), *Surgical Atlas of Sports Orthopaedics and Sports Traumatology*,
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15.1 ACL Reconstruction

M. Feucht, S. Hinterwimmer

15.1.1 Indication

Rupture of the anterior cruciate ligament with subjective and objective instability. Persistent subjective and objective instability after primary conservative treatment.

Specific indications for anatomic single bundle technique: small femoral or tibial insertion zone (length < 14 mm), narrow notch (< 12 mm), open growth plates, marked bone bruise of the lateral femoral condyle, multi-ligament injuries.

15.1.2 Operation Principle

Anatomic double-bundle technique: reconstruction of the anteromedial and posterolateral bundles with 2 autologous hamstring tendon grafts which are placed into two separate femoral and tibial tunnels (4-tunnels technique) at the anatomical insertion area for each bundle.

Anatomic single bundle technique: Reconstruction of the ruptured cruciate ligament with a hamstring tendon graft which is passed through a single femoral and tibial tunnels drilled at the center between the insertion foot print of the anteromedial and posterolateral bundles.

15.1.3 Preoperative Assessment

Diagnosis

Clinical

Symptom specific history: time and mechanism of injury, subjective instability, pain, functional demands.

Symptom specific examination: Assessment of the range of motion (extension deficit), anterior drawer test, Lachman test, pivot shift test, exclusion of associated instability and concomitant meniscal lesions.

Imaging

- X-ray of the knee joint in three views (AP, lateral, tangential patella) to exclude osseous lesions.
- Long leg standing AP view if there is marked malalignment.
- MRI to assess the ACL and verify other intraarticular lesions.

Patient Information/Consent

Surgery-specific risks: Morbidity after harvesting the tendon graft with at least temporary weakening of the knee flexion and internal rotation, injury of the saphenous nerve, rupture of the hamstring tendons during harvesting which may necessitates harvesting the contralateral hamstring, patellar tendon or the quadriceps tendon as grafts, injury of the neurovascular bundle in the popliteal fossa, injury of the peroneal nerve, flexion or extension deficit due to tunnel malpositioning or fixation of the graft in an incorrect position, fracture of the bony wall of the femoral tunnel with subsequent need to change the used technique, recurrent joint effusions as a reaction to bio-absorbable implants, arthrofibrosis, loosening of the graft fixation construct with recurrent stability, re-rupture.

15.1.4 Surgical Technique

Positioning and Preparation

- Supine position (with possibility to flex the knee to at least 120°)
- A thigh tourniquet is applied
- Examination under anesthesia (degree of instability, exclusion of combined instability)

Anatomical ACL Reconstruction in Double Bundle Technique and Direct Anatomical Fixation with Interference Screw "Aperture Fixation"

Diagnostic arthroscopy via the anterolateral portal to confirm the surgical indication as well as to assess possible associated injuries. The femoral and tibial footprints are measured with an arthroscopic ruler (◘ Fig. 15.1).

Harvesting and preparation of the semitendinosus tendon as described in ► Sect. 13.1. If the total length of the semitendinosus tendon is at least 30 cm, it can be used for both bundles grafts. The tendon is divided so that a graft of at least 16 cm length for the anteromedial bundle and the other of at least 14 cm length for the posterolateral bundle are available.

If the tendon length is less than 30 cm, the gracilis tendon should be additionally harvested. The tendons are used to prepare doubled grafts. The procedure requires establishing an anteromedial well as a medial portal (◘ Fig. 15.2).

The femoral and tibial foot prints are meticulously and carefully prepared (◘ Fig. 15.3). The femoral sockets are first drilled starting with the anteromedial one. The femoral guide is loaded through the anteromedial portal (trans portal) and positioned with the appropriate offset (e.g. 4 mm offset for the 7 mm socket and 5 mm offset for the 8 mm socket) against the posterior cortex of the lateral femoral condyle (◘ Figs. 15.4 and 15.8a). A guide pin with an eyelet is inserted via the femoral guide with the knee in 90° flexion for few millimeters at the center of the anteromedial bundle foot print, the knee is then flexed to at least 120° and the guide pin is drilled to exit the opposite cortex and the skin of the thigh. A cannulated femoral reamer corresponding to the graft thickness is inserted over the guide pin and the femoral socket is drilled to a depth of about 20–25 mm and a

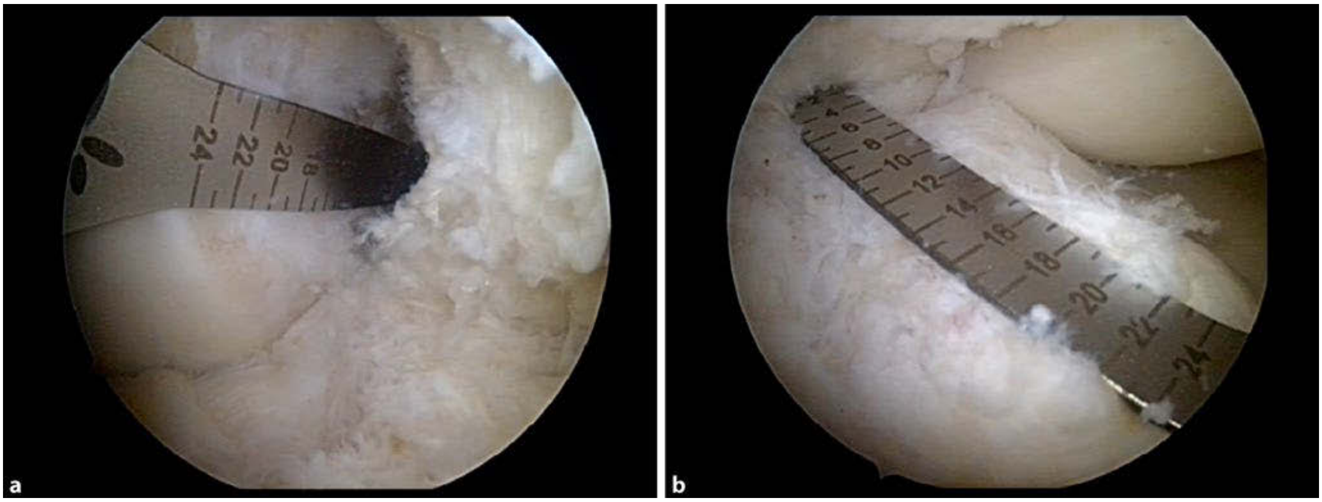


Fig. 15.1a,b measurement of the femoral (**a**) and tibial (**b**) footprints

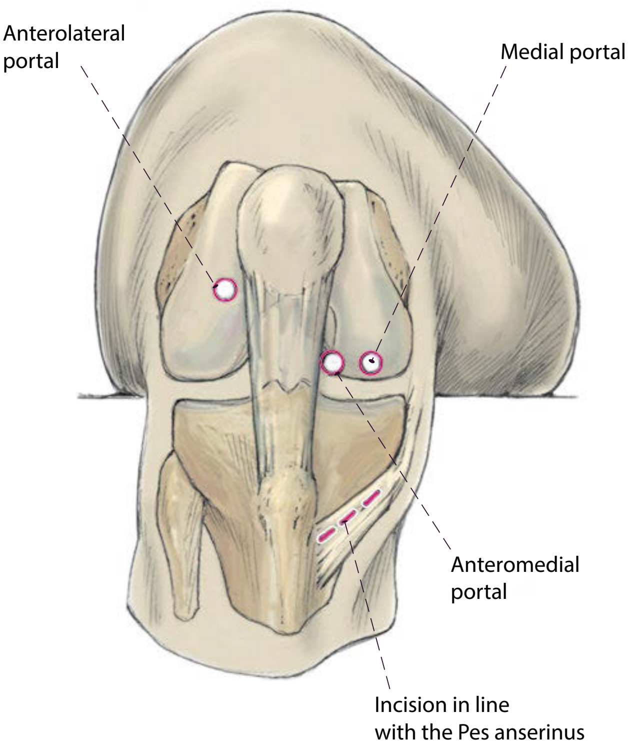


Fig. 15.2 Portals used for the double-bundle technique

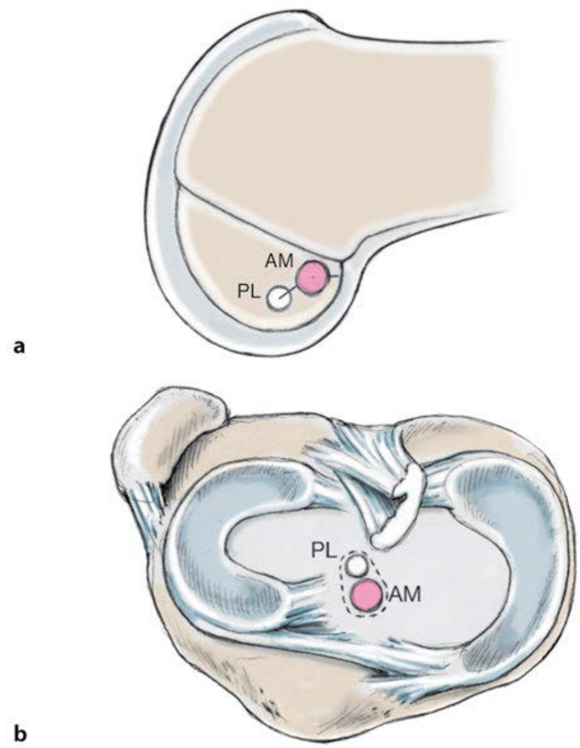
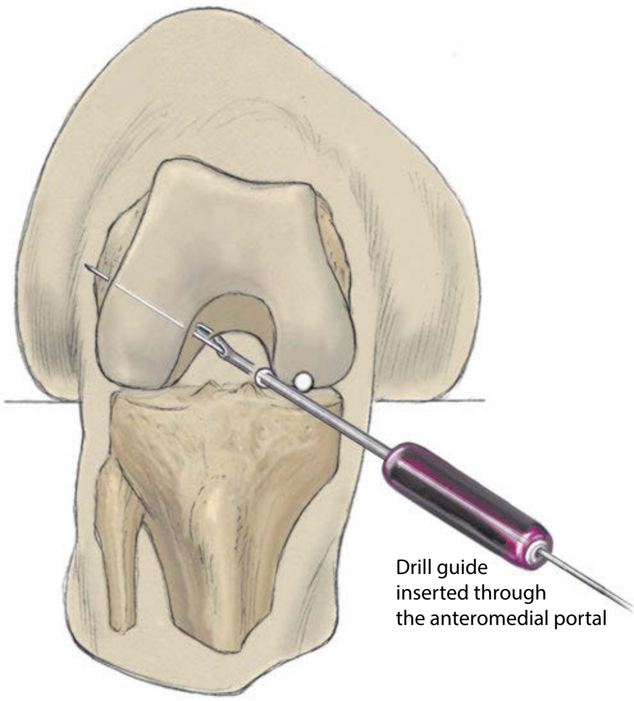


Fig. 15.3 Insertion zones of the ACL. **a** femoral insertion **b** tibial insertion. *AM* anteromedial bundle, *PL* posterolateral bundle

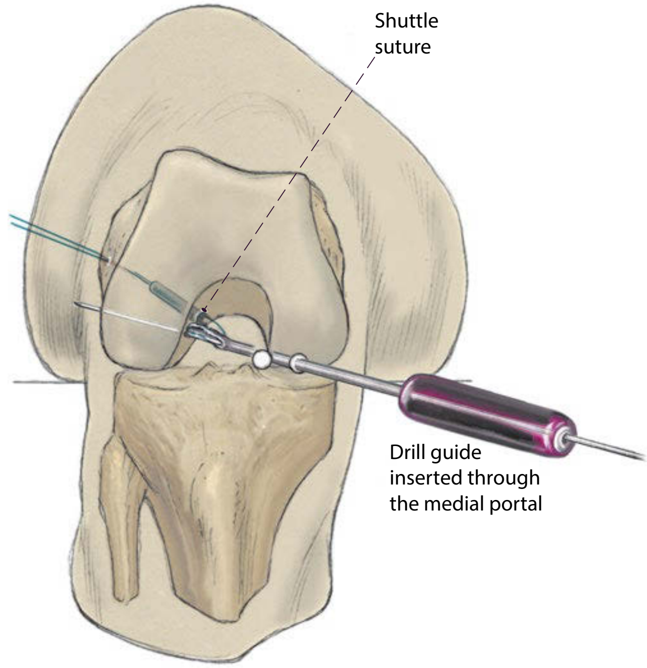
doubled passing suture is passed in via the guide pin, so that the suture loop remains outside the anteromedial portal.

For the posterolateral bundle socket, the femoral guide is then loaded through the medial portal to create the posterolateral socket and positioned with the appropriate offset (e.g. 4 mm offset for a 5 mm socket)against the anterior wall of the anteromedial socket (Fig. 15.8b). A guide pin with an eyelet is inserted via the femoral guide with the knee in 100° flexion and the bone is drilled at the center of the posterolateral bundle foot print until the pin exits the opposite cortex and skin (Fig. 15.5). Overdrilling with a cannulated reamer (Fig. 15.8c) to a depth of 20 mm and pulling in a doubled passing suture.

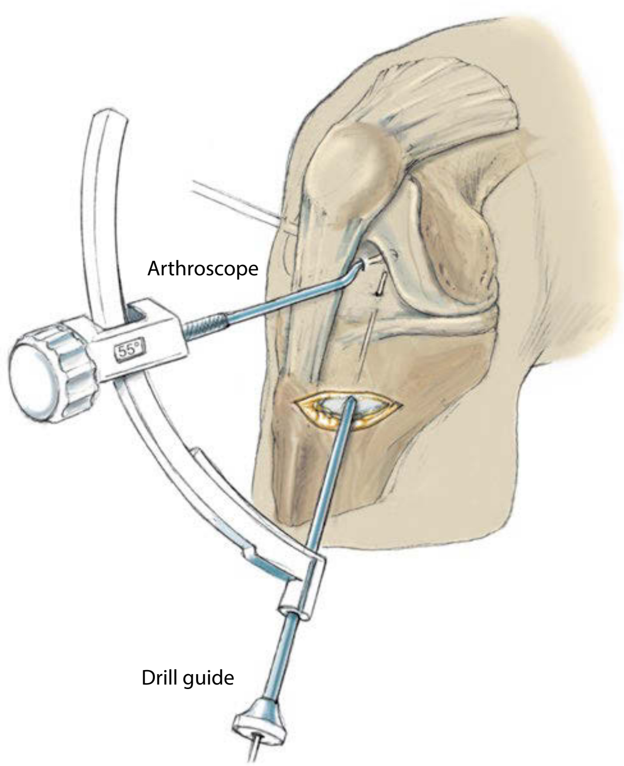
The tibial guide is used to insert a guide pin through the incision used for harvesting the tendon graft to the center of the posterolateral bundle footprint (Fig. 15.6) about 7 mm anterior to the posterior cruciate ligament at the middle of the intercondylar eminence. The angle of the tibial guide should be set to 55° and inclined 50° to the tibia longitudinal axis. For the anteromedial tibial tunnel, angle of the tibial guide is set to 45°, inclined 20° and exits intraarticularly at the center of the anteromedial bundle foot print, at the level of the lateral meniscus anterior horn. The guide pin is drilled through the tibial guide (Fig. 15.8). An intraarticular distance of about 1–2 mm should remain between the two tunnels (Fig. 15.7).



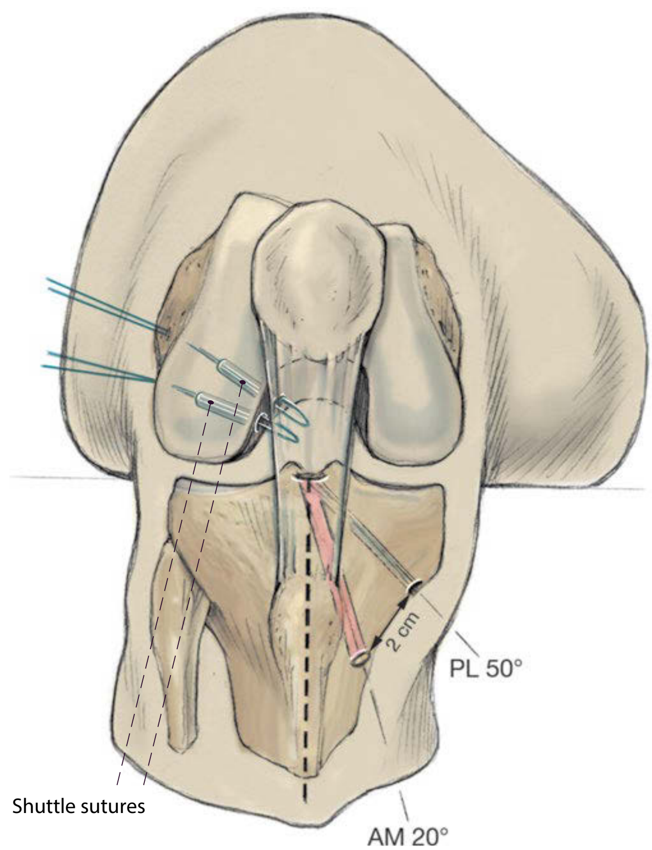
■ **Fig. 15.4** Femoral guide loaded through the anteromedial portal with the offset positioned over the posterior wall of the lateral femoral condyle with the knee in 120° flexion to insert a guide pin at the center of the anteromedial foot print



■ **Fig. 15.5** Femoral guide loaded through the medial portal with the offset positioned against the anterior wall of the anteromedial femoral socket with the knee in about 100° flexion to insert a guide pin at the center of the posterolateral foot print



■ **Fig. 15.6** Trans-tibial drilling using the tibial guide placed through the incision for graft harvesting



■ **Fig. 15.7** Position of the two tibial tunnels. *AM*: anteromedial bundle tunnel, *PL*: posterolateral bundle tunnel

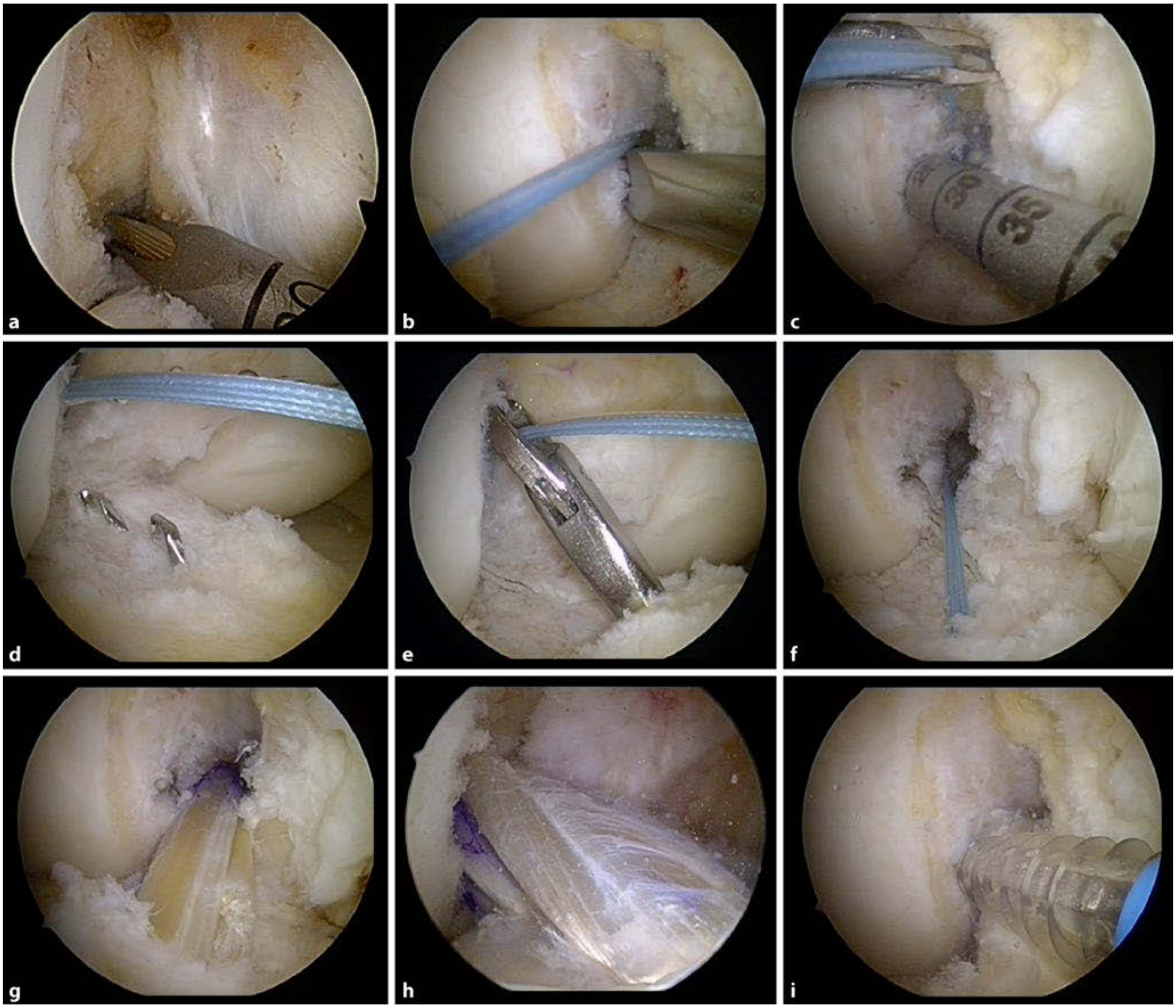


Fig. 15.8a–i Anatomic double bundle ACL reconstruction technique. **a** Insertion of the femoral guide pin for the anteromedial socket; **b** insertion of the femoral guide pin for the posterolateral socket; **c** over-drilling the guide pins with a cannulated reamer; **d** anatomically positioned tibial guide pins; **e** trans-tibial shuttling of the passing sutures after overdrilling the tibial guide pins; **f** both passing sutures after shuttling to outside the tibia; **g** anteromedial bundle pulled into the femoral socket; **h** both bundles pulled into the femoral sockets; **i** femoral fixation with interference screws

Impingement test is performed by extending the knee and assessing the position of the guide pins relative to the notch roof. Overdrilling the guide pins with a cannulated reamer corresponding to the graft diameter (usually 7 mm for the AM bundle and 5 mm for the PL bundle). A suture retriever is passed through the anteromedial tibial tunnel to retrieve the loop of the previously inserted passing suture for the anteromedial bundle graft out through the tibia (Fig. 15.8e). The same procedure is repeated for the posterolateral passing suture (Fig. 15.8f).

The anteromedial graft is pulled using the corresponding passing suture (Fig. 15.8g). A Nitinol wire is passed through the anteromedial portal into the socket between the graft and the bony wall.

The knee is flexed to 120° and the interference screw is inserted over the Nitinol wire to fix the graft on the femoral side. The same procedure is used to fix the posterolateral graft in 100° flexion through the medial portal (Fig. 15.8h,i). The screw diameter is the same as the socket diameter.

The graft is conditioned by moving the knee in flexion and extension 20 times under traction on the tibial pulling sutures. The tibial fixation of the posterolateral graft is performed using an appropriate interference screw (screw diameter 1 mm larger than the diameter of the drilled channel) in 15° knee flexion under traction of the graft with 80 N using tensioner device. The screw is advanced to just below the tibial articular surface. The same procedure is done for fixation of the anteromedial graft in 45° knee flexion. Graft position and tension as well as the free range of motion of the knee are confirmed at the end of the procedure.

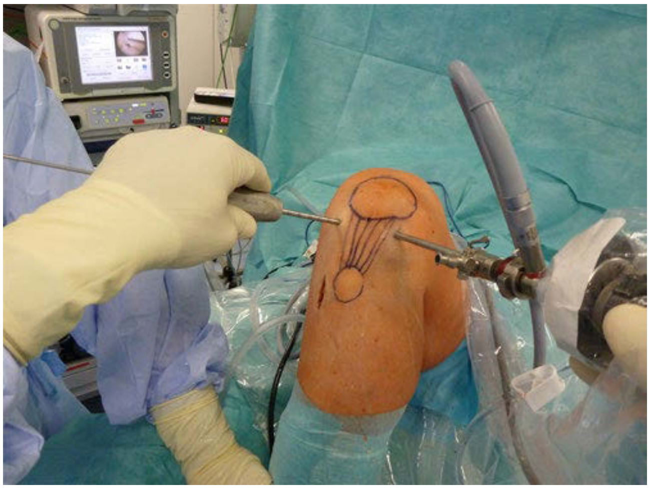


Fig. 15.9 Inserting the femoral guide pins through the anteromedial portal

Anatomical ACL Reconstruction in Single Bundle Technique and Direct Anatomical Fixation with Interference Screw "Aperture Fixation"

Diagnostic arthroscopy via the anterolateral portal to confirm the surgical indication as well as to assess possible associated injuries. Harvesting and preparation of the semitendinosus tendon as described in ► Sect. 13.1. If the total length of the semitendinosus tendon is at least 30 cm, it can be used alone as a graft.

A four-strand graft with a minimum length of 7–8 cm is prepared. The semitendinosus tendon is whipstitched at both ends and then folded to be M-shaped. If the tendon length is less than 28 cm, the gracilis tendon should be additionally harvested and both tendons are used, each as a two-strand graft.

The anteromedial portal is created and the femoral and tibial foot prints are meticulously and carefully prepared. The femoral sockets is then drilled. The femoral guide is loaded through the anteromedial portal and positioned with the appropriate offset (e. g. 4 mm offset for the 7 mm socket) against the posterior cortex of the lateral femoral condyle (Figs. 15.9 and 15.10a). A guide pin with an eyelet is inserted via the femoral guide with the knee in 90° flexion for few millimeters at the center of the femoral foot print, the knee is then flexed to at least 120° and the guide pin is drilled to exit the opposite cortex and the skin of the thigh. A cannulated femoral reamer corresponding to the graft thickness is inserted over the guide pin and the femoral socket is drilled to a depth of about 20–25 mm (Fig. 15.10b). A doubled passing suture is passed in via the guide pin, so that the suture loop remains outside the anteromedial portal (Fig. 15.10c).

The tibial guide is used to insert a guide pin through the incision used for harvesting the tendon graft to the center

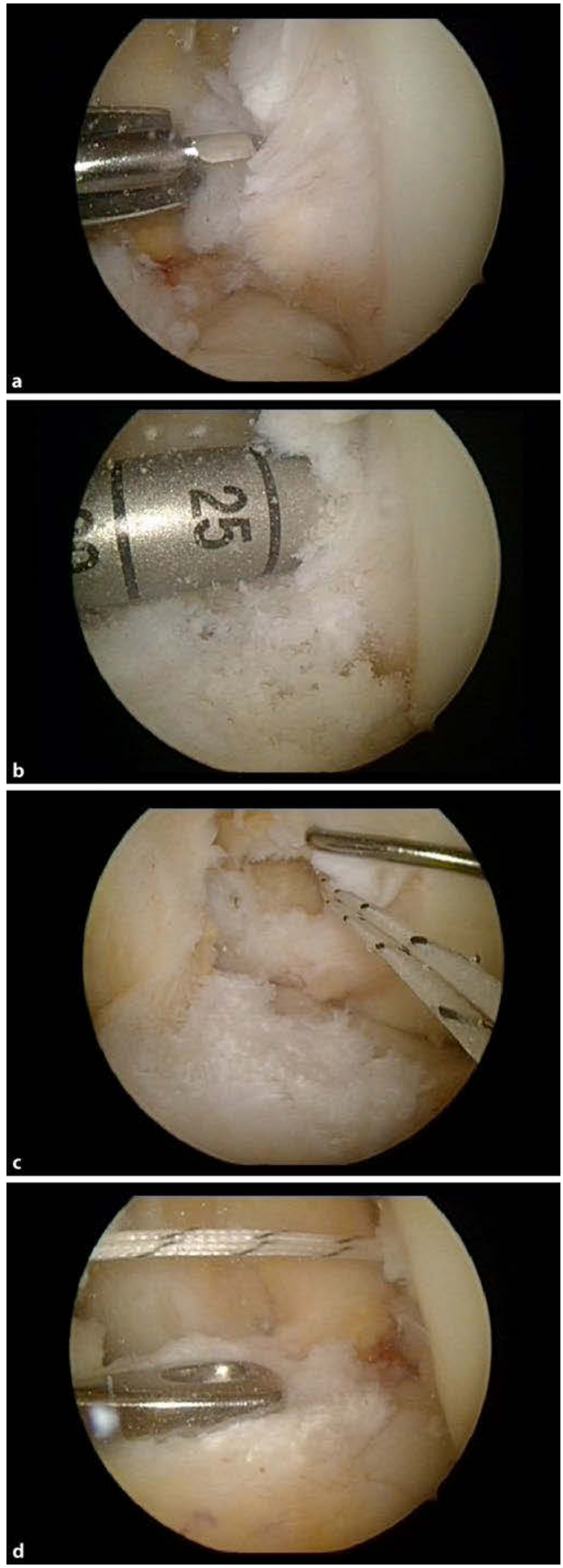
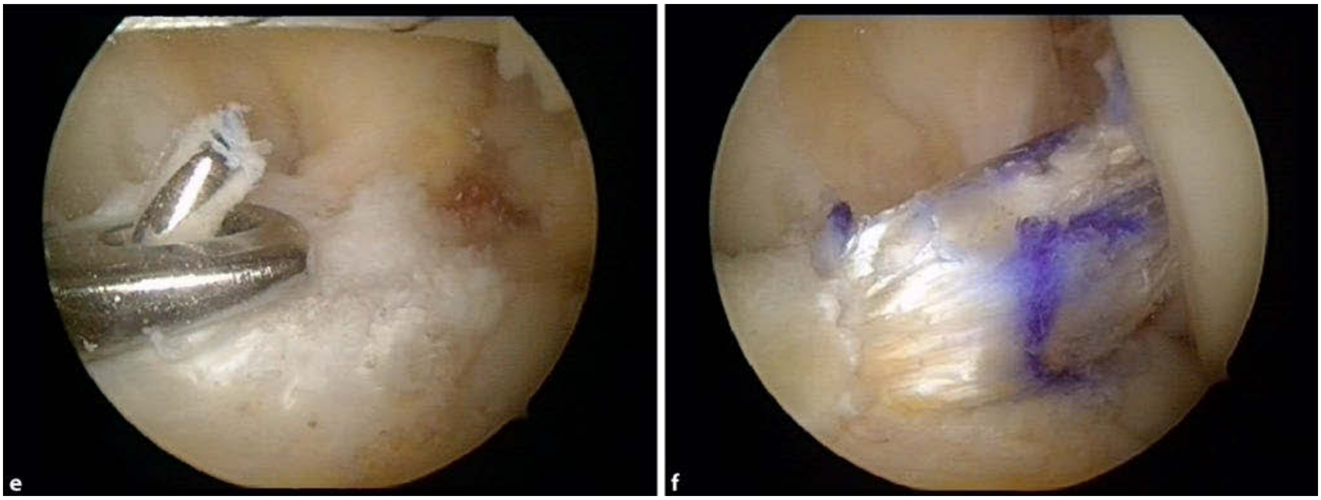
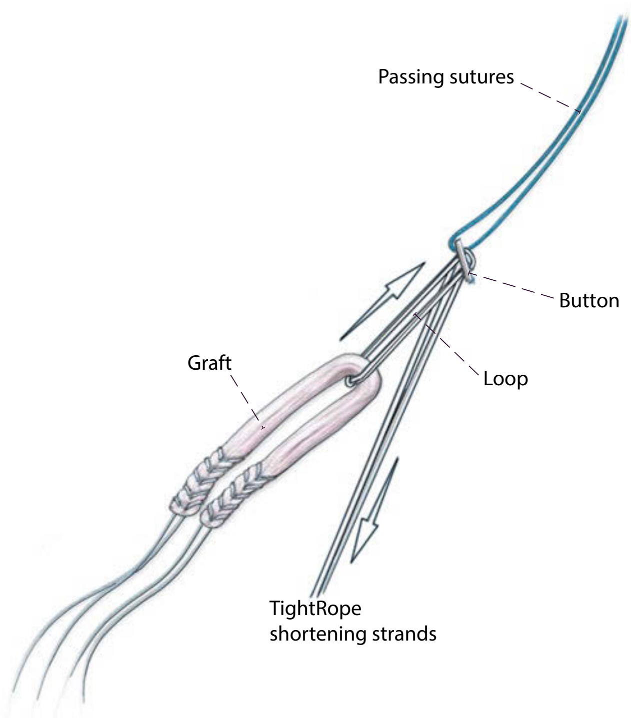


Fig. 15.10a–f Anatomic ACL reconstruction in single-bundle technique. **a** loading the femoral guide pin; **b** over-drilling with a cannulated reamer; **c** femoral socket at the center of the footprint; **d** positioning of the tibial guide.



■ **Fig. 15.10a–f** (*continued*), **e** introduction of a guide pin in the center of the tibial footprint; **f** passed graft



■ **Fig. 15.11** Principle of ACL TightRope system (Arthrex): The loop is shortened by pulling on the shortening strands to advance the graft into the femoral socket. (graft, loop, button, shortening strands to shorten the loop, passing sutures to pull the button)

of the tibial foot print, which lies along the posterior border of the anterior horn of the lateral meniscus (■ Fig. 15.10d,e).

Impingement test is performed by extending the knee and assessing the position of the guide pins relative to the notch roof. Overdrilling the guide pins with a cannulated reamer corresponding to the graft diameter. A suture retriever is passed through the tibial tunnel to retrieve the loop of the previously inserted passing suture out through the tibia. The same procedure is repeated for the posterolateral passing suture (■ Fig. 15.8f). The graft is pulled using the passing suture (■ Fig. 15.10f). A Nitinol wire is passed through the anteromedial portal into the socket between the graft and the bony wall. The knee is flexed to 120° and the interference screw (of the same diameter of the socket) is inserted over the Nitinol wire to fix the graft on the femoral side.

The graft is conditioned by moving the knee in flexion and extension 20 times under traction on the tibial pulling sutures. The tibial fixation of the graft is performed using an appropriate interference screw (screw diameter 1 mm larger than the diameter of the drilled channel) in 30° knee flexion under traction of the graft with 80 N using tensioner device. The screw is advanced to just below the tibial articular surface. Graft position and tension as well as the free range of motion of the knee are confirmed at the end of the procedure.

Anatomical ACL Reconstruction in Single Bundle Technique andFemoral Fixation Using ACL Tightrope.

The ACL TightRope (Arthrex) offers the possibility of an adjustable cortical fixation of the femoral graft.

Unlike other fixation buttons, this systems doesn't require measuring the length of the implant suture loop, in which the graft is suspended, can be calculated, as the loop is shortened when the graft is pulled (■ Fig. 15.11). Also, the graft fills the femoral socket completely), which makes this system also suitable for short femoral sockets.

As in the above described technique, a special guide pin (ACL TightRope Drill Pin, 4 mm, Arthrex) is inserted via the femoral guide at the center of the femoral foot print and overdrilled with a cannulated reamer corresponding to the graft diameter to a depth of about 20 mm. A doubled passing suture is passed in via the guide pin. The tibial tunnel is drilled in the same technique described above and the femoral passing sutures are retrieved out through the tibia. This suture is used to pull the blue passing sutures of the TightRope system

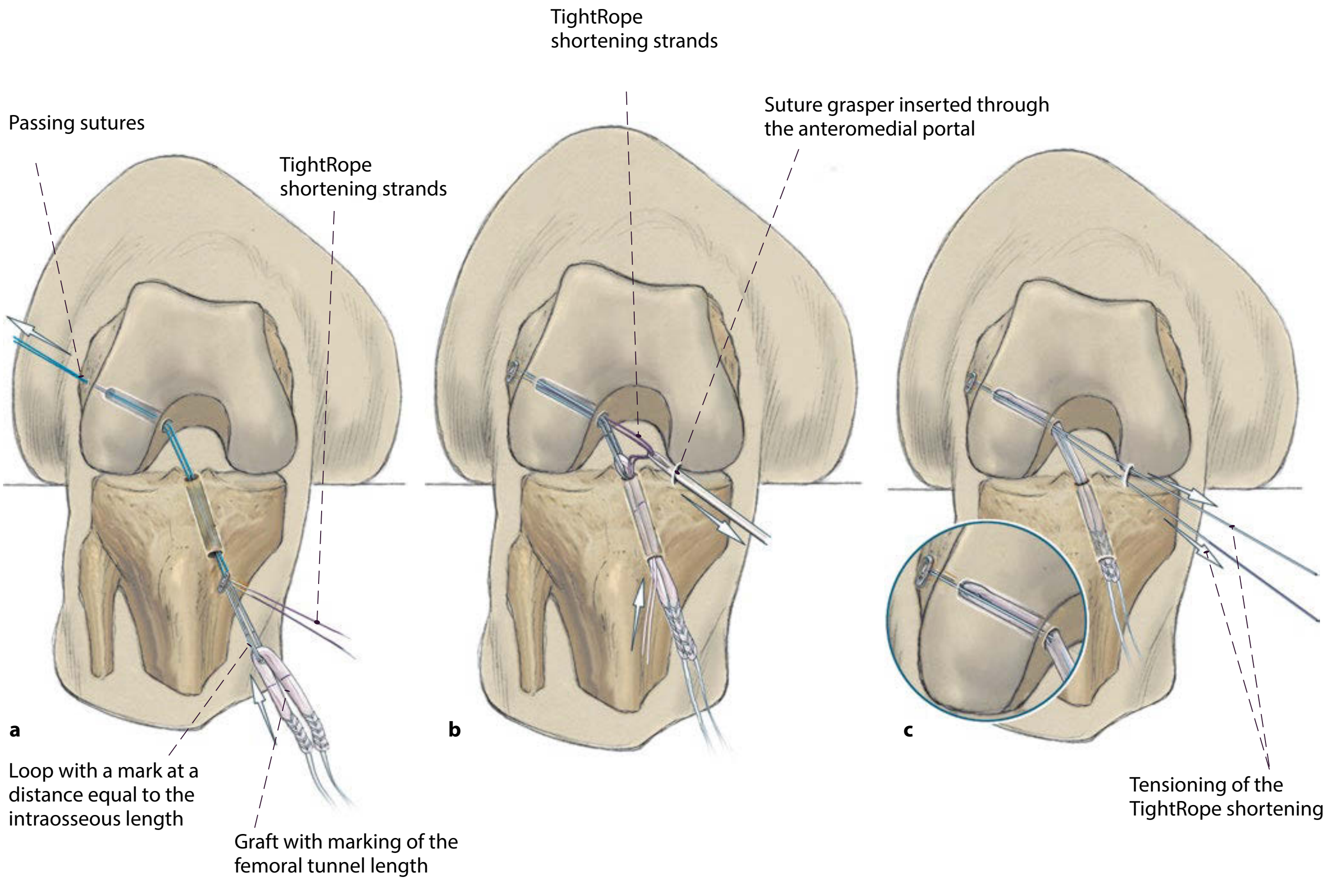


Fig. 15.12a–c **a** The blue passing sutures are used to pull the Tightrope system; **b** after flipping the button and being completely seated on the cortex, the shortening strands are shuttled out through the medial portal; **c** the graft is pulled into the femoral socket by individually tightening the two shortening strands

through both the tibial and femoral tunnels to exit through the skin of the lateral femur (Fig. 15.12a).

The blue passing sutures are used to pull the Tightrope button, with its surface facing laterally, until it passes through the lateral femoral cortex, which is then flipped by counter traction on the graft so that it rests directly on the cortex. In our own approach, this step is checked radiologically with the C-arm.

Pulling the buttons through the lateral cortex should be performed with great caution. If the button is pulled too far into the soft tissue, soft tissue interposition may prevent it from being directly positioned to the cortex at the end. To arthroscopically control of the passage of the button through the cortex, the intraosseous length of the femoral socket can be measured with the guide pin and this length is marked on the loop of the shortening strands (measured from the end of the vertically aligned button). When this mark reaches the femoral socket, this indicates that the button has completely passed through the cortex and can be flipped.

When the button is completely seated on the cortex, the two shortening strands are shuttled out through the medial portal (Fig. 15.12b). For a reliable identification of the correct sutures, these could be marked with a sterile marker before pulling in the system.

Each of the two shortening strands is individually tightened to finally pull the graft into the femoral socket (Fig. 15.12c).

The graft is conditioned by moving the knee in flexion and extension 20 times under traction on the tibial pulling sutures and tensioning the Tightrope system again. Finally, the shortening strands are cut with a FiberWire cutter at the entry of the femoral socket. The tibial fixation of the graft is performed using an interference screw as described above.

15.1.5 Postoperative Management

- Monitoring of peripheral circulation, motor and sensory innervation
- Use of elastic compressive bandages
- Cooling of the extremity
- Postoperative radiographs

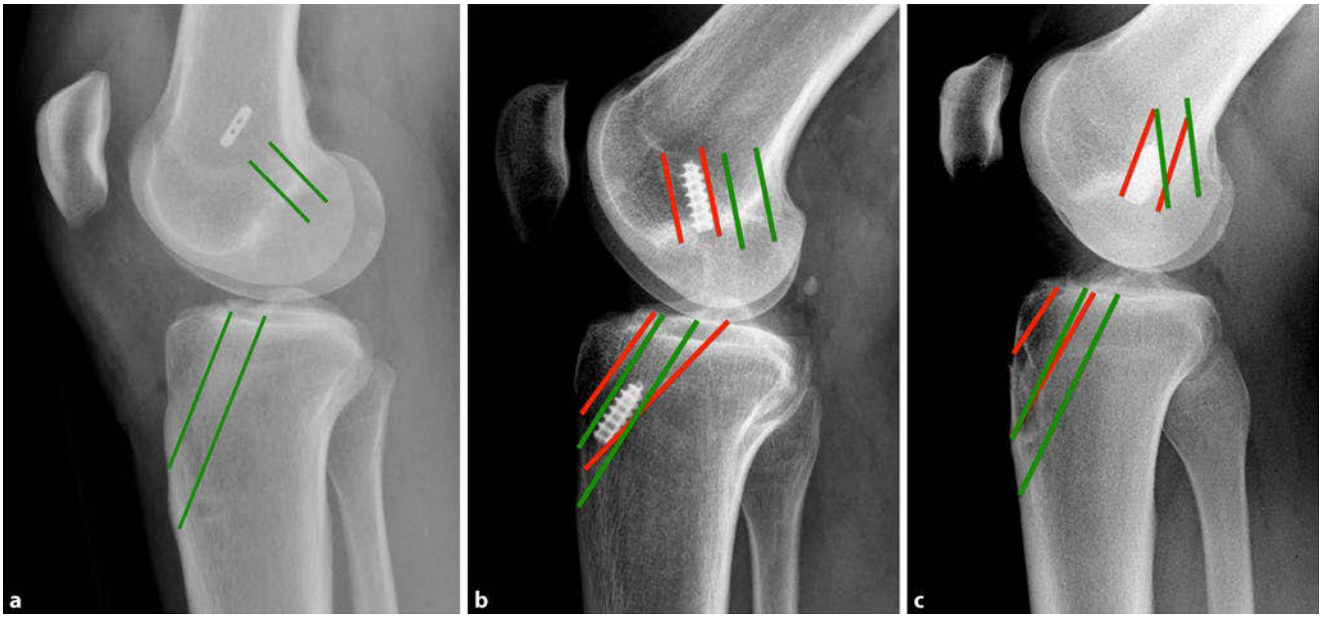


Fig. 15.13a–c Different situations with indication for revision ACL reconstruction. **a** correct position of the femoral and tibial tunnels without widening. The revision procedure can be performed as a single-stage using old tunnels. **b** Incorrect position of the femoral tunnel (*red*), a new tunnel (*green*) can be be generally drilled without affecting the old tunnel. The tibial tunnel (*red*) is significantly widened and needs first to be filled with cancellous bone to allow drilling of a new tunnel (*green*). **c** Incompletely incorrect tibial tunnel (*red*). The drilling of new correct tunnels (*green*) would lead to a large osseous defect, so that a two-stage procedure is required here. The exact position relationship of the femoral tunnels can't be judged from this view and a complementary CT scan is mandatory to precisely assess the position and width of the tunnels

15.1.6 Follow-up Management

A 4-point hard frame knee brace is used for 6 months. Partial weight bearing with 20 kg in 1st–2nd postoperative weeks with free range of motion allowed. Light activities such as treadmill or cycling can be started after 8 weeks. Sport-specific training after 6 months. Contact and high risk sports after 9–12 months.

15.1.7 Tips & Tricks

Before establishing the working portals, a cannulated needle should be used to confirm if the position of the femoral foot print of each bundle could be reached with enough distance to the medial femoral condyle to avoid subsequent cartilage injury during drilling.

To avoid malpositioning of the femoral tunnels, the desired position can be initially marked using an awl or drilling superficially with the guide pin followed by arthroscopic evaluation of the position with the arthroscope switched into the anteromedial or medial portal.

With both single as well as double bundle techniques, the transtibial drilling of the femoral tunnels should be avoided, as with such technique the anatomical femoral foot print are usually not within reach and the graft is relatively vertically positioned. Drilling through the anteromedial or medial portals allows an optimal access to the femoral footprints irrespective of the tibial tunnel.

When using the anteromedial portal, the knee must be flexed to at least 120° during drilling the femoral socket in the single-bundle technique and the anteromedial femoral socket in the double-bundle technique. Drilling in 90° flexion increases the risk of having a too short socket or fracture of the posterior condylar wall "posterior wall blow- out" as well as injury of the lateral neurovascular structures.

To tighten the femoral screws easily and accurately and avoid twisting of the graft during screw insertion, a special instrument (Notcher) is used to create a small notch at the entry of the femoral socket to facilitate screw insertion.

With controlled insertion of the interference screw, some correction of the graft position is still possible.

If the graft, for example, tends to be too far anteriorly at the femoral side, the screw is inserted anterior to the graft in order to push it more posterior.

15.2 ACL Revision and Bone Grafting of the Tunnels

S. Hinterwimmer, M. Feucht

15.2.1 Indication

Recurrent instability or persistent instability after ACL reconstruction, persistent restriction of motion due to graft malpositioning, persistent pain or recurrent effusions after ACL reconstruction without any other underlying cause.

15.2.2 Operation Principle

Recurrent Instability

- Single-stage technique: revision ACL reconstruction utilizing the already existing or newly drilled tunnels.
- Two-stage technique: filling the tunnels with autologous bone graft and revision ACL reconstruction after bony consolidation (3–4 months postoperatively)

Restriction of Motion

Removal of the graft and arthrolysis (as described in ► Sect. 20.3), so that the range of motion is restored intraoperative. If a symptomatic instability results, revision ACL reconstruction can be performed as one or two-stage technique.

Persistent Pain and Recurrent Effusions

Removal of graft and fixation implants. Complete arthroscopic examination to exclude other intra-articular causes of the symptoms or accentuating factors. If a symptomatic instability results, revision ACL reconstruction can be performed after regression of signs of irritation of the knee.

15.2.3 Preoperative Assessment

Diagnosis

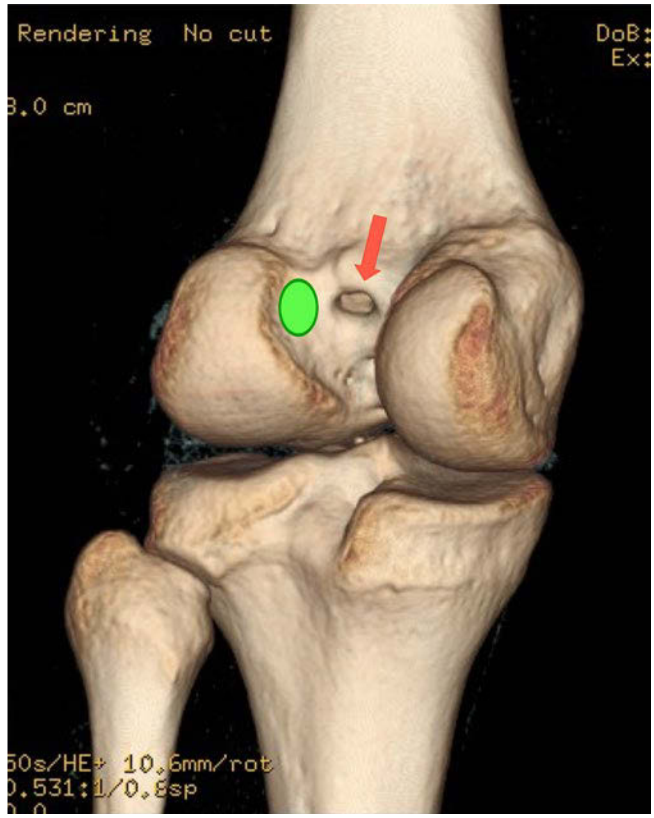
Clinical

Symptom specific history: Determination of the main complaints: instability vs. restricted motion pain/effusion; onset and cause of the complaint (directly postoperative or appeared after that; adequate trauma or no underlying cause could be determined); complications postoperatively or in the course of rehabilitation; infection history, activity demands.

Symptom specific examination: assessment of the lower limb alignment on inspection, gait (thrust phenomenon), evaluation and documentation of the range of motion, anterior drawer test in neutral position, internal and external rotation, Lachman test, pivot shift test, the exclusion of a combined instability (varus and valgus stress test, posterior drawer test in neutral position, internal and external rotation, Dial-Test), exclusion of concomitant meniscal lesions, cartilage lesions or osteoarthritis pain (meniscus sign, tenderness and pain on tapping over the medial/lateral joint spaces)

Imaging

- X-ray of the knee joint in three views (AP, lateral, tangential patella) for a well oriented assessment of the position and width of the tunnels (◘ Fig. 15.13), visualization of the radiopaque fixation materials and assessment of existing degenerative changes
- If notch impingement is suspected, a tunnel view is performed to evaluate the notch configuration.



◘ **Fig. 15.14** CT scan with 3D reconstruction for accurate assessment of tunnel position. Complete incorrectly positioned femoral tunnel (*red arrow*). A new tunnel can be drilled at the ACL foot print (*green oval*) without affecting the old tunnels

- Long leg standing AP view if there is marked malalignment.
- Stress views: in valgus or varus stress/anterior and posterior drawer stress if multiligamentous instability is suspected.
- MRI for the assessment of ligamentous status, menisci, cartilage and bone marrow signal
- CT, preferably with three-dimensional reconstruction for accurate assessment of tunnel position and width (◘ Fig. 15.14.)
- Bone scan to assess the bone metabolic status.
- Leukocyte scintigraphy to assess the probability of underlying low-grade infection

Planning

Multiple techniques and graft types can be used for ACL reconstruction which result in a very heterogeneous group of patients that necessitates an individualized analysis and planning for each patient.

Basically, it should be accurately planned before the operation whether the procedure is going to be performed in a single-stage or two-stages, if the fixation material must be removed and which graft type should be used. To ensure an individualized and flexible approach, the surgeon must mas-

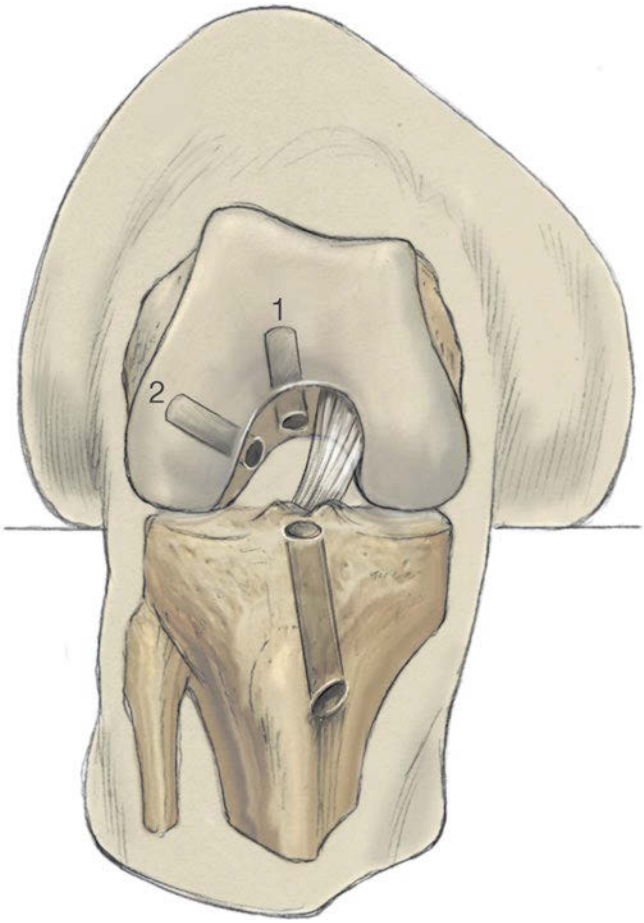


Fig. 15.15 Tunnel position after single bundle reconstruction with incorrect position of the femoral tunnel (*1*). In case of very steep drilled femoral tunnels as result of trans-tibial drilling, new tunnels can be easily drilled in the correct position using the anteromedial portal (*2*). The more horizontal position of the new tunnels decrease the possibility of tunnel confluence

ter the different techniques of ACL reconstruction and the corresponding instruments should be available.

The decision regarding a single- or two-stages approach is primarily determined by the position of the bone tunnels. This is classified based on the radiological diagnosis into: incorrect, correct and incompletely incorrect (Figs. 15.13 and 15.14). In addition, the tunnel diameter must be considered.

Correct: The tunnel was drilled in the correct position. If it is not widened, the tunnel can be used again (single-stage technique). With significant tunnel widening, the tunnel must be first filled with bone graft despite the correct position (two-stage technique).

Incorrect: the tunnel is drilled completely away from the correct position. A new tunnel can then be drilled in the correct position in a single-stage procedure as a rule without being tangential to the existing tunnel (Fig. 15.15).

Incompletely incorrect: The tunnel is located partially in the desired position. In such condition, a single-stage procedure is usually not possible, and the tunnel must be initially filled with bone graft.

A two-stage procedure is generally required also when the range of motion is limited, where the full range of motion must be restored in the first procedure. With marked axial malalignment, it must be determined whether a combined corrective osteotomy and revision ACL reconstruction can be performed or the osteotomy is performed first and the revision ACL reconstruction is performed in a second stage

A good review of the operative reports and patient documents related to the previous interventions provides very important information for the choice of the surgical technique, the graft to be used and the type of fixation. If removal of the fixation material is essential, it must be pre-operatively ensured that the necessary instruments are available or ordered from the corresponding company in advance.

Regarding the graft choice, it must be determined, based on the previous graft, which graft to be used and whether it is harvested from the ipsilateral or contralateral sides.

Patient Information/Consent

Surgery -specific risks: possible need for a second procedure, donor site morbidity (harvesting the tendon), flexion or extension deficit due to malpositioning of the tunnels or fixation in incorrect position, remaining foreign material, recurrent effusions, arthrofibrosis, increased risk of infection, loosening of the graft fixation construct with re-instability, re-rupture. Morbidity from harvesting cancellous bone graft from the iliac crest, loose bodies, failed osseous consolidation of the bone graft.

With revision procedures, the patient must be well informed that the postoperative results of a revision are often inferior the results of primary ACL reconstruction.

15.2.4 Surgical Technique

Positioning and Preparation

- A femoral catheter needs to be applied if arthrolysis is planned to control the postoperative pain.
- Supine position (with possibility to flex the knee to at least 120°)
- If graft harvesting from the contralateral side is planned, both legs should be draped.
- If filling the tunnels with cancellous bone grafting is planned, the ipsilateral or the contralateral iliac crest is draped.
- A thigh tourniquet is applied
- Examination under anesthesia (degree of instability, exclusion of combined instability)

Single-Stage Revision ACL Reconstruction

Diagnostic arthroscopy via the anterolateral portal to confirm the surgical indication as well as to assess possible associated injuries. Harvesting and preparation of the semitendinosus

Fig. 15.16 Postoperative radiograph after revision ACL reconstruction with double bundle technique after primary reconstruction with incorrect markedly vertical femoral tunnels

tendon as described in ► Sect. 13.1. Insufficient graft and ligament remnants are removed and the old tunnels are exposed. With correctly positioned tunnels without any significant widening, a guide wire can be directly used to probe the tunnels and remove the interference screws (partially resorbed bio- interference screws can be alternatively over-drilled).

If a tendon graft with bone block was already used in the first operation and shows complete bony consolidation, the drilling of the bone tunnels can be performed as in the primary ACL reconstruction done (► Sect. 15.1). If pure soft tissue grafts are used, they have to be removed with a shaver from the existing tunnels. The tunnel walls should be debrided and freshened with a shaver or reamer if it is sclerosed. Additionally, a microfracture awl can be used to penetrate the tunnel walls to promote local bleeding and thus improve the healing of the graft. The tunnel diameter is measured and may be drilled again according to the graft diameter if necessary.

If the tunnel position was completely incorrect, the new tunnels are drilled in the same technique described for the primary ACL reconstruction. It should be noted here that the single bundle reconstructions with malpositioned tunnels can be particularly well revised in a single- or two-stage procedure, either with a single bundle as well or with double bundle reconstruction (Figs. 15.14, 15.15 and 15.16). Double

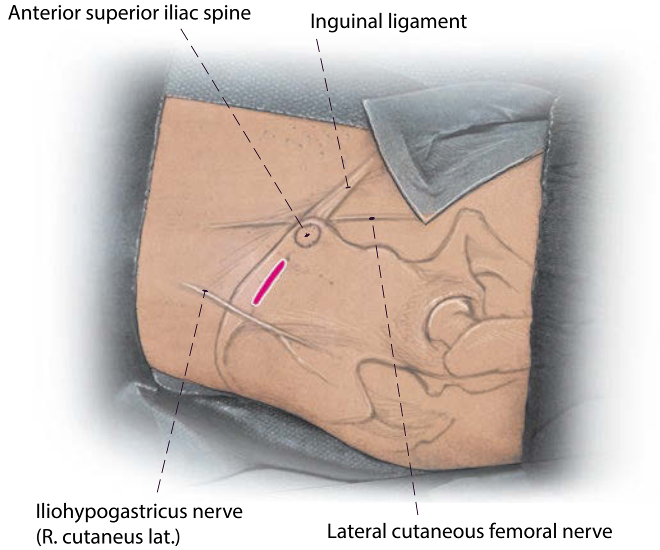


Fig. 15.17 Skin incision over the iliac crest, beginning 2 cm posterior to the anterior superior iliac spine

bundle revision reconstruction with completely incorrect tunnel positions can easily lead to a confluence of tunnels and thus should be primarily performed in a two-stage procedure. After creation of adequate tunnels in the correct position, the remaining operative steps are the same as for the primary ACL reconstruction.

Two-Stage Revision ACL Reconstruction with Primary Tunnel Filling

This approach is recommended with widened tunnels in the correct position, tunnels in incompletely incorrect positions as well as tunnels that are in completely incorrect positions after double bundle reconstruction.

Diagnostic arthroscopy via the anterolateral portal to confirm the surgical indication as well as to assess possible associated injuries. Old graft and ligament remnants are removed and the old tunnels are exposed and a guide wire is used to probe the tunnels. Unneeded fixation material is removed.

A guide wire is passed in the center of the old tunnel and overdrilled with a reamer until the bleeding cancellous bone is exposed. If the tunnel diameter becomes too wide as a result of reaming, microfracture of the tunnel wall may be performed to improve the perfusion and healing.

After tunnel preparation, cancellous bone graft cylinders are harvested, usually from the ipsilateral iliac crest as follows: skin incision over the iliac crest, beginning about 2 cm posterior to the anterior superior iliac spine (Fig. 15.17). Attached periosteum and muscle fascia are dissected. Two Hohmann retractors are then used to expose the iliac crest and visualize the inclination of the iliac bone (Fig. 15.18).

Bone cylinders are harvested using a specific chisel (e.g. OATS instruments, Arthrex, Inc.) according to the diameter of the tunnel to be filled (Fig. 15.19). The chisel should be

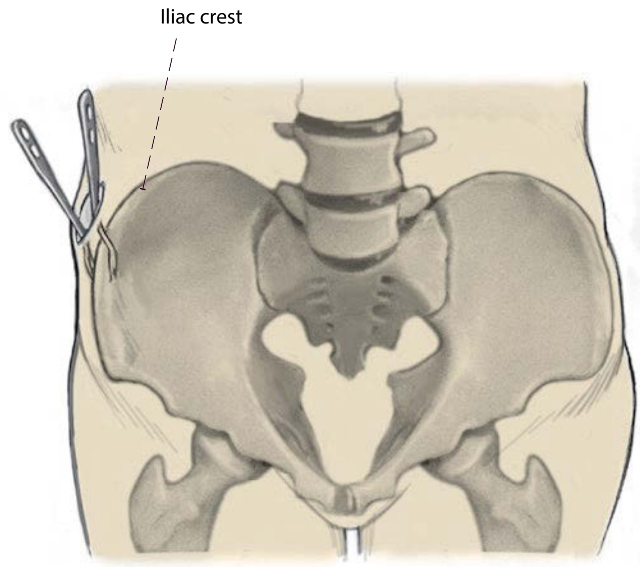


Fig. 15.18 Exposure of the iliac crest and determination of the inclination of the iliac bone with 2 Hohmann retractors

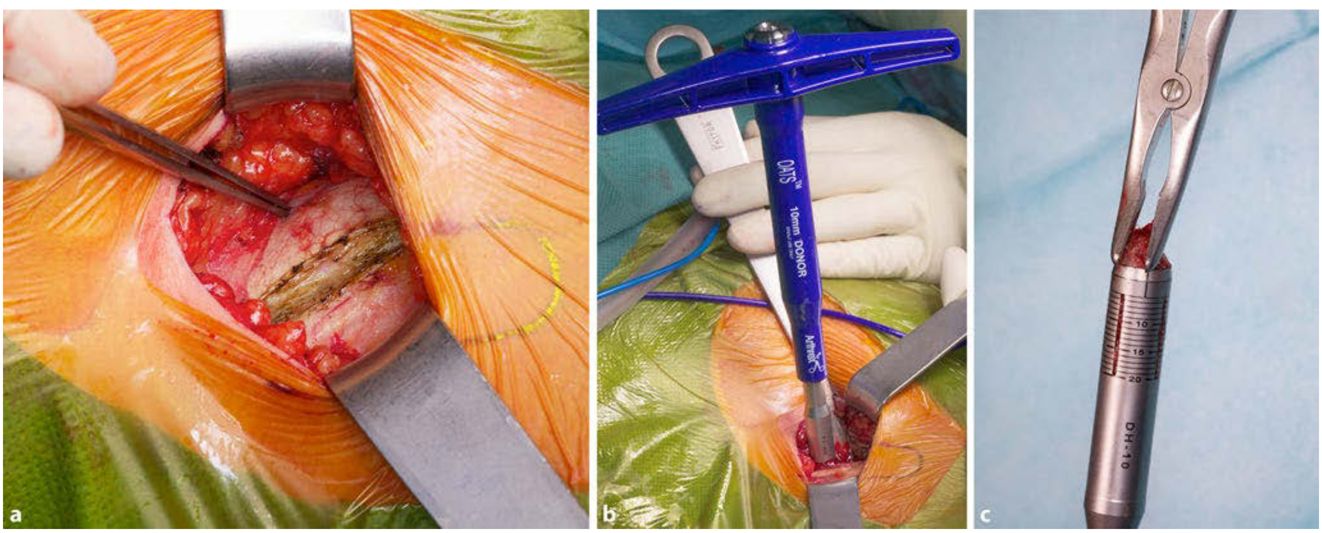


Fig. 15.19a–c Harvesting cortico-cancellous bone cylinders from the iliac crest. **a** Preparation of the iliac crest and detachment of the periosteum; **b** harvesting the with a hollow chisel (gouge); **c** Contouring and possibly length correction of the harvested cylinder with a bone nibbler

Fig. 15.20a–c Bone filling of the tibial tunnel. **a** Insertion of the cylinder into the tibial tunnel; **b** Impaction of the cylinder until it is flush with the intraarticular tunnel exit; **c** End result after insertion of two cylinders

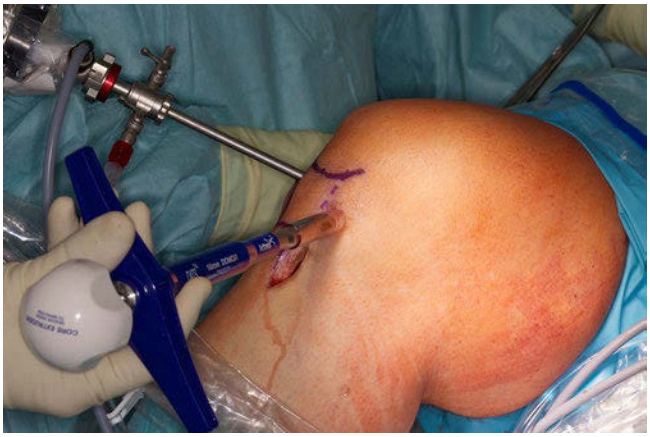


Fig. 15.21 Bone filling of the femoral tunnel: A gouge is used for the intraarticular placement of the cylinder into the femoral tunnel

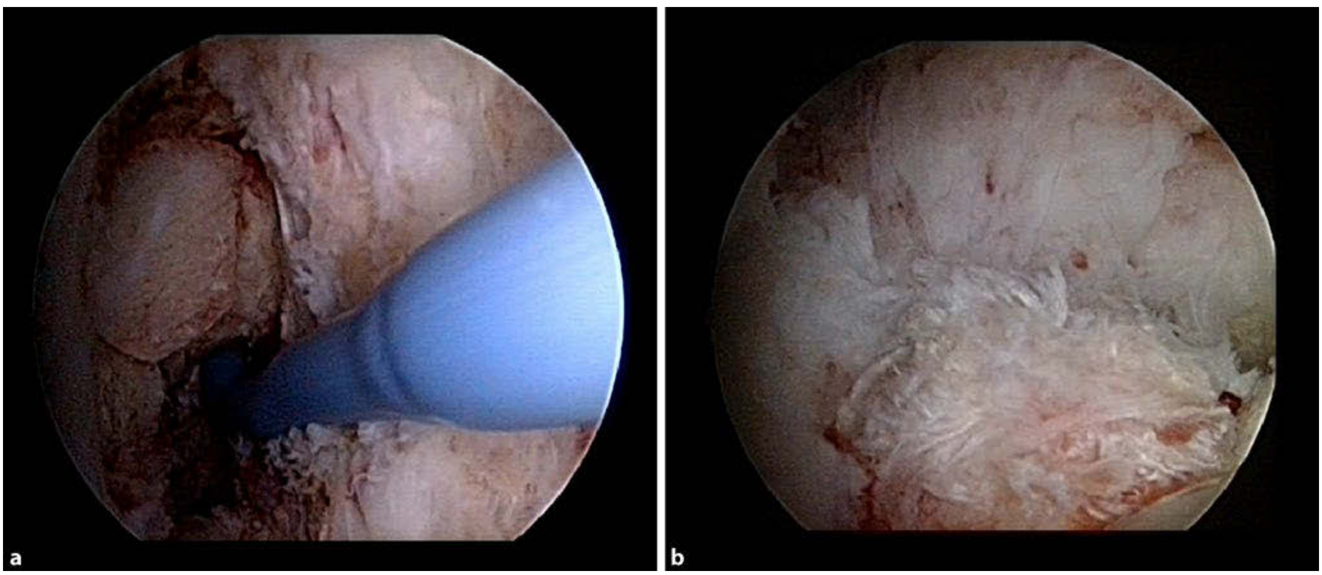


Fig. 15.22a,b Arthroscopic view of femoral (**a**) and tibial (**b**) bone filling. The cylinders should complete flush with the joint level

inserted parallel to the inclination angle of the iliac bone to avoid perforation of the inner or outer table. A sharp spoon curette can be used to harvest more cancellous bone.

The harvested cylinder is now inserted into the reamed tunnel under arthroscopic visualization. The tibial cylinder is inserted and impacted in a retrograde manner until it is flush with the intraarticular exit of the tunnel (Fig. 15.20). The intraarticular exit of the tunnel can be covered with a rasp to prevent intraarticular protrusion of the cylinder.

The depth of the femoral tunnel is measured and a corresponding graft cylinder is prepared. If the tunnel is too deep, it can be first filled with cancellous bone and the cylinder is finally inserted. The cylinder is then inserted into the femoral tunnel in a retrograde manner using a hollow chisel (Fig. 15.21). The cylinder should be completely flush with the joint articular surface (Fig. 15.22).

After complete osseous consolidation of the grafted cylinder, which can be confirmed with CT-scan about 3–4 months postoperatively, the ACL revision reconstruction can be performed similar to the primary ACL reconstruction.

15.2.5 Postoperative Management

- Monitoring of peripheral circulation, motor and sensory innervation
- Use of elastic compressive bandages
- Cooling and elevation of the extremity
- Postoperative radiographs

15.2.6 Follow-up Management

Revision ACL Reconstruction

A 4-point hard frame knee brace is used for 6 months. Partial weight bearing with 20 kg in 1st–2nd postoperative weeks with

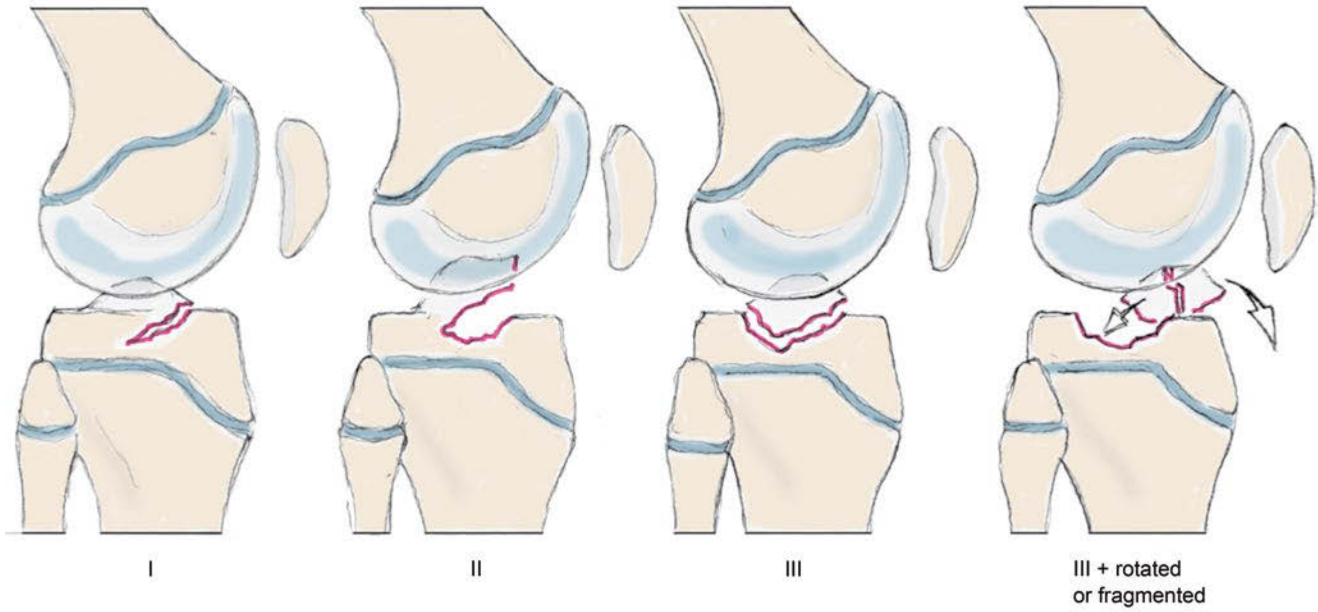


Fig. 15.23 Meyers and McKeever classification of the tibial eminence fracture

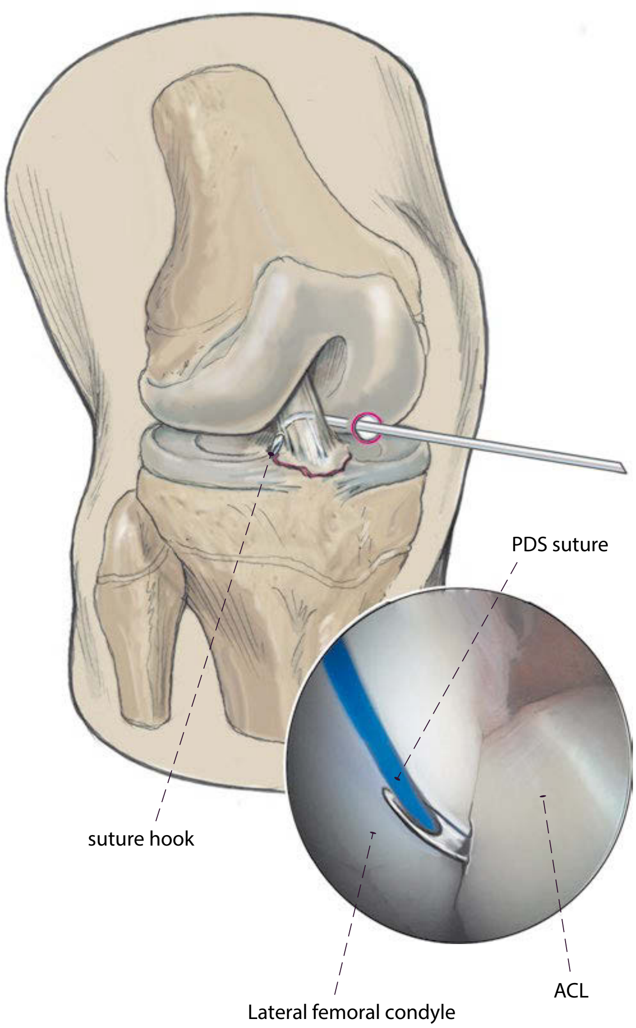


Fig. 15.24 Piercing the ACL base with a shuttle instrument from postero-medial towards anterolateral

free range of motion allowed. Light activities such as treadmill or cycling can be started after 8 weeks. Sport-specific training after 6 months. Contact and high risk sports after 9–12 months.

Tunnel Bone Grafting

Partial weight bearing with 20 kg for 2 weeks with free range of motion. From the 3rd week, gradually increased weight bearing.

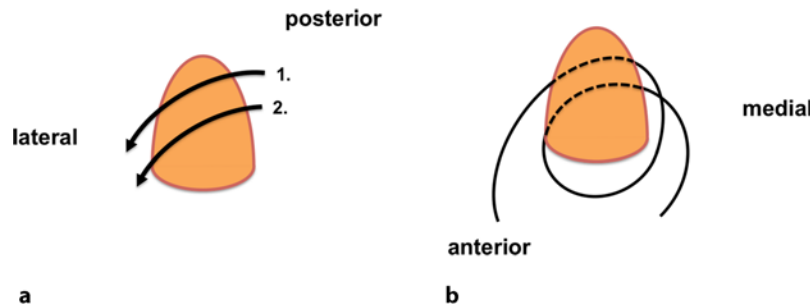
15.2.7 Tips & Tricks

Tunnel widening is found more frequently with extraarticular fixation techniques and pure soft tissue tendon grafts because of the increased graft movement inside the tunnel (windshield-wiper effect and Bungee cord effect) and influx of synovial fluid between the tunnel wall and graft under cyclic loading.

A too far anterior positioning of the tibial or the femoral tunnels leads to notch impingement with extension and excessive tension on the graft tension in flexion. This increases the tibiofemoral contact forces with resultant cartilage damage and pain (Nutcracker knee) with successive elongation of the graft and graft failure.

Tunnels in incorrect position can be optionally filled with bio-absorbable interference screws or BioComposite screws to avoid marked decrease in the bone stability when the new tunnels are drilled.

With borderline large tunnels, grafts with attached bone block (e. g. quadriceps) are preferred. As an alternative for revision procedures, one can use allografts, which are available with attached bone block.



■ **Fig. 15.25a,b** Axial section through the ACL base. **a** Schematic representation of ACL penetration with the shuttle instrument; **b** Course of the passed suture tape

In order to achieve a stable primary fixation with revision surgery, a hybrid fixation (e. g. fixation with buttons and interference screw) can be used, particularly if there is graft-tunnel mismatch (tunnel greater than graft).

In the so-called "unforgiving knee" with marked hyperextension and extremely vertical configuration of the notch, the tibial tunnel often must be drilled more posterior to avoid impingement of the graft at the notch roof.

With residual rotational instability after a single bundle reconstruction with predominantly reconstruction of the anteromedial bundle, a posterolateral augmentation with reconstruction of the posterolateral bundle only is a good still possible alternative option

15.3 Tibial Eminence Fracture

S. Döbele, M. Feucht, S. Hinterwimmer

15.3.1 Indication

Fracture of the intercondylar eminence type II and III according to Meyers and McKeever (■ Fig. 15.23).

15.3.2 Operation Principle

Arthroscopic reduction and fixation of the fractured tibial intercondylar eminence using trans-tibial suture tape cerclage or a compression screw (ante or retrograde).

15.3.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: timing and mechanism of injury, symptoms (pain, instability)
- Symptom specific examination: assessment of the range of motion (extension deficit); exclusion of concomitant instability or meniscal lesion (clinical diagnosis in the acute condition is sometimes not possible)

Imaging

- X-ray of the knee joint in two views (a.-p. and lateral) for verification and classification of injury
- If needed, MRI for assessment of the ACL and verification of other internal knee lesions
- CT may be sometimes needed to assess the fracture morphology.

Patient Information/Consent

Surgery-specific risks: secondary dislocation and probable need for a revision procedure, non-union of the fragment (pseudoarthrosis), fracture of the fragment, extension deficit. If fixation of the fragment is not possible, an ACL reconstruction using tendon grafts must be discussed.

15.3.4 Surgical Technique

Positioning and Preparation

- Supine position
- A thigh tourniquet is applied
- Examination under anesthesia to exclude and combined instability.

Arthroscopic Fixation of Tibial Eminence Fracture with Trans-Tibial Suture Tape Cerclage

Diagnostic arthroscopy via the standard anterolateral portal. The fragment and the fracture zone is visualized. The fragment bed is debrided with the shaver (■ Fig. 15.27a, b). The fragment is reduced using a retractors placed below the transverse ligament.

A shuttle instrument (e. g. 90° Suture Lasso, Arthrex) inserted through the medial portal is used to pierce the base of the ACL just above the bony fragment from posteromedial to anterolateral (■ Figs. 15.24 and 15.27c,d) and pass a suture tape (e. g. FiberWire, Arthrex).The ACL is pierced with the suture tape once again more anteriorly and the medial suture tape end is shuttled out (■ Fig. 15.25).

The tibial ACL guide is inserted and two guide wires are drilled transtibially at the anteromedial and anterolateral margins of the fracture (■ Fig. 15.26). Overdrilling the wires with a 4-mm cannulated drill bit (■ Fig. 15.27e).A suture lasso is passed intraarticularly through the cannulated drill bit and

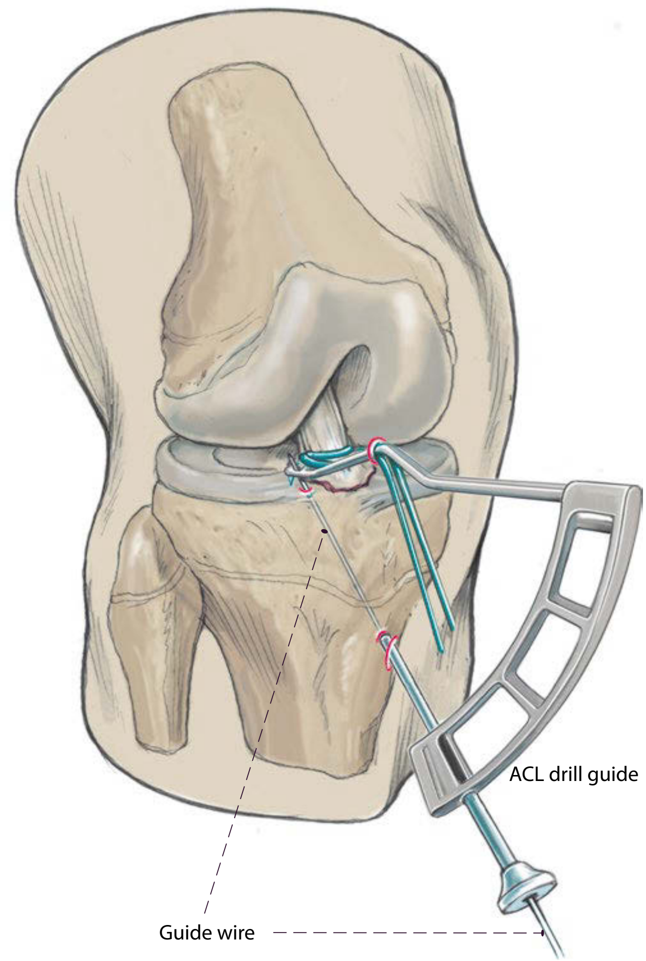


Fig. 15.26 Two Kirschner wires are drilled trans-tibial at the anteromedial and anterolateral margins of the fracture using an ACL tibial guide. (ACL guide, K-Wire)

the free crossed ends of the suture tapes are shuttled out extraarticular (Fig. 15.27f).

The tibial eminence fragment is reduced by pulling the suture tape ends under arthroscopic visualization, and if necessary arthroscopic hook may be used to aid the reduction.

When satisfactory reduction of the fragment, the suture tape ends are tied over the anterior tibial surface either directly over a bone bridge or using a small metallic button (Fig. 15.28).

Arthroscopically Assisted Fixation of Tibial Eminence Fracture with Screw

Larger tibial eminence fragments can be alternatively fixed with a screw. Here, a retrograde or antegrade cannulated screw is inserted under arthroscopic control over a previously inserted guide wire.

With antegrade fixation, the knee must be maximally to allow the superior insertion of the guide wire and the screw tip through the fragment. The fragment can be reduced using the guide wire tip. It must be noted here that the screw tip can impinge against the notch and can lead subsequently to an extension deficit.

The retrograde screw insertion (screw with short threading) is done in 90° flexion. This technique is only possible if the bone fragment is sufficiently large to allow a good fixation with the short threaded screw (Fig. 15.29).

15.3.5 Postoperative Management

- Monitoring of peripheral circulation, motor and sensory innervation
- Use of elastic compressive bandages
- Cooling and elevation of the extremity
- Postoperative radiographs (Fig. 15.30)

15.3.6 Follow-up Management

A 4-point hard frame knee brace is used for 6 months. Partial weight bearing with 20 kg in 1st–2nd postoperative weeks with free range of motion allowed.

15.3.7 Tips & Tricks

It should be noted that the fragment or fracture line can be concealed behind the anterior horns of the menisci or by the infrapatellar fat pad. The lateral meniscus anterior horn can particularly larger parts of the fragment and the fracture line and thus leads to a miscalculation of the extent of injury.

The transverse ligament shouldn't be violated during debridement of the fragment bed with the shaver.

Soft tissue interposition during reduction of the fragment with the meniscus anterior horn, the transverse ligament or the infrapatellar fat pad must be avoided to ensure adequate bony healing of the fragment. A partial resection of the Hoffa's infrapatellar fat pad may be sometimes necessary. The meniscus anterior horn and the transverse ligament may need to be retracted and kept away using an arthroscopic hook via an additional portal.

15.4 PCL Reconstruction

M. Feucht, S. Hinterwimmer

15.4.1 Indication

Symptomatic acute posterior instability with a posterior tibial translation more than 10 mm as compared to the opposite side. Symptomatic chronic posterior instability after conser-

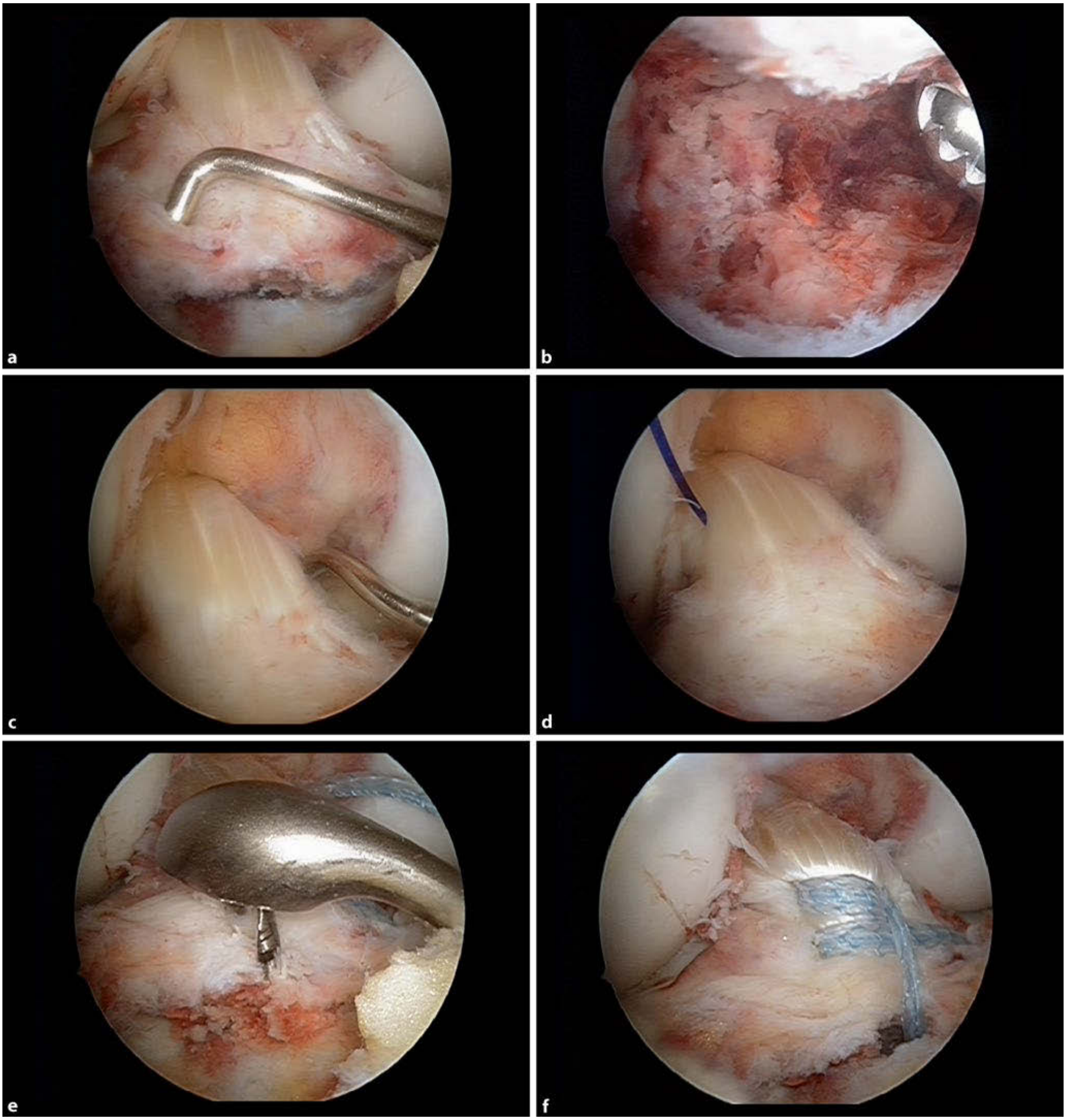


Fig. 15.27a–f Fixation of tibial eminence fracture using suture tape cerclage. **a** Trial reduction with an arthroscopic hook retractor; **b** Debridement of the fracture zone; **c** Piercing the ACL base with a shuttle instrument; **d** Shuttling suture through the ligament to pass the suture tape; **e** Over-drilling the inserted guide wires with protection of the tips using a spoon curette; **f** Re-fixed tibial eminence

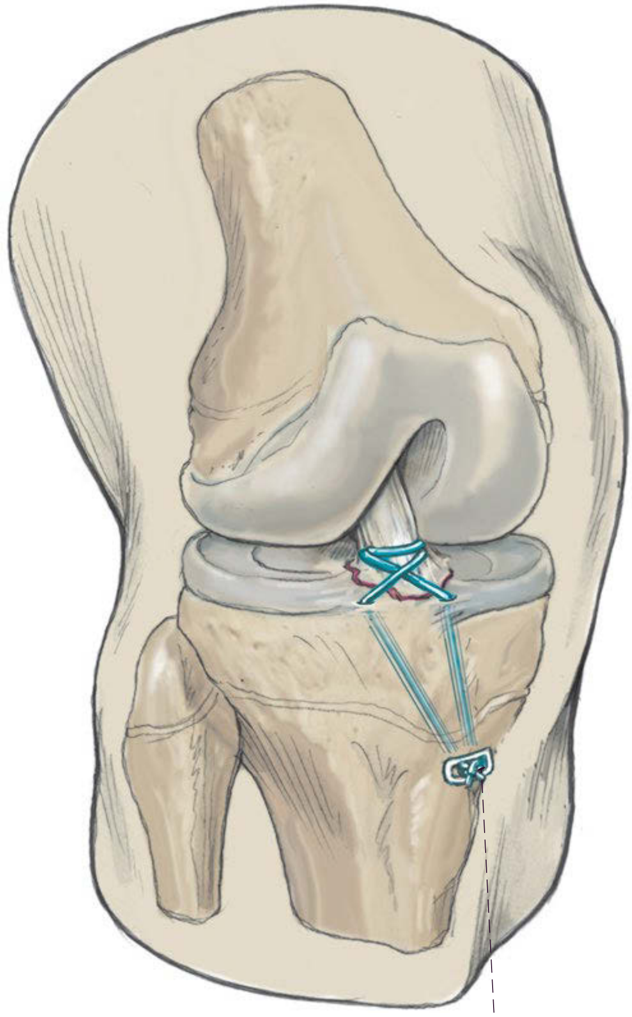


Fig. 15.28 Resultant tibial eminence fixation with crossed transtibially passed suture tapes that are tied extraarticular over a small metal plate (button)

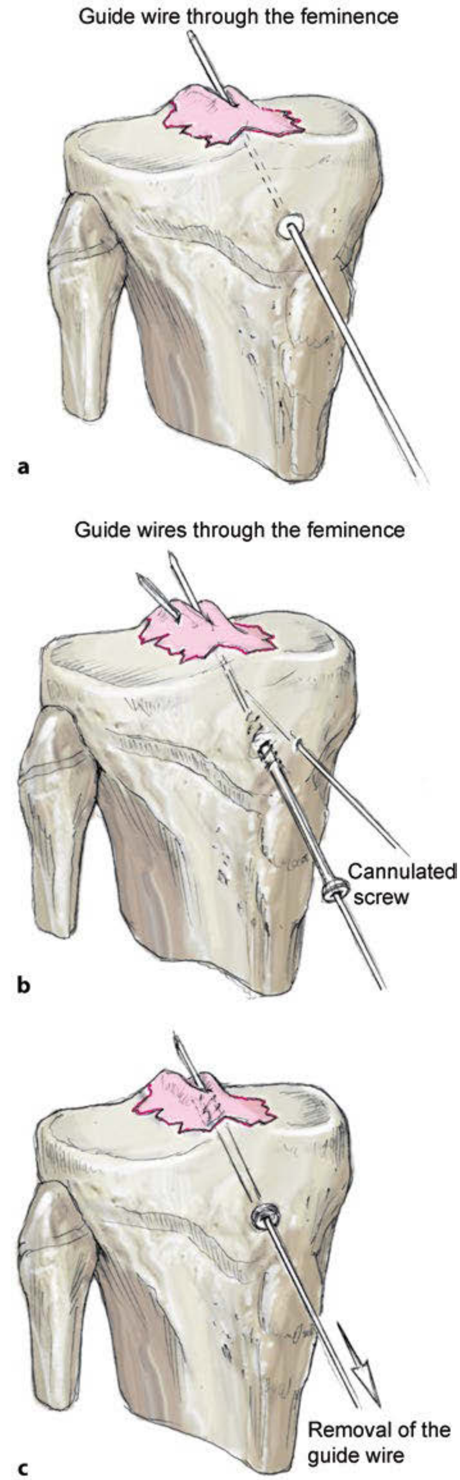


Fig. 15.29a–c Tibial eminence fixation with a retrograde cannulated screw

vative treatment with a persistent posterior tibial translation more than 10 mm in comparison with the opposite side after excluding a fixed posterior drawer test. Symptomatic posterior instability with a posterior tibial translation of more than 5 mm in comparison with the opposite side after a positive brace test and exclusion of a fixed posterior drawer test. As part of a combined procedure for treatment of multiligamentous knee injury or dislocation.

15.4.2 Operation Principle

Double bundle technique: Reconstruction of the anterolateral and the posteromedial bundles with an autologous hamstrings tendon graft, which is placed in 2 separate tunnels on the femoral side at the area of foot print of the corresponding bundle and on the tibial side in a single tunnels drilled in the center of the common foot print (3-tunnels technique).

Single bundle technique: Reconstruction of mainly the anterolateral bundle with an autologous hamstrings tendon graft, which is placed on both the femoral and tibial sides through a single tunnel drilled at the center of the foot print of the anterolateral bundle.

Fig. 15.30a–c Tibial eminence fracture type II according to Meyers and McKeever. **a** Preoperative radiograph; **b**, **c** postoperative recordings after fixation of the tibial eminence with trans-tibial suture tape cerclage

15.4.3 Preoperative Assessment

Diagnosis

Clinical

Symptom specific history: time and mechanism of injury, subjective instability, pain, previous operations.

Symptom specific examination: assessment of the lower limb alignment on inspection, gait (varus-recurvatum thrust phenomenon), inspection of anterior tibial contusions and hematoma or swelling in the popliteal region and over the posteromedial/posterolateral joint corners, tenderness (medial joint line, patella, popliteal fossa, lateral/posterolateral and medial/posteromedial corners), spontaneous posterior drawer sign (posterior sag sign), posterior drawer test in neutral position, internal and external rotation of the leg, external rotation of the leg in 30° and 90° flexion in prone position, varus and valgus stress tests in 0° and 3° flexion, assessment of the ACL stability.

Neurological/Vascular Examination

- Assessment of the peripheral nerves (mainly the peroneal nerve)
- Assessment of the peripheral vascular condition.

Imaging

- X-ray of the knee joint in three views (AP, lateral, tangential patella) to exclude osseous lesions.
- Long leg standing AP view if there is suspicion of axial malalignment.
- Stress functional views in 90° flexion within the first week after injury or after the 7th week (anterior and posterior drawer of both knee joints with 15 kg load)
- MRI for assessment of the PCL and verification of other possible concomitant injuries.
- CT or MRI Angiography with suspected vascular injury (usually indicated after knee dislocation injury)

Patient Information/Consent

Surgery-specific risks: Morbidity after harvesting the tendon graft with at least temporary weakening of the knee flexion and internal rotation, injury of the saphenous nerve, rupture of the hamstring tendons during harvesting which may necessitates harvesting the contralateral hamstrings, patellar tendon or the quadriceps tendon as grafts, injury of the neurovascular bundle in the popliteal fossa, injury of the peroneal nerve, flexion or extension deficit due to tunnel malpositioning or fixation of the graft in an incorrect position, recurrent joint effusions as a reaction to bio-absorbable implants, osteonecrosis of the medial femoral condyle with subchondral placement of the tunnel, arthrofibrosis, loosening of the graft fixation construct with recurrent stability, re-rupture, progression of the osteoarthritis, extensive rehabilitation.

15.4.4 Surgical Technique

Positioning and Preparation

- Supine position
- A thigh tourniquet is applied
- Examination under anesthesia (degree and direction of instability, isolated or combined instability)

Anatomical PCL Reconstruction in Double Bundle Technique and Direct Anatomical Fixation with Interference Screw "Aperture Fixation"

Usually 4 portals are needed: one high and one deep anterolateral, anteromedial and a posteromedial portals (Fig. 15.31).

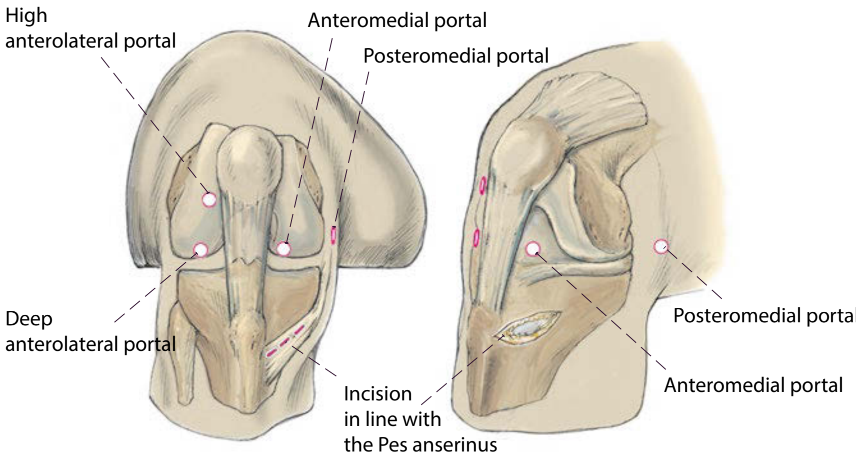


Fig. 15.31 Portals used for the double bundle technique

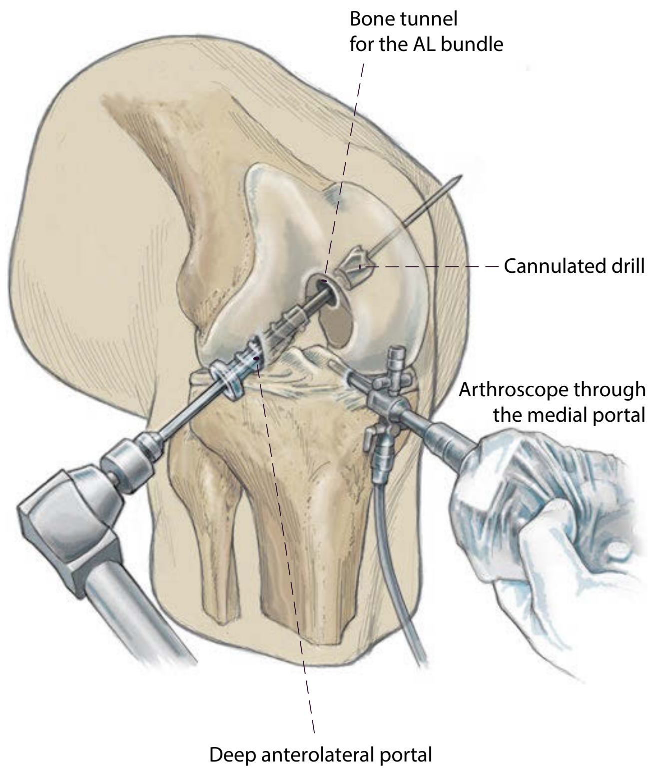


Fig. 15.32 Placement of the tunnel for the anterolateral bundle

Diagnostic arthroscopy is done to confirm the surgical indication as well as to assess possible associated injuries. Harvesting and preparation of the semitendinosus and gracilis tendons as described in ► Sect. 13.1.

The semitendinosus tendon is used for reconstruction of the anterolateral bundle and should be folded 3 times if possible, the gracilis tendon is used reconstruction of the posteromedial bundle and doubly folded. Folded tendon grafts should be at least 9–10 cm. Both tendon grafts are whipstitched together for about 3 cm length at the tibial end and each separately whipstitched for about 2 cm length at the femoral end.

The femoral tunnels are then drilled, beginning with the anterolateral tunnel. The femoral foot prints are first meticulously and carefully prepared and both bundles foot prints are marked with the electrocautery (Fig. 15.33a). A guide pin with an eyelet is inserted through the deep anterolateral portal and placed at the center of the anterolateral bundle foot print and drilled to exit the opposite cortex and the skin of the thigh (Fig. 15.33b). Overdrilling the guide pin with a cannulated reamer corresponding to the graft thickness to a depth of about 28–30 mm (Figs. 15.32 and 15.33c). A doubled passing suture is passed in via the guide pin. The posteromedial femoral tunnel is drilled in the same way at the center of the posteromedial foot print and a passing suture is shuttled (Fig. 15.33d,e).

For preparation of the tibial foot print, the arthroscope is inserted first through the anteromedial portal and passed medial to the ACL into the posterior joint compartment to allow establishing the posteromedial portal under arthroscopic visualization. A shaver or electrocautery is inserted via the posteromedial portal to prepare the tibial foot print which is located between the posterior horns of both menisci and about 10–15 mm below the posterior margin of the tibial plateau.

The arthroscope is switched to the posteromedial portal. The tibial guide is inserted through the anteromedial portal and a guide pin is drilled trans-tibial into the center of the tibial footprint through the incision used for harvesting the tendons (Fig. 15.34). The guide pin is overdrilled with a cannulated reamer corresponding to the graft diameter. The superior edge of the intraarticular tunnel end is smoothened (so-called "Killer turn") with a shaver or a special rasp. A passing suture is inserted through the tibial tunnel from the extraarticular end to intraarticular and shuttled out using a suture retriever from intraarticular to extraarticular through the anteromedial portal.

The arthroscope is switched into the deep anterolateral portal. The anteromedial portal is widened and the two separate femoral ends of the graft are pulled using the already placed passing sutures into the corresponding femoral tunnels (Fig. 15.35). Lastly, the tibial end of the graft is pulled in an antegrade manner through the tibial tunnel using the corresponding passing suture.

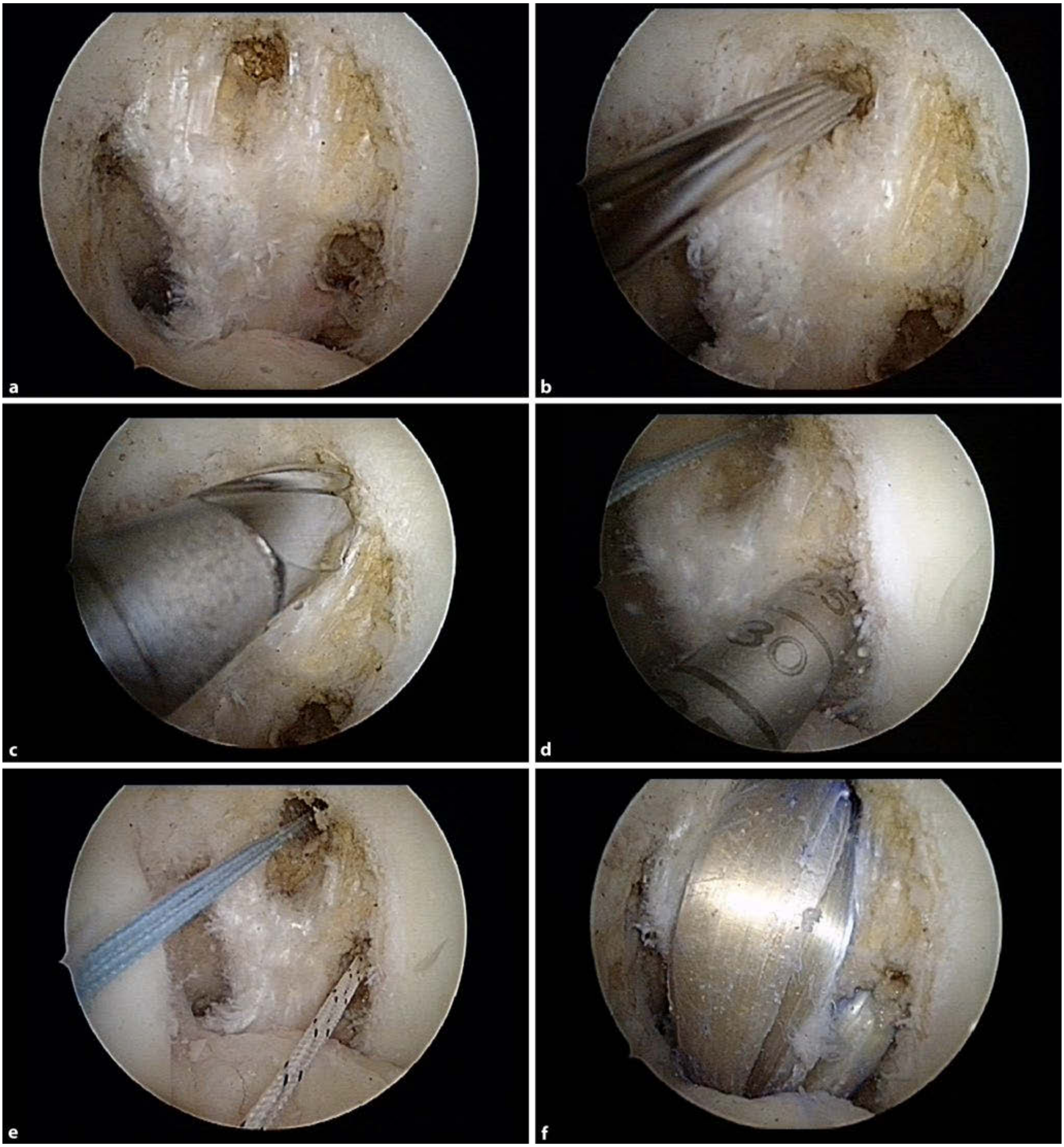


Fig. 15.33a–f Preparation of the femoral tunnel. **a** An electrocautery is used to mark the centers of the anterolateral and posteromedial foot prints; **b** A guide pin is drilled into the center of the anterolateral foot print; **c** over-drilling of the guide pin with a reamer; **d** drilling of the posteromedial tunnel; **e** anatomically correct position of the two tunnels; **f** End result

The fixation of the grafts performed in the following sequence: femoral posteromedial bundle, common tibial graft and then the femoral anterolateral bundle.

A Nitinol wire is passed through the high anterolateral portal into the tunnel between the posteromedial graft and the tunnel wall and an interference screw is inserted over it. From now, a continuous anterior drawer stress must be exerted through the assistant. The common tibial graft is then fixed in extension with an interference screw followed by fixation of the femoral anterolateral bundle in 80° flexion using a Nitinol wire and interference screw under tension of about 80 N over the femoral graft.

The manual anterior drawer stress must be maintained until the leg is positioned in the knee extension brace with a dorsal calf padding ("posterior tibial support", PTS-brace).

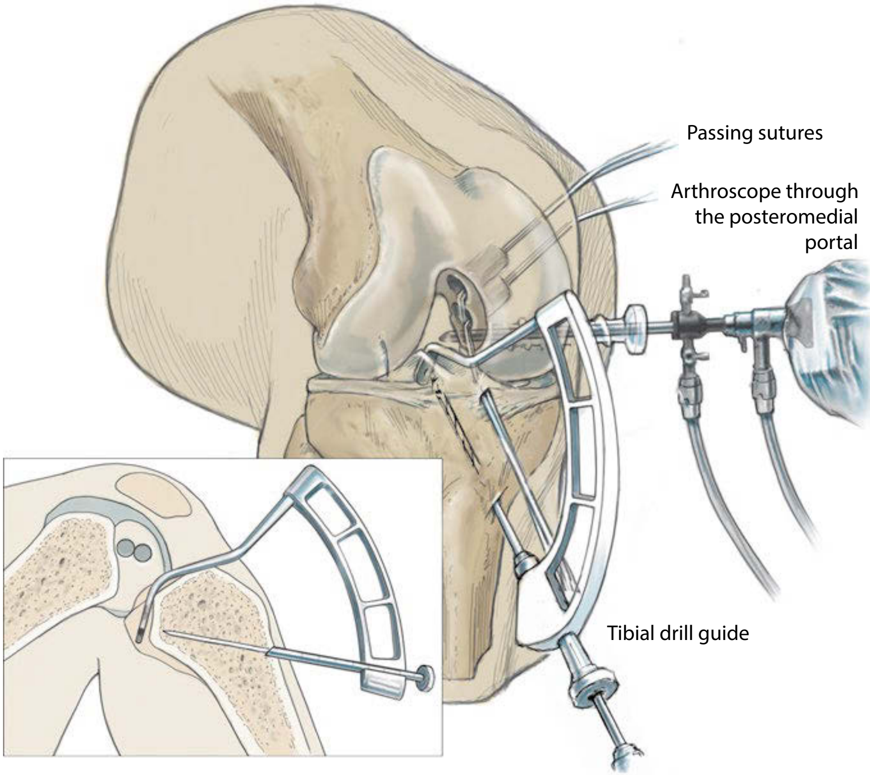


Fig. 15.34 Preparation of the tibial tunnel

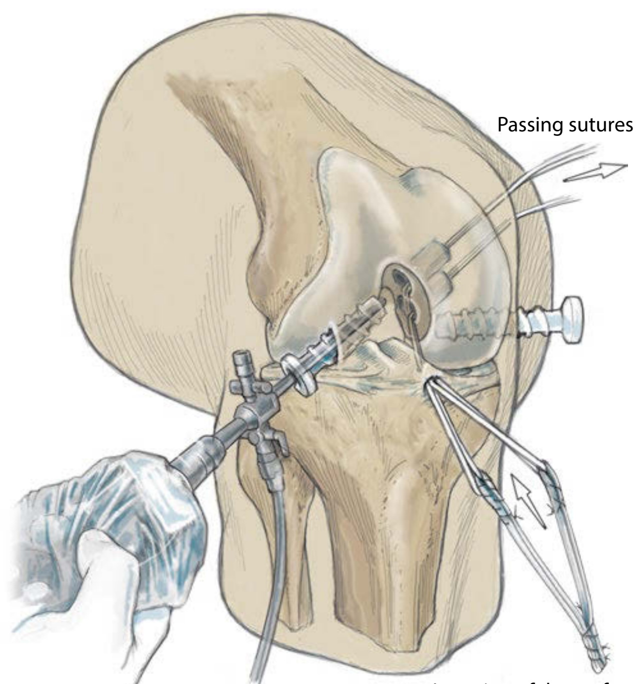


Fig. 15.35 Transportal insertion of the graft

Anatomical Reconstruction of the PCL Anterolateral in Single Bundle Technique and Direct Anatomical Fixation with Interference Screw "Aperture Fixation"

Usually 4 portals are needed: one high and one deep anterolateral, anteromedial and a posteromedial portals (Fig. 15.31).

A diagnostic arthroscopy is performed to confirm the surgical indication as well as to assess possible associated injuries. Harvesting and preparation of the semitendinosus and gracilis tendons as described in ▶ Sect. 13.1. The semitendinosus tendon is folded 3 times if possible and the gracilis tendon is doubly folded. The resultant graft should be four or five strands with a minimum length of about 10 cm. The graft is whipstitched for about 3 cm length at the tibial end and about 2 cm length at the femoral end.

The femoral tunnel is then drilled. The femoral foot print is meticulously and carefully prepared with preservation of the PCL remnants as well as the meniscofemoral ligaments. A guide pin with an eyelet is inserted through the deep anterolateral portal and placed at the center of the anterolateral bundle foot print and drilled to exit the opposite cortex and the skin of the thigh. Overdrilling the guide pin with a cannulated reamer corresponding to the graft thickness to a depth of about 25–30 mm (Figs. 15.32 and 15.36b). A doubled passing suture is passed in via the guide pin and shuttled out through the anteromedial portal.

For preparation of the tibial foot print, the arthroscope is inserted first through the high anterolateral portal and passed medial to the ACL into the posterior joint compartment to al-

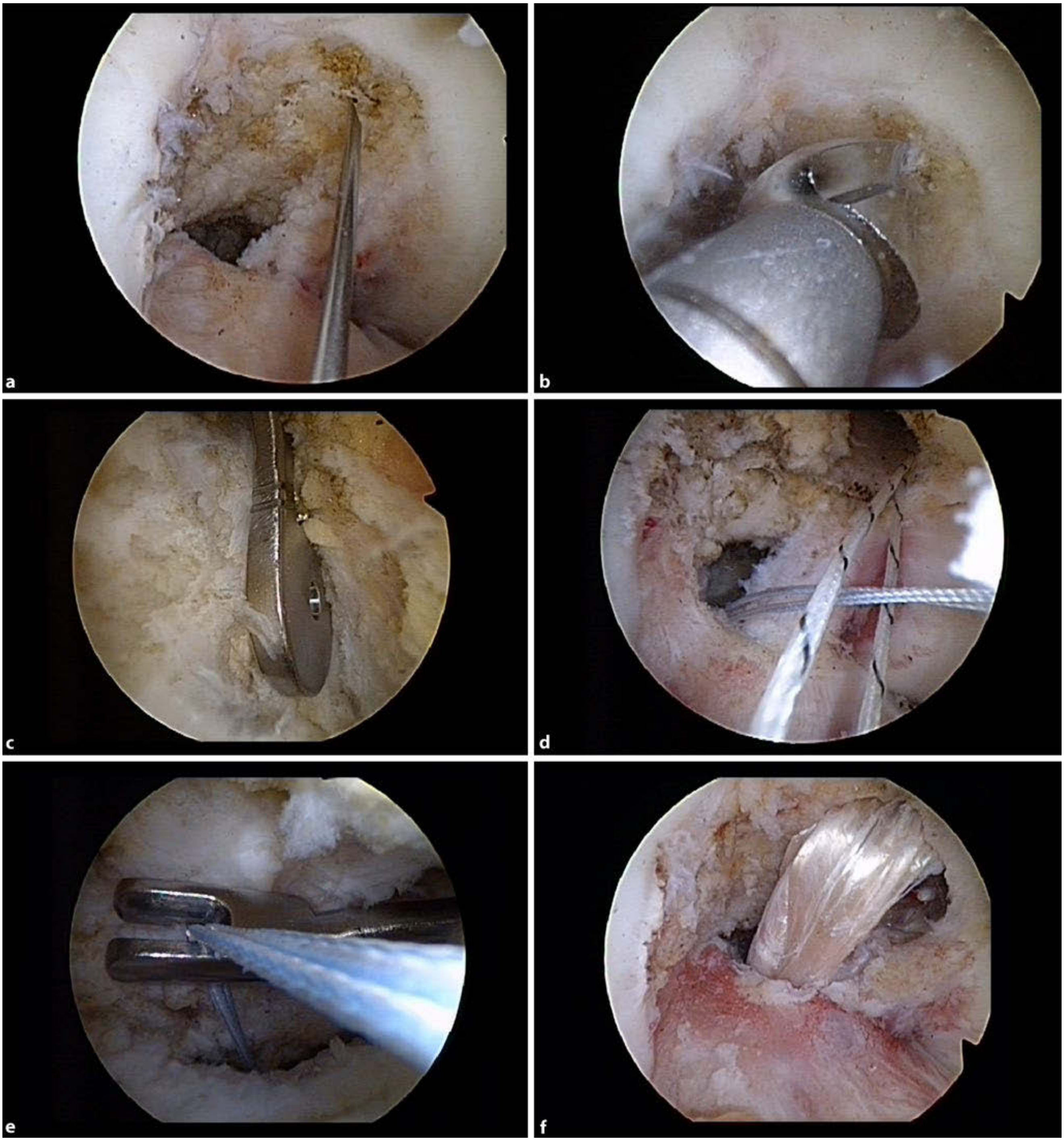


Fig. 15.36a–f Reconstruction of anterolateral bundle. **a** Placement of the portal using a needle; **b** drilling the femoral tunnel for the anterolateral bundle; **c** Drilling tunnel placement; **d** Shuttling the tibial passing sutures through the femoral tunnel; **e** pulling the graft with the aid of a fork instrument; **f** End result

low establishing the posteromedial portal under arthroscopic visualization. A shaver or electrocautery is inserted via the posteromedial portal to prepare the tibial foot print which is located between the posterior horns of both menisci and about 10–15 mm below the posterior margin of the tibial plateau.

The arthroscope is switched to the posteromedial portal. The tibial guide is inserted through the anteromedial portal and a guide pin is drilled trans-tibial into the center of the tibial footprint through the incision used for harvesting the tendons (Fig. 15.36c). The guide pin is overdrilled with a cannulated reamer corresponding to the graft diameter. The superior edge of the intraarticular end of the tunnel is smoothened (so-called "Killer turn") with a shaver or a special curved rasp. The arthroscope is switched into the high anterolateral portal. A passing suture is inserted through the tibial tunnel from the extraarticular end to intraarticular so that the suture loop remains extraarticular. The two free ends of the suture loop are shuttled out using a suture retriever from

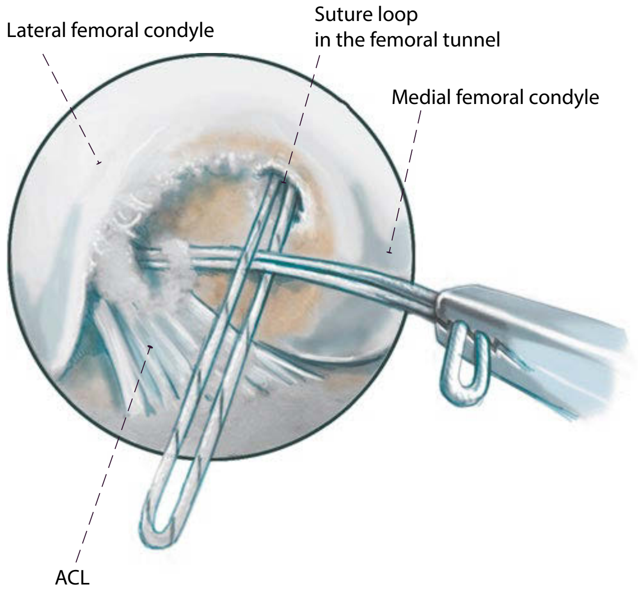


Fig. 15.37 Intraarticular shuttling of the tibial passing sutures through the femoral passing sutures

intraarticular to extraarticular through the anteromedial portal. The femoral passing sutures that are previously shuttled out through the anteromedial portal are used to pull the two free ends of the tibial passing suture through the femoral tunnel. This step may alternatively be carried out intra-articular (Figs. 15.36d and 15.37). The graft is pulled using the suture loop coming out through the tibial tunnel (Fig. 15.36e, f).

The femoral side of the graft is then fixed. A Nitinol wire is passed through the high anterolateral portal into the tunnel between the graft and the tunnel wall and an interference screw is inserted over it. The fixation of the tibial end is performed in 80° flexion under continuous anterior drawer stress under tension of about 80 N using an interference screw.

The manual anterior drawer stress must be maintained until the leg is positioned in the knee extension brace with a dorsal calf padding ("posterior tibial support", PTS-brace).

15.4.5 Postoperative Management

- Monitoring of peripheral circulation, motor and sensory innervation
- Application of elastic compressive bandages as well as a knee extension brace with posterior calf padding (PTS-brace) under anesthesia.
- Cooling and elevation of the extremity
- Postoperative radiographs in the PTS-brace.

15.4.6 Follow-up Management

A PTS brace is used for the first 6 weeks for 24 hours a day, then a functional PCL 4-point brace during the day and a PTS brace at night from the 7th to the 12th weeks. The functional PCL 4-point brace is then used alone in the 12th–24th weeks. Partial weight bearing with 20 kg in the first 6 weeks. Physiotherapeutic exercises are performed in the first weeks outside the brace in the prone position with passive exercises and limited to the range of motion of flexion/extension: 90°/0°/0°. Free range of motion is increasingly allowed from the 7th week (as tolerated) and active flexion exercises are allowed without load. Proprioceptive training and flexion exercises are started after 3 months. Sport beginning after 6 months, contact or risky sports after 9–12 months.

15.4.7 Tips & Tricks

Stress radiographs to quantify the posterior tibial translation and to exclude a fixed posterior drawer is the most important diagnostic tool. The measurement is performed with the technique described by Jacobsen.

A fixed posterior drawer (tibia doesn't reduce into the neutral position with anterior translation) must be managed before the operative PCL reconstruction. This is done by using knee braces for 6–8 weeks (PCL 4-point brace during the day time and a PTS brace at night) and re-evaluation of the success of treatment through repeated stress radiographs.

If the fixed posterior drawer can't be conservatively corrected, a two-stage procedure with a primary arthroscopic arthrolysis may be required.

If concomitant posterolateral or posteromedial instability is present and only an isolated PCL reconstruction is performed, the achieved stability will not be sufficiently enough and the remaining excessive stresses can lead to graft failure. The same applies also for accompanying varus and recurvatum deformities. Such concomitant deformities must be corrected, either before or with the planned PCL reconstruction.

To reduce rubbing of the graft at the superior edge of the intra-articular tibial tunnel opening "killer turn", gentle smoothing with a shaver or a special rasp is important. A fork Instruments (Fig. 15.36e) or a switching stick may be passed through the posteromedial portal and used as a fulcrum to help controlling the passage of the graft over this edge.

The use of an ipsilateral patellar tendon or quadriceps tendon graft is not recommended in our point of view as it may lead to weakening of the extensor mechanism which is an important PCL agonist. Harvesting of these grafts may lead to accentuation of the patellofemoral problems already caused by the PCL insufficiency.

To avoid injury of the popliteal neurovascular structures, the shaver or the electrocautery device used for preparation of the tibial foot print should be always directed towards the tibial plateau.

To facilitate wound closure and dressing while exerting an anterior drawer stress, the leg may be placed on a high instrument table (Fig. 15.38).

■ **Fig. 15.38** Positioning of the leg on a high instrument table during wound closure and dressing to maintain an anterior drawer stress

15.5 Posterolateral Reconstruction

M. Feucht, S. Hinterwimmer

15.5.1 Indication

Symptomatic isolated posterolateral rotatory instability. Symptomatic posterolateral rotatory instability with concomitant reconstruction of the posterior cruciate ligament. As part of a combined procedure for management of multiligamentous knee injuries or dislocation.

15.5.2 Operation Principle

Modified Larson technique: isometric reconstruction of the posterolateral structures with an autologous semitendinosus tendon, which is passed through the head of the fibula and fixed into a femoral tunnel placed between the site of insertion of the lateral collateral ligament and the popliteus tendon.

The anterior limb of the resultant triangle represents the lateral ligament, the posterior limb should approximately perform the function of the popliteofibular ligament and the popliteus tendon (■ Fig. 15.39).

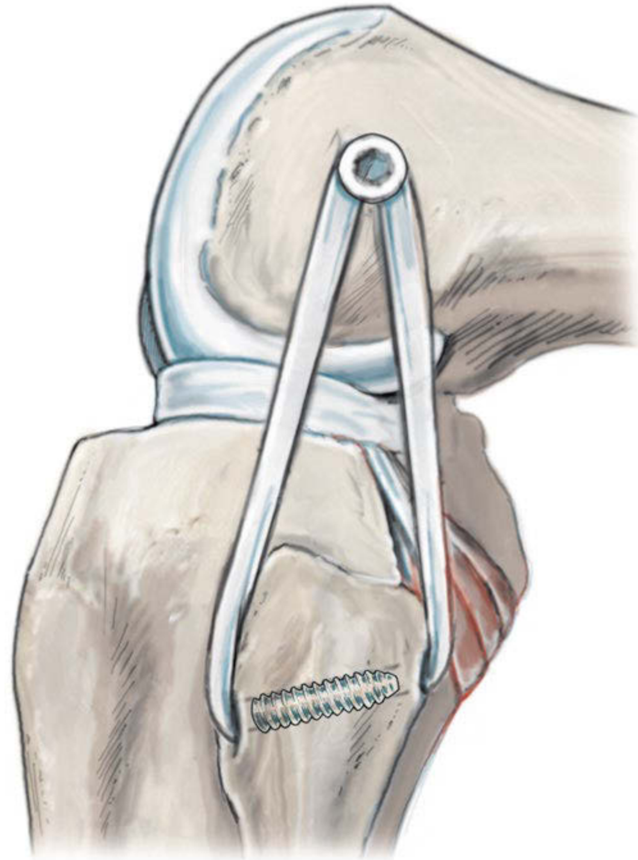
La Prade technique: anatomical reconstruction of the lateral collateral ligament, popliteus tendon and the popliteofibular ligament utilizing two tendons grafts, which are fixed into tunnel in the femur, tibia and fibula at the corresponding anatomical insertion sites (■ Fig. 15.46).

15.5.3 Preoperative Assessment

Diagnosis

Clinical

Symptom specific history: time and mechanism of injury, subjective feeling of instability, pain, previous operations.



■ **Fig. 15.39** Schematic illustration of the modified Larson technique

Symptom specific examination: inspection for malalignment, gait (varus-recurvatum thrust phenomenon), inspection of anterior tibial contusions and hematoma or swelling in the popliteal region and over the posterolateral corner, tenderness (popliteal fossa, lateral/posterolateral corners), external rotation recurvatum test, spontaneous posterior drawer sign (posterior sag sign), posterior drawer test in neutral position, internal and external rotation of the leg, external rotation of the leg in 30° and 90° flexion in prone position, varus and valgus stress tests in 0° and 3° flexion.

Neurological/vascular examination

- Assessment of the peripheral nerves (peroneal nerve)
- Assessment of the peripheral vascular condition after knee dislocation.

Imaging

- X-ray of the knee joint in three views (AP, lateral, tangential patella) to exclude osseous lesions.
- Long leg standing AP view if there is suspicion of axial malalignment.
- Stress functional views in 90° flexion within the first week after injury or after the 7th week (anterior and posterior drawer of both knee joints with 15 kg load)

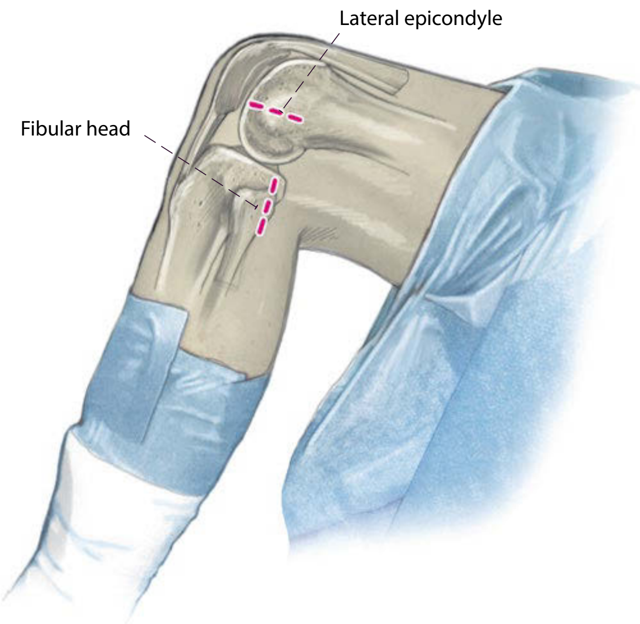


Fig. 15.40 Vertical skin incision over the fibula and horizontal skin incision over the lateral epicondyle

Fig. 15.41 A Kirschner wire is drilled through the fibular head in slightly ascending direction

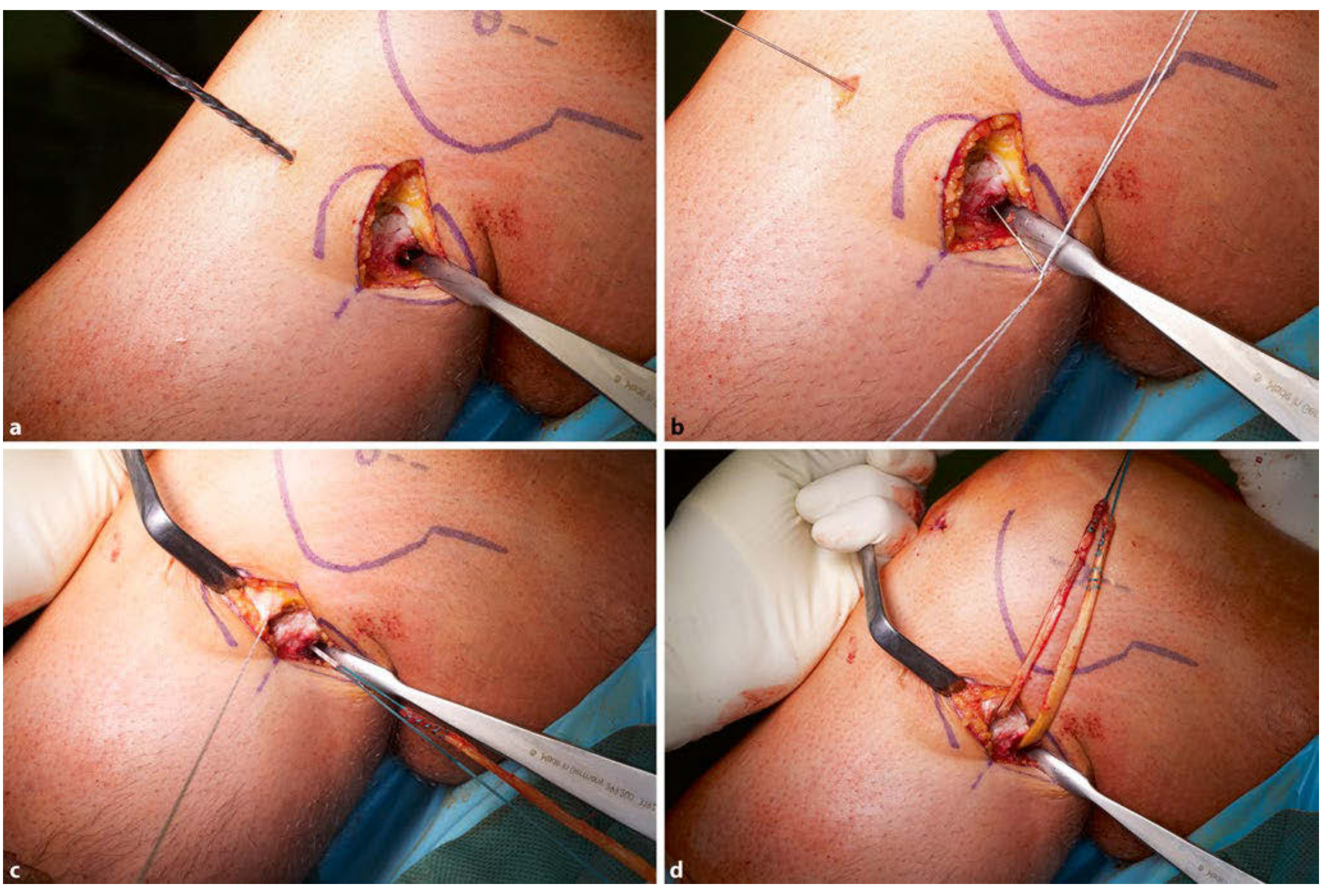


Fig. 15.42a–d Isometric reconstruction of the posterolateral structures. **a** overdrilling the Kirschner wire; **b** passing a shuttle suture; **c** pulling the graft through the tunnel; **d** transfibular passed graft

- MRI to verify the injured structures and exclude concomitant lesions.
- CT or MRI Angiography with suspected vascular injury (usually indicated after knee dislocation injury)

Patient Information/Consent

Surgery-specific risks: Morbidity after harvesting the tendon graft with at least temporary weakening of the knee flexion and internal rotation, injury of the saphenous nerve, injury of the peroneal nerve, flexion or extension deficit due to tunnel malpositioning or fixation of the graft in an incorrect position, fracture of the head of the fibula, loosening of the graft fixation construct with recurrent stability, re-rupture, progression of the osteoarthritis, extensive rehabilitation.

15.5.4 Surgical Technique

Positioning and Preparation

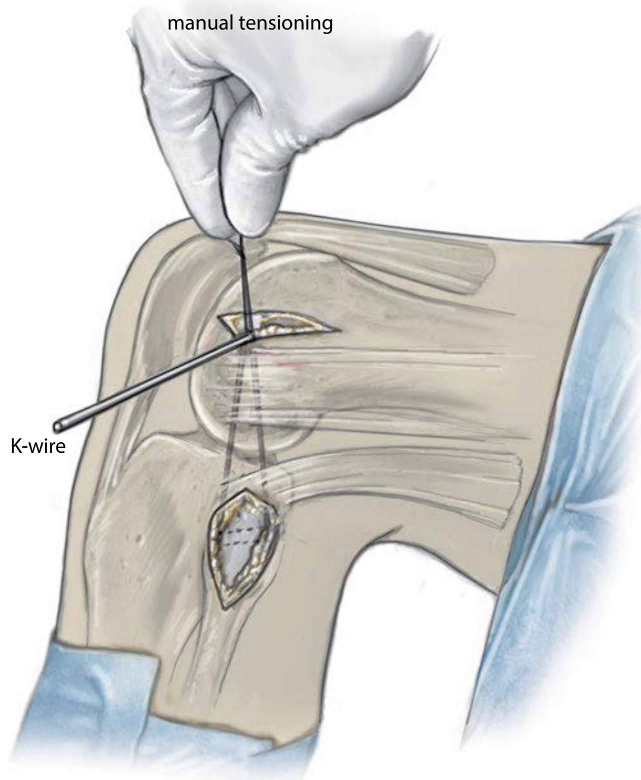
- Supine position (when a combined PCL and posterolateral corner reconstruction is planned utilizing the hamstring tendons as a graft, both legs should be positioned and draped as the contralateral tendons must be also harvested).
- A thigh tourniquet is applied
- Examination under anesthesia (degree and direction of instability, isolated or combined instability)

Isometric Reconstruction of the Posterolateral Structures with the Modified Larson Technique

The semitendinosus tendon is harvested and prepared as described in ► Sect. 13.1. The tendon should have a total length of about 24 cm. Both ends of the graft are whipstitched for about 2 cm. The rest of the procedure is performed with the knee in 90° flexion.

A vertical skin incision of about 2–3 cm length is carried out over the head of the fibula (◘ Fig. 15.40). The tendon of the biceps femoris is identified and an approximately 2 cm long horizontal incision is done at its lower border directly over the head of the fibula. Cave: Due to the close proximity of the peroneal nerve, it should be identified and exposed if there is any doubt. Dissection is continued to expose the posterior surface of the head of the fibula.

A stab incision is made approximately 2 cm anterior to the fibular head. The index finger is used to palpate the posterior surface of the head of the fibula through the incision along the lower border of the biceps femoris and thus protecting the peroneal nerve while drilling a guide pin inserted from the anterior aspect through the stab incision in a slightly ascending direction trans-fibular with the other hand (◘ Fig. 15.41). The index finger is used to evaluate whether the guide pin is drilled centrally in the fibular head or not.



◘ **Fig. 15.43** Testing the isometric positioning of the femoral guide pin

The position of the Kirschner wire should be also radiologically checked with an image intensifier. If the position is correct, the guide pin is overdrilled according to graft thickness and a shuttle suture is passed through the tunnel (◘ Fig. 15.42).

The next step is to prepare the femoral insertion. A horizontal skin incision of about 2–3 cm length over the lateral epicondyle is used (◘ Fig. 15.40) to expose the iliotibial band which is split it in line of its fibers.

The femoral insertion site of the lateral collateral ligament as well as the popliteus tendons are prepared and a guide pin with an eyelet is drilled midway between the two insertions (anterior and superior to the lateral epicondyle).

To test the isometricity, the two ends of the fibular shuttling suture are passed proximally using an over hold clamp underneath the iliotibial band. The posterior suture end must be also passed under the biceps tendon. The two suture ends are manually tensioned over the already drilled guide pin while the assistant moves the knee several times (◘ Fig. 15.43). There should be no change in the length of both suture limbs, otherwise the position of the guide pin must be corrected. If the position is correct, the guide pin is overdrilled corresponding to the graft thickness and to a depth of about 4–5 cm and a shuttle suture is passed.

The two ends of the fibular passing sutures are pulled distally to pass the tendon graft through the fibular head until

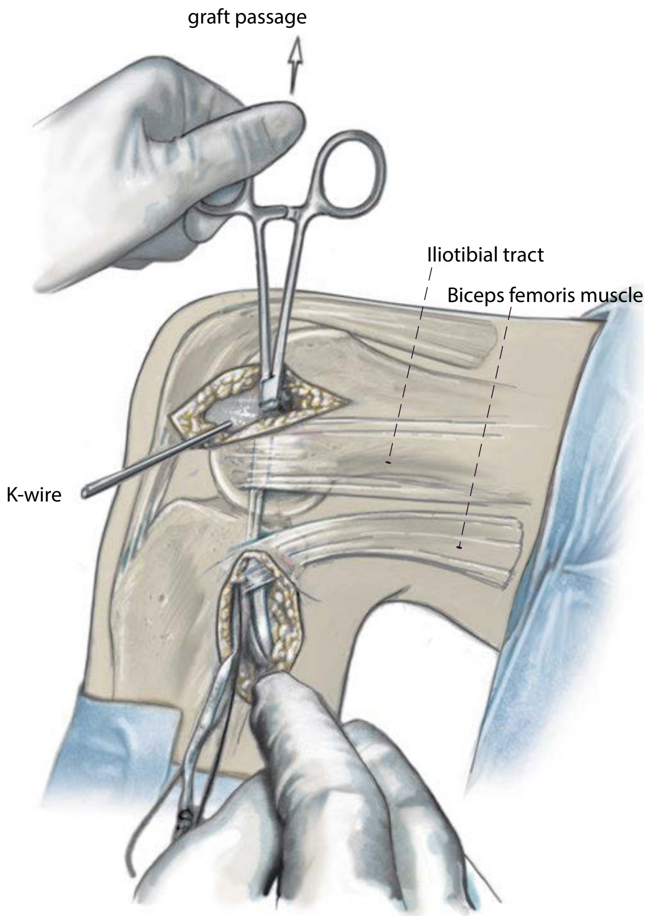


Fig. 15.44 Passing the graft out to the femoral side

both tendon graft limbs, anterior and posterior to the fibular head are of the same length.

Fibular fixation is done with an interference screw inserted over a Nitinol wire through the anterior stab incision between the graft and the wall of the drill hole.

The free graft ends are pulled proximally (Fig. 15.44) and into the femoral socket using the femoral shuttle suture previously passed. Femoral fixation is carried out with an interference screw inserted over a Nitinol wire passed between the graft and the wall of the socket under manual tension over the sutures pulling the graft limbs with the knee in approximately 30° flexion and mild valgus and internal rotation (Fig. 15.45).

Anatomical Reconstruction of the Posterolateral Structures with La Prade Technique

In the original described technique, a 23 cm long Achilles tendon allograft with attached bone block is used, which is split longitudinally into 2 grafts. Hamstring tendon graft may be alternatively used. The procedure is performed in 70–80° knee flexion.

A curved skin incision along the lower border of the iliotibial tract down to the Gerdy tubercle. The tendon of the biceps femoris is exposed. The peroneal nerve is dissected and released (neurolysis).

The insertion of the lateral collateral ligament at the anterolateral aspect of the fibular head as well as the insertion of the popliteofibular ligament at the posteromedial aspect are exposed.

A guide instrument (e.g. ACL guide) is used to pass a Kirschner wire transfibular from anterolateral to posteromedial through both insertion sites and overdrilled corresponding to the graft thickness.

The musculotendinous junction of the popliteus muscle and the overlying bony sulcus on the posterior surface of the tibia are identified with palpation in the interval between the lateral head of the gastrocnemius and soleus muscles.

The guide instrument is used to drill a guide pin from anterior, distal and medial to the tubercle of Gerdy in the direction of the already palpated bony sulcus (or the musculotendinous junction of the popliteus muscle.

The posterior neurovascular structures are protected with appropriately placed hooks. The exit of the guide pin should be located at least 1 cm medial and 1 cm proximal to the fibular tunnel. Overdrilling the guide pin to a diameter corresponding to the graft thickness.

Exploration of the femoral insertions of the lateral collateral ligament and the popliteus tendon. Two guide pins with eyelets are inserted through the centers of these insertion areas. Overdrilling the guide pins to create bone sockets with a diameter corresponding to the graft thickness and to a depth of about 25 mm and passing sutures are passed.

The grafts is pulled into both femoral tunnels and fixed in each tunnel using interference screws or Bio-Swivelock, Arthrex. The graft used for reconstruction of the lateral collateral ligament is passed distally under the iliotibial band and the biceps femoris and then passed through the fibular tunnel from anteromedial to posterolateral using the previously placed passing sutures.

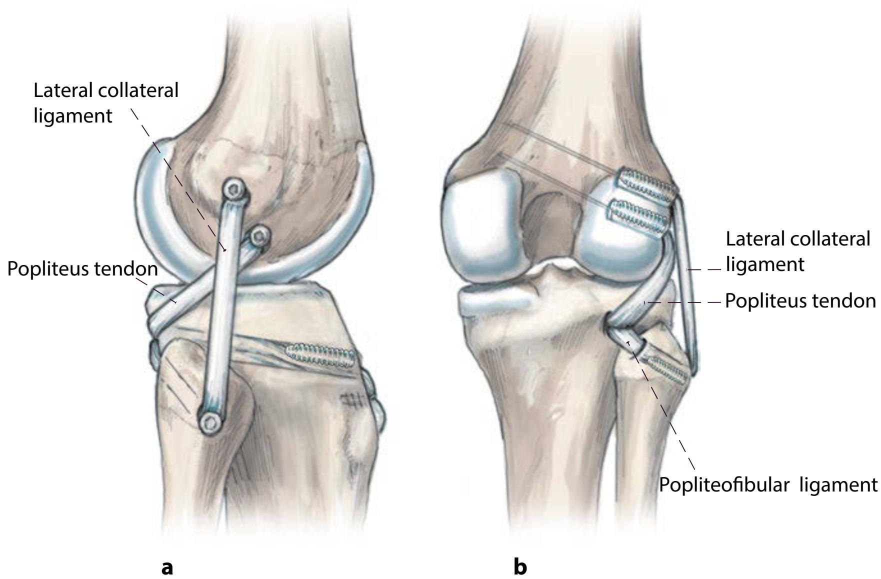
Fibular fixation is carried out with an interference screw under manual tension to the graft with the knee in 20° flexion and mild valgus and neutral rotation.

The graft aimed to reconstruct the popliteus tendon is passed distally along the popliteal hiatus and then together with the graft for the lateral collateral ligament emerging from the posteromedial aspect of the fibular tunnel are passed anteriorly through the tibial tunnel.

Both graft are manually tensioned and fixation is performed with the knee in 60 flexion using an interference screw inserted from the anterior aspect over a Nitinol wire (Fig. 15.46).

Fig. 15.45a–c Isometric reconstruction of the posterolateral structures. **a** overdrilling the Kirschner wire; **b** pulling the graft through the femoral tunnel; **c** femoral fixation with an interference screw

Fig. 15.46a,b Posterolateral reconstruction with La Prade technique. **a** lateral view; **b** Posterior view



15.5.5 Postoperative Management

- For combined posterolateral and PCL reconstruction, elastic compressive bandages are applied followed by a knee extension brace with a posterior calf padding ("posterior tibial support" PTS brace) while the patient is still under anesthesia.
- Monitoring of the peripheral circulation, motor and sensory innervation
- Cooling and elevation of the extremity
- Postoperative radiographs.

15.5.6 Follow-up Management

Isolated Posterolateral Reconstruction

A knee brace in 20° flexion is used for 2 weeks followed by a 4 points hard knee brace with limitation of the range of motion to flexion/extension 90°/10°/0° for further 6 weeks, after which free range of motion is allowed.

Alternatively, a valgus producing knee brace can be used. Partial weight bearing with 20 kg in the first 6 weeks. Sport begin is allowed after 6 months, contact or high-risk sports are allowed after 9–12 months.

Combined Posterolateral and PCL Reconstruction

A PTS brace is used for the first 6 weeks for 24 hours a day, then a functional PCL 4-point brace during the day and a PTS brace at night from the 7th to the 12th weeks. The functional PCL 4-point brace is then used alone in the 12th– 24th weeks. Physiotherapeutic exercises are performed in the first weeks outside the brace in the prone position with only passive exercises and in the range of motion of flexion/extension: 90°/0°/0°. Free range of motion is increasingly allowed from the 7 th week (as tolerated) and active flexion exercises are allowed without load. Proprioceptive training and flexion exercises against resistance are started after 3 months.

15.5.7 Tips & Tricks

After posterolateral reconstruction with a concomitant varus deformity, excessive loads on the graft will eventually lead to insufficiency and failure of the graft. A valgus producing

Fig. 15.47 Kirschner wires at the insertion area of the popliteus tendon (anterior) and the lateral collateral ligament (posterior)

osteotomy should therefore be performed in the same or a subsequent procedure.

If both posterolateral corner and PCL reconstruction are to be simultaneously performed, the tibial fixation of the PCL is done only after completing the posterolateral reconstruction.

The femoral tunnel or both the femoral tunnels should be should be drilled in a cranially ascending direction to avoid penetration of the notch and confluence with femoral tunnel of the PCL in the medial femoral condyle if simultaneously performed.

A very careful and accurate testing for the Isometricity is required with the modified Larson technique. A non- isometric positioning of the femoral tunnel would lead to graft failure or restriction of motion.

To reduce postoperative irritation of the iliotibial band, the femoral interference screw should inserted to below the level of the femoral cortex.

A more anatomical reconstruction of the posterolateral structures and a better rotational stability can be achieved with the modified Larson technique by drilling two femoral tunnels, one at the insertion of the lateral collateral ligament and the other one at the insertion of the popliteus tendon (Fig. 15.47). The posterior limb of the graft passes under the anterior limb to be inserted into the popliteus foot print.

15.6 Medial Collateral Ligament Reconstruction

G. Meidinger, M. Feucht, S. Hinterwimmer

15.6.1 Indication

Chronic grade 3 lesions of the medial collateral ligament after failed conservative treatment.

Specific contraindications: Genu valgus > 5°

15.6.2 Operation Principle

Reconstruction of the superficial part of the medial collateral ligament (MCL) and the posterior oblique ligament (POL) using an autologous contralateral semitendinosus.

15.6.3 Preoperative Assessment

Diagnosis

Clinical

Symptom specific history: time and mechanism of injury, subjective feeling of instability, pain, previous treatments and operations.

Symptom specific examination: inspection of the lower limb alignment and gait, medial joint opening in 0° and 30° flexion of the knee, exclusion of concomitant ligamentous injuries or instability.

Imaging

- X-ray of the knee joint in three views (AP, lateral, tangential patella) to exclude ligamentous bony avulsion.
- Valgus stress views of both sides to quantify the degree of medial opening.
- Long leg standing AP view if there is suspicion of axial malalignment.
- MRI to assess the medial collateral ligament regarding the localization of the tear (chronic tears are often not identifiable), remaining intact fibers as well as to exclude associated internal knee injuries.

Patient Information/Consent

Surgery-specific risks: Morbidity after harvesting the tendon graft with temporary weakening of the knee flexion and internal rotation, injury of the saphenous nerve, injury of the peroneal nerve, restricted range of motion tunnel malpositioning, loosening of the graft fixation construct with recurrent stability, re-rupture.

15.6.4 Surgical Technique

Positioning and Preparation

- Supine position
- Sterile draping of both legs
- A thigh tourniquet is applied
- Examination under anesthesia to conform the operative indication and exclude other ligamentous insufficiencies.

Reconstruction of the Superficial MCL and POL with a Contralateral Hamstring Tendon Graft

The semitendinosus tendon is harvested from the contralateral knee and the ends are whipstitched in the same technique described in ► Sect. 13.1. The graft is then folded and the junction area is whipstitched also. It must be ensured that the graft limb used for reconstruction of the superficial part of the MCL is longer than the limb used for reconstruction of the POL. The graft should be therefore folded in a ratio of 2:1 (◘ Fig. 15.48).

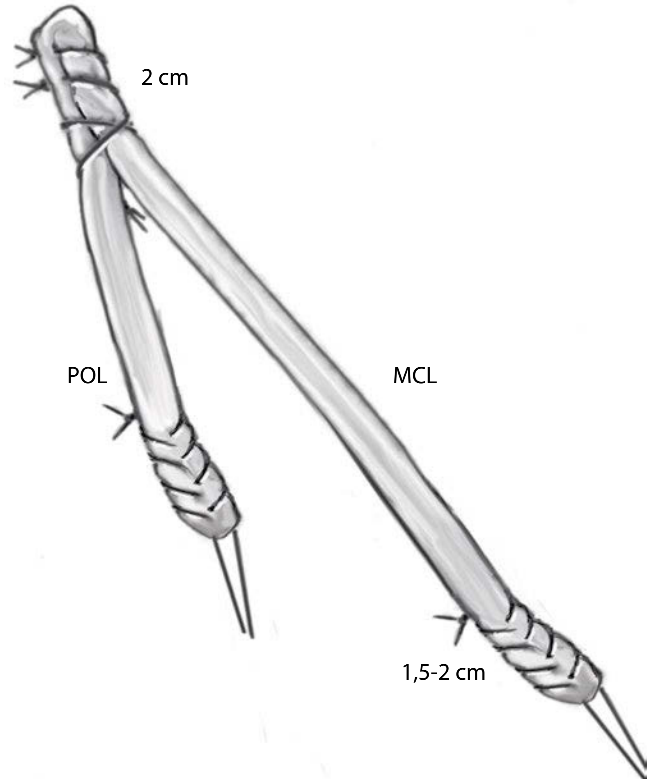
Skin incision over the medial epicondyle in the direction of the adductor tubercle with care to spare the saphenous nerve. The femoral insertion of the superficial MCL is exposed (about 3 mm proximal and 5 mm posterior to the medial epicondyle) as well as the insertion of the POL (about 8 mm distal and 6 mm posterior to the adductor tubercle). A guide pin with eyelet is drilled at the center between the two insertions and passed until it penetrates the lateral femoral cortex and skin. Overdrilling the guide pin with a cannulated reamer to a depth of about 30 mm. The diameter of the cannulated reamer must be the same of the diameter of the doubled graft. The doubled graft is pulled into the femoral socket over the guide pin and fixed with an interference screw inserted over a Nitinol wire passed between the socket wall and the graft.

Another skin incision is made over the area of insertion of the pes anserinus and the tibial insertion of the superficial MCL is exposed (slightly dorsal and distal to the pes anserinus). A guide pin with eyelet is drilled at this point until it penetrates the lateral tibial cortex and skin. The guide pin must be directed anteromedially to avoid injury to the peroneal nerve. The guide pin is overdrilled up to the opposite cortex with a cannulated reamer corresponding to the thickness of the MCL graft limb.

Blunt dissection is carried out from the tibial insertion along the superficial MCL fibers to the femoral insertion. The superficial MCL graft limb is passed distally with a clamp or using a shuttle suture under the tendons of the pes anserinus. The graft is pulled into the tunnel over the guide pin.

A third skin incision is made over the tibial insertion of the POL and dissection is carried out down to the bone followed by drilling a guide pin strictly in an anteromedial direction to penetrated the opposite tibial cortex and skin. The exit point of the pin must be anterior to the fibular head to avoid injury to the peroneal nerve. The guide pin is overdrilled up to the opposite cortex with a cannulated reamer corresponding to the thickness of the POL graft limb. Blunt dissection is carried out from the tibial insertion of the POL over the joint capsule and up to the femoral insertion.

The POL graft limb is pulled distally with a clamp or using a shuttle suture and passed into the bone tunnel over the guide pin. Tibial Fixation of MCL is carried out with an interference screw with the knee in 20° flexion and slight varus stress and the graft under manual tension over the lateral pulling sutures. Fixation of the POL limb similarly in 60° flexion (◘ Fig. 15.49).



◘ **Fig. 15.48** Schematic illustration of the graft. The limb for reconstruction of the MCL should be twice as long as the limb for the POL

15.6.5 Postoperative Management

- Monitoring of the peripheral circulation, motor and sensory innervation
- Use of elastic compressive bandages
- Cooling and elevation of the extremity
- Postoperative radiographs.

15.6.6 Follow-up Management

A 4 point hard knee is used for 6 weeks. Partial weight bearing with 20 kg in the first 6 postoperative weeks. The ROM is limited in the 1st and 2nd postoperative weeks to flexion/extension 60°/20°/0°, in the 3rd and 4th postoperative weeks to 90°/10°/0° and in the 5th and 6th postoperative weeks to 90°/0°/0°. Free ROM is allowed from the 7th postoperative week.

15.6.7 Tips & Tricks

Graft harvesting from the contralateral side is recommended as the semitendinosus contributes to the medial stability.

With valgus malalignment more than 5°: correction to a straight leg axis (mechanical axis passing through the center of the tibial plateau, 50%) with a valgus producing osteotomy

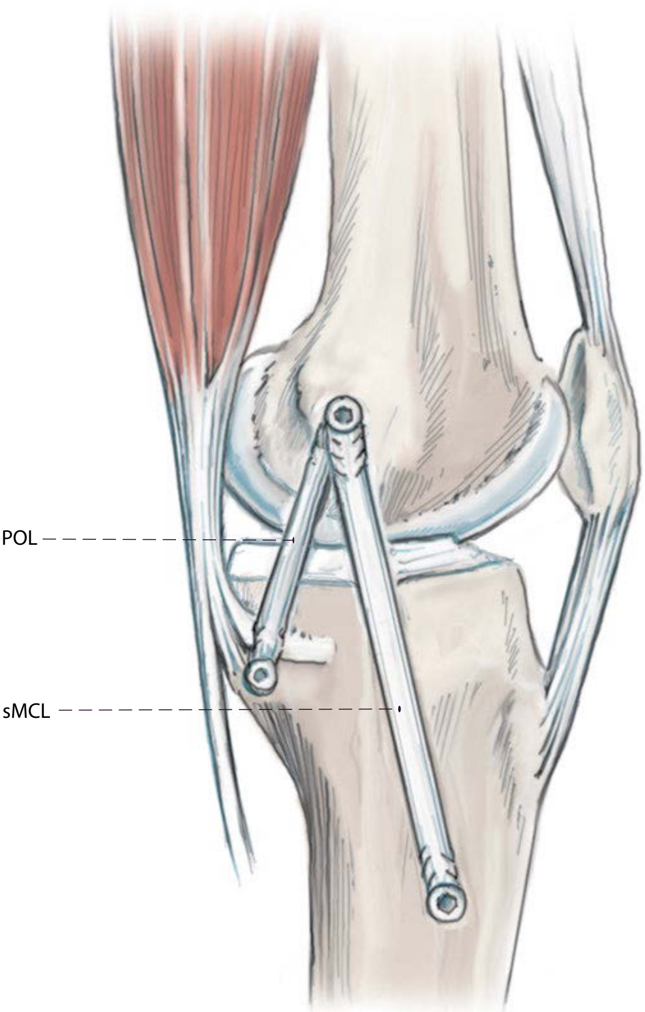


Fig. 15.49 Reconstructed medial collateral ligament complex using a tendon graft. *sMCL* superficial part of the medial collateral ligament, *POL* posterior oblique ligament

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should be performed, at the site of deformity (distal femoral or proximal tibial after measuring the LDFA [lateral distal femoral angle] and MPTA [medial proximal tibial angle]).

Since the MCL graft limb is relatively very long, it should be sutured to the existing residual fibers after fixation, which can increase the tension of the graft to some extent.

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Tendons

T. Saier, P. Brucker

A. B. Imhoff, M. J. Feucht (Eds.), *Surgical Atlas of Sports Orthopaedics and Sports Traumatology*,
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16.1 Quadriceps Tendon Repair

T. Saier, P. Brucker

16.1.1 Indication

Acute loss of active extension of the knee due to complete rupture of the quadriceps tendon near the insertion; inability to walk with lost active knee extension (concomitant lesion of the patellar retinacula = reserve extension mechanism).

Partial rupture of the quadriceps tendon close to its insertion with preserved reserve extensor mechanism, associated with subjectively unstable gait with giving way of the knee and/or high functional or sporting demands

16.1.2 Operation Principle

Reattachment of the tendon stump to the patella with suture anchors,

16.1.3 Preoperative Assessment

Diagnosis

Clinical

Symptom specific history: time and mechanism of the injury, severity of complaint, functional and sporting demands, risk factors: smoking, systemic (metabolic) diseases, steroids, anabolic steroids, antibiotics (Quinolones).

Symptom specific examination: buckling in the anterior distal part of the thigh, soft tissue swelling and hematoma in the anterior part of the thigh; tenderness and palpable defect/gap at the insertion of the quadriceps, lost or decreased active knee extension.

16

Imaging

- X-ray of the knee joint in three views (AP, lateral, tangential patella) to exclude osseous avulsions or bipartite patella
- Ultrasound/MRI of the thigh and knee to assess the lesion (complete/partial, localization, extension, retraction), and exclude concomitant internal knee derangement.

Patient Information/Consent

Surgery -specific risks: permanent loss of the strength of the knee extension, limited range of motion, thigh atrophy, rerupture, suture failure, increased risk of patellofemoral osteoarthritis; intra-/postoperative fracture of the patella; limited mobility of the patella, patella baja (infera), anterior knee pain, long recovery time with restricted mobility and the use of a restricting knee brace, crutches and prophylaxis against thrombosis until full weight bearing.

16.1.4 Surgical Technique

Positioning and Preparation

- Supine position
- Tourniquet is applied to the thigh as proximal as possible (optionally used)

Repair of the Quadriceps Tendon with Suture Anchors

About 8–10 cm longitudinal midline skin incision, extending from the upper pole of the patella proximally (▣ Fig. 16.1). Splitting the thigh fascia as well as the prepatellar bursa. The tear site is identified and carefully debrided. Tissue biopsy for histological examination is taken from the central tear site.

The entire tear must be visualized. If the tear extends into the parapatellar retinacula (reserve extension mechanism), they must also be repaired with absorbable sutures.

The upper border is prepared and freshened and a transverse bone bed is made (▣ Fig. 16.2). 3–4 suture anchors (e. g. Corkscrew 5.5 mm, Arthrex, Inc.) are inserted into bone bed created on the upper border of the patella after pre-drilling/tapping. Anchor placement should respect the force balance and cover the whole extent of the anatomical insertion site (foot print) of the quadriceps tendon (▣ Fig. 16.3). The proximal quadriceps tendon stump is then stitched securely with one suture limb of each anchor in an ascending and descending pattern ("baseball stitches") (▣ Fig. 16.3). The corresponding suture limbs are then tied in about 30–40° Flexion so the quadriceps tendon is securely pulled to the foot print on the upper pole of the patella (▣ Fig. 16.4). Intraoperative passive knee flexion of at least 90° must be achievable. Finally, fine adaptation of the tendon stumps with interrupted sutures (absorbable suture material).

16.1.5 Postoperative Management

- Monitoring of peripheral circulation, motor and sensory innervation
- Use of elastic compressive bandages
- cooling of the extremity
- Postoperative radiographs of the knee joint (AP and lateral views; ▣ Fig. 16.5)

16.1.6 Follow-Up Management

Mobilization on crutches with partial weight bearing (15–20 kg) with the use of a hinged knee brace for at least 6 weeks. Knee flexion is limited to 30° in the first 2 postoperative weeks. Passive mobilization of the knee joint in prone position and the use of a CPM machine up to 60° flexion is also allowed. From the 3rd Week, flexion is allowed to 60° in the brace. From the 6th Week, 90 degrees of flexion. From the 7th postoperative week active flexion and extension under physiotherapeutic observation with gradually increased weight bearing (20 kg/week). Simultaneously, a physiotherapeutic coordinated rehabilitation program for strengthening and Improvement of the proprioception. Ergometer training can be started postoperatively after reaching 110° flexion. Sport specific training should not be started earlier than 6 months postoperatively, contact or high risk sports not before 9–12 months after the procedure.

16.1.7 Tips & Tricks

Special attention is required during exposure of the tear site to evaluate the reserve extensor mechanism (parapatellar retinacula), which must be necessarily repaired if involved.

With chronic tendon rupture and inability to adapt both tendon stumps, an autologous interposition tendon graft (e. g. hamstring tendon) can be used. Alternatively, transpatellar fixation of the quadriceps tendon can be performed instead of suture anchors, e. g. bipartite patella. In certain circumstances both techniques can also be simultaneously used. Tissue sample could be obtained for histological examination (forensic causes).

16.2 Patellar Tendon Repair

T. Saier, P. Brucker

16.2.1 Indication

Absolute: Complete rupture of the patellar tendon with inability to extend the knee and feelings of instability, avulsion of the tibial tuberosity (particularly in adolescents).

Relative: partial tendon rupture.

16.2.2 Operation Principle

Rupture close to the insertion: reattachment of the patellar tendon with suture anchors and cerclage. With tibial tuberosity avulsion: fixation with screws and FiberTape cerclage. The target of the procedure is to create a stable construct that can bear exercises.

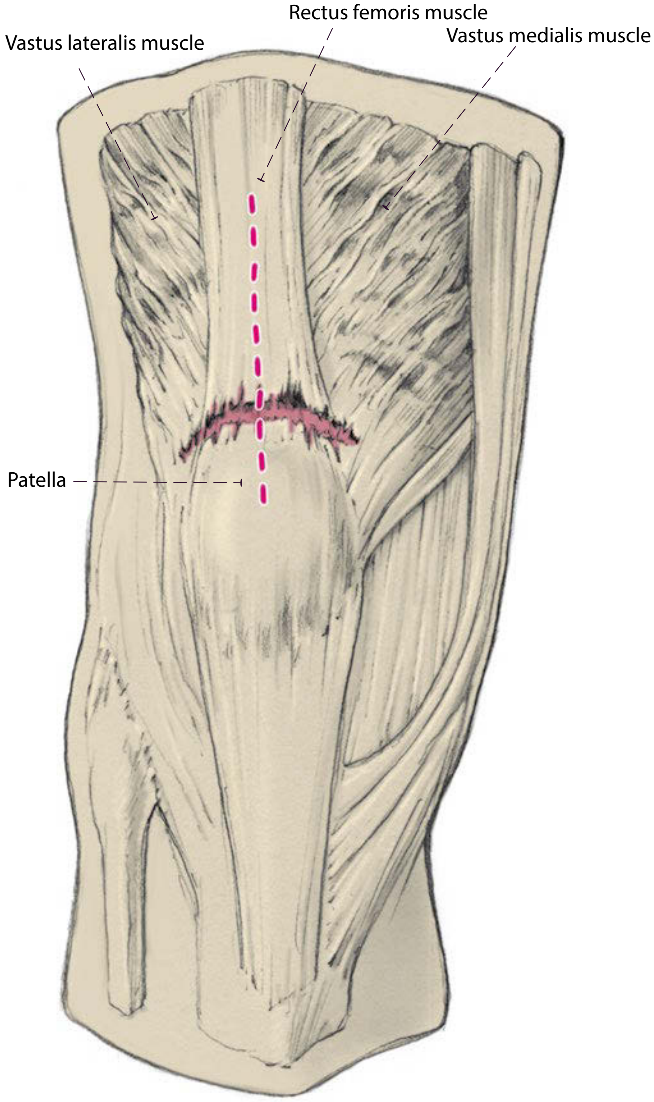


Fig. 16.1 Access through a 8–10 cm long median incision extending from the upper patellar pole proximally

16.2.3 Preoperative Assessment

Diagnosis

Clinical

Symptom specific history: mechanism of injury, feelings of instability, loss of active knee extension, risk factors: smoking, chronic systemic diseases, steroids, anabolic steroids, antibiotics (Quinolones).

Symptom specific examination: proximal displacement of the patella (patella alta) compared to the other side, hematoma/ecchymosis over the patellar tendon, a palpable defect

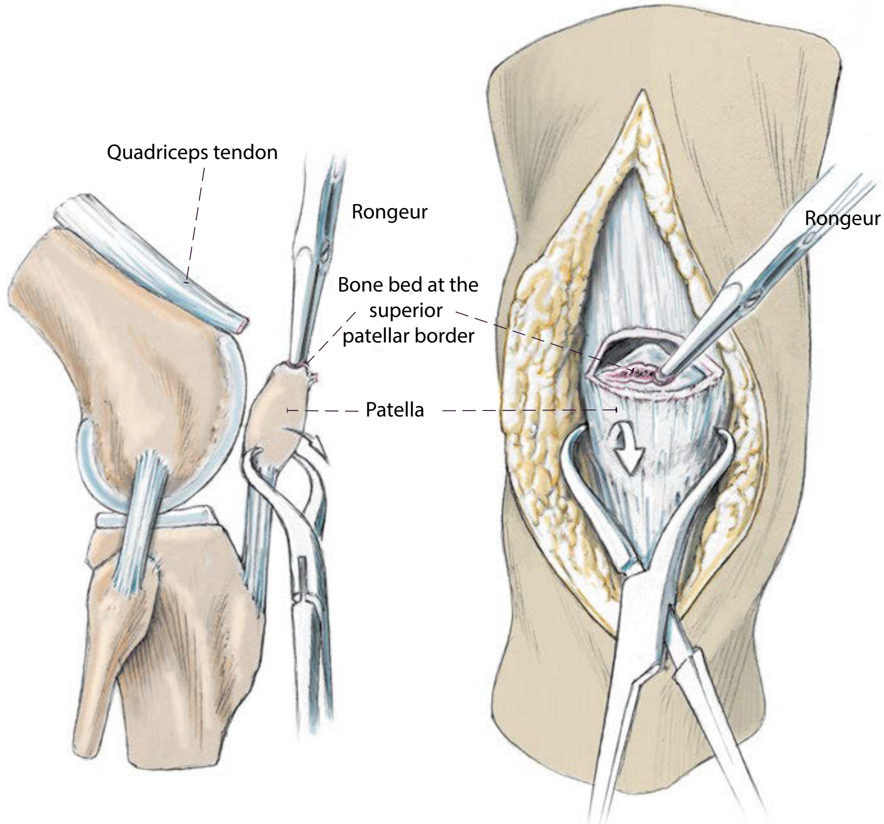
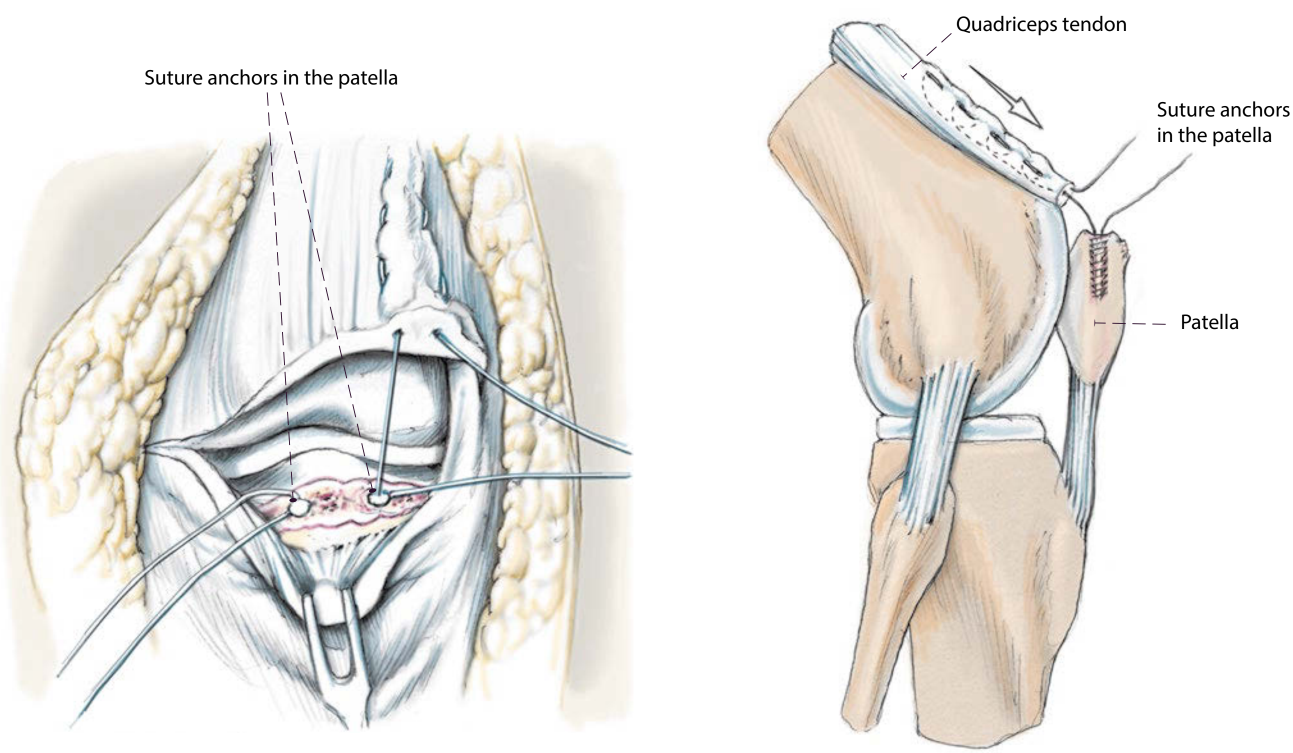


Fig. 16.2 A transverse bone bed is made at the upper border of the patella with a bone nibbler



a **b**

Fig. 16.3a,b **a** Insertion of 3–4 suture anchors in the bone bed created at the upper border of the patella and stitching the proximal stump of the quadriceps tendon. **b** The tendon is repositioned by pulling the free ends of the anchor sutures

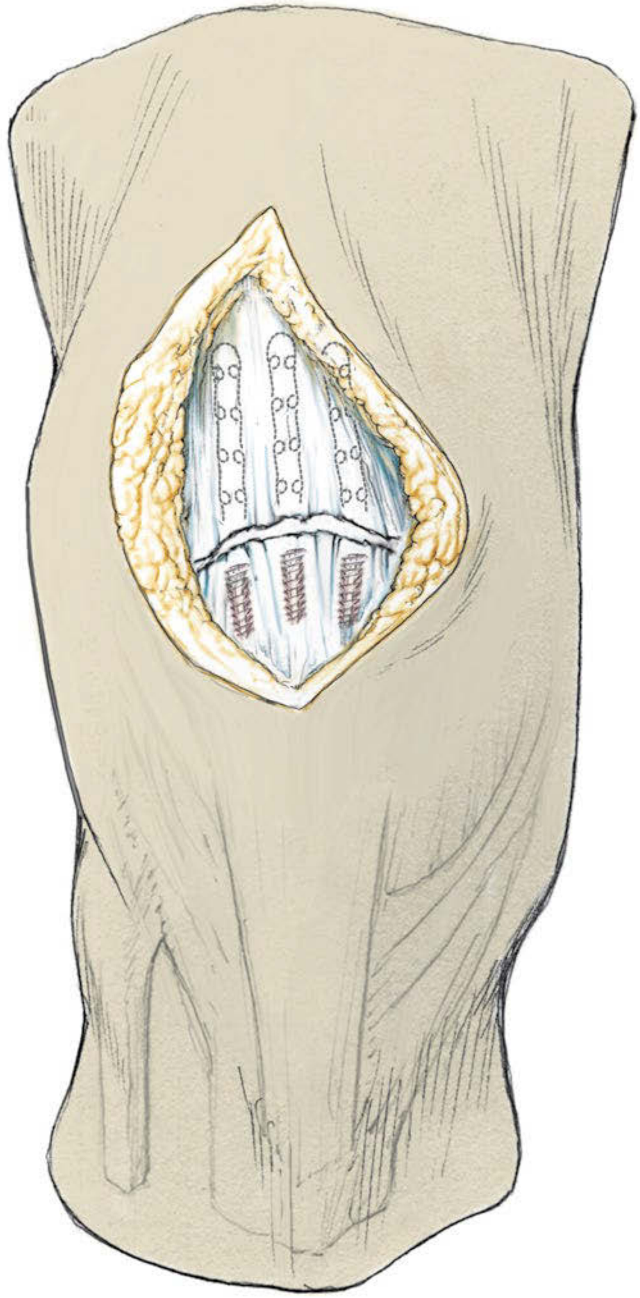


Fig. 16.4 Quadriceps tendon repaired with 3 suture anchors

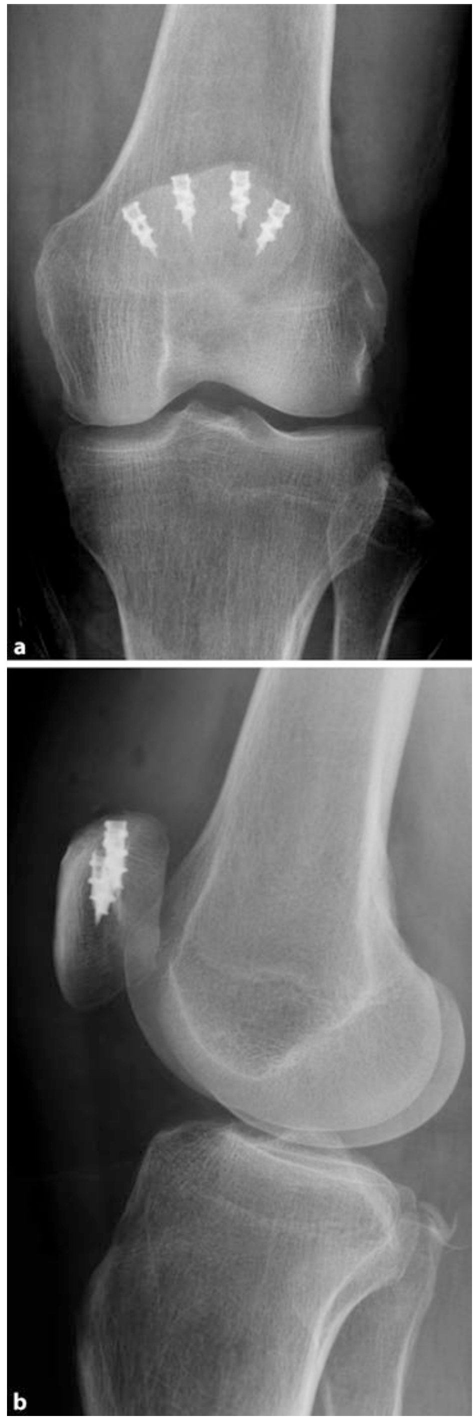


Fig. 16.5a,b Postoperative radiographs after quadriceps tendon repair using 4 metallic suture anchors **a** AP view; **b** lateral view

at the level of rupture with local tenderness and loss of the muscle tension and buckling, loss of active extension of the knee joint (lag sign) or decreased strength of extension against resistance compared to the other side.

Imaging

- X-ray of the knee joints on both sides in three views (AP, lateral, tangential patella) to exclude concomitant osseous lesions and to evaluate the height of the patella in side-to-side comparison (Insall-Salvati/Caton-Deschamps index).
- MRI to assess the lesion (complete/partial, localization, extension, retraction), evaluate the integrity of the parapatellar retinacula (reserve extensor mechanism) and exclude potential concomitant internal knee derangement.

Patient Information/Consent

Surgery-specific risks: long recovery time with restricted mobility (min. 4–6 months), weakness of the knee extension, discomfort when kneeling and limited ROM, re-rupture of

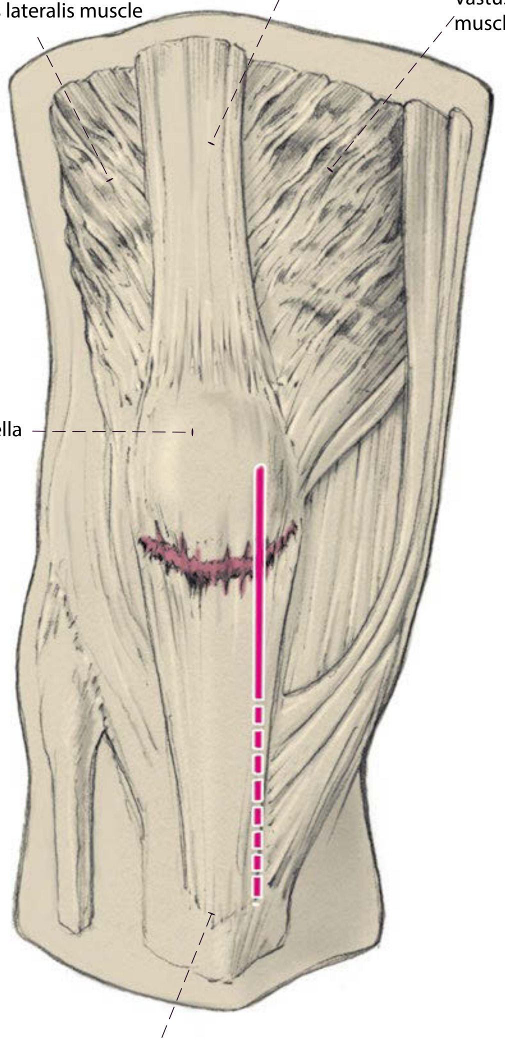


Fig. 16.6 Schematic illustration of the skin incision

the tendon, avulsion or insufficiency of the suture material, higher risk of postoperative patellar fracture, patellofemoral osteoarthritis, patella baja (infera), limited mobility of the patella.

16.2.4 Surgical Technique

Positioning and Preparation

- Supine position
- Tourniquet is applied to the thigh as proximal as possible (optionally used)
- A foot support is used to position the knee in 90° of flexion
- The contralateral leg is draped free for intraoperative adjustment of the patellar height.

Repair of the Patellar Tendon with Suture Anchors and FiberTape Cerclage

Paraligamental longitudinal incision of about 2–3 cm proximal to the inferior pole of the patella to just above the tibial tuberosity (Fig. 16.6). With distal bony avulsion of the tendon, the incision must be extended more inferiorly and not necessarily exposing the tendon origin. The entire rupture zone is exposed and the tendon stumps are mobilized and the tear zone is meticulously debrided.

If the tear extends into the parapatellar retinacula (reserve extension mechanism), they must also be repaired with absorbable sutures. The inferior patellar pole is freshened and the tendon is then repaired using 2–3 metallic suture anchors (e. g. Corkscrew 5.5 mm, Arthrex). The anchors are completely buried in the patella. The patellar tendon is then stitched securely with one suture limb (non-absorbable suture material, such as FiberWire, Arthrex) of each anchor in an ascending and descending pattern ("baseball stitches"). The tendon is then repositioned by pulling the free suture limbs (Fig. 16.7).

The knee joint should be flexed to a right angle for correct levelling of the patella. The superior patellar pole should be radiologically at the level of a tangential line to the anterior distal femoral cortex (Fig. 16.7).

Subsequent transosseous cerclage with non-absorbable suture cord (e. g. FiberTape, Arthrex) or alternatively wire cerclage is performed to stabilize the fixation construct. The patella is centrally drilled with a 2- mm drill pit transversely. A similar parallel hole is drilled through the tibial tuberosity. Suture cords are then shuttled through the holes using a Lasso system (e. g. Suture Lasso, Arthrex). The patellar height is checked again and the cerclage sutures are tied along the side close to the bone (Fig. 16.8).

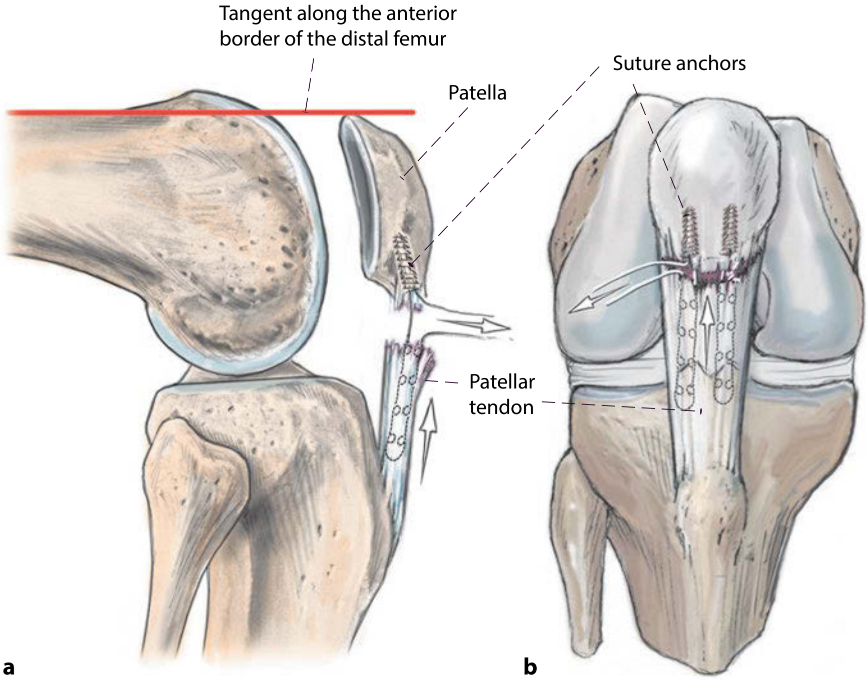
The strength of the double repair construct is checked intraoperative by passively moving the knee joint under direct visualization. A stable construct must be guaranteed with knee flexion more than 90°.

Screw Fixation and FiberTape Cerclage

Approach is as described above. A FiberTape cerclage is performed as described above and after checking the correct patellar height, the avulsed bony fragment is fixed to the tibia according to its size (using a bicortical lag screw or suture anchors). The fixation is then secured with an additional cerclage.

16.2.5 Postoperative Management

- Monitoring of peripheral circulation, motor and sensory innervation
- Use of elastic compressive bandages
- cooling of the extremity
- Postoperative radiographs of the knee joint (AP and lateral views)



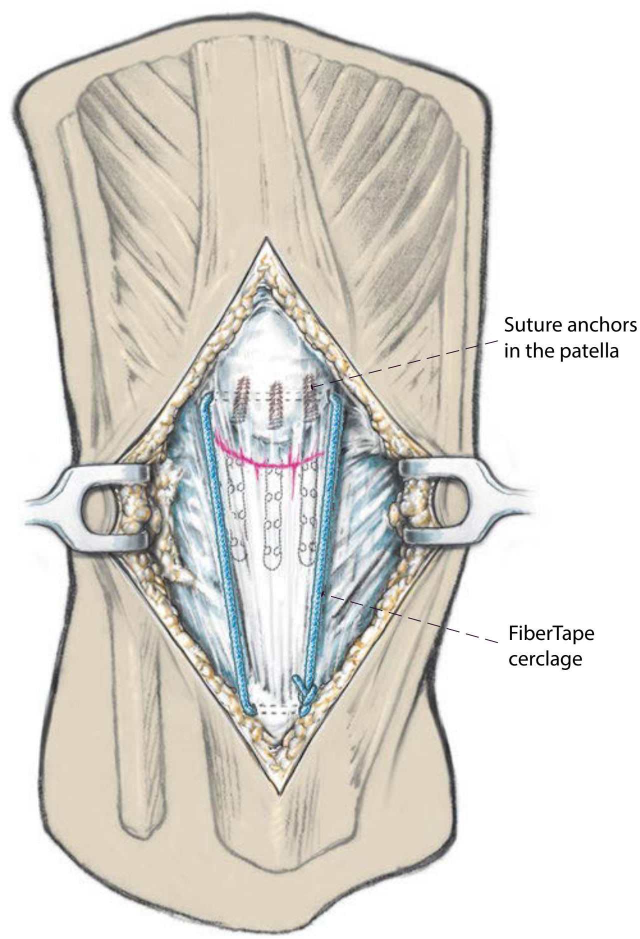
■ **Fig. 16.7a,b** Insertion of 2–3 metallic suture anchors at the upper patellar pole and stitching the patellar tendon with one suture limb of each anchor in an ascending and descending pattern. The tendon is then repositioned by pulling the free suture limbs. **a** lateral view, **b** frontal view

16.2.6 Follow-Up Management

Mobilization on crutches with only sole contact with the use of a hinged knee brace, initially maintained in the extended position for about 4–6 weeks. Early functional exercises with passive mobilization of the knee using a CPM machine up to 60° flexion from the first postoperative day, increased to 90° in the 3rd and 4th postoperative weeks. From the 7th post-operative week increased weight bearing (20 kg/week) with free ROM is started. Physiotherapeutic measures for conditioning of the proprioception and gradual strengthening of the muscles crossing the knee joint (closed chain exercises). 8–12 weeks are needed for sufficient tendon healing. For protection, the use of the hinged knee brace is recommended for up to 12 weeks postoperatively. Ergometer training can be started after about 8 weeks postoperatively, treadmill training after about 3 months. Beginning with sport-specific training after about 6 months. Return to competitive sports after 9–12 months postoperatively.

16.2.7 Tips & Tricks

Preoperative radiographs should be performed for both knee joints to assess the patellar height. The patellar height could be adjusted intraoperatively relative to the contralateral knee in 90° flexion (sterile draping of both legs is required). In addition, the patellar height should intraoperative radiologically checked, so that the superior patellar pole lies at the level of a tangent to anterior distal femur. The skin incision being medial to the tendon has the advantage of avoiding complaints to the anterior with kneeling.



■ **Fig. 16.8** Patellar tendon repaired with suture anchors and FiberTape cerclage

If the tissue quality of the patellar tendon is markedly reduced or with substantial loss of tendon, the semitendinosus tendon can be used for augmentation. To protect the tendon graft, a FiberTape cerclage is additionally used, as described above.

In patients with chronic ruptures of the patellar tendon a considerable distance between the tendon stumps may exist. In extreme cases, an external fixator may be necessary to gradually move the patella distally.

Tissue sample could be obtained for histological examination (forensic causes).

16.3 Repair of the Distal Hamstring Tendons

P. Brucker

16.3.1 Indication

Partial or complete rupture of a distal hamstring tendons (semitendinosus, semimembranosus, biceps femoris) in physically active patients with high functional demands.

Limited indication: low morbidity after harvesting the semitendinosus and gracilis tendons for ACL reconstruction.

16.3.2 Operation Principle

Suture anchor repair with complete tendon avulsion, transosseous fixation with osseous avulsion and suturing of the tendon-fascia with musculotendinous ruptures.

16.3.3 Preoperative Assessment

Diagnosis

Clinical

Symptom specific history: triggering event/trauma; typical mechanism of injury: forceful contraction of the hamstrings against resistance or forced stretching of the knee with hyperextension, acute posteromedial/posterolateral pain with loss of strength.

Symptom specific examination: swelling/bloody effusion in the in the popliteal fossa medial/lateral, proximal retraction of the affected muscle belly, palpable defect at the site of rupture.

Neurovascular Status

The peroneal nerve lies lateral to distal biceps femoris ruptures. The saphenous nerve lies medial to distal semitendinosus or semimembranosus rupture.

Imaging

- X-ray of the knee joints on both sides in two views to exclude osseous avulsions.
- MRI of the knee and thigh to confirm the diagnosis and evaluate the lesion (localization, complete vs. incomplete, retraction, muscle quality).

Patient Information/Consent

Surgery-specific risks: re-rupture and/or loosening or avulsion of the suture anchors or knots and if necessary revision surgery; intolerance/allergy to the implanted material lesion of the peroneal or saphenous nerves; decreased strength of knee flexion.

16.3.4 Surgical Technique

Positioning and Preparation

- Supine position (or alternatively prone positioning depending on the lesion).

Repair of the Distal Hamstring Tendons

Incision over the site of rupture (biceps femoris: lateral for distal ruptures, posterolateral for lesions of the musculotendinous junctions, medial side hamstrings: anteromedial for distal ruptures in the region of pes anserinus, posteromedial for lesions of the musculotendinous junctions).

The distal tendon stump or the ruptured ends are exposed and stitched with a stay suture and the insertion zone is eventually freshened. Distal ruptures are reattached using suture anchors (1–2 anchors). The tendon stump is stitched with each suture limb (e.g. FiberWire, Arthrex) in an ascending and descending pattern ("continuous locked Sutures"). Intratendinous ruptures are repaired with end-to- end sutures (e.g. Kessler sutures), lesions at the musculotendinous junction: the tendon is sutured at the tendinous site of the lesion and repaired to the fascia on the muscular site of the lesion.

16.3.5 Postoperative Management

- Monitoring of peripheral circulation, motor and sensory innervation
- Use of elastic compressive bandages
- Cooling and elevation of the extremity
- Postoperative radiographs

16.3.6 Follow-Up Management

Mobilization on crutches with non-weight bearing or partial weight bearing with 20 kg in the first 6 postoperative weeks.

Active and passive loading of the hamstrings (combined hip flexion and knee extension) is avoided in the first 6 postoperative weeks, then gradually increased weight bearing.

Resumption of treadmill training and cycling (ergometer) at about 8–12 weeks after surgery. Sport-specific training can be started from the 4th month postoperatively. Return to competitive sport after 5–6 months postoperatively.

16.3.7 Tips & Tricks

Risk of iatrogenic nerve injury: peroneal nerve with lateral/posterolateral approaches to access the distal biceps tendon lesions, saphenous nerve with medial/posteromedial approach to repair ruptures of the medial tendons (semitendinosus or semimembranosus).

Chronic partial tears of the semimembranosus at the distal musculotendinous junction have a higher risk of poorer clinical outcome if surgical treatment is delayed due to permanent muscle damage.

Assessment of the degree of fatty infiltration or the extent of retraction of the affected muscle in the MRI helps to predict the possibility of reconstruction, particularly with delayed diagnosis.

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Patella

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A. B. Imhoff, M. J. Feucht (Eds.), *Surgical Atlas of Sports Orthopaedics and Sports Traumatology,*
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17.1 Reconstruction of the Medial Patellofemoral Ligament

M. Feucht, S. Hinterwimmer

17.1.1 Indication

Symptomatic chronic patellofemoral instability without or with only mild osseous deformity (trochlear dysplasia type A and B according to Dejour, mild valgus and internal rotation deformity).

First time patellar dislocation in the presence of risk factors for recurrent dislocation (age at the first dislocation < 14 years, positive family history, Subluxation/dislocation on the opposite side, hyperlaxity, associated osseous deformities).

In higher-grade osseous deformities, reconstruction of the medial patellofemoral ligament (MPFL) is done in combination with corrective bony procedures (varus/derotational femoral osteotomy, tibial tuberosity transfer, trochleoplasty)

17.1.2 Operation Principle

Minimally invasive anatomical reconstruction of the two functional bundles of the MPFL with autologous gracilis tendon graft and direct screw fixation (Fig. 17.1).

17.1.3 Preoperative Assessment

Diagnosis

Clinical

Symptom specific history: time and mechanism of the first dislocation (traumatic, atraumatic), reduction (spontaneous, self-reduced, external help), number of recurrences, patellofemoral pain symptoms, conducted treatment to date, history of risk factors (positive family history, Subluxation/dislocation of the opposite side, age < 14 years at the first dislocation)

Symptom specific examination: inspection for the presence of valgus deformity, alignment of the patellae ("grasshopper" sign), atrophy of the vastus medialis obliquus, abnormal internal rotation of the legs with walking, ratio of the hip internal rotation to the external rotation (> 1 indicates increased femoral anteversion angle), patellar compression pain and tenderness on palpation of the under surface, patellar tracking, medio-lateral mobility of the patella, apprehension test in different degrees of flexion, J-sign, Ober's test to assess tightness of the iliotibial tract.

Imaging

- X-ray of the knee joint in three views (AP, lateral, tangential patella) to exclude osseous lesions and to assess the specific morphological parameters: patellar height (Insall-Salvati or Caton index) trochlear dysplasia ("crossing sign": overlapping between the trochlear sulcus and the lateral femoral condyle), patellar tilt and shift, sulcus angle, Patellar tilt and -shift, sulcus angle
- Long leg standing AP view if valgus deformity is suspected.
- MRI to assess the MPFL, cartilage status, trochlear shape (Dejour), TTTG distance (distance between the tibial tuberosity and the trochlear groove), patellar tilt and shift.
- CT rotation analysis if internal rotation deformity is suspected (MRI rotational analysis can be alternatively performed in very young patients).

Patient Information/Consent

Graft and material failure, redislocation, patellar fracture, limitation of motion, patellofemoral pain, possible donor site morbidity after harvesting the gracilis tendon, saphenous nerve injury.

17.1.4 Surgical Technique

Positioning and Preparation

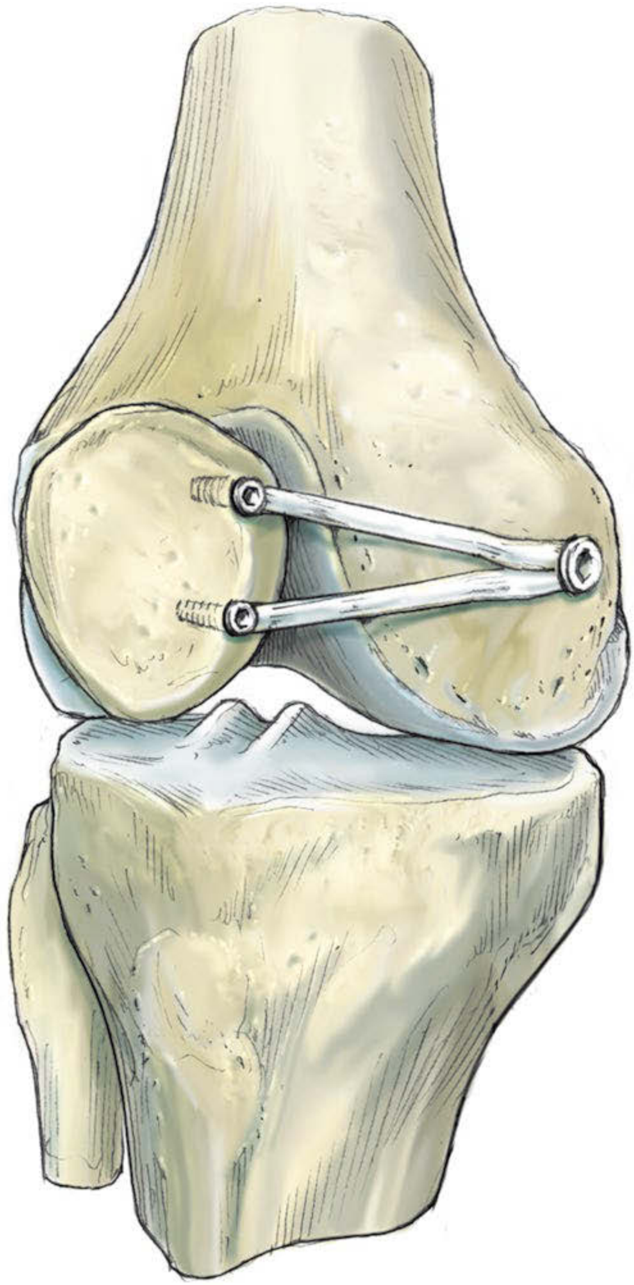
- Supine position
- A thigh tourniquet is applied
- Examination under anesthesia (degree of instability)

Anatomical MPFL Reconstruction in Double Bundle Technique and Direct Anatomical Screw Fixation ("Aperture Fixation")

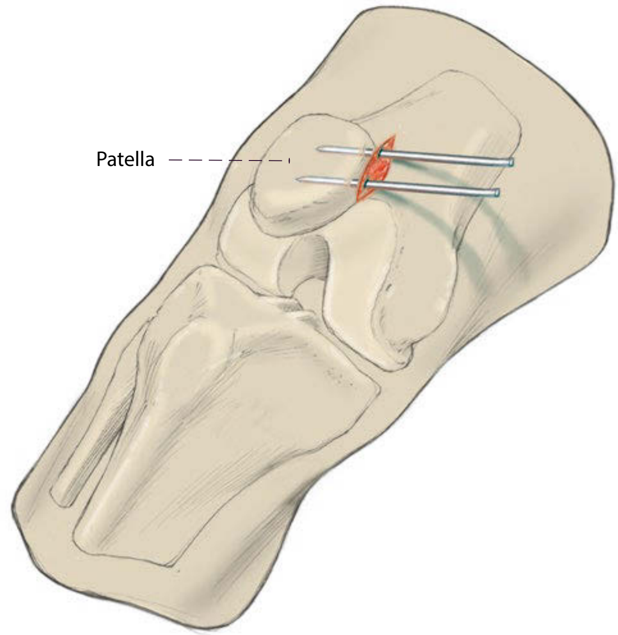
Arthroscopy is performed to assess the condition of cartilage and the trochlear shape. Harvesting and preparation of the gracilis with the technique described in ▶ Sect. 13.1. Whipstitching about 1 cm at both ends of the tendon. For the double bundle technique, a graft of at least 18 cm length is needed.

A 2 cm skin incision over the superior half of the medial patellar facet is made followed by dissection and exposure of the medial border of the patella.

Two Kirschner wires are tangentially drilled into the patella at the proximomedial corner and about 15–20 mm distal to it (Fig. 17.2). Overdrilling the wires with a cannulated 4 mm drill bit to a depth of 2 cm. The sutures of one graft end are passed through the eyelet of a tenodesis screw (e.g. SwiveLock™ 4.75 mm, Arthrex). The screw is inserted into one of the drill holes in the patella while maintain the tension on the sutures. The procedure is repeated with the second graft end (Fig. 17.3).



■ **Fig. 17.1** Anatomical MPFL reconstruction with double bundle technique and direct screw fixation



■ **Fig. 17.2** Placement of two guide wires at the patellar insertion of the MPFL

The central part of the vastus medialis obliquus is exposed and dissected from the underlying layer (second layer of the medial capsuloligamentous complex) towards the medial epicondyle with preservation of the deep capsule (third layer).

Image intensifier is used to accurately determine the femoral insertion point in the lateral view. A stab incision is made over this point and a guide pin with an eyelet is inserted under fluoroscopic control across the femur out through to the opposite cortex and skin of the thigh (■ Fig. 17.4).

The direction of drilling should be ascending from medial-distal towards lateral-proximal to avoid penetration of the notch. Overdrilling the guide wires with a cannulated reamer up to the opposite cortex.

The diameter of the reamer is determined according to the diameter of the graft loop, usually about 6 mm. The guide wire is left in place. A suture loop is passed between the second and third layers of the medial capsuloligamentous complex and used to pull the graft out to the femoral insertion (■ Fig. 17.5).

A Nitinol guide wire is placed into the femoral drill hole and the graft is pulled with help of the guide wire in the femoral drill hole (■ Fig. 17.6a) using a clamp as a pulley. Fixation of the graft with a Bio-Interference screw (the same diameter as that of the drill hole) in 30° knee flexion (■ Fig. 17.6b). During Fixation, the graft is tensioned so that the lateral patellar facet is flush with the edge of the lateral femoral condyle (■ Fig. 17.7). Final assessment of the full range of motion and the stability of the patella.

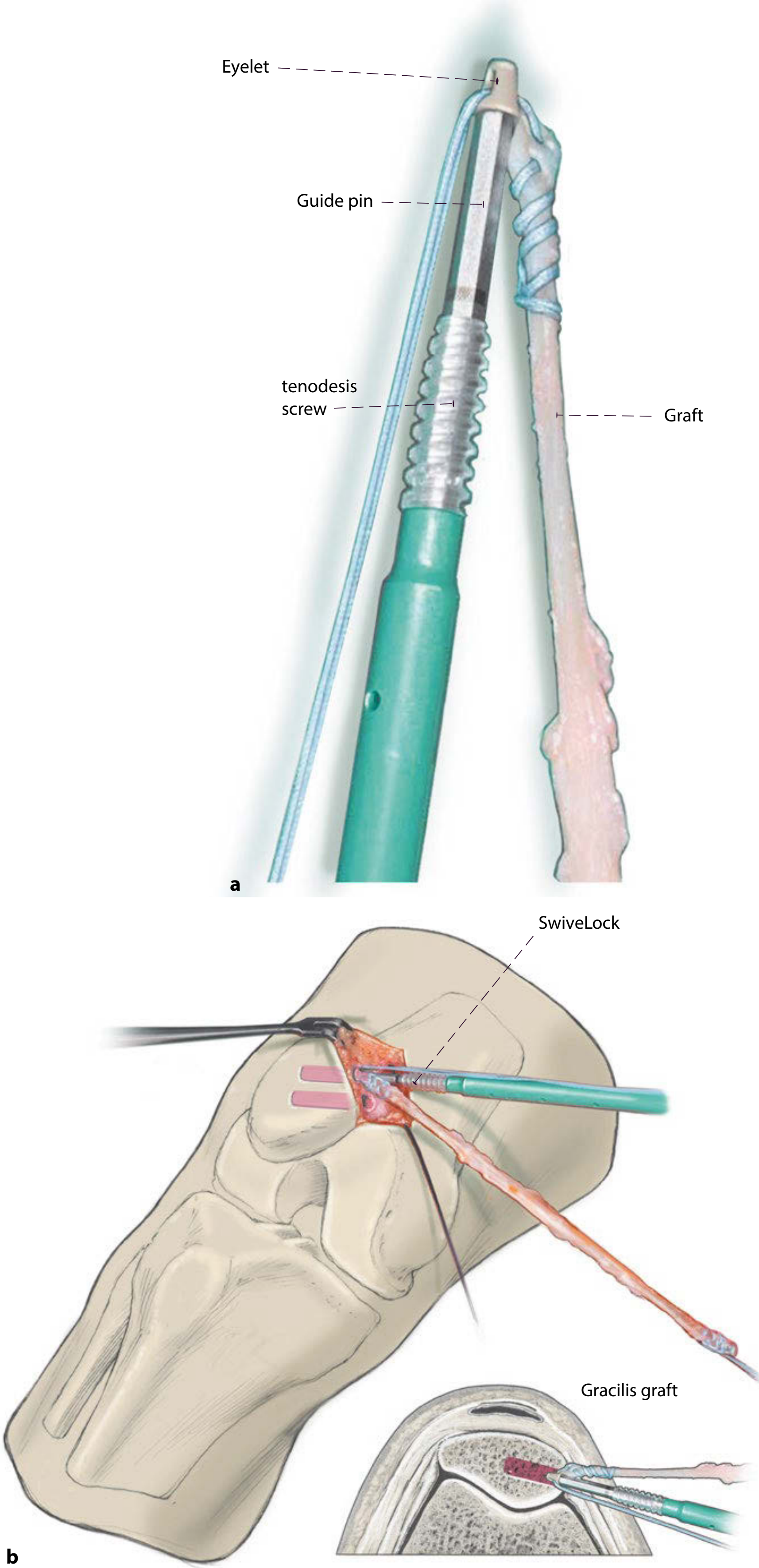


Fig. 17.3a,b **a** Passing the suture tail of one tendon end through eyelet of a tenodesis screw (SwiveLock). **b** fixation in one of the patellar drill holes . The other graft end is fixed in the 2nd drill hole in the same technique

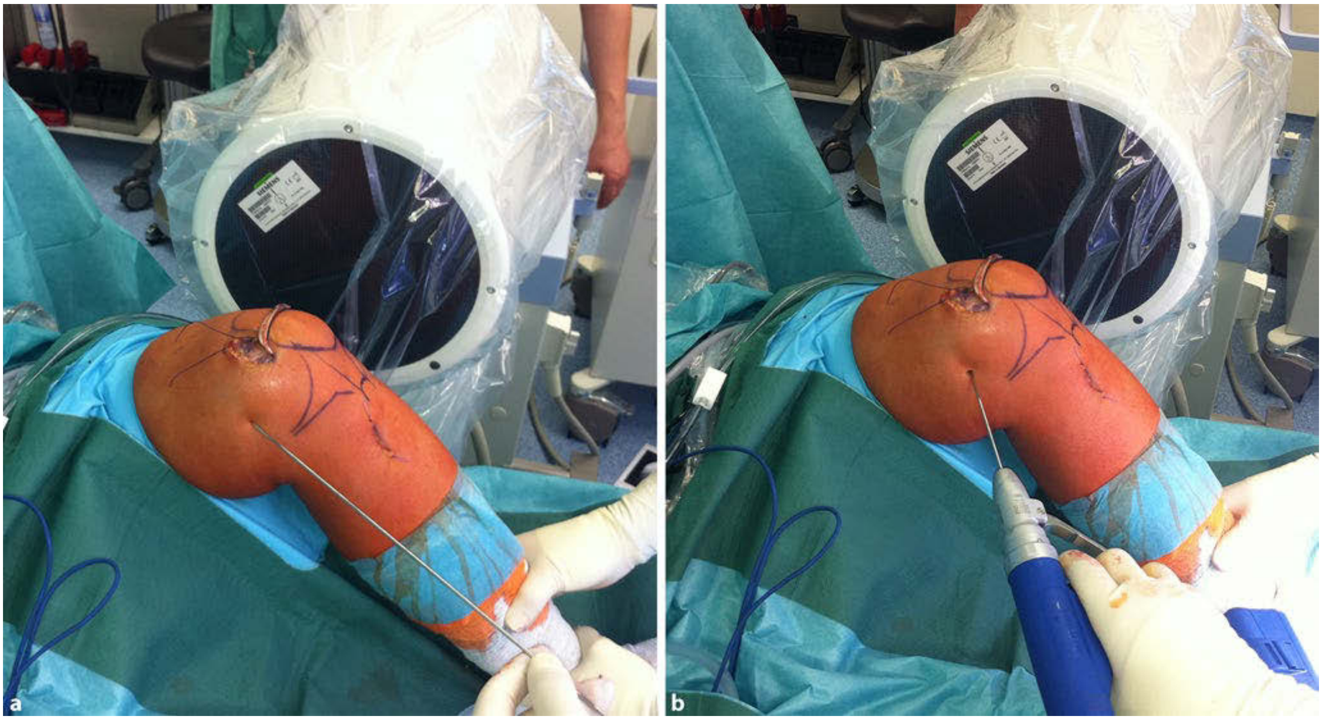
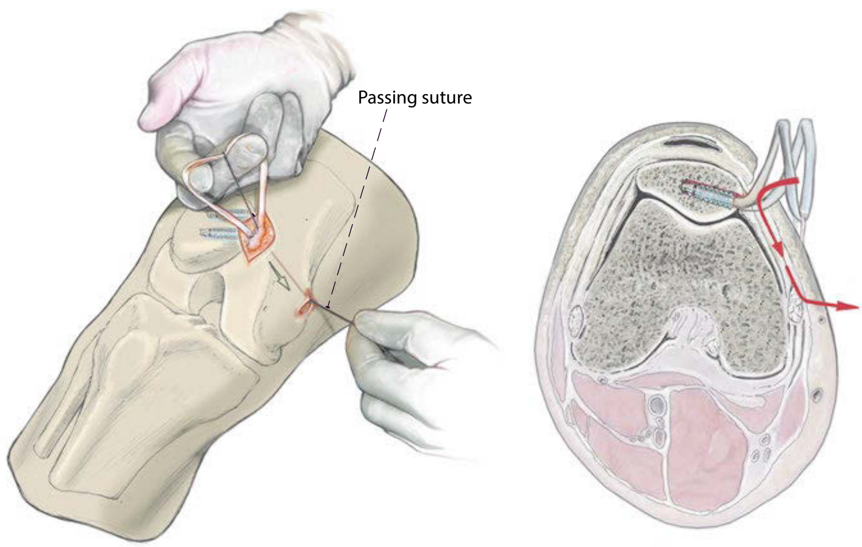


Fig. 17.4a,b **a** Localization of the femoral insertion **b** Insertion of the guide wire under fluoroscopic control

Fig. 17.5 Pulling the graft loop to the femoral side between the second and third layers of the medial capsuloligamentous complex



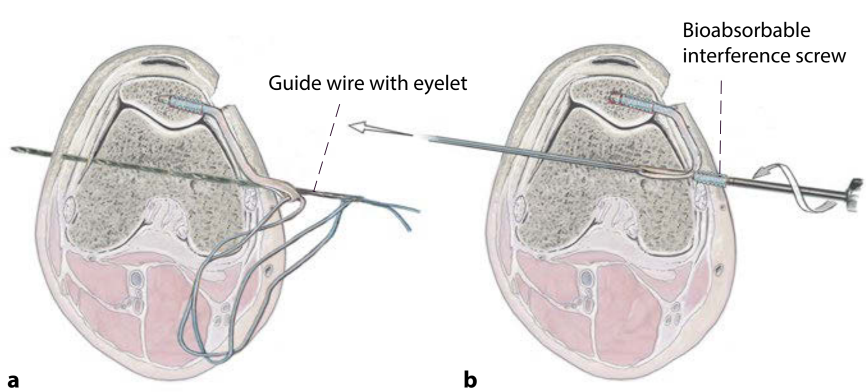


Fig. 17.6a,b **a** Pulling the graft loop through the femoral drill hole using the already placed guide wire **b** fixation with a Bio-Interference screw

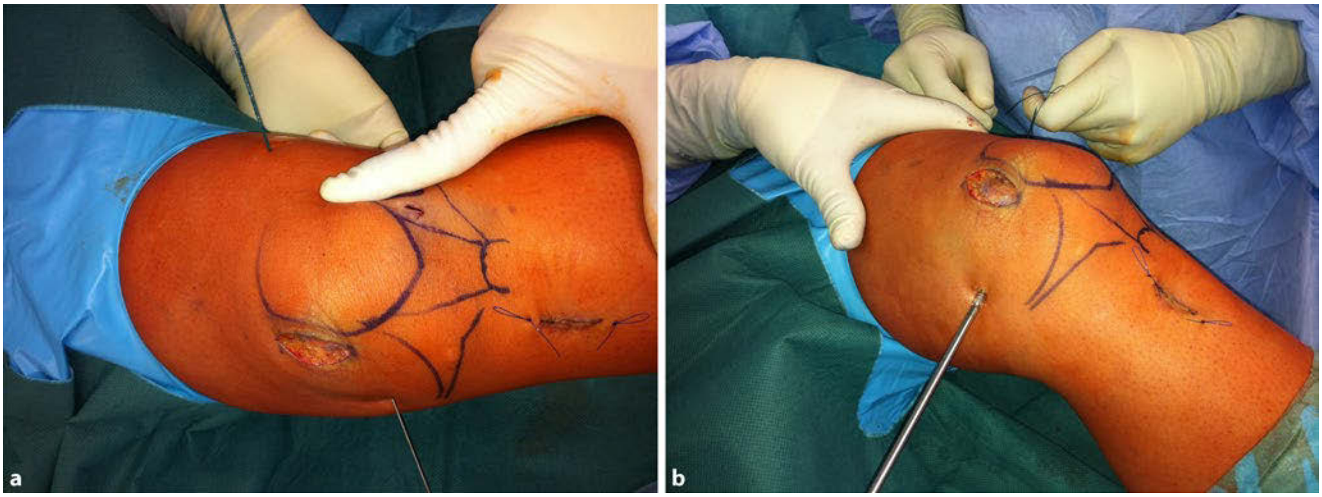


Fig. 17.7a,b Femoral fixation of the graft. **a** The ideal graft tension is determined by palpating the border of the patella and the lateral femoral condyle. The edge of the lateral patellar facet should be flush with the edge of the lateral femoral condyle. **b** After correct tensioning of the graft, femoral fixation is performed with a Bio-Interference screw in 30° flexion

17.1.5 Postoperative Management

- Monitoring of peripheral circulation, motor and sensory innervation
- Use of elastic compressive bandages
- cooling of the extremity
- Postoperative radiographs

17.1.6 Follow-up Management

A 4-point hard frame knee brace is used for 6 weeks. Partial weight bearing with 20 kg in 1st–2nd postoperative week, limitation of movement in the first 6 postoperative weeks to flexion/extension 90°/0°/0°. Light activities such as walking or cycling can be started after 6 weeks. Sport-specific training after 3 months.

17

17.1.7 Tips & Tricks

The correct anatomical femoral insertion must be respected to avoid postoperative increase of the patellofemoral pressure as well as flexion deficit. The femoral insertion is located on true lateral radiographs just anterior to the posterior cortex extension line, between the proximal border of the medial condyle and the most posterior point of the Blumensaat's line (Fig. 17.8).

Reconstruction of the MPFL alone is not sufficient in cases with severe bony deformities (trochlear dysplasia type C and D according to Dejour, femoral anteversion > 20°, valgus deformity > 5°, TTTG-distance > 20 mm). In such cases, the underlying deformity must be corrected before or with the MPFL reconstruction.

The anterior cortex and the patellar cartilage should not be penetrated and this can be confirmed by probing the patellar drill holes with a K-wire.

The femoral fixation screw must be inserted to just below the cortex to avoid postoperative soft tissue irritation. This can be checked by palpating the screw head with a forceps. The lateral side of the screw head is encountered with the forceps within the bone when the screw is sunk far enough (Fig. 17.9).

The Nitinol wire in the femoral drill hole should be removed only after assessment of the full ROM and the position of the patella. If the motion is limited or the MPFL is very tight and the femoral fixation screw must be removed, this would be very much easier if the Nitinol wire is still in place.

17.2 Trochleoplasty

G. Meidinger, S. Hinterwimmer

17.2.1 Indication

Indications: Chronic patellofemoral instability associated with high grade trochlear dysplasia (Dejour types C/D)

Contraindications: chondral lesions of the trochlea and the patella, open growth plate.

17.2.2 Operation Principle

Deepening and lateralization of the medialized flat to convex shaped trochlea and thus ensuring restoration of the physiological sliding of the patella between 10° and 30° flexion without tendency for lateralization.

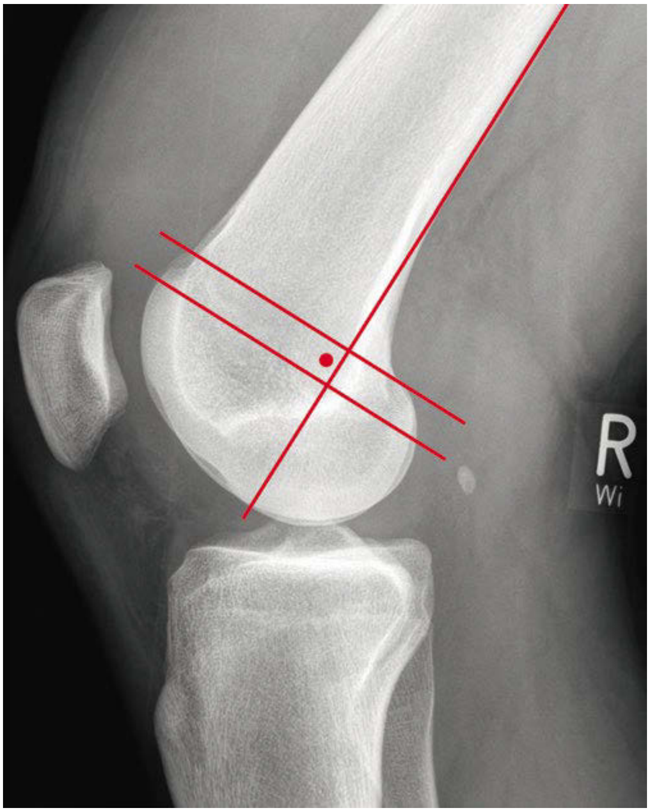


Fig. 17.8 Anatomical femoral insertion of the MPFL as described by Schoettle

Fig. 17.9 palpation of the depth of insertion of the femoral screw with a forceps

17.2.3 Preoperative Assessment

Diagnosis

Clinical

Symptom specific history: timing and mechanism of the first dislocation, number and frequency of recurrent dislocations, previous surgery, pain, family history, instability of the opposite side

- Symptom-specific investigation: inspection to assess the gait and the leg axis, position of the patella in standing and sitting (Grasshopper sign), internal rotation of the feet while lying down (intoeing), apprehension sign in different degrees of flexion (0–90°), J-Sign, reverse J-Sign, medial and lateral patellar mobility, patellar hypercompression pain, facet tenderness, patellofemoral crepitus, extension of the leg against resistance at 90°, 60°, 30° and 0° to clinically assess and localize the area of cartilage damage, assessment of the degree of tightness of the iliotibial band (Ober's test) and the rectus femoris muscle (heel-to-buttock distance), evaluation of an increased internal rotation of the hip/anteversion of the femur in the prone position (Craig-test).

Imaging

- X-ray of the knee joint in three views (AP, lateral, tangential patella) to assess the epiphyseal plates, exclusion of degenerative changes and assessment of specific morphological parameters: patellar height (Insall-Salvati or Caton index), trochlear dysplasia (crossing sign: overlapping of the trochlear sulcus and the lateral femoral condyle), patellar tilt and shift, sulcus angle
- Long Leg standing radiograph AP view with suspected valgus deformity
- MRI to assess the trochlear morphology (according to Dejour classification) and the patellofemoral cartilage status, condition of the MPFL, patellar tilt and shift, TTTG-distance (distance between the tibial tuberosity and the trochlear groove)
- CT rotational scan with suspicion of internal rotation deformity (MRI rotational analysis can be alternatively performed in very young patients).

Patient Information/Consent

Surgery-specific risks: lack of healing and detachment of the osteochondral flap, chondrolysis, secondary medial patellar instability with insufficient lateral closure, arthrofibrosis, osteoarthritis.

17.2.4 Surgical Technique

Positioning and Preparation

- Supine position
- A thigh tourniquet is applied
- Examination under anesthesia to assess the instability in different degrees of flexion.

Trochleoplasty

A lateral parapatellar approach is followed by a lateral arthrotomy. The patella is retracted medially in full extension of the knee to expose the trochlea.

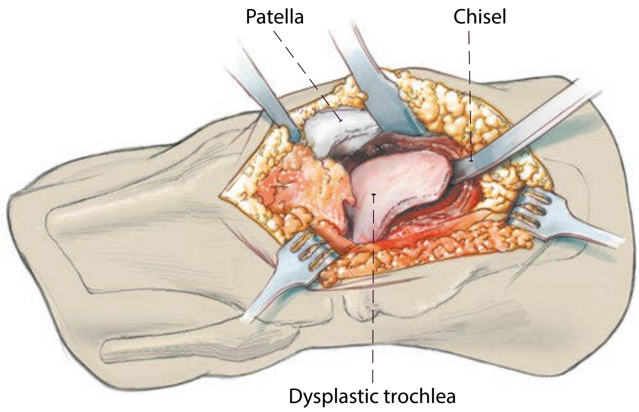


Fig. 17.10 Elevation of an osteochondral flap with about 2 mm thick subchondral bone layer

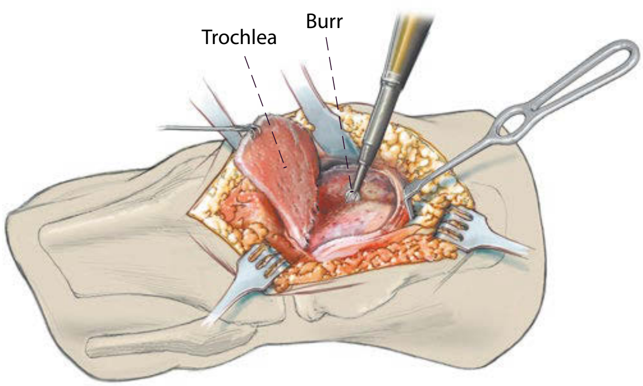


Fig. 17.11 Deepening and lateralization of the trochlear groove using a high-speed burr

The cartilaginous margins of the trochlea are sharply dissected from the adherent synovium. An osteochondral flap is elevated using curved and straight periosteal elevators and osteotomes from proximal to about 5 mm above the more distally extending, so that a subchondral bone layer of about 2 mm thickness should be left (Fig. 17.10). Extreme care must be taken that the flap is elevated in one piece and the cartilage is not perforated.

Osteotomes and a high-speed bur are used to reconstruct the edges of the trochlea by deepening and lateralization into the subchondral bone of the dysplastic trochlea (Fig. 17.11). Extreme care must be taken to meticulously elevate the flap as one piece and not to perforate the cartilage. The physiological anatomy of the trochlea should be considered, where the trochlear groove is wide and flat and increase in its depth distally.

During elevation of the osteochondral flap, the prominent subchondral bone is resected, so that the flap can be curved and adapted to the new trochlear shape. After molding the osteochondral flap to the newly created trochlea, fixation is done using two 3 mm broad Vicryl tapes, from the deepest point of the groove and in a U-shaped pattern extending from proximal to distal. The ends of the Vicryl tapes are passed laterally through 3 drill holes in the lateral femoral condyle and

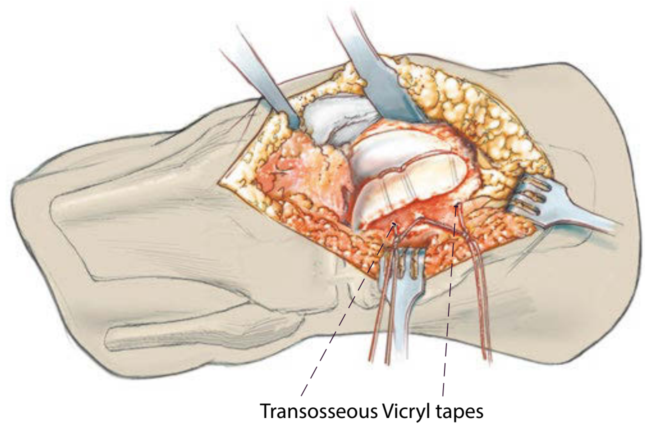


Fig. 17.12 Refixation of osteochondral flap into the newly reconstructed trochlea with the Vicryl tapes passed laterally

knotted (Fig. 17.12). Alternatively, the Vicryl tapes can be fixed using 3 bioabsorbable anchors (e. g. 3.5 mm SwiveLock or PushLock, Arthrex) (Fig. 17.13). Finally, the synovium is reattached with absorbable sutures to the marginal cartilage.

17.2.5 Postoperative Management

- Cooling and elevation of the operated extremity
- Use of elastic compressive bandages
- Postoperative radiographs

17.2.6 Follow-up Management

A 4-point hard frame knee brace is used for 6 weeks (24 hours/day). Limitation of active ROM in the 1st and 2nd postoperative weeks to flexion/extension: 60°/20°/0° with total non-weight bearing on the operated leg. Increased flexion/extension to 90°/10°/0° in the 3rd–6th postoperative weeks with only sole contact allowed. From the 7th postoperative week free ROM is allowed with gradual weight bearing at a rate of 20 kg/week.

17.3 Lateral Release and Lateral Retinaculum Lengthening

G. Meidinger, S. Hinterwimmer

17.3.1 Indication

Lateral patellar hypercompression not associated patellar instability or patellofemoral osteoarthritis.

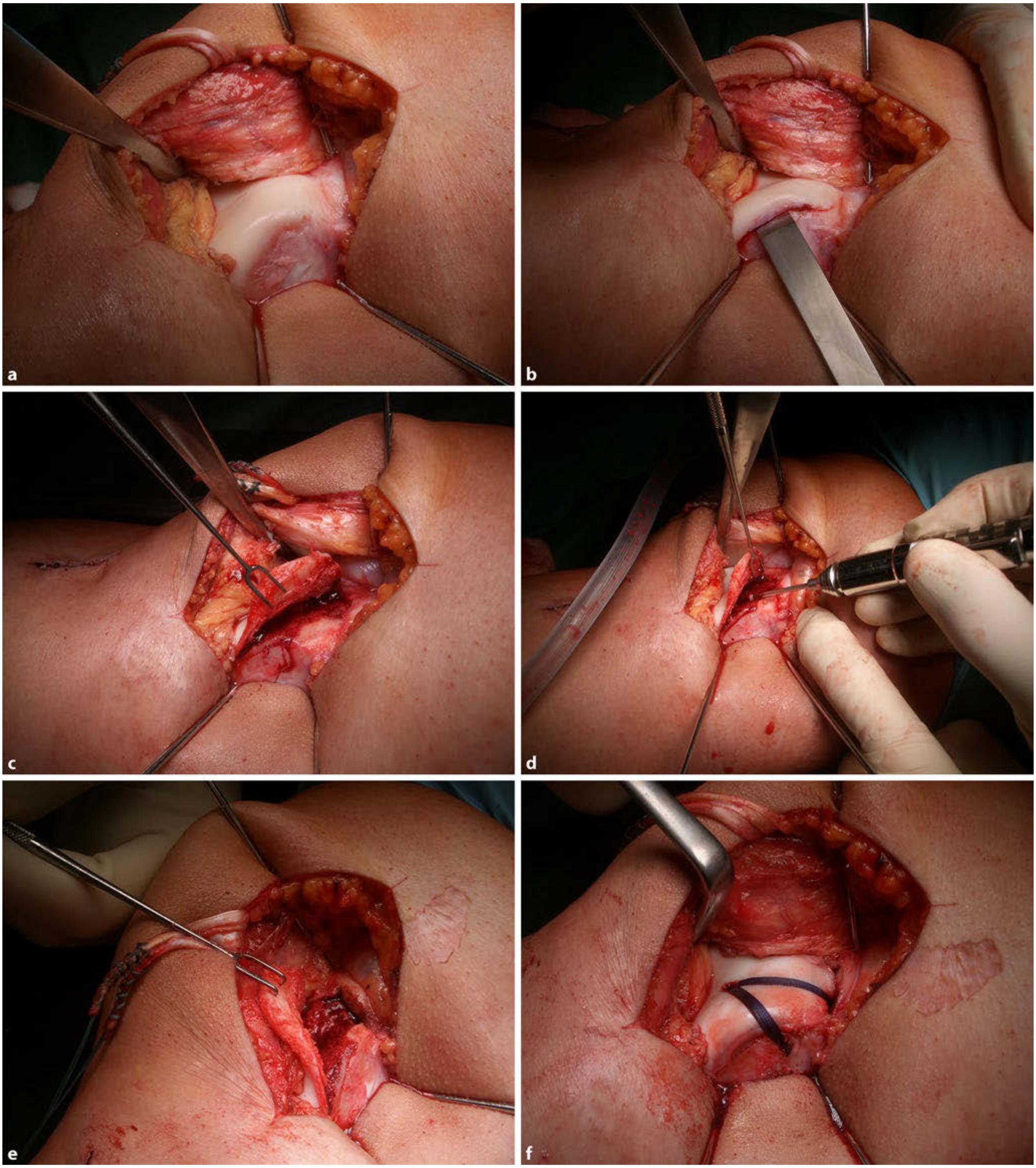


Fig. 17.13a–f Trochleoplasty **a** Exposure of the dysplastic trochlea; **b** preparation of the osteochondral flap; **c** elevation of the osteochondral flap; **d** creation of a trochlear groove in the subchondral bone with a high-speed burr; **e** newly created trochlear groove; **f** Refixation of osteochondral flap with a Vicryl tape and 3 bioabsorbable anchors

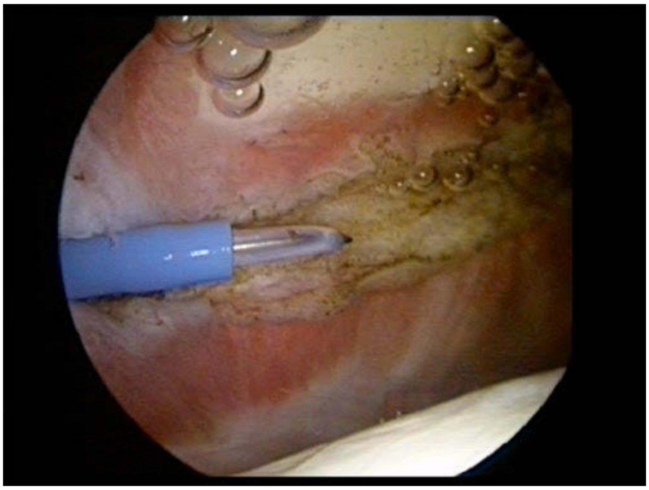


Fig. 17.14 Arthroscopic lateral release with a hooked electrode

17.3.2 Preoperative Assessment

Releasing the two layers of the lateral retinaculum either open or arthroscopically (including the capsule of the knee joint) without subsequent closure to reduce the lateral compression.

With lateral retinaculum lengthening, the lateral retinaculum is closed with a Z-plasty to avoid a secondary medial patellar instability.

17.3.3 Preoperative Preparation

Diagnosis

Clinical

Symptom specific history: Beginning and cause of the symptoms, injuries, previous surgeries, patellar instability, locking

Symptom specific examination: inspection of the gait and leg alignment, medial and lateral mobility of the patella in supine position, palpation of the lateral border of the patella and the lateral retinaculum, patellar hypercompression pain, patellar facet tenderness, patellofemoral crepitation, leg extension against resistance in 90°, 60°, 30° and 0° to clinically localize the site of the chondral lesion, evaluation of the degree of the tightness of the iliotibial band (Ober's test) and of the rectus femoris (heel-to-buttock distance), apprehension test in different degrees of flexion (0–90°) and (reversing) J-Sign to exclude patellar instability.

Imaging

- X-ray of the knee joint in three views (AP, lateral, tangential patella) to assess degenerative changes/signs of osteoarthritis, patellar tilt and shift.
- MRI to assess the trochlear morphology, patellofemoral cartilage, patellar tilt and shift, TTTG distance.

Patient Information/Consent

Surgery-specific risks: medial patellar instability, postoperative bleeding, mostly if the superior lateral genicular artery is injured, thermal skin injury with the arthroscopic procedure, persistent or progression of symptoms.

17.3.4 Surgical Technique

Positioning and Preparation

- Supine position
- A thigh tourniquet is applied
- Examination under anesthesia to exclude patellar instability.

Lateral Retinacular Release

Arthroscopy is first performed via the standard approaches to evaluate the cartilage status as well as other intraarticular structures of the knee. When the lateral retinaculum release is performed arthroscopically, the joint capsule as well as the deep and superficial layers of the lateral retinaculum are successively divided with an electro-thermal device (Fig. 17.14). Release begins lateral parapatellar and, if necessary, is extended proximally up to the insertion of the muscle fibers of the vastus lateralis and distally.

With the open technique, a vertically oriented lateral parapatellar skin incision of about 2.5 cm is performed followed by dividing both layers of the lateral retinaculum with protection of the knee joint capsule and if necessary, may be extended proximally or distally.

Lateral Retinacular Lengthening

The approach for the lateral retinacular lengthening is identical to that used for open lateral release. The superficial layer of the lateral retinaculum is cut about 1 cm to the lateral patellar border (Fig. 17.15). The superficial layer is meticulously dissected from the deep layer in a dorsal direction followed by dividing the deep layer about 2 cm dorsal to the superficial layer cut with extreme care to protect the joint capsule (Fig. 17.16). The two layers are displaced and sutured to each other in a tension free manner as a z-plasty with the knee flexed 80° (Fig. 17.17).

The aim of this procedure is to mobilize the patella reducing the lateral patellar hypercompression and avoiding a secondary medial patellar instability.

Alternatively, a periosteal flap may be used for reconstruction. After open lateral retinacular release, a periosteal flap is dissected from the anterior patellar surface and reflected laterally und sutured in a tension free manner to the anterior edge of the dorsal part of the cut lateral retinaculum.

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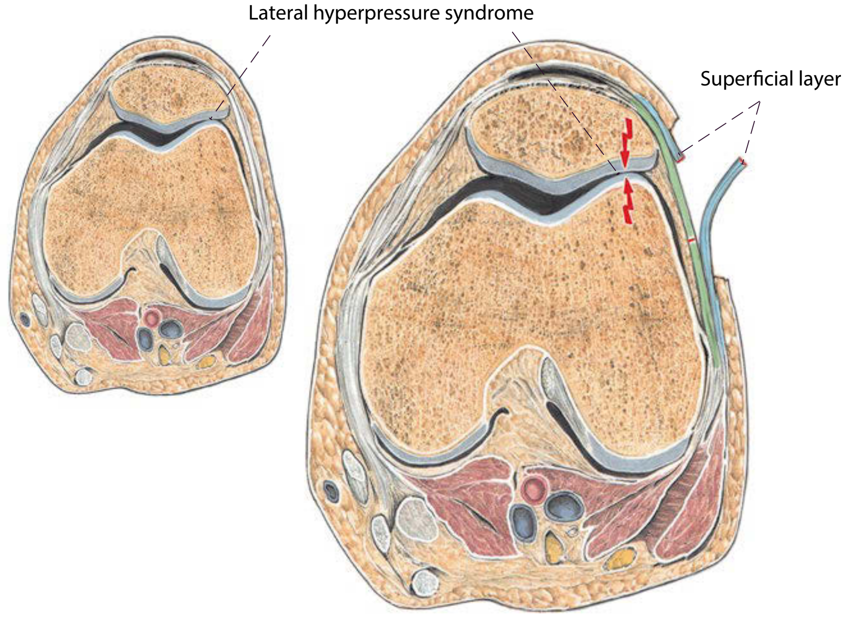

Fig. 17.15 Parapatellar cutting of the superficial layer of the lateral retinaculum

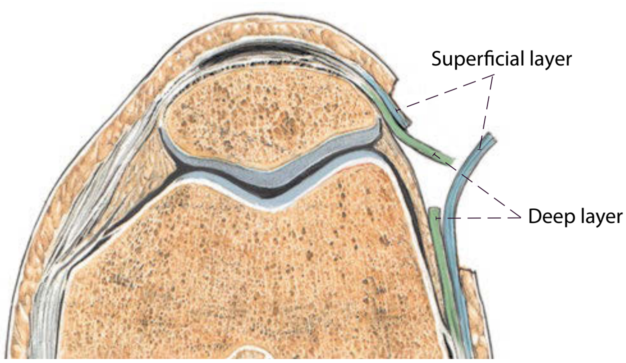

Fig. 17.16 Cutting the deep layer of the lateral retinaculum more dorsally

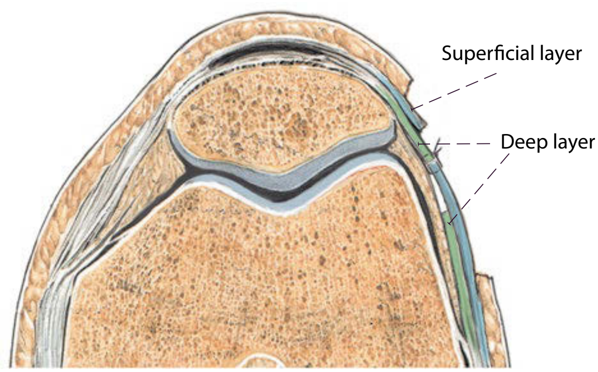

Fig. 17.17 Tension-free suturing of the ventral part of the deep layer to the dorsal part of the superficial layer resulting in lengthening of the lateral retinaculum

17.3.5 Postoperative Management

- Monitoring of the peripheral circulation, motor and sensory innervation
- Cooling and elevation of the extremity

17.3.6 Follow-up Management

Lateral release: full active mobility is allowed from the first postoperative day. Partial weight bearing with 20 kg using crutches for 2 weeks postoperatively followed by gradual weight bearing at a rate of 20 kg/week.

Lateral retinacular lengthening: A four-point hard knee brace is used for 6 weeks. Partial weight bearing with 20 kg in the 1st and 2nd postoperative weeks. ROM is limited in the 1st and 2nd postoperative weeks to flexion/extension: 30°/0°/0°, increased to 60°/0°/0° in the 3rd and 4th weeks and to 90°/0°/0° in the 5th and 6th weeks.

17.3.7 Tips & Tricks

The patellar mobility in extension should not postoperatively exceed one fourth of the patellar width medially or laterally.

Lateral release should be initially very cautiously performed and can be gradually deepened as required or extended proximally or distally according to the intraoperative findings.

With the arthroscopic release, skin burn from the intraarticular electerothermal device must be avoided.

The superior lateral genicular artery must be protected to avoid postoperative bleeding. This artery runs approximately 2.5 cm proximal to the superolateral border of the patella.

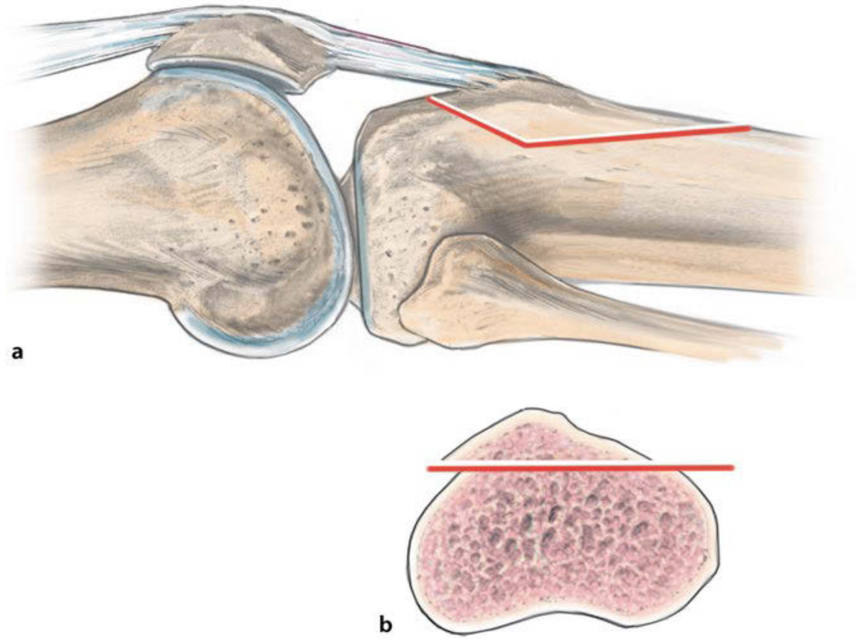

Fig. 17.18a,b After a V-shaped osteotomy, the tibial tuberosity can be displaced medially in its bed without changes in patellar height (**a**, lateral view; **b**, axial view)

17.4 Tibial Tuberosity Transfer

S. Hinterwimmer

17.4.1 Indication

Patellar instability with pathologically increased TTTG-distance (> 20 mm) and Q-angle (> 20°), patellofemoral hypercompression or patella infera refractory to conservative treatment.

17.4.2 Operation Principle

Medialization, proximalization or anteriorization of the tibial tuberosity. Combined medialization and proximalization. In each procedure, the change in patellar tracking and sliding in the trochlea leads to stabilization and relief of the hypercompression or increase in the range of flexion.

17.4.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: Characteristics (instability, pain, limitation of motion), onset and duration of symptoms, previously conducted treatment, previous surgery
- Symptom specific examination: inspection of the lower limb and patellar alignment in standing and walking, exclusion inwardly pointing knee, assessment of the position of the tibial tuberosity, evaluation of the range of motion, apprehension sign, palpation of the patellar undersurface both medially and laterally and assessment of any resulting provocation of pain.

Imaging

- X-ray of the knee joint in 3 views (AP, lateral and tangential patella) to assess the patellar height (according to Insall & Salvati or Caton), patellar tilt and shift as well as the degree of osteoarthritis.
- Standing long leg X-ray AP with suspected malalignment.
- MRI to assess the cartilage condition, measure the TTTG distance (distance between the tibial tuberosity and the trochlear groove) and evaluation of the trochlear morphology according to Dejour.

Patient Information/Consent

Surgery-specific risks: over-correction with marked medialization or proximalization of the tibial tuberosity resulting in marked patellofemoral pressure and consequently osteoarthritis or weakness at the terminal degrees of extension; risk of recurrent distal displacement of the patella owing to fibrosis of the patellar tendon; delayed union of the osteotomy, fracture of the osteotomized fragment, breakage of the screws with required revision surgery; discomfort from the screw heads.

17.4.4 Surgical Technique

Positioning and Preparation

- Supine position
- A thigh tourniquet is applied
- Examination under anesthesia (patellar instability and ROM).

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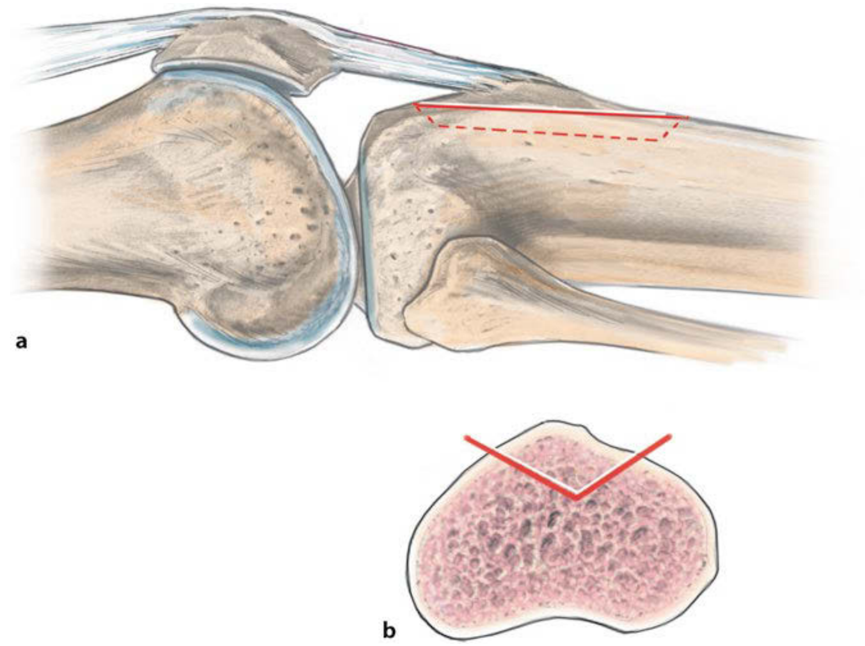

■ **Fig. 17.19a,b** V-shaped osteotomy of the tibial tuberosity. **a** lateral view, **b** axial

Medialization of the Tibial Tuberosity (Elmslie–Trillat Technique)

A longitudinal skin incision of 6–8 cm length just lateral to the tibial tuberosity is used. The patellar tendon, the tibial tuberosity and the anterior border of the tibia distal to the tibial tuberosity are exposed. The patellar tendon is protected using a Langenbeck retractor placed under the patellar tendon at its bony insertion. A v-shaped osteotomy of the tibial tuberosity is performed from the lateral aspect with the short limb of the v located proximally and the long limb distally (■ Fig. 17.18a). The osteotomized tuberosity fragment can then be displaced medially in its bed without change of the patellar height (■ Fig. 17.18b).

The capsular tissue medial and lateral to the patellar tendon must be released for better mobilization of the tuberosity. The amount of correction is checked after temporary fixation with two Kirschner wires and repeatedly moving the knee and observing the patellar movement and tracking. Definitive fixation is achieved with 2 compression screws.

Proximalization the Tuberosity

A Longitudinal skin incision of 6–8 cm length just lateral to the tibial tuberosity starting from the level of insertion of the patellar tendon and extending distally. The patellar tendon, the tibial tuberosity and the anterior border of the tibia distal to the tibial tuberosity are exposed. A Langenbeck retractor is placed underneath the patellar tendon to protect it. A v-shaped osteotomy is done in the axial plane (medial and lateral limbs, so-called quill osteotomy) (■ Fig. 17.19). The osteotomy must be completed distally with a transverse osteotomy. The capsular tissue medial and lateral to the patellar tendon must be released for better proximal mobilization of the osteotomized tuberosity. Temporary fixation of the tuberosity with two Kirschner wires after achieving the desired height target is replaced with the definitive final fixation with 2 compression screws.

Anteriorization the Tuberosity (Maquet Technique)

A Longitudinal skin incision of 6–8 cm length just lateral to the tibial tuberosity is used. The patellar tendon, the tibial tuberosity and the anterior border of the tibia distal to the tibial tuberosity are exposed. The patellar tendon is protected using a Langenbeck retractor placed underneath the patellar tendon at its bony insertion.

Frontal osteotomy of the tibial tuberosity from lateral towards medial and extending about 5 cm caudally is done. The osteotomy should be about 1 cm thickness in the anteroposterior direction proximally at the level of the tendon insertion and tapers distally so that a distal hinge remains intact and the tuberosity can be tilted anteriorly.

The resultant gap can be filled with autologous bone from the iliac crest (tricortical block) (■ Fig. 17.20). Temporary fixation of the tuberosity with two Kirschner wires after achieving the desired anteriorization target is replaced with the definitive final fixation using 2 compression screws.

Anteromedialization of the Tibial Tuberosity (Fulkerson Technique)

A Longitudinal skin incision of 6–8 cm length just lateral to the tibial tuberosity is used. The patellar tendon, the tibial tuberosity and the anterior border of the tibia distal to the tibial tuberosity are exposed. The patellar tendon is protected using a Langenbeck retractor placed underneath the patellar tendon at its bony insertion.

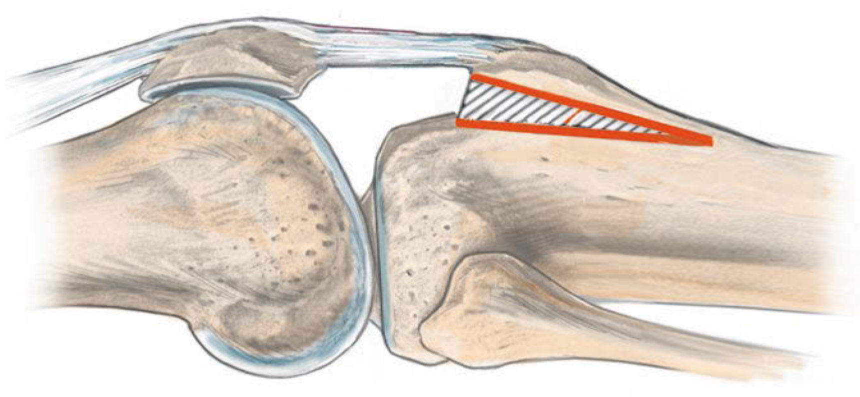

Fig. 17.20 anteriorization of the tibial tuberosity with interposition of a tricortical block (represented by the black and white shaded area)

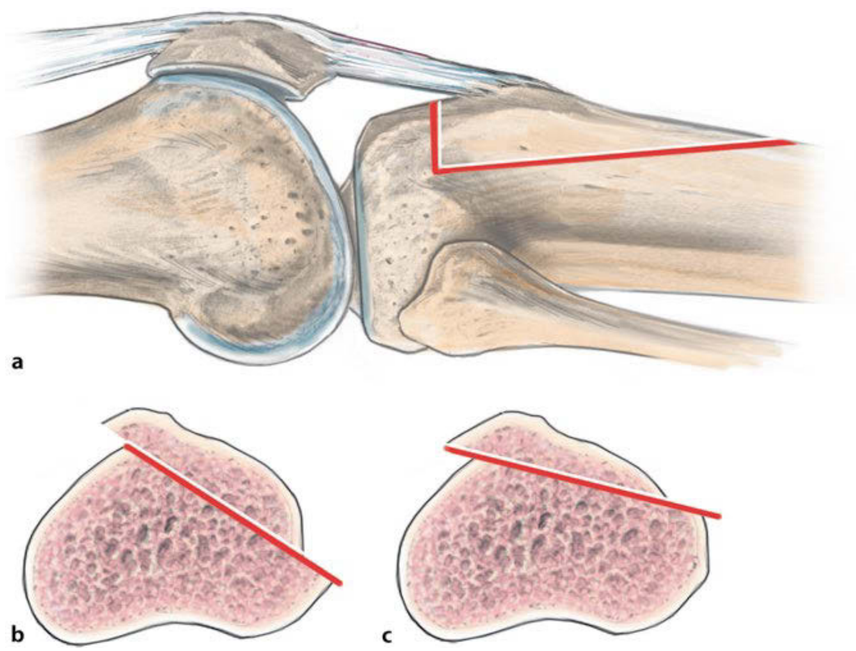

Fig. 17.21a–c Anteromedialization of the tibial tuberosity. **a** oblique osteotomy extending from posterolateral to anteromedial (lateral view), **b**, **c** by adjusting the degree of obliquity of the osteotomy, the degree of anteriorization and medialization can be controlled (axial view)

An Oblique osteotomy extending from posterolateral to anteromedial is done (Fig. 17.21a). Thus, by adjusting the obliquity of the osteotomy, the degree of anteriorization and medialization can be controlled: the more oblique, the more the anteriorization and the less the medialization are and vice versa (Fig. 17.21b,c). Temporary fixation of the tuberosity with two Kirschner wires after achieving the desired amount of correction is replaced with the definitive final fixation using 2 compression screws.

17.4.5 Postoperative Management

- Monitoring of the peripheral circulation, motor and sensory innervation
- Cooling and elevation of the extremity
- Use of elastic compressive bandages.
- Postoperative radiograph

17.4.6 Follow-up Management

A 4-point hard frame knee brace is used with limitation of the range of motion to: 20–30° flexion in the 1st–2nd postoperative weeks, 60° flexion in the 3rd–4th weeks, and 90° flexion in the 5th–6th weeks. Partial weight bearing with 20 kg is allowed during this period.

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Chondral and Osteochondral Lesions

M. Berninger, S. Vogt

A. B. Imhoff, M. J. Feucht (Eds.), *Surgical Atlas of Sports Orthopaedics and Sports Traumatology,*
DOI 10.1007/978-3-662-43776-6_18,

18.1 Microfracture

M. Berninger, S. Vogt

18.1.1 Indication

Symptomatic isolated, small (< 2 cm^2) and well demarcated chondral lesion of the femoral condyles and trochlea (ICRS grade 3 or 4) with intact subchondral plate and subjective complaints. This procedure is less recommended at the patella and tibia.

Specific contraindications: osteoarthritis, osteochondral defects, osteonecrosis.

18.1.2 Operation Principle

Induction of regenerative cartilage tissue formation through releasing mesenchymal stem cells after penetration of the subchondral lamella. In case of autologous matrix induced chondrogenesis (AMIC), a collagen membrane is additionally sutured to the edges of the defect aiming to stabilize the formed blood clot.

18.1.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: pain character, duration of complaint, limitation of movement, trauma, sporting and functional demands.
- Symptom specific examination: tenderness, pain on motion, range of motion, crepitation, lower limb alignment, instability.

Imaging

- Conventional X-ray of the knee in 3 views (AP, lateral and tangential patella) for evaluation of osteonecrosis, cysts and arthritic changes.
- Standing long-leg AP radiographs to asses malalignment with subsequent overloading.
- MRI (with intra-articular/intravenous contrast agent injection) to assess the extent of the cartilage damage, associated subchondral reactions, osteoarthritic changes and the presence of loose bodies, special radiological studies could be helpful (e. g. MRI T2-Mapping)
- CT with intraarticular contrast agent injection, when MRI is not possible e. g. presence of metallic implants

Patient Information/Consent

Specific operative risks: insufficient regenerative tissue, subsequent failure of the regenerative tissue, induction of osteonecrosis, non-weight bearing for many weeks (compliance willingness), revision with possible shift to other cartilage restorative procedures, progressive cartilage damage and osteoarthritis.

18.1.4 Surgical Technique

Positioning and Preparation

- Supine position
- Freely movable knee
- A thigh tourniquet is applied

Arthroscopic Microfracture

Arthroscopic portals (anterolateral/anteromedial) are established and a diagnostic arthroscopy is performed. The size and depth of the chondral lesion is assessed.

Unstable cartilage flaps are removed using a shaver or a curved curette. A stable vertical rim of the normal cartilage is created using a ring curette (◘ Figs. 18.1a and 18.2a). The defect is debrided down to the subchondral bone with removal of the calcified cartilage layer in the defect area with ring curette or sharp spoon curette (◘ Fig. 18.1b). Any possible sclerotic bone should be removed.

The subchondral bone is opened using microfracture awls (◘ Figs. 18.1c and 18.2b). Awls of different curvatures are available and depending on the location of the cartilage lesion, the most suitable one should be used so that the penetration is as perpendicular to the subchondral lamella as possible.

Perforation of the subchondral bone should start from the periphery and gradually proceed to the center of the lesion. The depth of the perforation should be approximately 3 mm and the holes should be 3–4 mm apart (◘ Fig. 18.2c). Successful penetration is evidence by flow of blood or bone marrow substance/fat globules after withholding arthroscopic fluid inflow and releasing off the tourniquet (◘ Fig. 18.2d).

Autologous Matrix-Induced Chondrogenesis (AMIC)

A collagen I/III membrane (e. g. Chondroguide, Geistlich) is additionally fixed over the prepared cartilage defect. The membrane is fixed using sutures and fibrin glue in the same technique described in ► Sect. 18.2 (◘ Fig. 18.3). The membrane should stabilize the blood clot and promote the differentiation and chondrogenesis of the migrating stem cells.

18.1.5 Postoperative Management

- Monitoring of peripheral circulation, motor and sensory innervation.
- Use of elastic compressive bandages
- Cooling and elevation of the extremity.

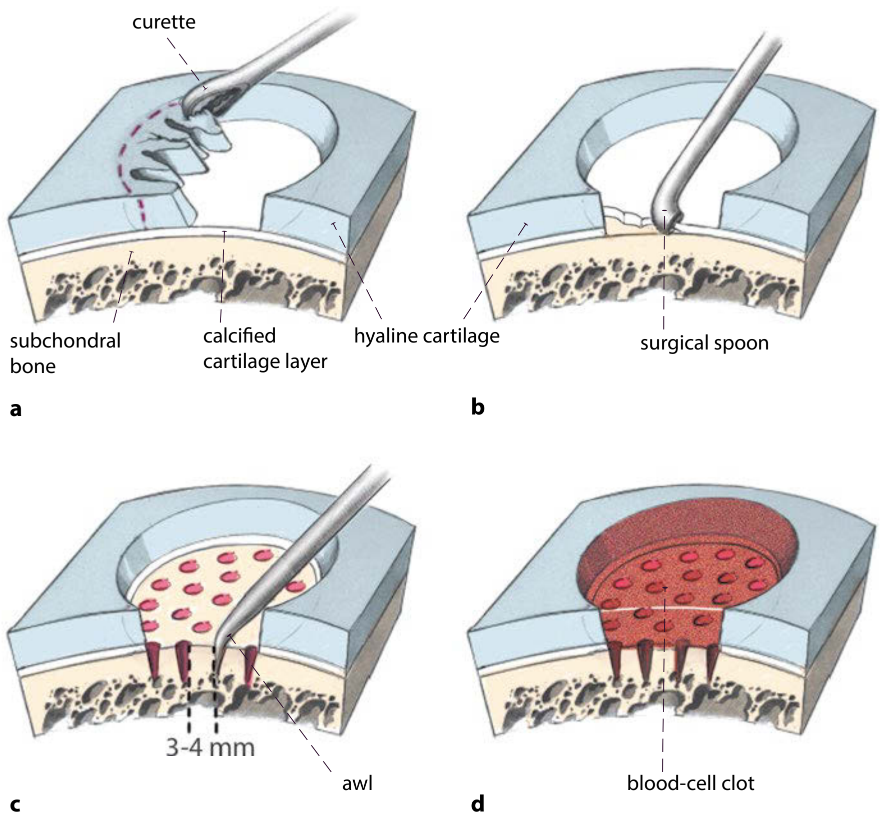


Fig. 18.1a–d Schematic representation of microfracture: **a** creating a stable rim of the surrounding normal cartilage using a ring curette; **b** removal of the calcified cartilage layer with a sharp spoon curette, **c** perforation of the subchondral bone with the microfracture awl e; **d** defect filled with blood clot

18.1.6 Follow-Up Management

Immobilization in the first 2 postoperative days to stabilize the blood clot.

Non weight bearing in the 1.–6. postoperative weeks. Gradual weight bearing with 20 kg/week with free active motion are allowed from the 7th week. CPM machine ("continuous passive motion") should be used from the third postoperative day and for at least 6–8 h/day for 6 weeks for an early continuous stimulation of chondrogenic matrix production under physiological pressure and deforming forces. Physiotherapy with isometric exercises and dynamic strengthening of the quadriceps muscle (with extended knee, no flexion of the knee) in the 1st week. Exercises without resistance (under water, ergometer) after 1–2 weeks, exercises against resistance after 6 weeks, running after 3 months and demanding sports after 8–12 months.

18.1.7 Tips & Tricks

Good preparation of the defect area (debridement of sclerosis, creation of stable cartilage margins) before performing microfracture is fundamental to obtain good postoperative result.

Creating a stable defect margin is of particular importance because at the beginning of regeneration process, the newly formed tissue is still weak and unstable and requires protection from the surrounding normal cartilage.

Microfracture is sometimes difficult to be performed in cases of chronic cartilage defects with markedly hard or sclerotic layer over the subchondral bone. In such cases, preliminary few perforations are performed to evaluate the thickness of the hardened bone and followed by removal of the sclerotic layer down to the subchondral bone and finally microfracture.

Perforations should be as close as possible to the surrounding healthy cartilage in the marginal zone.

Preservation of adequate bone bridges between the perforations should be kept in mind to maintain the stability of the subchondral plate. Moreover, the perforations should be orthograde (perpendicular) to the subchondral bone, otherwise the holes may converge towards each other with the risk of collapse of the subchondral Bone. It is therefore recommended to perform the procedure in different degrees of flexion to attain the ideal orientation relative to the defect as well as to use awls of different degrees of curvature.

To ensure sufficient opening of the subchondral lamella, the inflow of arthroscopy medium is stopped or the tourniquet is released, which should result in outflow of blood, bone marrow and fat cells from the perforations.

Strict avoidance of intraarticular drains to avoid unintended disruption of the newly formed blood clot. If a drain is necessary, it should be without vacuum suction!

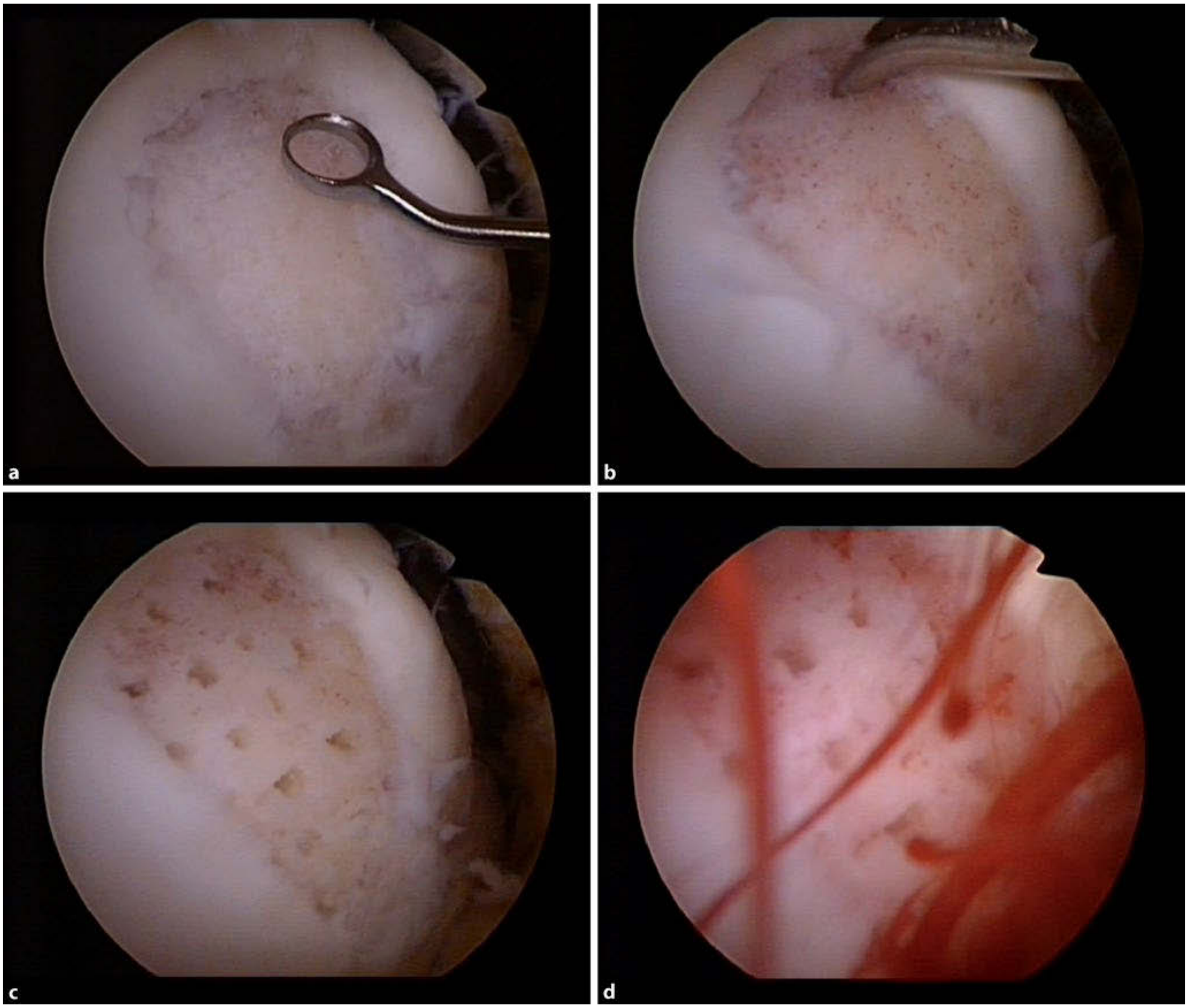


Fig. 18.2a–d microfracture of the medial femoral condyle. **a** debridement of the defect area with ring curette; **b** opening of the subchondral bone with the microfracture awl beginning peripherally; **c** completed microfracture; **d** outflow of blood from the opened bone marrow space after stopping the inflow of fluid

18.2 Chondrocyte Transplantation

M. Berninger, S. Vogt

18.2.1 Indication

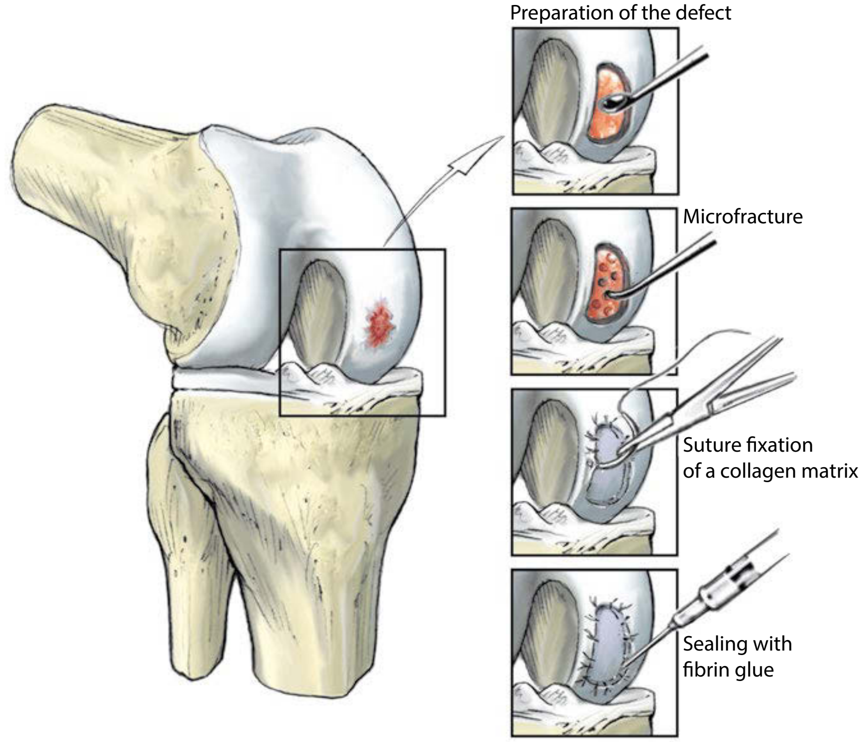
Symptomatic cartilage lesion (ICRS grade 3 and 4) of the knee joint of ≥ 2 cm^2 in size with intact subchondral bone.

18.2.2 Operation Principle

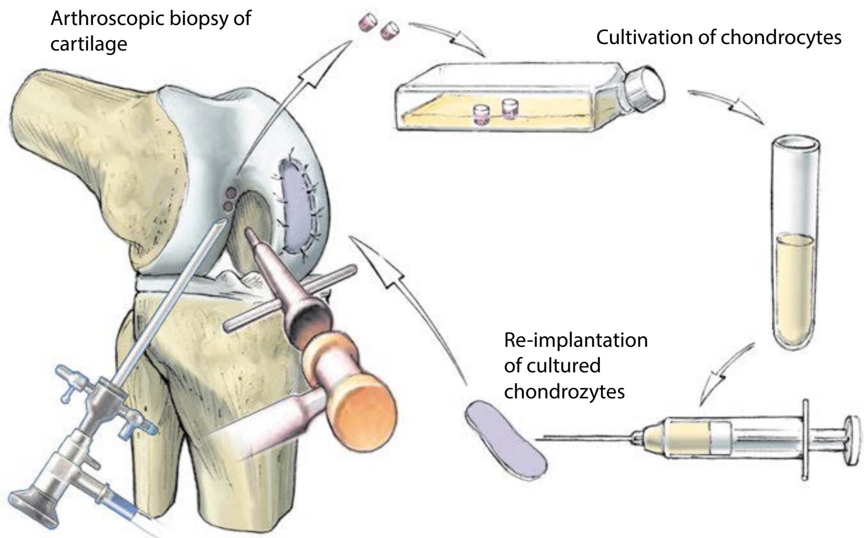
Two-stage procedure (Fig. 18.4): The first step is to harvest arthroscopically plugs of autologous chondrocytes from a low weight bearing area of the knee joint.

These cells are then cultivated and proliferated under laboratory conditions. In the second procedure, the cells are reimplanted into the cartilage defect. Principally, two different methods could be distinguished:

- ACT (autologous chondrocyte transplantation): injection of a suspension of the cultured autologous chondrocytes into the cartilage defect, which is then covered with a periosteal flap.
- MACT (matrix associated chondrocyte transplantation):
  - MACT with a collagen membrane: seeding of the cultured chondrocytes on a type I–III collagen membrane (exposure time 15 min) in the theatre and Injection of the remaining cells under the membrane after suturing it to the edges of the defect.
  - MACT with three dimensional matrix: short proliferative phase in the two dimensional monolayer culture followed by in vitro seeding on a three-dimensional cell carrier material (collagen, hyaluronic acid, PLLA



■ **Fig. 18.3** Schematic representation of the autologous matrix induced chondrogenesis (AMIC)



■ **Fig. 18.4** Principle of chondrocyte transplantation

["poly-L-lactic acid"], etc.). The in vitro seeded membrane is then applied to the defect using sutures.

18.2.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: pain character and duration, limitation of motion, trauma and pattern of injury, relevant comorbidities (e. g. rheumatoid arthritis, osteoarthritis, ligamentous instabilities)
- Symptom Specific examination: tenderness, painful movement, range of motion, crepitations, lower limb alignment, exclusion of concomitant ligamentous instability.

Imaging

- Plain X-ray of the knee in 3 views (AP, lateral and tangential patella) for evaluation of osteonecrosis, cysts and arthritic changes.
- Standing long-leg AP radiographs to asses malalignment with subsequent overloading.
- MRI (with intra-articular/intravenous contrast agent injection) to assess the extent of the cartilage damage,

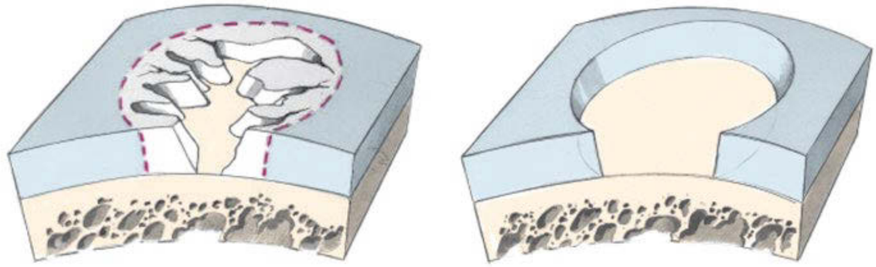


Fig. 18.5 Creation of stable vertical margins of the intact adjacent cartilage

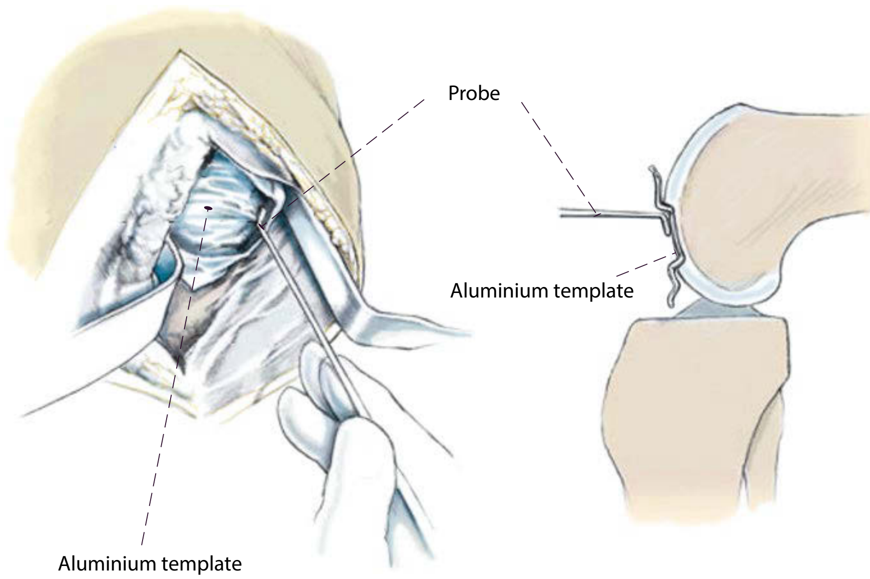


Fig. 18.6 Creation of a template tailored to the defect with a sterile aluminum foil

associated subchondral reactions, degenerative changes, presence of loose bodies and to exclude concomitant pathologies (special radiological studies, if required (e. g. MRI T2-Mapping)
- CT with intraarticular contrast agent injection, when MRI is not possible e. g. presence of metallic implants

Patient Information/Consent

Specific operative risks: insufficient regenerative tissue, subsequent failure of the regenerative tissue, progressive cartilage damage and osteoarthritis, non-weight bearing for many weeks (willingness for compliance), revision with possible shift to other cartilage restorative procedures, double operative burden (two-stage procedure), obligatory serological testing for hepatitis, HIV syphilis for laboratory cultivation, allergic reactions (in animal) to foreign proteins in the matrix, residual risk of viral or bacterial Infections couldn't be excluded, periosteal hypertrophy (with ACT).

18

18.2.4 Surgical Technique

Positioning and Preparation

- Supine position
- Applying a thigh tourniquet

Arthroscopic Harvesting of Cartilage Biopsy

Standard portals (anterolateral/anteromedial) are established followed by a diagnostic arthroscopy to evaluate the defect margins and the surrounding cartilage (for thickness, quality) and the size of the cartilage defect is measured. Cartilage biopsy is harvested (2–3 cylindrical plugs of about 3 mm in diameter) from low weight bearing area of the knee (intercondylar notch).

About 200–300 mg of cartilage are needed for a successful laboratory cultivation. Sufficient number of cells could be usually achieved after 3–5 weeks of in vitro culture. The cells are then ready for implantation or could be temporarily cryopreserved.

Chondrocyte Implantation

A medial or lateral parapatellar arthrotomy is used for exposure of the cartilage defect depending on its location. Reevaluation of the defect and assessment of its size. A scalpel is used to incise the cartilage vertically, separating the defect area from the surrounding normal cartilage. The unstable and damaged cartilage is then completely removed using a sharp spoon or ring curette tangentially without violating the subchondral lamella. Removal of the calcified zone and partially the sclerotic zones is necessary.

The aim is to create stable vertical margins of the surrounding intact cartilage (Fig. 18.5).

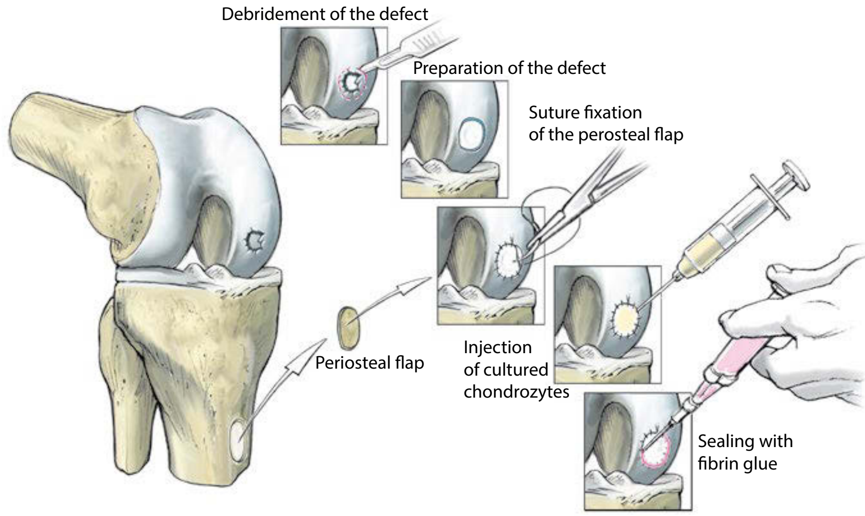


Fig. 18.7 Principle of ACT with periosteal flap

A sterile aluminum foil (e.g. from the suture package) is used to make a tailored template of the defect area. The foil is placed over the defect area (Fig. 18.6) and the defect edges are then outlined over it followed by cutting out the template to be used to accurately harvest the periosteal flap (ACT) or the membrane/matrix (MACT).

ACT with Periosteal Flap

The periosteal flap is harvested from the proximal medial tibia, distal to the pes anserinus or from below the insertion of the semitendinosus. Electrocoagulation shouldn't be used (to avoid injury to the periosteum).

The prepared aluminum template is then used to outline and harvest the periosteal flap. The periosteal flap is then sutured using simple interrupted sutures technique (5 mm interval between the adjacent sutures) and the knots should be positioned on the periosteal flap so that they lie below the level of the adjacent cartilage (to prevent spontaneous loosening with shear forces). The final knot at one end of the defect is not placed until after injection of the cells.

Water tightness should be tested before injecting the cells by injecting physiological saline solution into the defect under the periosteal flap. Cave: saline solution must be removed with proved sufficient tightness.

The chondrocytes are then implanted: the cell suspension is withdrawn into a sterile syringe and then injected carefully into the defect under the membrane using a flexible needle.

Finally, the remaining suture is completed and fibrin glue is used for sealing (e.g. Tissucol Duo S Immuno, Baxter) (Fig. 18.7).

MACT with Collagen Membrane

Technique is similar to described for ACT with periosteal flap. The difference is additional seeding of the collagen membrane shortly before implantation with a portion of the cell suspension (for about 15 min; Fig. 18.8). The remaining chondrocytes suspension is then injected under the sutured collagen membrane in the same technique described for ACT (Fig. 18.9).

MACT with Three Dimensional Matrix

In MACT with three-dimensional matrix, an already in vitro chondrocyte seeded matrix is matched to the defect using a template and then fixed using sutures and/or fibrin glue as described above.

18.2.5 Postoperative Management

- a knee brace or posterior splint is used to immobilize the knee in 0° position to prevent displacement of the graft as well as for better cell adherence in the first 48 hours.
- Monitoring of peripheral circulation, motor and sensory innervation.
- Cooling and elevation of the extremity.

18.2.6 Follow-Up Management

Immobilization and rest for 48 h. CPM machine is used and physiotherapy is started from the 2nd postoperative day. Allowed range of motion and weight bearing: Non weight bearing in the 1.–6. postoperative weeks.

The range of motion is dependent on the defect location: free range of motion is allowed for defects at the femoral condyles whereas with patellar defects the flexion is limited to 30° (1.–2. weeks), 60° (3.–4. weeks) and 90° (5.–6. weeks). Gradual weight bearing with 20 kg/week with free active motion are allowed from the 7th postoperative week.

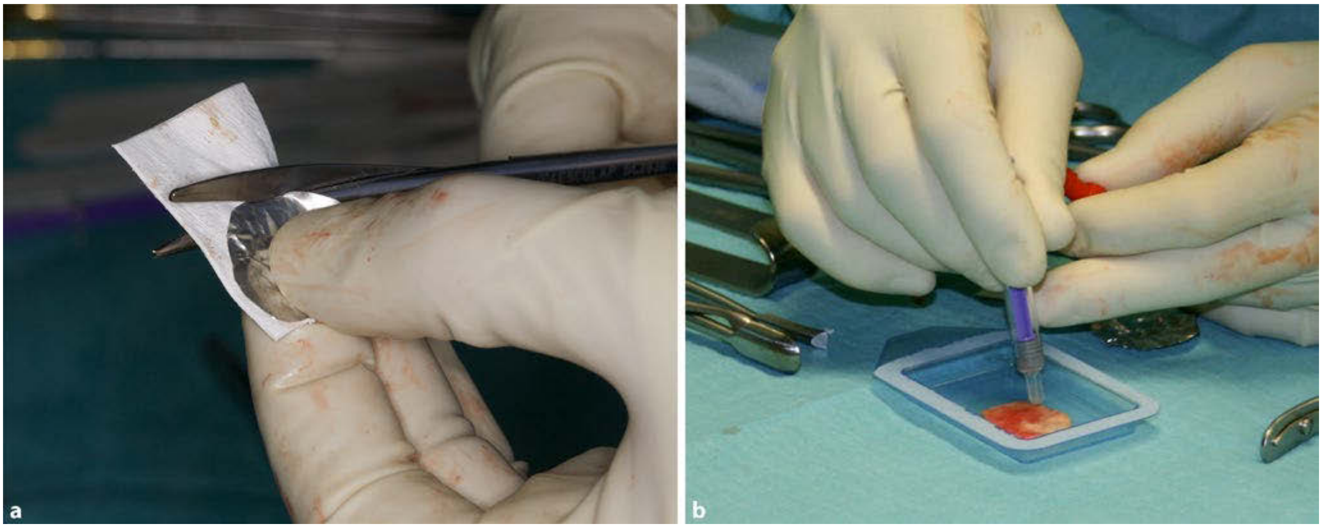


Fig. 18.8a,b MACT with collagen membrane. **a** cutting of the collagen membrane using the prepared aluminum template **b** seeding the prepared membrane with the cell suspension

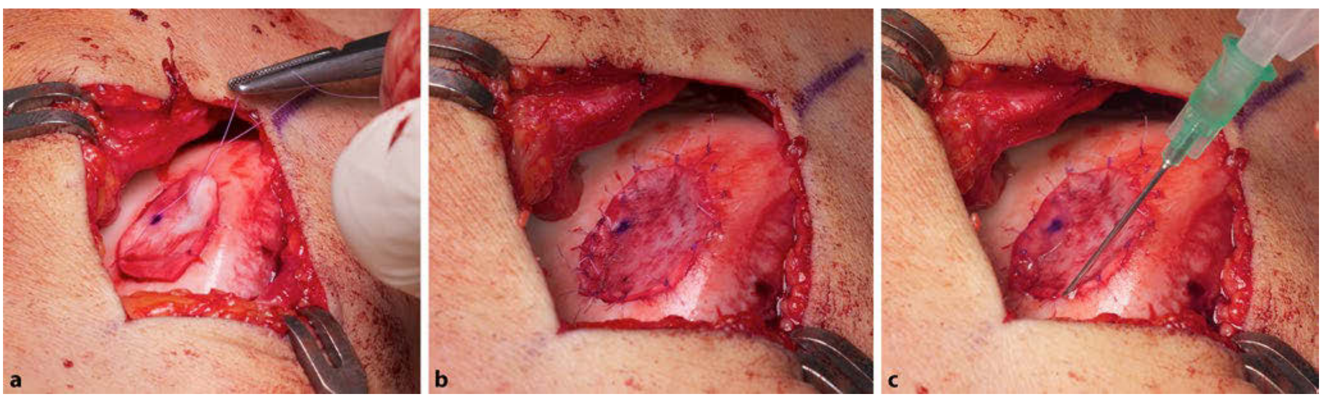


Fig. 18.9a–c MACT with collagen membrane. **a** suturing of the membrane; **b** completed suturing; **c** final sealing of sutures with fibrin glue

18.2.7 Tips & Tricks

For MACT with collagen membrane as well as with three-dimensional matrix, the polarity of the matrix must be kept in mind (see related instructions of the manufacturer).

To improve healing of the defect, the defect area down to the subchondral bone must be completely freed from sclerotic areas, which e. g. have arisen through previous microfracture.

It is essential to prevent perforation of the subchondral bone during preparation of the defect bed, otherwise the blood and stem cells will migrate and mix with the implanted chondrocytes and can interfere with adequate defect healing. If the subchondral plate is accidentally injured, the defect bed could be sealed off with fibrin glue.

Before implantation of the chondrocytes (sometimes in the same setting), other predisposing factors for cartilage damage (lower limb malalignment, patellofemoral malalignment, ligamentous instabilities and meniscal lesions) must be corrected.

It is recommended to seed the membrane with the cells before debridement and preparation of the defect bed and thereby making use of the time needed for seeding the membrane with cells, and so reducing the operative time.

When using a drain, it should be without suction (only overflow) and placed in the contralateral suprapatellar pouch.

18.3 Autologous Osteochondral Transplantation

M. Berninger, S. Vogt

18.3.1 Indication

Autologous Osteochondral Transplantation

(“Osteochondral Autograft Transfer System,” OATS)

Symptomatic focal localized osteochondral lesion in the weight bearing region of the knee joint (defect size to up to max. 3 cm^2):

- Osteochondral lesions (ICRS/OCL grade 3 and 4)
- localized focal osteonecrosis

Specific contraindication: isolated chondral lesion, osteoarthritis.

Mega-OATS

Large osteochondral lesions (defect size up to 35 mm in diameter).

Specific contraindications: isolated chondral damage osteoarthritis, kneeling activities and jobs (e. g. bricklayer)

18.3.2 Operation Principle

OATS

Transfer of one or more osteochondral (cartilage and bone) cylinders from areas of low weight bearing of the knee joint (preferably from the proximal lateral trochlea, alternatively from the proximal medial trochlea or the intercondylar notch) to replace a localized osteochondral defect in the weight bearing region of the knee joint.

Mega-OATS

The posterior femoral condyle (medial or lateral) is harvested in maximal flexion of the knee (120–130°) and a single large osteochondral cylinder is prepared and implanted into the prepared defect zone with press-fit technique.

18.3.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: pain character, limitation of motion, trauma, sporting and functional demands, relevant concomitant disorders (e. g. patellofemoral osteoarthritis, ligamentous instability, malalignment)
- Symptom specific examination: tenderness, painful motion, crepitation, limb alignment, ligamentous stability.

Imaging

- Plain X-ray of the knee in 3 views (AP, lateral and tangential patella) for evaluation of osteonecrosis, cysts and arthritic changes.
- Standing long-leg AP radiographs to asses malalignment with subsequent overloading.
- MRI (with intra-articular/intravenous contrast agent) to assess the extent of the osteochondral lesion and the associated subchondral reactions, degenerative changes, presence of loose bodies and to exclude concomitant pathologies.
- CT with intraarticular contrast agent, when MRI is not possible (e. g. presence of metallic implants) for good evaluation of the bony lesion.

Patient Information/Consent

Specific operative risks: failure of healing of the osteochondral cylinder (graft necrosis), cyst formation, donor site morbidity at the knee, possibility of harvesting osteochondral cylinders from the contralateral knee if necessary, cartilage surface incongruity (step formation), induction of osteonecrosis, progression of the cartilage damage, long postoperative management for several weeks, revision with possible shift to other cartilage restorative or (partial-) endoprosthetic procedures, possibility of switching to open approach if needed even if the procedure was initially planned to be performed arthroscopically, risk of developing osteoarthritis.

Additional specific operative risks of the mega OATS procedure:

Possibility of graft fixation with small-fragment screw and subsequently a second arthroscopic procedure for screw removal, additional underlying cancellous bone grafting with deep osseous defect, osteochondral graft dislocation, risk of fracture of the posterior bony rim between the defect bed and donor site.

18.3.4 Surgical Technique

Positioning and Preparation

- Supine position with possibility to position the knee in flexion.
- Applying a thigh tourniquet

Autologous Osteochondral Transplantation

Could be performed arthroscopically (orthograde implantation should then be possible) or through an open approach (particularly if transplantation of more than one cylinder is required). Intraoperative surface assessment and measuring the size of the defect with templates (◘ Fig. 18.10).

Either a single cylindrical plug, as large as possible (slightly overlapping if necessary) could be transferred aiming to obtain a congruent surface or many small cylinders (mosaicplasty) could be used to reconstruct the surface. The principle of mosaicplasty involves a higher risk of incongruity and increased gap formation.

The osteochondral defect is removed using a special cylindrical chisel (e. g. osteochondral transfer system OATS, Arthrex) (◘ Fig. 18.11), followed by harvesting congruent cylinders from the donor site. The length of the graft is dependent on the size of the lesion, which must be analyzed preoperatively in the MRI; usually a graft length of 15–20 mm is sufficient.

Incomplete harvesting of the graft (fracture of the cylinder in the recipient socket) could be prevented by shortly waiting after insertion of the harvester (allowing the bone cylinder to swell inside the harvester). Subsequently, rapid rotation of the harvester 90° without tilting aiming to fracture the bone between the cylinder and its bed

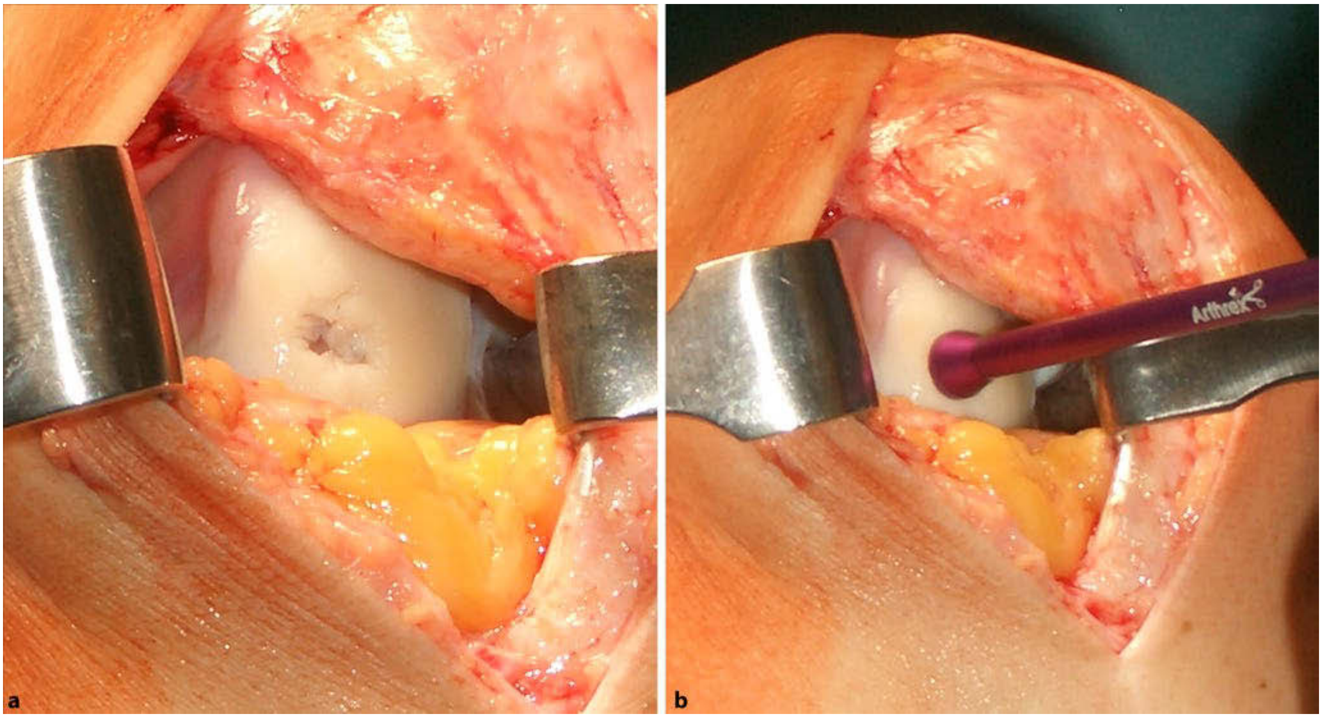


Fig. 18.10a,b Exposure of the defect (**a**) and measuring the size using specific templates (**b**)

Fig. 18.11a,b Preparation of the graft bed. **a** Removal of the defect area with a hollow chisel (recipient harvester) **b** graft bed after removal of two slightly overlapping cylinders

The cylinder is removed, the socket depth is measured and substance of the lesion could be sent for histopathological analysis.

The donor cylinder is harvested through a separate approach (proximo-lateral parapatellar) with the same technique described for preparation of the recipient socket (Fig. 18.12). The donor harvester has a slightly larger diameter than the recipient harvester, so that the graft could be fixed with press-fit technique. The cartilage surface of the donor cylinder should be congruent with the recipient area, which should be considered during harvesting the graft (by adjusting the impaction angle).

Preparation of the osteochondral cylinder for implantation: the length of the cylinder is measured and shortened if longer than the depth of the recipient socket. The cylinder is then implanted in press-fit technique using a special delivering tube and a tamp (Fig. 18.13).

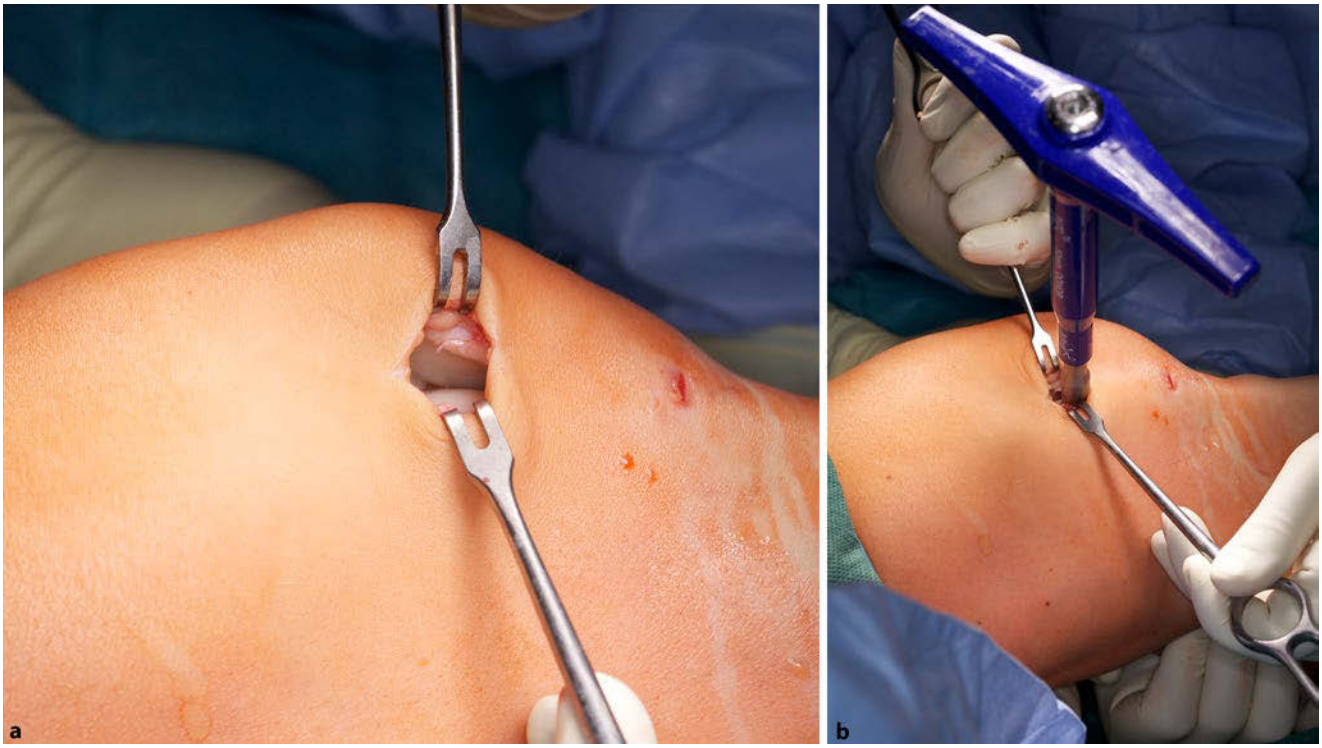


Fig. 18.12a,b Harvesting the donor cylinder. **a** proximo-lateral parapatellar approach **b** harvesting the donor cylinder from the proximo-lateral trochlea with the donor harvester

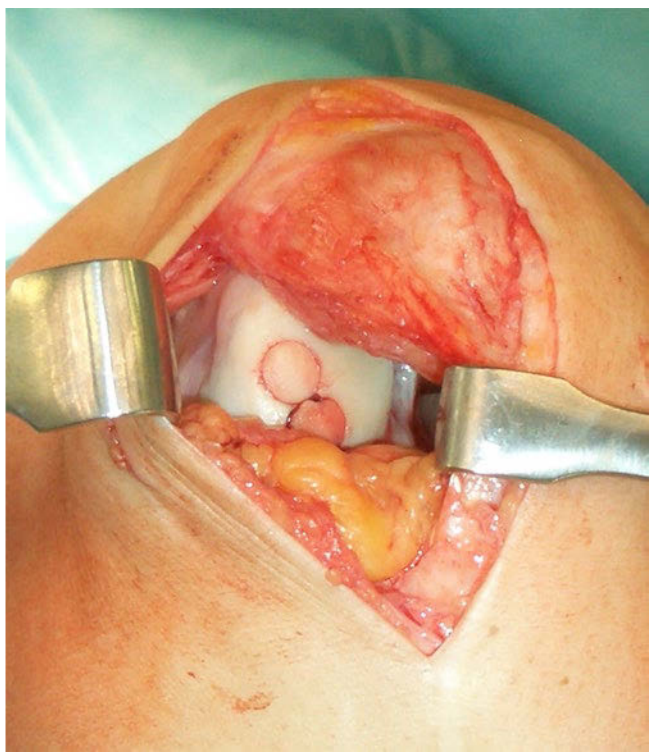


Fig. 18.13 Final result after implantation of the donor cylinder

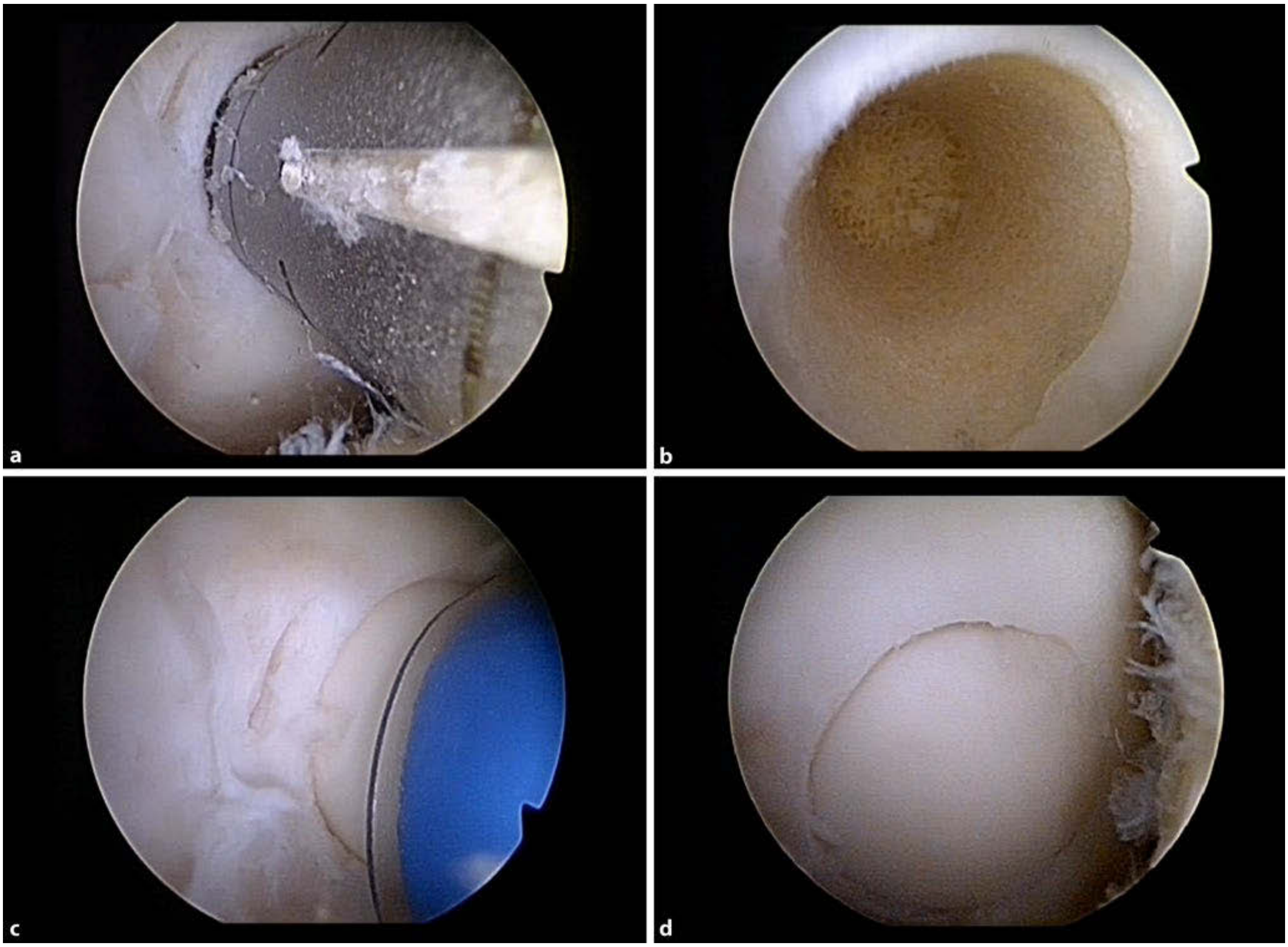


Fig. 18.14a–d Arthroscopic autologous osteochondral transplantation. **a** removal of the defect zone with the recipient harvester. **b** graft bed for implantation of the donor cylinder. **c** insertion of the donor cylinder. **d** final result

The procedure could be also performed arthroscopically if orthograde implantation is possible (Fig. 18.14).

Autologous Osteochondral Transplantation for Retro-Patellar Cartilage Defects

Arthrotomy, eversion of the patella and identification of the lesion. Exposure and preparation of the recipient area as follow: a guide wire is placed centrally into the defect (using a crown drill bit as a guide) which is then overdrilled to the required depth using a crown/diamond drill bit corresponding to the size of the lesion. Graft harvesting and insertion of the cylinder then follows as in the above described technique (Fig. 18.15).

Mega-OATS Technique

Central midline incision extending from the superior patellar pole down to the tibial tuberosity followed by a medial or lateral arthrotomy (depending on defect location) and then displacing the patella to one side. The osteochondral defect is exposed macroscopically, the edges are marked with a sterile marker and the lesion is measured using a ruler or specific Mega-OATS sizing templates (Mega-OATS instruments (Arthrex).

Depending on the size of the defect, a corresponding fragment of the posterior femoral condyle is harvested in maximum flexion (Fig. 18.16). This is done using osteotome with initially directing its inclined blade side caudally. Two Hohmann retractors are placed posterior to the condyle to protect the neurovascular structures. The osteotomy is started in the longitudinal direction of the femoral shaft with continuously changing the blade side of the osteotome to prevent anterior or posterior slipping relative to the femur longitudinal axis. A K-Wire is used to temporarily stabilize the posterior femoral condyle before completing the osteotomy (to prevent accidental slipping of the graft away).

The graft is then prepared according to the previously measured diameter of the defect. This is accomplished using a hollow chisel and mill after centering the posterior condyle in the workstation (Fig. 18.17). The diameter of the Mega-OATS cylinder should be about 0.5 mm larger than the diameter of the prepared defect bed to unsure press-fit fixation of the graft.

A K-wire with the desired template is placed and drilled centrally and perpendicular to the surface of the defect area (to be used as a guide for other instruments used for prepara-

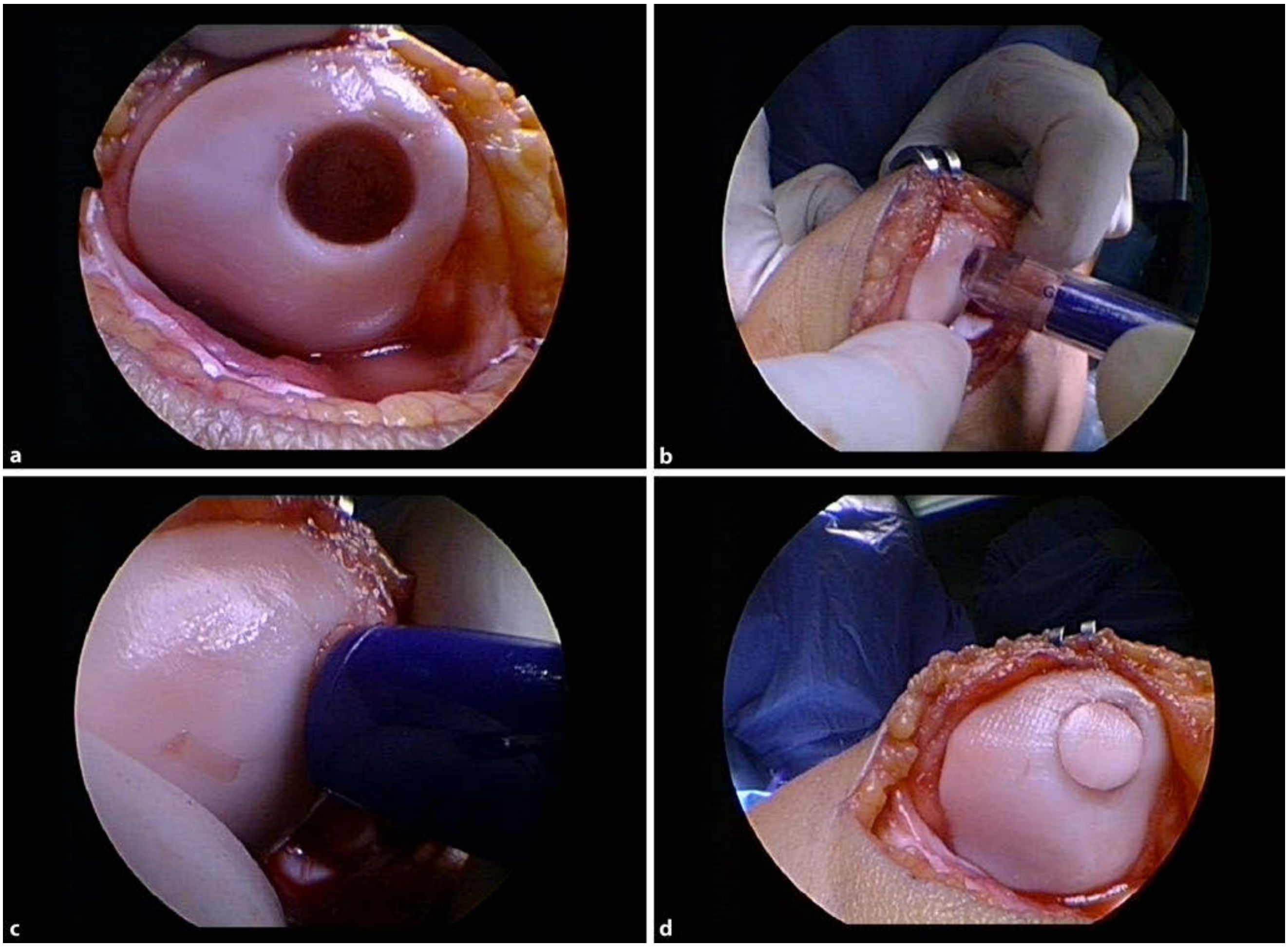


Fig. 18.15a–d Autologous osteochondral transplantation at the patella. **a** prepared graft bed (socket). **b** insertion of the donor cylinder using a delivering tube. **c** careful impaction of the cylinder with a tamp. **d** end result

tion of the defect bed). Stable cartilaginous rim surrounding the lesion is created using a hollow chisel (Fig. 18.18) and the graft bed is then prepared using a crow drill (mill) (Fig. 18.19). Having an intact cancellous bone bed for the graft should be ensured intraoperatively. The final depth of the defect bed is measured again (filling with cancellous bone should be done when required).

The Mega-OATS cylinder is finally implanted in press-fit technique using the specific instruments (Fig. 18.20). A temporary fixation with a small fragment screw (30 mm) for 6 weeks could be performed in case of marginal lesions or poor stability.

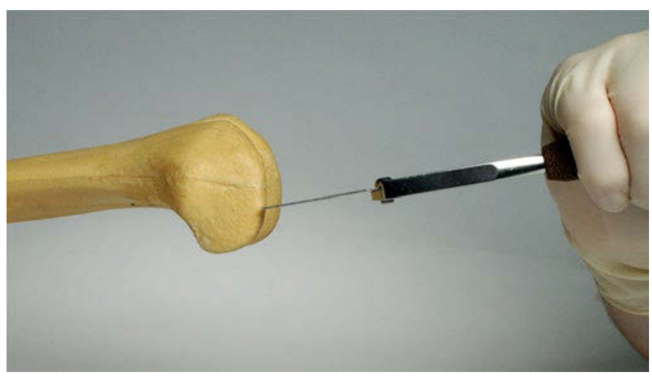


Fig. 18.16 Schematic representation of osteotomy of the posterior femoral condyle

18.3.5 Postoperative Management

- Monitoring of the peripheral circulation, motor and sensory innervation.
- Use of elastic compressive bandages.
- Cooling and elevation of the extremity.
- Postoperative radiographic evaluation

18.3.6 Follow-Up Management

Immobilization in the 1st postoperative day. A CPM machine is used and physiotherapy is started from the 1st postoperative day.

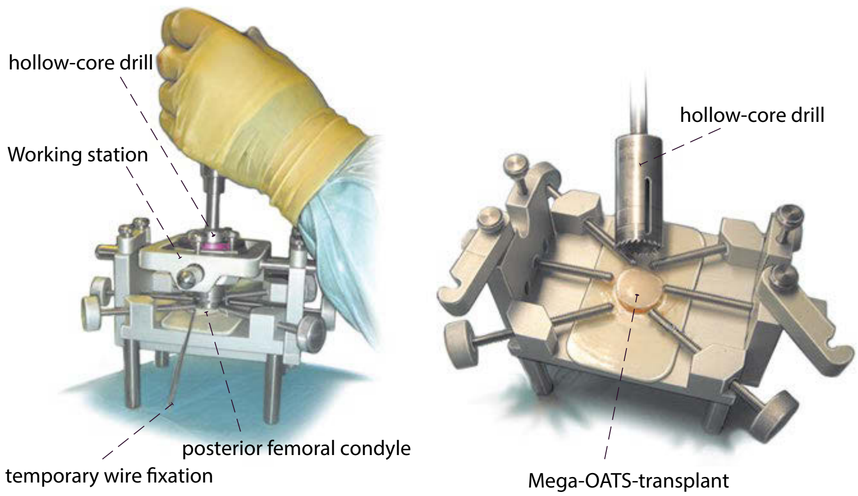


Fig. 18.17 Preparation of the Mega-OATS cylinder from the posterior femoral condyle using the specific workstation

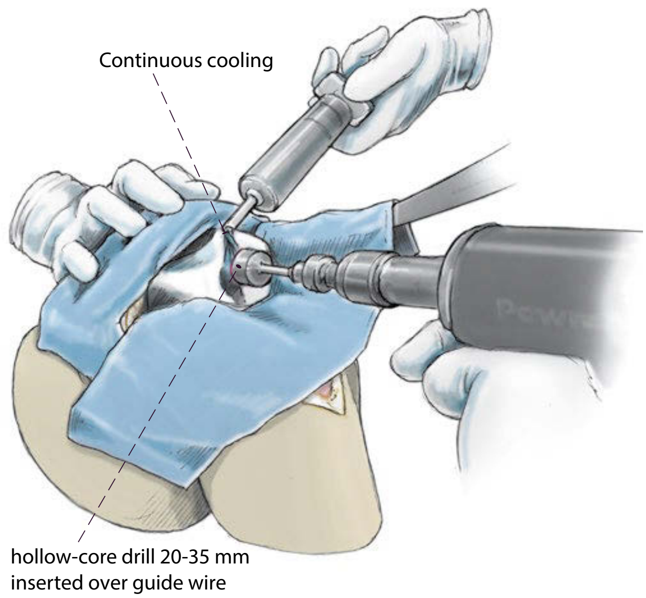


Fig. 18.18 Creation of a stable cartilaginous rim using the hollow reamer

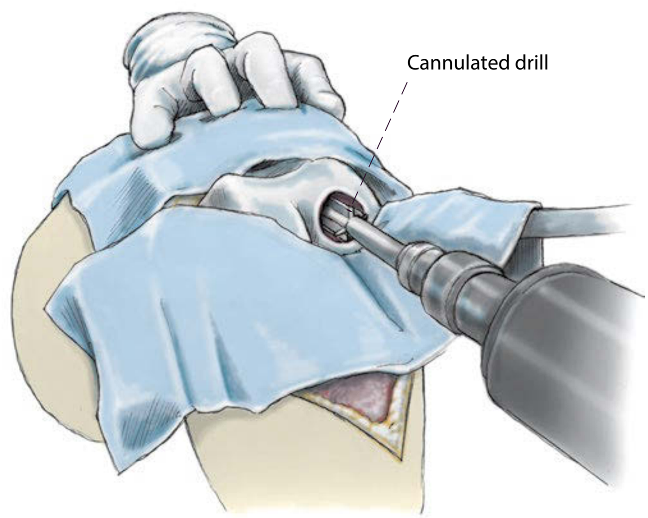


Fig. 18.19 Preparation of the graft bed (socket) using a crown drill

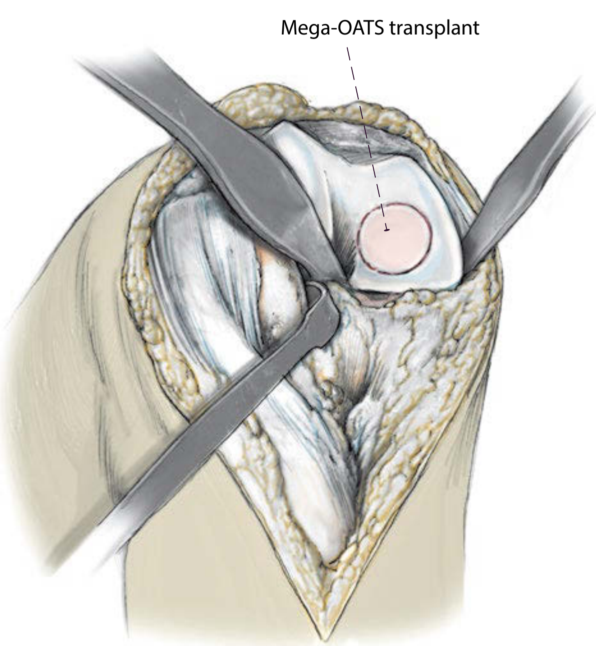


Fig. 18.20 Final result after implantation of the Mega-OATS cylinder with press-fit technique

Autologous Osteochondral Transplantation

At the Femoral Condyles

- 1st–6th postoperative weeks: sole contact, free passive and active range of motion immediately; non-weight bearing if a small fragment screw is used, or in cases of low stability and multiple OATS cylinders
- From the 7th Week: gradually increased weight bearing at a rate of 20 kg/week after surgeon's consultation

At the Patella

- Knee extension brace for 6 weeks postoperatively
- 1st–6th postoperative weeks: partial weight bearing (20 kg) in extension, active flexion/extension 90°/0°/0°
- From the 7th Week: gradually increased weight bearing at a rate of 20 kg/week after surgeon's consultation, free active range of motion

Mega-OATS

- 1st–6th postoperative weeks: sole contact, active and passive flexion/extension 90°/0°/0°, 4-point hard frame orthosis for 6 weeks limited to 90°/0°/0° (due to removal of the posterior femoral condyle).
- From the 7th Week: gradually increased weight bearing at a rate of 20 kg/week.
- When using a screw fixation: Removal of the screw 6 weeks postoperatively depending on the radiological follow up.

18.3.7 Tips & Tricks

Autologous Osteochondral Transplantation

A too short donor cylinder could be compensated by reducing the depth of the recipient socket with cancellous bone grafting. Cave: necrotic bone removed from the defect zone shouldn't be used even for filling the donor cylinder socket.

Tendentially, a deeply seated cylinder is preferred over a protruding cylinder.

If the grafted cylinder is too deeply seated, a corkscrew or chisel inserted below the cylinder in case of marginal defects could be used to remove it. The bed of the socket is then grafted with sufficient cancellous bone to achieve a new flush and congruent position of the graft.

The harvester should be left about 60 seconds in the bone after insertion to allow swelling of the bone inside and subsequently secured removal of the cylinder.

The graft should be always kept moist with a physiological saline solution to prevent apoptosis (in a wet towel) and not immersed in fluid (cartilage swells and results in more difficult implantation).

Minimal force should be used during implantation of the cylinder to avoid cartilage damage.

For easier insertion of the donor cylinder, the edge of the bone end could be smoothened ("torpedo shape").

Mega-OATS

The Mega-OATS cylinder could be fixed with a small-fragment screw if sufficient press-fit stability couldn't be achieved (in most cases with remaining less than two-thirds of the defect rim).

With incorrect positioning of the cylinder, it should be removed, rotated and reinserted. Usually, a good congruence could be achieved if the graft is rotated 90° to the position in the posterior femoral condyle.

Healing could be improved by drilling the graft bed with non-fully intact cancellous bone without deeper preparation.

18.4 Cancellous Bone Grafting and Chondrocytes Transplantation with Collagen Membrane

S. Vogt

18.4.1 Indications

Symptomatic focal localized osteochondral lesion in the weight bearing region of the knee joint (defect size > 20 mm, diameter up to 35 mm): osteochondral lesions (ICRS/OCL grade 3 and 4) , localized focal osteonecrosis

Specific contraindication: isolated chondral lesion, osteoarthritis.

18.4.2 Operation Principle

Two-stage surgical procedure:

- 1st Stage: chondrocyte biopsy (► Sect. 18.2)
- 2nd Stage (after 3–4 weeks): bone grafting and cell implantation with membrane

Alternative Procedure:

- 1st stage: chondrocyte biopsy and bone grafting
- 2nd stage (after 3–4 months): cell implantation with membrane

It is not known which procedure results in better results. Advantages of the first method include lower morbidity (only one open procedure) and more rapid rehabilitation.

18.4.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: pain character, limitation of motion, trauma, sporting and functional demands, relevant concomitant disorders (e.g. ligamentous instability, malalignment)
- Symptom specific examination: tenderness, painful motion, crepitation, limb alignment, ligamentous stability.

Imaging

- Plain X-ray of the knee in 3 views (AP, lateral and patella tangential) for evaluation of osteonecrosis, cysts and arthritic changes.
- Standing long-leg AP radiographs to asses malalignment with subsequent overloading.
- MRI (with intra-articular/intravenous contrast agent) to assess the extent of the osteochondral lesion and the associated subchondral reaction, degenerative changes, presence of loose bodies and to exclude concomitant pathologies.
- CT with intraarticular contrast agent, when MRI is not possible (e.g. presence of metallic implants) for good evaluation of the bony lesion.

Patient Information/Consent

Specific operative risks: failure of bone healing (graft necrosis), cyst formation, donor site morbidity at the knee/pelvis, lack of cartilage formation, detachment of the regeneration tissue, induction of osteonecrosis, progression of the cartilage damage in adjacent joint areas, long postoperative management for several weeks, two-stage procedure, revision with possible shift to other cartilage restorative or (partial-) endoprosthetic procedures.

18

18.4.4 Surgical Technique

Positioning and Preparation

- Supine position with possibility to position the knee in flexion.
- Applying a thigh tourniquet

Cancellous Bone Grafting with MACT ("Sandwich Technique")

In the first stage, chondrocytes are harvested in the same technique described in ► Sect. 18.2. According to the selected procedure, cancellous bone grafting of the defect bed could be performed at the same time or during the second stage. We prefer bone grafting to be done during the second stage together with chondrocyte transplantation. The technique of the bone grafting procedure is basically the same:

Central midline incision extending from the superior patellar pole down to the tibial tuberosity followed by a medial or lateral arthrotomy (depending on defect location) and then displacing the patella to one side. The osteochondral defect is exposed macroscopically, the edges are marked with a sterile marker and the lesion is measured using a ruler or specific Mega-OATS sizing templates (Mega-OATS instruments (Arthrex).

For preparation of the defect bed we use the Mega-OATS instruments (Arthrex). A K-wire with the desired template is placed and drilled centrally and perpendicular to the surface of the defect area (to be used as a guide for other instruments used for preparation of the defect bed).

Stable cartilaginous rim surrounding the lesion is created using a hollow chisel (◘ Fig. 18.18) and the graft bed is then prepared using a crow drill (mill) (◘ Fig. 18.19). Having an intact cancellous bone bed for the graft should be ensured intraoperatively.

If the Mega-OATS instruments are not suitable for preparation of the osteochondral defect (e.g. more longitudinally oval than round lesions), the graft bed could then be prepared using for example sharp spoon and ring curettes.

The prepared defect zone is filled with cancellous bone chips, in successive layers up to the cartilage junction with repetitive impaction using a bone impactor.

According to the chosen procedure, the cancellous bone graft is covered with a collagen I/III membrane (e.g. Chondrogide) not seeded with chondrocytes with consequent chondrocytes implantation after 3–4 months or, in the same technique described in ► Sect. 18.2, a chondrocyte seeded collagen membrane is placed over the cancellous bone graft in the same procedure (◘ Fig. 18.21).

18.4.5 Postoperative Management

- Monitoring of the peripheral circulation, motor and sensory innervation.
- Use of elastic compressive bandages.
- Cooling and elevation of the extremity.
- Postoperative radiographic evaluation

18.4.6 Follow-Up Management

1st operation: Chondrocytes Harvesting, 2nd operation: Cancellous Bone Grafting and Chondrocytes Implantation

After chondrocytes harvesting: partial weight bearing for 2 weeks with free active flexion/extension, from the 3rd Week:

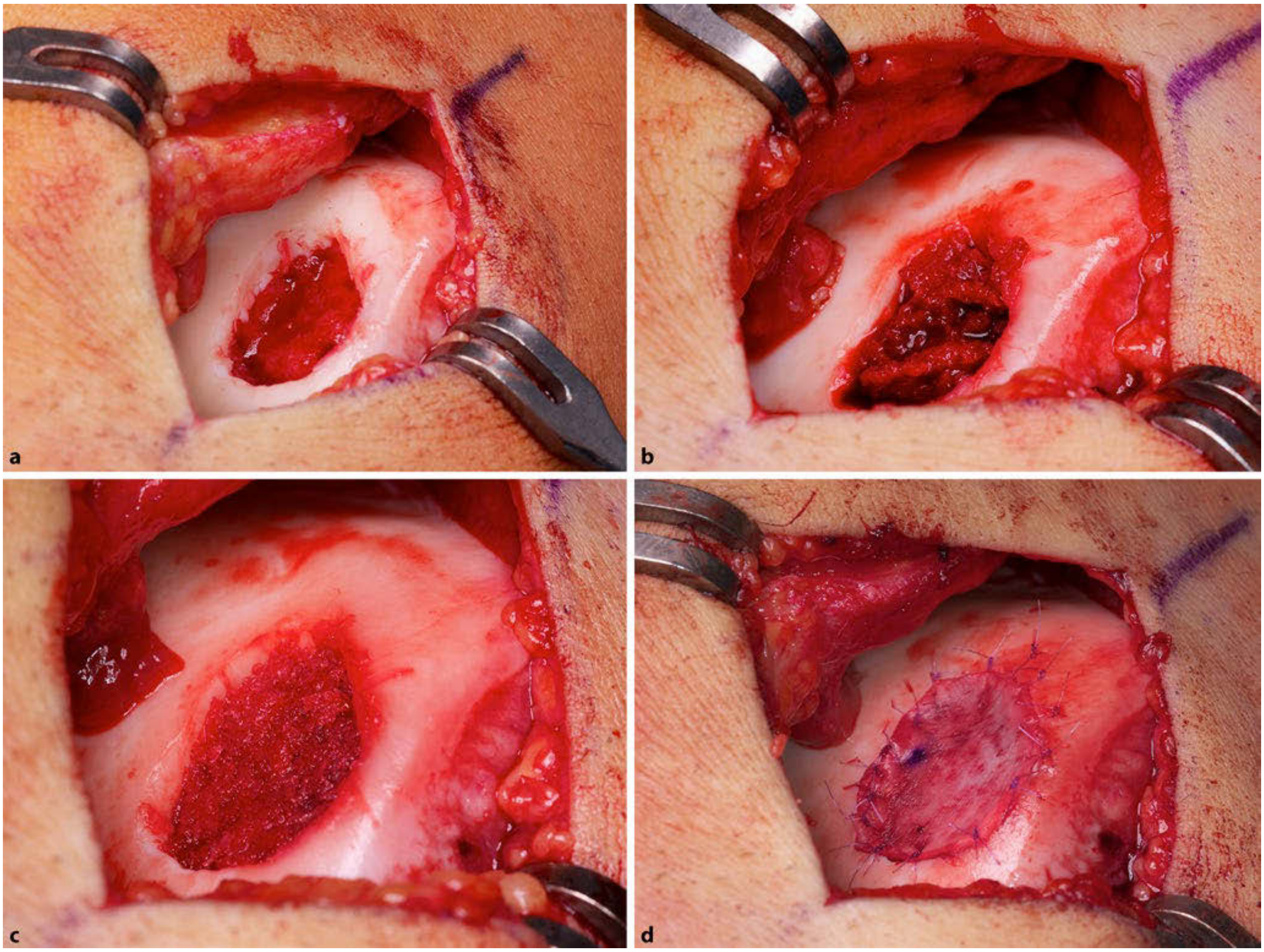


Fig. 18.21a–d Cancellous bone grafting and MACT (in one-stage). **a** large osteochondral defect of the lateral femoral condyle; **b** filling the defect with cancellous bone chips from the ipsilateral iliac crest; **c** completed cancellous bone grafting after impacting the cancellous bone chips in successive layers; **d** final result following MACT

pain adapted gradually increased weight bearing until full weight bearing.

After cancellous bone grafting and cell implantation: an extension knee brace is used with immobilization for 48 h postoperatively. Allowed range of motion and weight bearing after that is similar to that described for MACT (► Sect. 18.2).

1st operation: Chondrocytes Harvesting and Cancellous Bone Grafting, 2nd operation: Chondrocytes Implantation

After chondrocytes harvesting and cancellous bone grafting: an extension knee brace is used with immobilization for 48 h postoperatively. Allowed range of motion and weight bearing after that is similar to that described for MACT (► Sect. 18.2).

After cell implantation: an extension knee brace is used for 48 h postoperatively. Allowed range of motion and weight bearing after that is similar to that described for MACT (► Sect. 18.2).

18.4.7 Tips & Tricks

Defect preparation and cancellous bone grafting is markedly easier with the use of Mega-OATS instruments (Figs. 18.18 and 18.19)

Cancellous bone graft is impacted successively in layers.

If cancellous bone grafting is performed in the first operation, it should be covered with a (collagen) membrane for protection.

If cancellous bone grafting and MACT are not done in the same procedure, a sufficient time interval (at least 3–4 months) should exist between both operations. Follow-up with MRI is recommended.

When using a drain, it should be without suction (only overflow) and placed in the contralateral suprapatellar pouch.

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Osteotomy

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19.1 High Tibial Osteotomy (Valgus Producing)

M. Feucht, S. Hinterwimmer

19.1.1 Indication

Varus deformity with:

- Symptomatic medial unicompartmental osteoarthritis of the knee
- Cartilage regenerative procedures or meniscus replacement
- Unicompartmental medial hypercompression (overload)
- Ligament reconstruction on the convex side of the deformity

Intact cartilage of the lateral compartment (maximal damage level ICRS Grade II) and a preserved lateral meniscus are prerequisites.

19.1.2 Operation Principle

- Medial open-wedge technique: shifts the mechanical axis laterally through opening an ascending (directed from medial to lateral) osteotomy at the proximal tibial metaphysis.
- Lateral closed-wedge technique: shifts the mechanical axis laterally by closing a wedge-shaped metaphyseal osteotomy on the lateral side of the proximal tibia

19.1.3 Preoperative Assessment

Diagnosis

Clinical

Symptom specific history: pain (related to activity, at rest, at night etc.), site of pain, pain free walking distance.

Symptom specific examination: inspection of the weight-bearing alignment, gait pattern (thrust), tenderness at the medial or lateral joint line, tenderness on patellar compression/palpation of the undersurface, passive and active flexion/extension, ligamentous stability.

Imaging

- X-rays of the knee in three views (AP, lateral and tangential patella) to assess the degree of osteoarthritis of all compartments.
- Standing long-leg AP radiographs to analyze the deformity and plan the osteotomy (see below)
- Stress radiographs (in valgus and varus) with collateral ligaments laxity.
- MRI to evaluate the condition of the articular cartilage, bone marrow signal, exclude concomitant ligamentous and meniscal lesions.
- CT with contrast medium, if the MRI is contraindicated or with presence of metallic artifacts.

Planning

Analysis of the deformity and planning of the osteotomy could be performed either using appropriate computer software (e. g. mediCAD, Hectec) or conventional planning using radiographs.

On an anteroposterior full length leg radiograph, the center of the femoral head (FHC), the center of the ankle joint (AJC) and the center of the knee joint (KJC) are marked. The mechanical axis of the leg corresponds to the angle between the mechanical axes of the femur (line connecting the FHC and the KJC) and the tibia (line connecting KJC and the AJC). The line between the FHC and the AJC represents the weight bearing axis of the lower extremity (Mikulicz line).

The point where this line intersects the tibial plateau is expressed as a percentage of total width of the tibial plateau (medial border = 0%, lateral border = 100 %). The site of deformity is determined through measuring the tibial and femoral joint angles. These represent the angle between the knee joint line of the femur and the tibia (line tangential to the femoral and tibial articular surface) and the corresponding mechanical axis. Routinely, the mechanical lateral distal femoral angle (mLDFA) and the mechanical medial proximal tibial angle (mMPTA) are measured (Fig. 19.1). The correction angle and the height of the wedge base are planned according to the desired amount of correction (position of the Mikulicz line) using e. g. the Miniaci method.

The planned correction target means to establish a new individualized leg axis. In our own approach, the amount of correction is related to the underlying pathology, as explained in Table 19.1. The new mechanical axis is planned to be within a specific 5 % area measured on the tibial plateau diameter (Fig. 19.1). (Fig. 19.2). The articular cartilage of the lateral compartment should be intact. In the indication groups 1 and 2, this is performed due to the young age of these patients, the mild medial osteoarthritis or the focal, mostly traumatic medial cartilage lesions. In the indication group 3 with a concomitant articular cartilage degeneration of the lateral compartment, the indication for HTO should be reviewed critically and the correction shouldn't extend so far into the lateral compartment.

Patient Information/Consent

Specific operative risks: persistent pain, under-/overcorrection (in the coronal plane), angular deformity: axial (rotational deformity) and sagittal (slope over-or under-correction), leg shortening/lengthening, articular fracture, non-union, im-

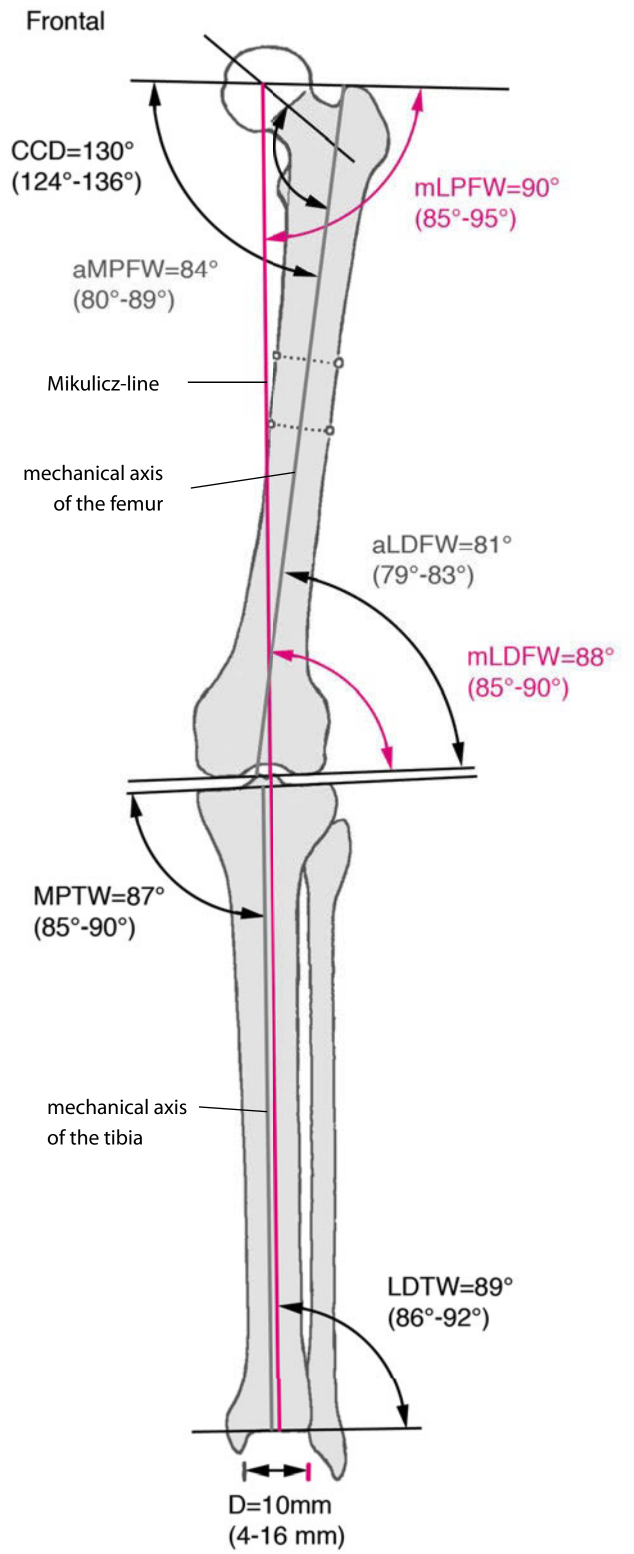


Fig. 19.1 Axes and joint angles of the lower extremity in the frontal plane

Table 19.1 Degree of correction according to the main underlying pathology. The new mechanical axis is planned to be within a specific 5 % area measured on the tibial plateau diameter (Fig. 19.1)

Indication group	Pathology	Position of the new mechanical axis in relation to the tibial plateau diameter (%)
1	varus deformity with painful medial overload without relevant cartilage damage	50–55
2	-varus deformity with medial Osteoarthritis grade 1 and 2 Varus deformity with cartilage therapy (OATS, ACT, MACT) Varus deformity with chronic lateral or posterolateral instability	55–60
3	varus deformity with medial osteoarthritis grade 3 and 4	60–65

OATS: osteochondral autograft transfer system, *ACT:* autologous chondrocyte transplantation, *MACT:* matrix associated chondrocyte transplantation

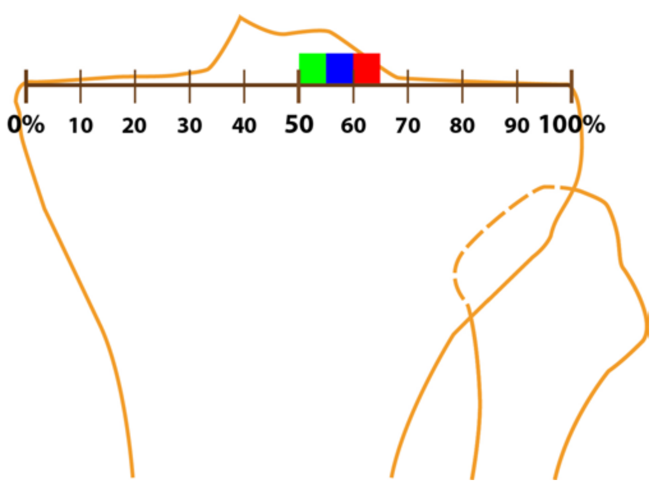
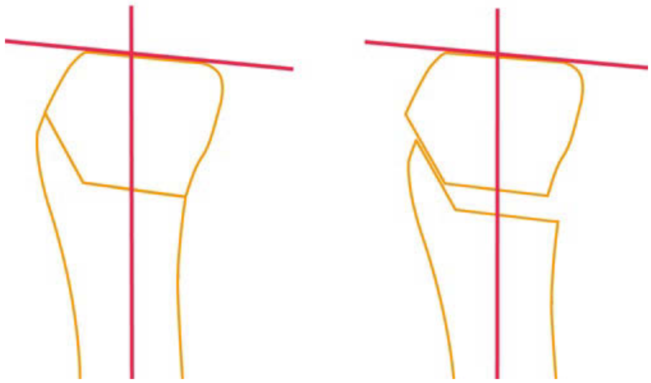
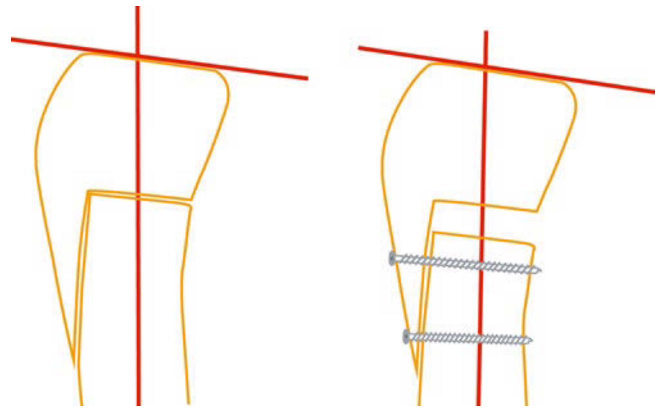


Fig. 19.2 Target position of the mechanical axis in relation to the transverse diameter of the tibial plateau from medial to lateral, depending on the specific indication (Table 19.1). Green area = 50–55%, blue area = 55–60%, % red area = 60–65



■ Fig. 19.3 Proximally aimed frontal osteotomy above the tibial tuberosity



■ Fig. 19.4 Distally aimed frontal osteotomy below the tibial tuberosity

plant failure, progression of the course of osteoarthritis, annoying fixation implant, potential need for cancellous bone graft from the iliac crest.

19.1.4 Surgical Technique

Positioning and Preparation

- Supine position
- A thigh tourniquet is applied
- Preparation of a measuring instruments needed to check the amount of correction (e.g. electrocautery cable, alignment rod, grid plate or navigation)

Bi-Planar Medial Valgus-Producing Open-Wedge HTO

Diagnostic arthroscopy is performed via the anterolateral portal to confirm the operative indication, the amount of planned correction as well as for assessment and treatment of possible concomitant lesions.

A 8–10 cm longitudinal anteromedial skin incision is performed, beginning just above the level of the tibial tuberosity (■ Fig. 19.5a). After subcutaneous dissection, the pes anserinus is exposed and the sartorius fascia with the underlying periosteum are incised with the electrocautery device along the upper border of the gracilis tendon until the anterior fibers of the superficial medial collateral ligament.

The semitendinosus and gracilis tendons are carefully mobilized using a periosteal elevator. The long fibers of the superficial medial collateral ligaments lying distal to the osteotomy are completely mobilized, to avoid an increase of their tension during subsequent opening of the osteotomy.

Our standard technique is to perform the osteotomy in a bi-planar fashion that comprises osteotomies in both the axial and the frontal planes. The frontal plane osteotomy could be carried out either proximal or distal to the tibial tuberosity. The tibial tuberosity remains attached to the distal bone block with a proximally oriented osteotomy (■ Fig. 19.3), so that a possible increase of the patellofemoral contact pressure could occur after opening of the axial osteotomy and distal displacement of the patella.

This variant is technically easier and should be only performed in cases with unremarkable clinical, radiological and arthroscopic findings of the patellofemoral joint. Otherwise we recommend a distally directed osteotomy, so that the tibial tuberosity remains attached to the proximal bone block (■ Fig. 19.4) without changing the patellar height. The site of the osteotomy is marked in the frontal and axial planes using an electrocautery.

Rotation and slope are controlled intraoperatively using two Kirschner wires placed parallel to each other's in the transverse and sagittal planes, proximal and distal to the axial osteotomy (► Sect. 19.1.7).

For the axial osteotomy, the hamstring tendons are retracted distally, and two parallel wires are inserted under fluoroscopic control along the plane of the osteotomy until reaching the lateral cortex (■ Fig. 19.6b). The wires are inserted medially about 4–5 cm distal to the medial tibial plateau and extend laterally in an obliquely upward direction to a point approximately 2 cm distal to the lateral tibial plateau.

The tibial tuberosity osteotomy is done using an oscillating saw (■ Fig. 19.5b). A complete osteotomy of the opposite cortex must be ensured, otherwise opening of the axial osteotomy wouldn't be possible. The axial osteotomy is then performed along the already inserted wires using an oscillating saw (■ Fig. 19.5c) and then gradually opened by inserting multiple osteotomes to about 0.5–1 cm from the lateral cortex (■ Figs. 19.5d and 19.6c, d), with protection of the posterior neurovascular structures by inserting a Hohmann retractor directly posterior to the tibia along the plane of the axial osteotomy. The osteotomy is done below the inserted wires to minimize the risk of fracture of the lateral tibial plateau. The lateral cortex should be kept intact to preserve a stable bony bridge of the osteotomy.

The length of the osteotomy could be indirectly determined in advance by measuring the length of the wires inserted into the bone. A complete osteotomy of the posterior

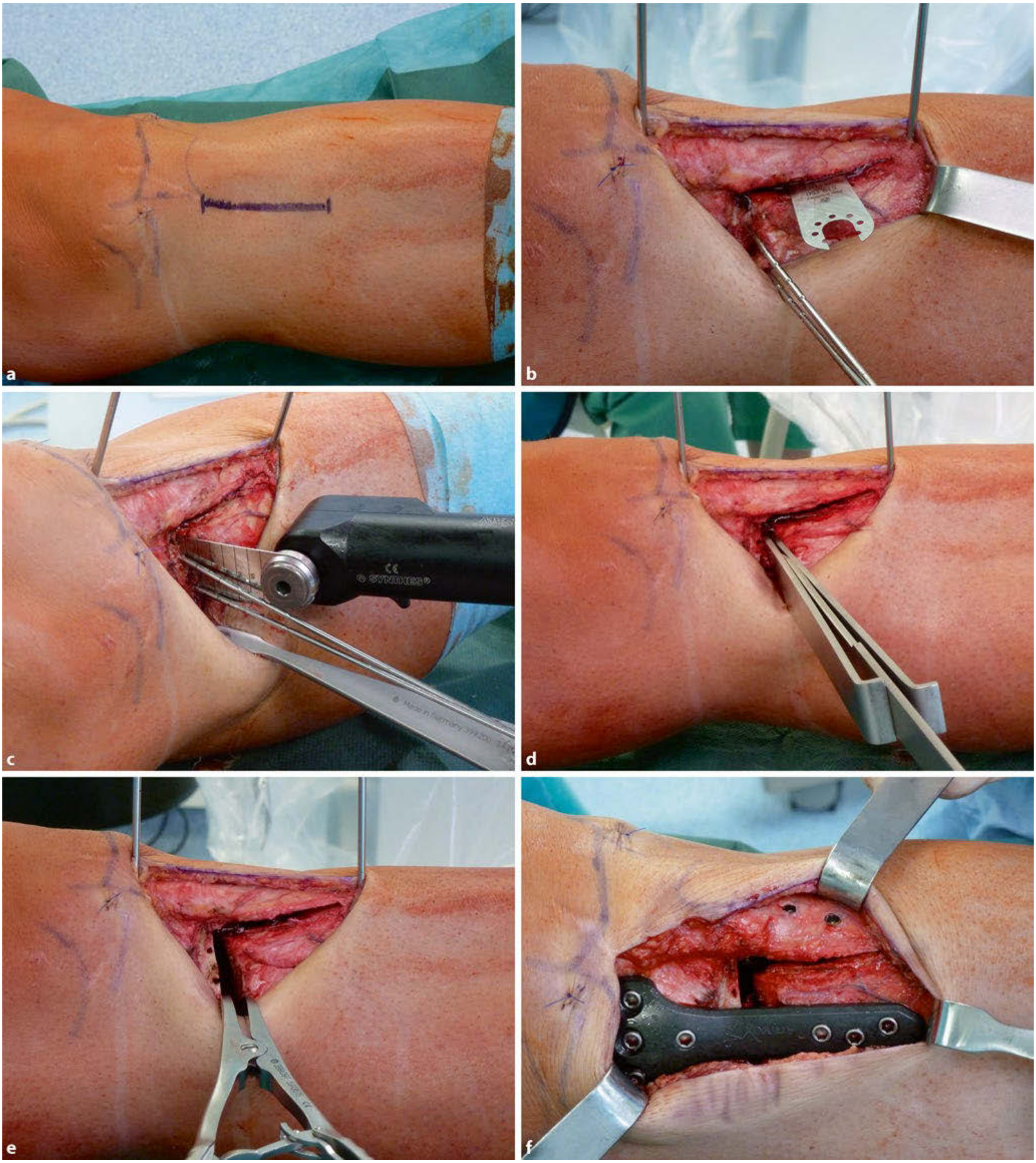


Fig. 19.5a–f Bi-planar medial open-wedge HTO with distally aimed frontal osteotomy and fixation with PeekPower HTO plate (Arthrex). **a** Approximately 8 cm longitudinal anteromedial incision, starting just above the tibial tuberosity **b** distally aimed frontal osteotomy of the tibial tuberosity (saw blade in the osteotomy) **c** osteotomy in the axial plane along (*below*) the already inserted wires **d** multiple osteotomes are inserted to about 0.5–1 cm distance from the lateral cortex, **e** gradual opening of the osteotomy gap with an osteotomy distractor placed far posteriorly **f** after final fixation with PeekPower HTO plate (Arthrex) and two cortical screws at the tibial tuberosity

cortex is very essential to avoid marked unintended increase of the slope during opening of the osteotomy.

The osteotomy is then gradually opened to the desired correction target using the osteotomy spreader that should be placed as far posteriorly as possible (Figs. 19.5e and 19.6e). As a general rule and if the slope is planned to remain neutral after the osteotomy, the height of the osteotomy posteriorly must be twice the height anteriorly.

The degree of correction is then checked radiologically. In our approach we recommend the use of a grid plate placed

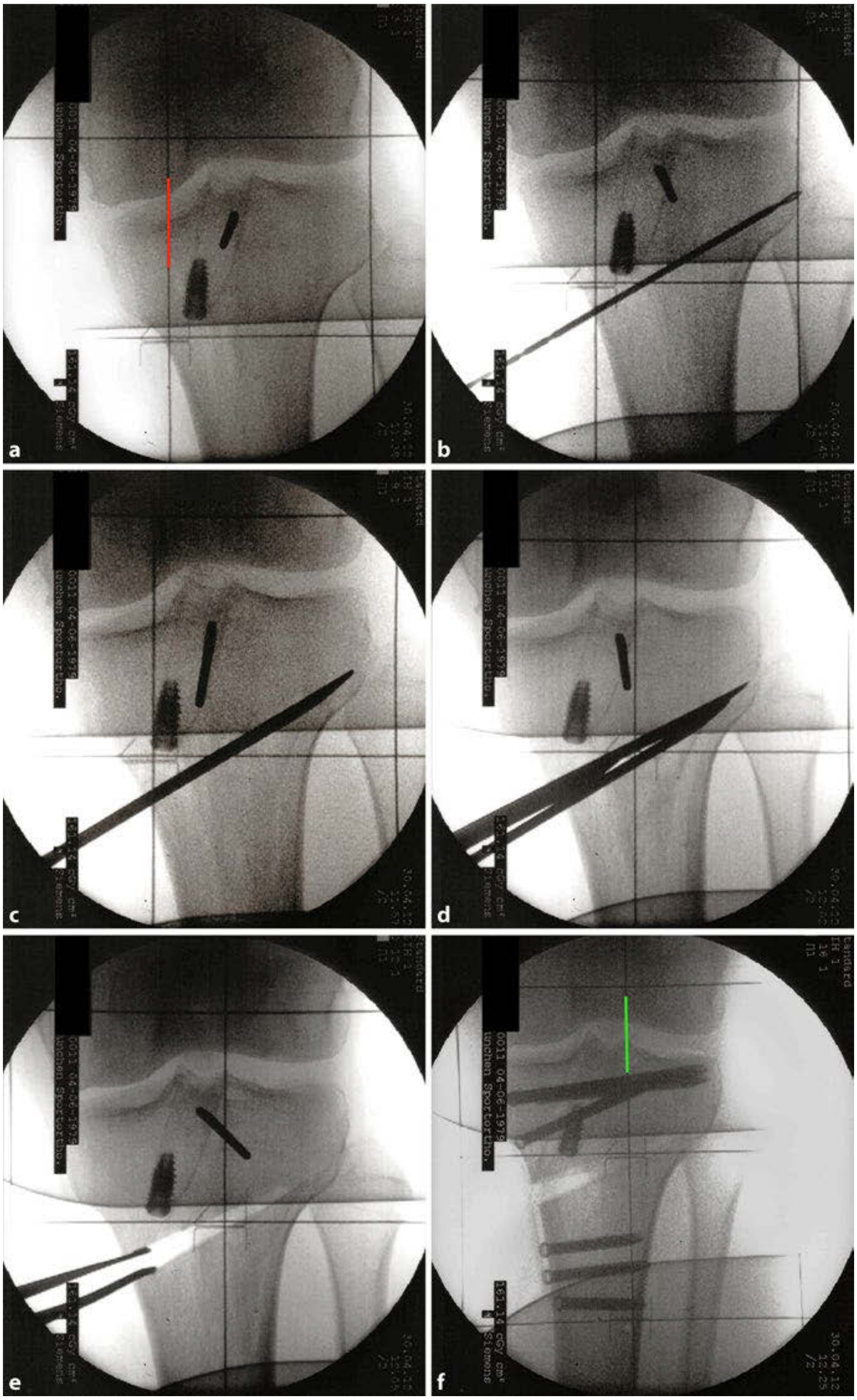


Fig. 19.6a–f Intraoperative fluoroscopic image. **a** Pre-operative mechanical axis (*red line*), **b** marking the axial plane osteotomy with 2 parallel Kirschner wires; **c** osteotomy performed using an osteotome until to just before the lateral cortex; **d** introduction of multiple osteotomes, **e** gradual opening of the osteotomy with a distractor; **f** new mechanical axis (*green line*) after fixation of the osteotomy with a PeekPower plate (Arthrex)

under the patient's leg to check the new mechanical axis (Fig. 19.6f). This could be performed using the electrocautery cable or an alignment rod as an alternative. The Osteotomy is finally fixed with a fixed angle plate (e. g. PEEKPower HTO Plate, Arthrex or TomoFix, Synthes), as specified by the manufacturer (Fig. 19.5f). With distally aimed frontal osteotomy, additional fixation of the tuberosity fragment with 2 bi-cortical cortical screws is needed.

Valgus-Producing Closed-Wedge HTO

Diagnostic arthroscopy is performed via the anterolateral portal to confirm the operative indication as well as for assessment and treatment of possible concomitant lesions. Curved skin incision over the lateral tibial plateau. The proximal part of the tibialis anterior muscle is released.

The head of the fibula is exposed and an oblique osteotomy is performed from superolateral to inferomedial direction, starting laterally just distal to the insertion of the lateral collateral ligament and the biceps femoris tendon and

Fig. 19.7a,b Postoperative radiographs after a medial open-wedge HTO with proximally directed frontal osteotomy and fixation with a PeekPower HTO plate (Arthrex). **a** a.p. and **b** lateral views

this ensures being proximal to the lateral popliteal nerve as it winds around the neck of the fibula. This oblique osteotomy allows the distal part of the fibula to slide superiorly over the proximal part during closure of the tibial wedge. K-wires are inserted freehand or using the appropriate guides to mark the wedge to be removed.

The more obliquely ascending from lateral to medial the wedge is, the less is the degree of displacement of the lateral cortex during closure of the wedge.

An oscillating saw is used to perform the wedge osteotomy between the placed K-wires. The bone wedge is then removed. The medial hinge must preserved but weakened to about 5 mm from the medial cortex. The osteotomy wedge is closed with valgus strain using the medial cortex as a pivot followed by fixation with a conventional or a fixed angle plate.

For more compression of the two osteotomy surfaces, a tension device could be applied distally with the plate already fixed proximally.

19.1.5 Postoperative Management

- Monitoring of peripheral circulation, motor and sensory innervation
- Use of elastic compressive bandages
- Cooling and elevation of the extremity
- Postoperative radiograph in 2 planes (Figs. 19.7 and 19.8)
- Standing long-leg AP radiographs to evaluate the new mechanical axis

19.1.6 Follow-up Management

Partial weight bearing with 20 kg in first 2 postoperative weeks with free range of motion. Gradually increased weight bearing from the 3rd week to reach full weight bearing within the next 4 weeks. Follow up x-ray is performed after 6 weeks. Resumption of the high physically demanding activities after about 3 months.

19.1.7 Tips & Tricks

Two k-wires inserted parallel to each other in axial and sagittal planes, one proximal and the other distal to the osteotomy can be used for intraoperative control of the slope and the axial rotation (Fig. 19.9).

With the medial open -wedge technique, the bi-planar osteotomy offers a better intraoperative control of rotation, more primary stability and faster healing in contrast to the mono-planar osteotomy.

Fig. 19.8a,b Postoperative radiographs after a medial open-wedge HTO with distally directed frontal osteotomy and fixation with a PeekPower HTO plate (Arthrex). **a** a.p. and **b** lateral views

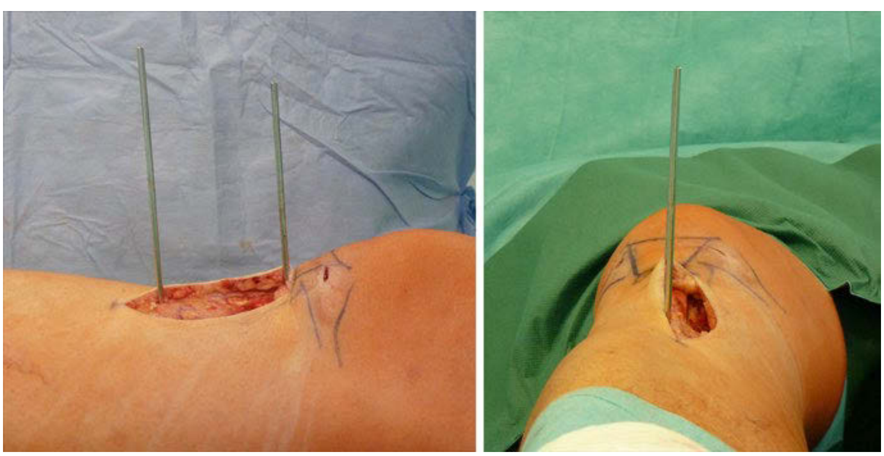


Fig. 19.9 Controlling the slope and rotation with 2 k-wires inserted parallel in both the sagittal and axial planes

Completing the osteotomy of the posterior cortex must be ensured during performing the axial osteotomy, otherwise the osteotomy couldn't be opened.

A careful and slow opening of the osteotomy is essential to protect the lateral cortex.

Filling the osteotomy with cancellous bone graft from the iliac crest is recommended in smokers, intraoperatively recognized fracture of the lateral cortex or when the length of the base of the osteotomy is more than 10 mm.

The tibial slope influences the anteroposterior stability and the range of motion of the knee and thus could be therapeutically modified during the HTO. Our approach in patients with varus osteoarthritis of the knee with concomitant posterior or posterolateral instability and/or hyperextension is to perform a HTO together with increasing the degree of the slope, and in case of anterior or anteromedial instability and/or extension deficit to decrease the slope together with the HTO.

In patients with posterior/posterolateral instability and medial osteoarthritis we consider the isolated valgus and flexion producing HTO (= increasing the slope) as the primary treatment (Fig. 19.10). Additional ligamentous reconstruction is often not necessary in these patients.

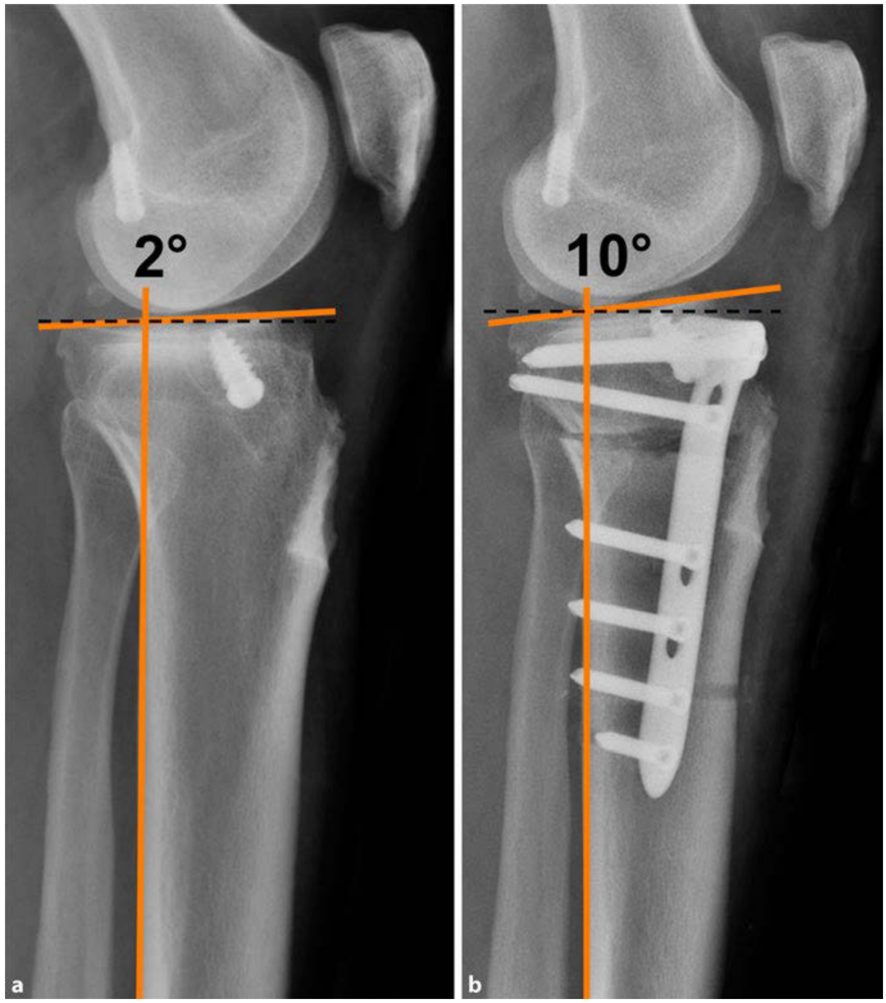


Fig. 19.10a,b Lateral radiograph before (**a**) and after (**b**) flexion medial open wedge HTO in a patient with symptomatic posterior and posterolateral instability with symptomatic hyperextension of about 10°. The preoperative slope of 2° was increased after a flexion HTO postoperatively to 10°. The orange lines mark the posterior tibial cortex and a tangent to the tibial plateau. The angle between the tangent and the line perpendicular to the posterior tibial cortex (*dashed black Line*) corresponds to the tibial slope angle

19.2 Distal Femoral Osteotomy (Varus Producing)

M. Feucht, S. Hinterwimmer

19.2.1 Indication

Valgus deformity with:
- Symptomatic, lateral unicompartmental osteoarthritis of the knee
- Cartilage treatment or meniscus replacement procedures
- Lateral unicompartmental overload/hyper compression.
- Ligament reconstruction on the convex side of the deformity

Prerequisites are intact cartilage of the medial compartment (maximal damage grade 2 according to the ICRS classification) and preserved medial meniscus.

19.2.2 Operation Principle

- Lateral open-wedge technique: shifts the mechanical axis medially through opening a lateral metaphyseal osteotomy of the distal femur.
- Medial closed-wedge technique: shifts the mechanical axis medially by closing a wedgeshaped metaphyseal osteotomy on the medial side of the distal femur

19.2.3 Preoperative Assessment

Diagnosis

Clinical

Symptom specific history: pain (related to activity, at rest, at night etc.), site of pain, pain free walking distance.

Symptom specific examination: inspection of the standing axial alignment, gait pattern (thrust), tenderness at the medial or lateral joint line, tenderness on patellar compression/palpation of the undersurface, passive and active flexion/extension, ligamentous stability.

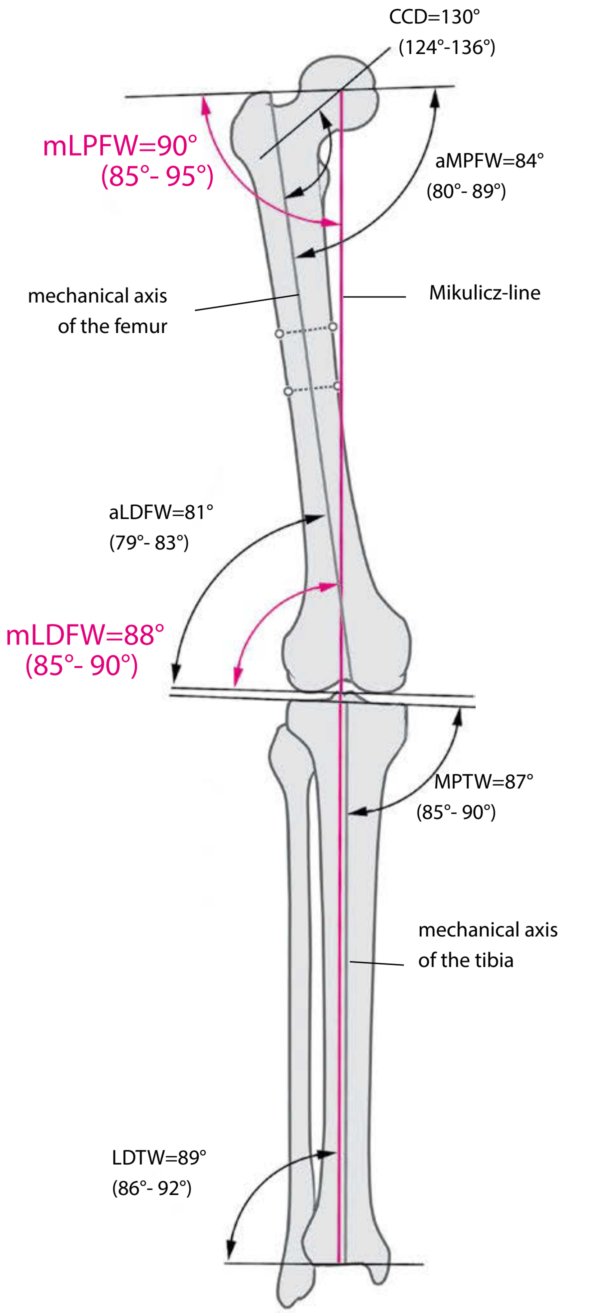


Fig. 19.11 Axes and joint angles of the lower extremity in the frontal plane

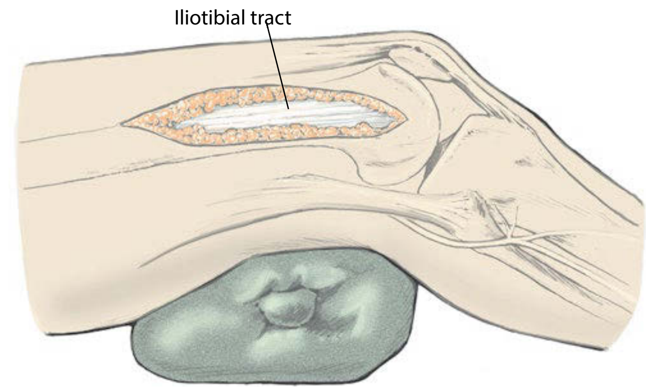


Fig. 19.12 Skin incision of about 10 cm in length, beginning on the lateral epicondyle

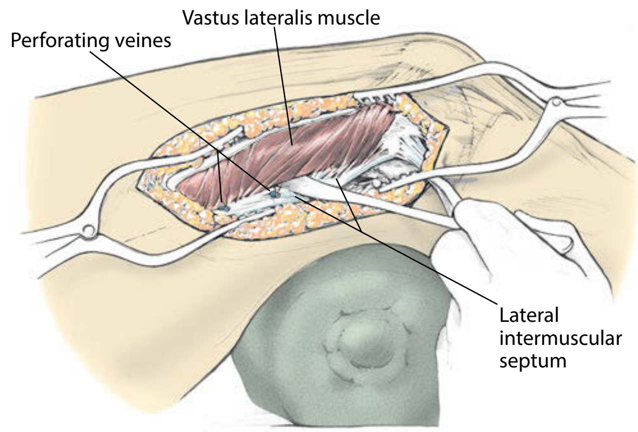


Fig. 19.13 After incising the iliotibial tract, the vastus lateralis muscle is mobilized from the lateral intermuscular septum anteriorly

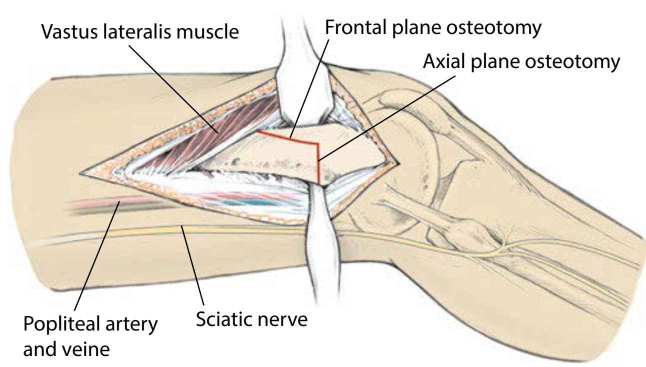


Fig. 19.14 marking the bi-planar osteotomy

Imaging

- X-rays of the knee in 3 views (AP, lateral and tangential patella) to assess the degree of osteoarthritis of all compartments.
- Standing long-leg AP radiographs to analyze the deformity and plan the osteotomy (see below)
- Stress radiographs (in valgus and varus) with collateral ligaments laxity.
- MRI to evaluate the condition of the articular cartilage, bone marrow signal, exclude concomitant ligamentous and meniscal lesions.
- CT with contrast medium, if the MRI is contraindicated or with presence of metallic artifacts.

Planning

Analysis of the deformity and planning of the osteotomy could be performed either using appropriate computer software (e. g. mediCAD, Hectec) or conventional planning using radiographs.

On an anteroposterior long leg radiograph, the center of the femoral head (FHC), the center of the ankle joint (AJC) and the center of the knee joint (KJC) are marked. The mechanical axis of the leg corresponds to the angle between the

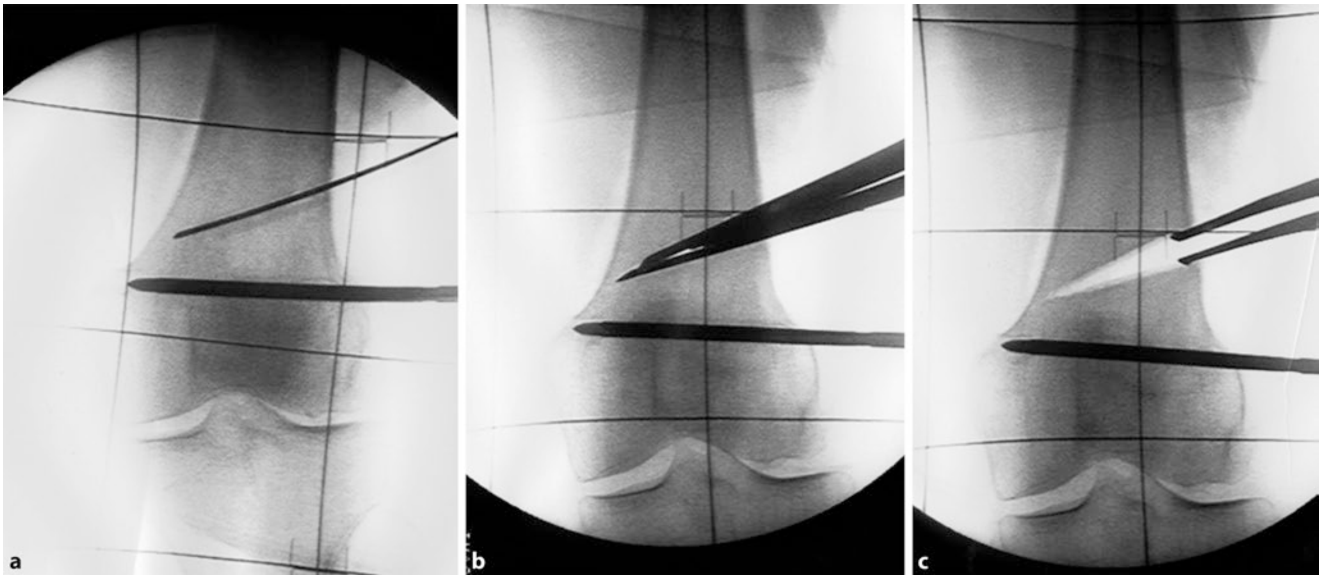


Fig. 19.15a–c Intraoperative fluoroscopic images. **a** Insertion of two parallel wires to mark the axial osteotomy **b** after osteotomy with the saw and insertion of multiple osteotomes to about 0.5–1 cm from the medial cortex, **c** opening of the osteotomy to the desired Correction angle with a spreader

mechanical axes of the femur (line connecting the FHC and the KJC) and the tibia (line connecting KJC and the AJC). The line between the FHC and the AJC represents the weight bearing axis of the lower extremity (Mikulicz line).

The point where this line intersects the tibial plateau is expressed as a percentage of total width of the tibial plateau (medial border = 0%, lateral border = 100 %). The site of deformity is determined by measuring the tibial and femoral joint angles. These represent the angle between the knee joint line of the femur and the tibia (line tangential to the femoral and tibial articular surface) and the corresponding mechanical axis. Routinely, the mechanical lateral distal femoral angle is (mLDFA) and the mechanical medial proximal tibial angle (mMPTA) are measured (Fig. 19.11). The correction angle and the height of the wedge base are planned according to the desired amount of correction (position of the Mikulicz line).

Patient Information/Consent

Specific operative risks: persistent pain, under-/overcorrection (in the coronal plane), angular deformity: axial (rotational deformity) and sagittal (tilting of the femoral condyles), leg shortening/lengthening, articular fracture, non-union, iliotibial band friction syndrome, implant failure, progression of the course of osteoarthritis, annoying fixation implant, potential need for cancellous bone graft from the iliac crest.

19.2.4 Surgical Technique

Positioning and Preparation

- Supine position
- A thigh tourniquet is applied
- Preparation of the instruments needed for measurement of the amount of correction (e.g. electrocautery cable, alignment rod, grid plate or navigation)

Bi-Planar Varus Open-Wedge DFO

Diagnostic arthroscopy is performed via the anterolateral portal to confirm the operative indication, the amount of planned correction as well as for assessment and treatment of possible concomitant lesions.

About 10 cm longitudinal lateral incision just above the joint line. Starting over the lateral epicondyle and extending proximally (Fig. 19.12). The iliotibial tract is longitudinally incised in the line of its fibers and the vastus lateralis muscle is anteriorly mobilized from the lateral intermuscular septum (Fig. 19.13).

The bi-planar osteotomy (axial and frontal) is marked with an electrocautery (Fig. 19.14). Two parallel wires are inserted to mark the axial osteotomy to reach the medial cortex and image intensifier control (Fig. 19.15a).

Osteotomy is then performed in the frontal plane along the marking using an oscillating saw. This is followed by the axial osteotomy using an oscillating saw and then osteotomes are inserted along the already placed wires up to about 0.5–1 cm from the medial cortex to leave a stable medial hinge as possible (Fig. 19.15b). Osteotomy is preferably performed proximal to the wires to leave the medial hinge and the insertion of the medial collateral ligament intact.

The length of the osteotomy could be indirectly determined in advance by measuring the length of the wires inserted into the bone.

A Hohmann retractor is placed to protect the structure posterior to the linea aspera during osteotomy. Careful

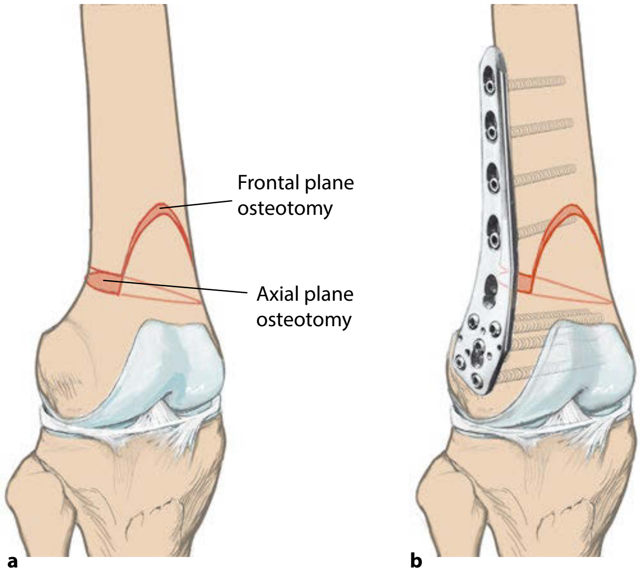


Fig. 19.16a,b Diagrammatic illustration of fixation of the bi-planar osteotomy with a fixed angle plate

opening of the osteotomy to the desired angle of correction (Fig. 19.15c). The osteotomy spreader must be correctly positioned so that the plate for fixation could be easily placed.

The degree of correction is checked radiologically and the mechanical axis is evaluated using the electrocautery cable, alignment rod or a grid plate. The Osteotomy is finally fixed with a fixed angle plate (e.g. PEEKPower LDFO Plate, Arthrex or TomoFix, Synthes), as specified by the manufacturer (Fig. 19.16).

Bi-Planar Varus Closed -Wedge DFO

Diagnostic arthroscopy is performed via the anterolateral portal to confirm the operative indication, the amount of planned correction as well as for assessment and treatment of possible concomitant lesions.

About 8–10 cm longitudinal medial incision, starting about 3–5 cm above the joint line and extending proximally. Longitudinal incision of the fascia over the vastus medialis and mobilization of the muscle from the medial intermuscular septum anteriorly.

The frontal plane osteotomy is marked with an electrocautery and the osteotomy wedge in the axial plane is marked with 4 k-wires; two wires proximal and 2 wires distal to the wedge to be removed. Osteotomy is then performed in the frontal plane along the marking using an oscillating saw. Osteotomy in the axial plane is then performed with the oscillating saw followed by osteotomes inserted within the placed wires. The lateral cortical hinge should not be violated. A Hohmann retractor is placed to protect the structure posterior to the linea aspera during osteotomy. The bone wedge is removed and the osteotomy is closed.

The degree of correction is checked radiologically and the mechanical axis is evaluated using the electrocautery cable, alignment rod or a grid plate. The Osteotomy is fixed with a fixed angle plate (e.g. TomoFix, Synthes), as specified by the manufacturer.

19.2.5 Postoperative Management

- Monitoring of peripheral circulation, motor and sensory innervation
- Use of elastic compressive bandages
- Cooling and elevation of the extremity
- Postoperative radiograph in 2 planes (Fig. 19.17)
- Standing long-leg AP radiographs to evaluate the new mechanical axis

19.2.6 Follow-up Management

Partial weight bearing with 20 kg in first 2 postoperative weeks with free range of motion. Follow up x-ray is performed after 6 weeks to determine further increase of loading. Resumption of daily and sport activities after about 3 months.

19.2.7 Tips & Tricks

Be cautious with varus open-wedge osteotomies with a wedge height > 1 cm in patients with congenital valgus deformity as there is a high risk of traction injury to the peroneal nerve.

The bi-planar osteotomy offers a better intraoperative control of rotation, more primary stability and faster osseous healing in contrast to the mono-planar osteotomy.

Careful placement of the Hohmann retractor posterior to the linea aspera to protect the underlying vessels during the osteotomy.

Two K- wires or Schanz pins are inserted parallel to each other's in the axial and sagittal planes, one proximal and the other distal to the osteotomy for intraoperative control of the axial rotation as well as flexion and extension.

A careful and slow opening of the osteotomy is essential to protect the medial cortex.

Filling the osteotomy gap in open-wedge DFO is more generously indicated due to the reduced bone formation potential at the distal femur.

In smokers, the indication for open-wedge DFO must be very critically considered.

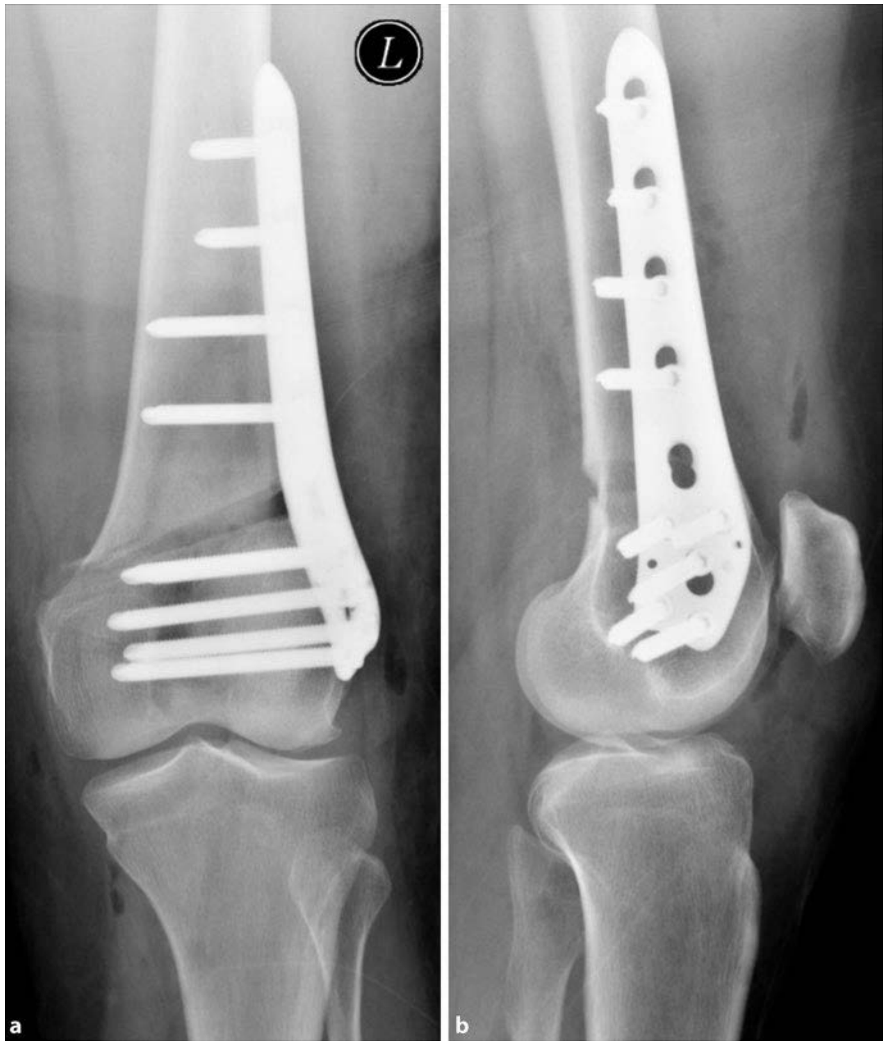


Fig. 19.17a,b Postoperative radiographs after lateral open-wedge DFO. **a** a.p. view, **b** lateral view

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Gonarthrosis

T. Kraus, I. Banke, S. Lorenz,

A. B. Imhoff, M. J. Feucht (Eds.), *Surgical Atlas of Sports Orthopaedics and Sports Traumatology,*
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20.1 Tibiofemoral Resurfacing Arthroplasty

T. Kraus, S. Braun

20.1.1 Indication

The tibiofemoral resurfacing arthroplasty fills the gap between the biological treatment procedures and a unicondylar knee prosthesis. The cartilage or osteochondral lesion is replaced on the tibial and/or the femoral side. Such a small anatomical implant allows maintaining the surrounding bone, cartilage and meniscus. Focal resurfacing arthroplasty is indicated when a corrective osteotomy is not recommended based on the lower limb alignment and at the same time an OATS ("osteochondral autograft transfer system") or MACT (matrix-associated chondrocyte implantation) are not considerable options due to advanced age of the patient.

20.1.2 Operation Principle

The arthroscopically assisted implantation allows a minimally invasive procedure. Arthroscopic visualization allows accurate placement of the implant. The minimal amount of bone loss make the rehabilitation easier and if necessary, implantation of a unicompartmental or total knee prosthesis in the future is not compromised.

20.1.3 Preoperative Assessment

Diagnosis

Clinical

Symptom specific history: onset and duration of complaints, symptoms (pain intensity and location), subjective stability, previous surgery, age.

Symptom specific examination: alignment, gait, range of motion, tenderness/tenderness on percussion, exclusion of concomitant instability or meniscal lesion.

Imaging

- X-rays of the knee in three views (AP, lateral and tangential patella) for assessment of the osseous status and exclusion of advanced osteoarthritis of the knee.
- Standing long-leg AP radiographs if lower limb Malalignment is suspected (indication for corrective osteotomy)
- MRI to evaluate the osteochondral status, to verify other chondral/osteochondral lesions and to exclude any concomitant lesion.

Patient Information/Consent

Specific operative risks: Implant loosening, malpositioning of the implant, formation of cysts, osteolysis, polyethylene wear, arthrotomy if necessary, conversion to a unicompartmental prosthesis/total knee prosthesis with time.

Planning

The expected size of the implant is determined using the product specific X-ray templates.

20.1.4 Surgical Technique

Positioning and Preparation

- Supine position
- A thigh tourniquet is applied
- Examination under anesthesia (to exclude concomitant instability)

Arthroscopically Assisted Resurfacing Arthroplasty of the Medial Compartment

A diagnostic arthroscopy is performed via the anterolateral portal to confirm the indication as well as to assess possible concomitant lesions. An anteromedial portal is used for inserting both instruments and implants.

The correct size and position of the implant on the tibial plateau and the femoral condyle are determined and measured using the product-specific sizing templates. The implant socket is created on the femoral condyle and tibial plateau using unique instruments (◘ Fig. 20.1). The femoral implant is inserted through the anteromedial portal (◘ Fig. 20.2). The tibial implant is inserted in a retrograde manner (shuttle technique) after drilling a tunnel in the medial tibial plateau using a drill guide (◘ Figs. 20.3 and 20.4).

20.1.5 Postoperative Management

- Monitoring of peripheral circulation, motor and sensory innervation
- Use of elastic compressive bandages
- Cooling and elevation of the extremity
- Postoperative radiograph (◘ Fig. 20.5)

20.1.6 Follow-up Management

Partial weight bearing with 20 kg in 1st and 2nd postoperative weeks with free range of motion. After 2 weeks, light activities such as treadmill training or cycling could be started according to the pain and swelling, sport-specific training can be started after 6 months while contact and high-risk sports after 9–12 months.

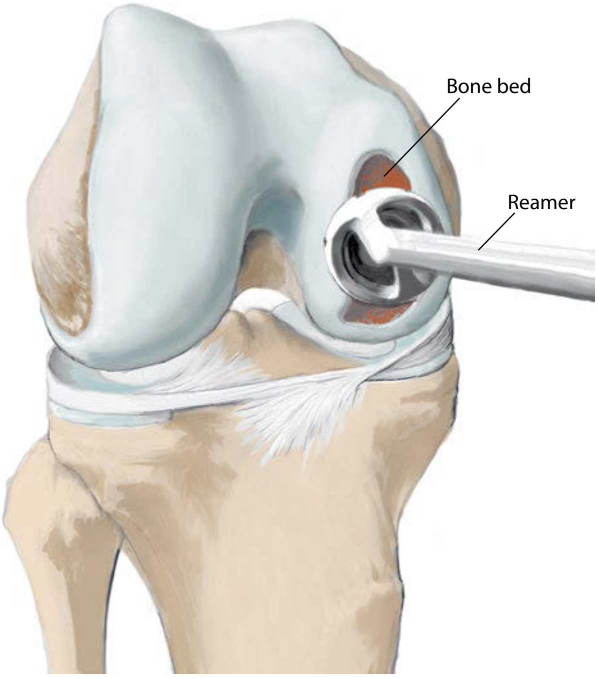


Fig. 20.1 Reaming the implant socket at the medial femoral condyle

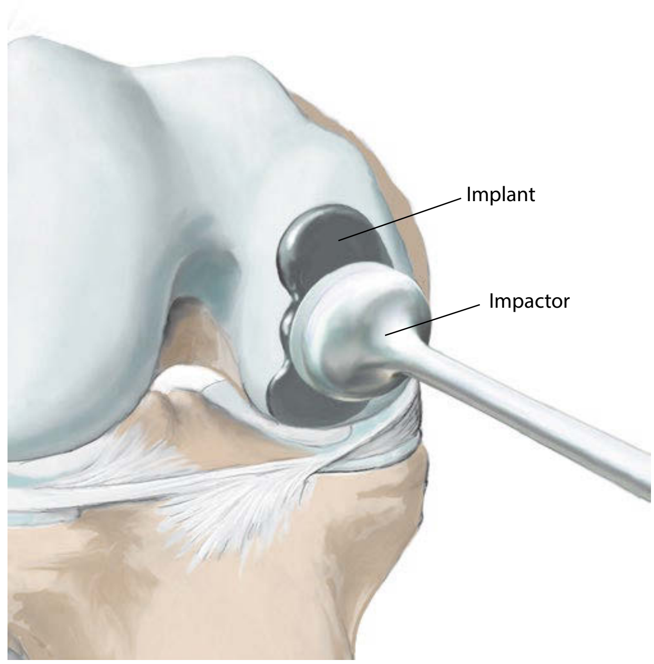


Fig. 20.2 Insertion of the implant with several taps of the impactor

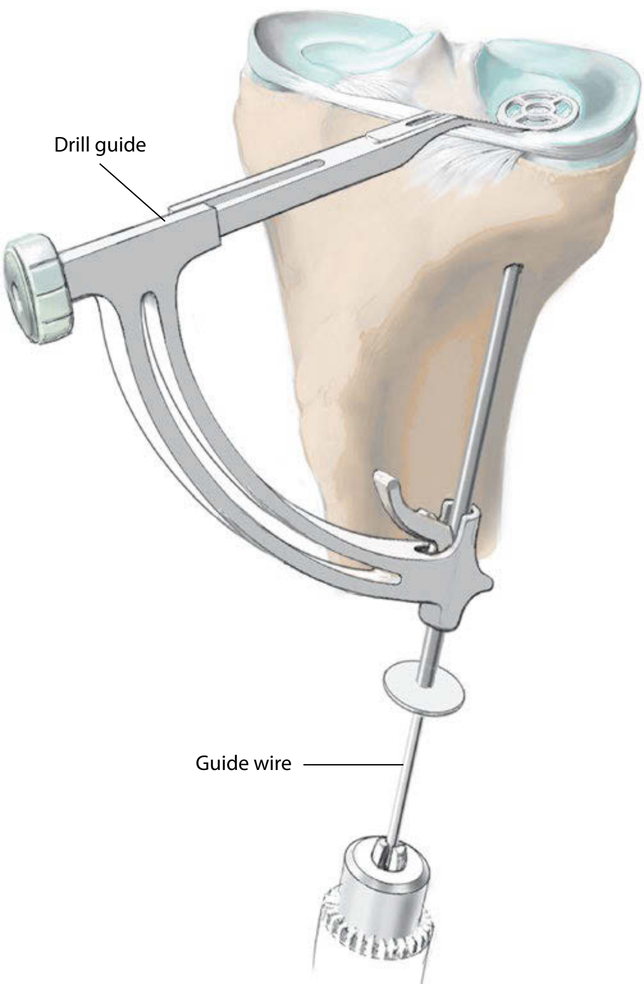


Fig. 20.3 Insertion of a guide wire in the center of the defect at the medial tibial plateau using a drill guide

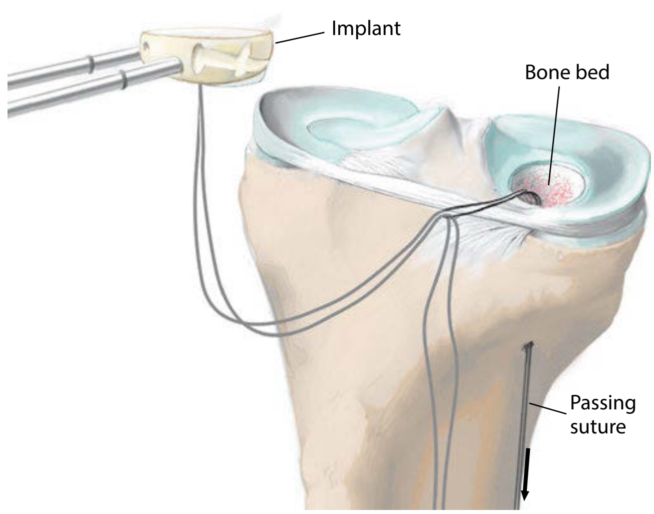


Fig. 20.4 Retrograde insertion of the tibial implant after reaming a bone socket

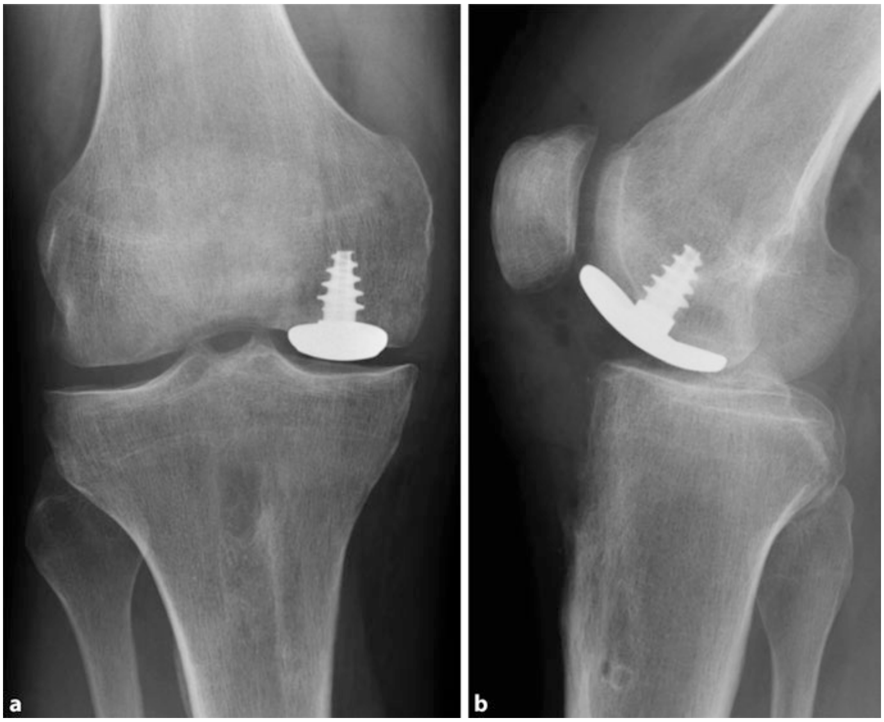


Fig. 20.5a,b Postoperative radiographs after resurfacing arthroplasty of the medial femoral condyle with the HemiCAP-prosthesis (Arthrosurface). **a** anteroposterior view; **b** lateral view

20.2 Patellofemoral Resurfacing

I Banke, S. Lorenz

20.2.1 Indication

Symptomatic, isolated patellofemoral chondral or osteochondral lesions, patellofemoral osteoarthritis, high grade trochlear dysplasia in biologically young patients (age < 50 years) and in patients with high functional demands.

In patellofemoral osteoarthritis induced by instability, patellofemoral resurfacing should be combined with MPFL reconstruction, distal femoral osteotomy, proximal tibial osteotomy, or tibial tuberosity transfer if necessary.

20.2.2 Operation Principle

Congruent reconstruction of the patellofemoral articular surfaces with a trochlear prosthesis (patellar component is optional). This aims is to improve the function while preserving the biomechanics of the lower limb and to obtain pain reduction by relieving the pressure over the lesion existing before surgery. Conversion to a total knee prosthesis is not difficult due to the minimal amount of bone resected.

20.2.3 Preoperative Assessment

Diagnosis

Clinical

Symptom specific history: etiology, symptoms (retropatellar pain, patellar instability), functional demand, metal allergy, previous treatment (intraarticular injection, e.g. cortisone), previous surgery, relevant comorbidities.

Symptom specific examination: range of motion (active and passive; retropatellar pain with extreme flexion), pain on patellar compression/movement or compression of the undersurface, Zohlen sign, detailed examination for patellofemoral instability.

Imaging

- X-rays of the knee in three views (AP, lateral and tangential patella) to evaluate the patellofemoral compartment (osteoarthritis, osteochondral lesion, patellar tilt and shift, patellar index measured according to Insall & Salvati or Caton methods, trochlear dysplasia) as well as to exclude any concomitant tibiofemoral osteoarthritis.
- Standing long-leg AP radiographs (AP view) if a mechanical axis deviation is suspected.
- MRI to evaluate the retropatellar and trochlear osteochondral condition, trochlear morphology (Dejour's classification), TT-TG distance (between the tibial tuberosity and the trochlear groove), patellar tilt and shift, as well as the tibiofemoral osteochondral condition.

CT is indicated only with unclear osseous situation (e.g. cysts/osteolysis) or as rotational CT with suspected rotation deformity.

Patient Information/Consent

Specific operative risks: Technical faults (size, angle, height), material failure (breakage, disconnection), material wear, early loosening, progressive joint degeneration, osteolysis, fracture, allergy/hypersensitivity reaction, conversion to a total knee prosthesis with time.

20.2.4 Surgical Technique

Positioning and Preparation

- Supine position with a roll below the knee
- A thigh tourniquet is applied
- Examination under anesthesia (patellofemoral instability)

Implantation of a Wave Prosthesis

Approach is via a medial or lateral arthrotomy with eversion of the patella. The deepest point in the middle of the trochlea is localized. The size of the trochlea is measured using the appropriate sizing templates to determine the appropriate size of the reamer and the prosthesis. Three dimensional reaming of the trochlea using the guide block corresponding to the measured offset. The central fixation screw (taper post) is advanced down to the proper depth. The femoral resurfacing component (Wave prosthesis) is seated over the taper post with careful impaction using a mallet (◘ Figs. 20.6 and 20.7).

Implantation of a PFJ – Trochlea Shield

Approach is via a medial arthrotomy and the patella is everted to the lateral side. After extramedullary alignment and medullary reaming, an intramedullary guide rod is introduced and an anterior cutting block is applied to it. Rotational alignment is adjusted with extramedullary tibial reference and the level of anterior bone resection is determined using the boom of the anterior cutting block. After adjusting the femoral jig, the trochlear reaming guide is inserted and the trochlea is reamed and contoured down to the marked depth. The jig is removed followed by milling and drilling holes for the implant pigs. Bone cement is used to fix the implant (◘ Fig. 20.8).

20.2.5 Postoperative Management

- Monitoring of peripheral circulation, motor and sensory innervation
- Use of elastic compressive bandages
- Cooling and elevation of the extremity
- Postoperative radiograph

20.2.6 Follow-up Management

Free range of motion is allowed from the 1st postoperative day. Partial weight bearing with 20 kg in 1st and 2nd postoperative weeks (according to the pain and swelling). Gradually increased weight bearing is allowed from the 3rd week at a rate of about 20 kg/week.

20.2.7 Tips & Tricks

Strict and correct indication is the key to the success of the patellofemoral arthroplasty. This type of arthroplasty should be only reserved for isolated patellofemoral chondral or osteochondral lesions or osteoarthritis.

During implantation of the Wave prosthesis, the anterior curvature of the lateral femoral condyle is very relevant for measuring the size of the prosthesis. The Wave prosthesis must be well seated so that it lies flush or slightly below the articular surface.

The joint must be thoroughly irrigated and cleaned as well as the surrounding of the central screw with a special conical device to secure the connection between the two parts of the prosthesis.

The amount of bone resected during implantation of the trochlea shield depends on the position of the trochlear reaming guide.

20.3 Arthrolysis

S. Lorenz

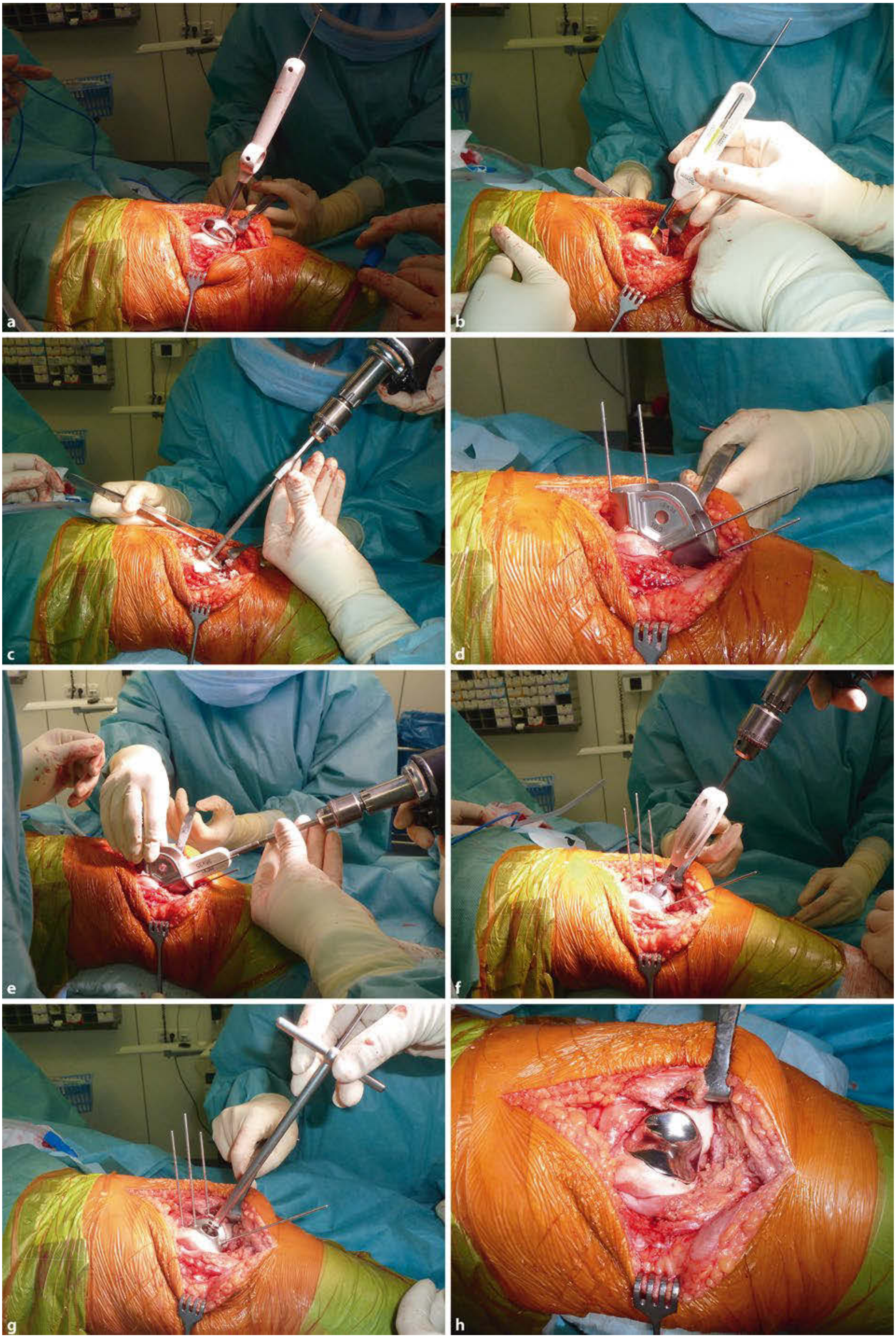
20.3.1 Indication

Symptomatic motion deficit. Causes of flexion or extension deficit are shown in ◘ Table 20.1.

20.3.2 Operation Principle

Evaluation of the underlying pathology (Millet nine-step arthroscopic evaluation) (◘ Fig. 20.9):

1. suprapatellar pouch
2. medial gutter
3. lateral gutter
4. pretibial recess
5. lateral retinaculum
6. medial retinaculum
7. Intercondylar notch with the anterior and posterior cruciate ligaments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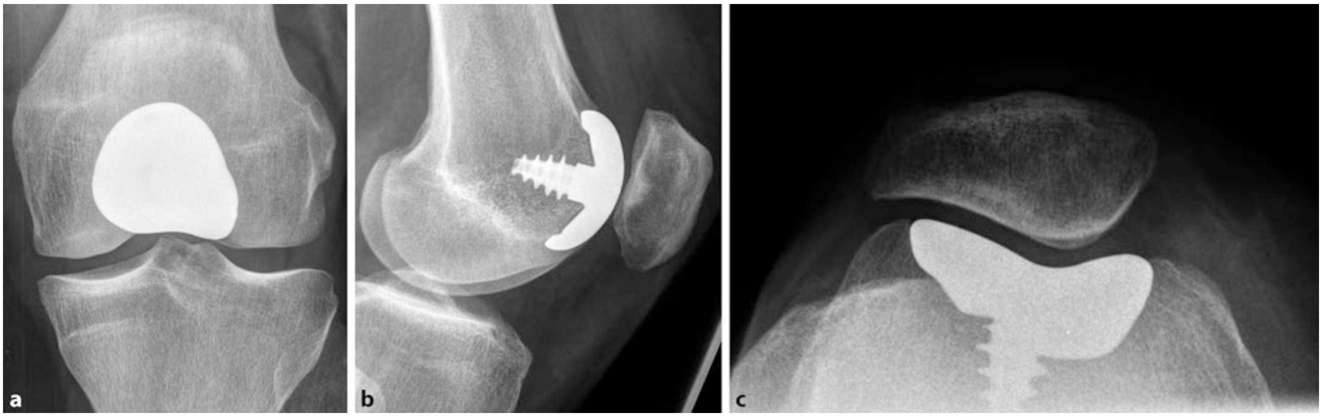

Fig. 20.7a–c Postoperative radiographs after trochlear resurfacing arthroplasty (inlay technique) with the Wave prosthesis (Arthrosurface). **a** anteroposterior view; **b** lateral view; **c** tangential patella view

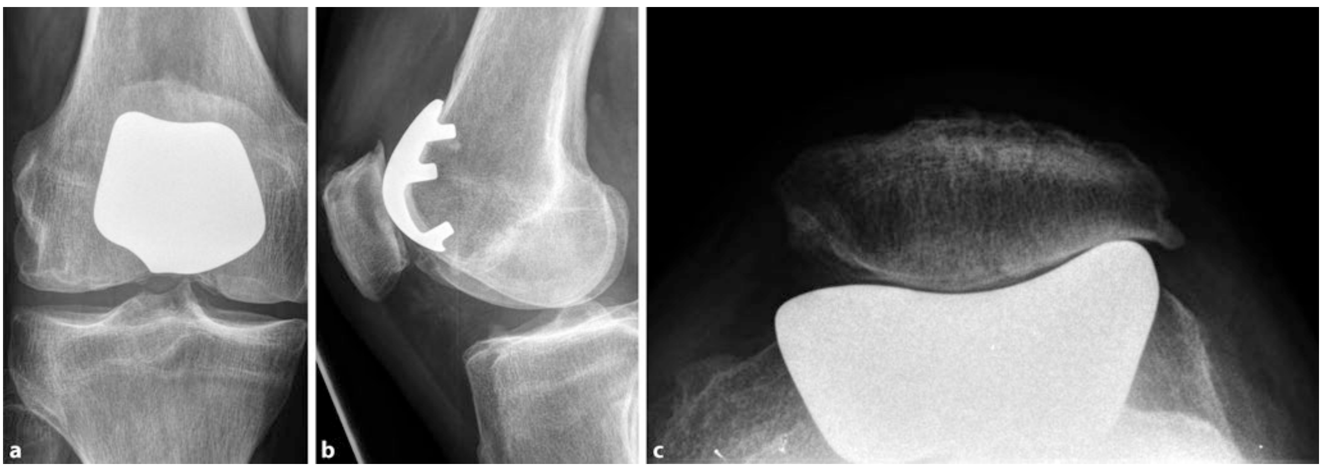

Fig. 20.8a–c Postoperative radiographs after trochlear resurfacing arthroplasty (onlay technique) with the PJF- Trochlea shield (Smith & Nephew). **a** anteroposterior view; **b** lateral view; **c** tangential patella view

8. tibial insertion of the posterior capsule
9. femoral insertion of the posterior capsule

Management should be directed to the underlying pathology.

Table 20.1 Causes of flexion or extension deficits

Extension deficit	Flexion deficit
Notch impingement	Suprapatellar adhesions
Cyclops lesion after ACL-Rupture	Adhesions in the medial and lateral gutters
ACL graft malpositioning	
Malpositioned prosthetic implants	
Contracture of the patellar tendon with subsequent depression of the patella (Patella baja)	
Soft tissue calcification	
Idiopathic arthrofibrosis	
Complex regional pain syndrome (CRPS or Sudeck's atrophy)	
Infection	

Fig. 20.6a–h Trochlear resurfacing arthroplasty (inlay technique) with the Wave prosthesis (Arthrosurface). **a** guide wire is introduced at the center of the trochlea using an offset guide; **b** The size of the trochlea is measured to determine the size of the reamer and the prosthesis; **c** The central part of the trochlea is reamed over the guide wire; **d** The guide block is then applied to complete further reaming; **e** Reaming of the inferior and superior parts of the trochlea; **f** drilling a guide hole for the central fixation screw using a template; **g** Tapping for the screw threads; End result after insertion of the screw and prosthesis.

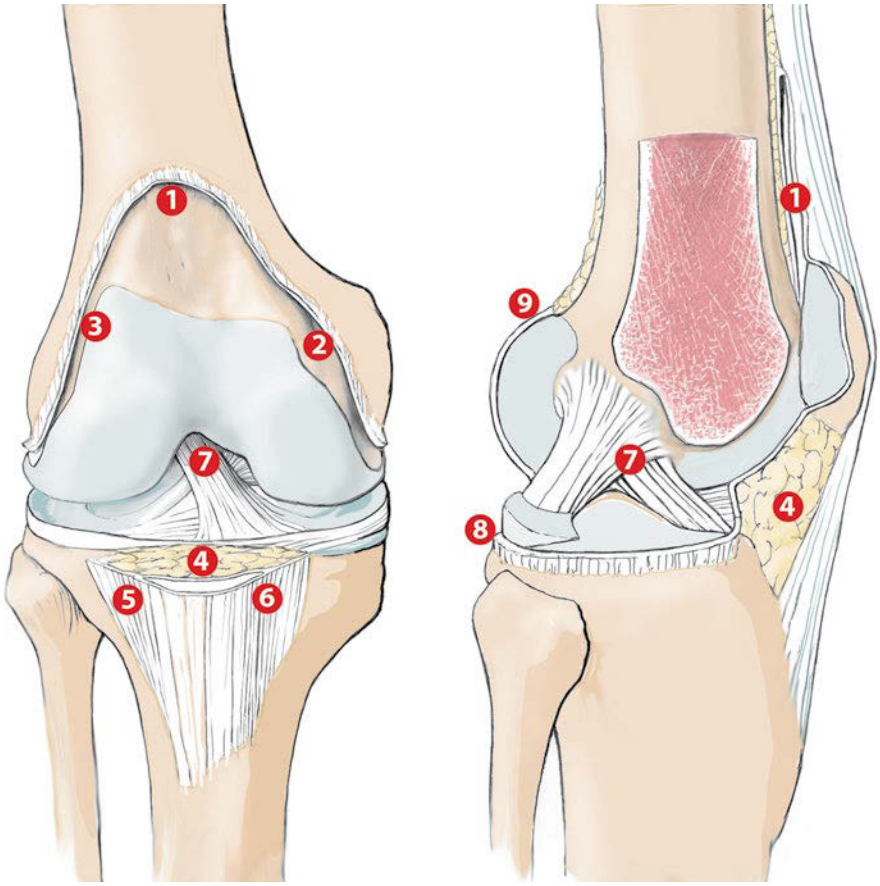

Fig. 20.9 Evaluation of the underlying Pathology (Millet nine-step arthroscopic evaluation). *1* suprapatellar pouch; *2* medial gutter; *3* lateral gutter; *4* pretibial recess; *5* lateral retinaculum; *6* medial retinaculum; *7* intercondylar notch with the anterior and posterior cruciate ligaments; *8* tibial insertion of the posterior capsule; *9* femoral insertion of the posterior capsule

20.3.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: complaints (painful/painless motion deficit, blocking/foreign body sensation, tightness), duration of symptoms, etiology (trauma, surgery, immobilization, idiopathic), previous surgery, previous treatment, relevant comorbidities (e.g. autoimmune diseases, rheumatoid arthritis)
- Symptom specific examination: measurement of the passive and active range of motion, localization of the site of tightness or pain with the terminal degrees of motion, evaluation of the motion end point (hard/soft), assessment of mobility and level of the patella compared to the other side, assessment of the menisci and ligamentous stability (ACL, PCL, collateral ligaments, posterolateral corner)

20

Imaging

- X-rays of the knee in three views (AP, lateral and tangential patella) and optionally an additional Rosenberg view to assess possible osteophytes leading to mechanical impingement, fixation implants, assessment of patellar height, tunnel position after ligament reconstruction and the condition of any implanted prosthesis.
- MRI for further analysis of the etiology, cyclops lesion, ganglion, meniscal tears, prominent plica, reactive capsular or ligamentous changes (scar tissue, hypertrophy), loose bodies, assessment of the position and signal intensity of reconstructed ligaments, signs of complex regional pain syndrome (sudeck's atrophy) or disuse atrophy and osteoporosis.
- CT (CT-Arthrography with intraarticular contrast agent, if needed): for further assessment of bony causes (osteophytes causing mechanical impingement, malalignment, loose bodies), tunnel position after ligament reconstruction, localization of metallic and fixation implants.

Planning

If removal of a reconstructed ligament is anticipated, the fixation material as well as the required removal instruments should be properly planned and prepared or ordered if not available.

Patient Information/Consent

Specific operative risks: nerve/vessel injury (especially popliteal vessels, tibial nerve), soft tissue (patellar tendon or quadriceps tendon rupture), persistent motion deficit, instability, progressive degeneration or osteoarthritis), postoperative bleeding, tissue necrosis (skin, subcutaneous tissue, muscle) with subsequent reconstructive surgeries.

In case of already present ligament reconstruction: possible complete resection of the graft, filling the drill holes with autologous cancellous bone (Iliac crest) or bone substitutes. Risk of HIV and hepatitis C infection with using allogeneic cancellous bone.

20.3.4 Surgical Technique

Positioning and Preparation

- Supine position
- A thigh tourniquet is applied
- Assessment of the range of motion under anesthesia using a goniometer with photographic documentation as well as in the operative sheet.

Arthroscopic Arthrolysis

Distension of the knee with about 180 ml sterile Ringer's solution (injected into the suprapatellar pouch from superolateral using a needle and syringe) before arthroscopic arthrolysis can be helpful in case of sever arthrofibrosis.

Diagnostic arthroscopy via the anterolateral portal. An electrocautery device is introduced via the anteromedial portal. If the anteromedial portal is difficult to be established, a superolateral portal at the level of the upper pole of the patella could be initially used.

Arthrolysis is then performed stepwise with the electrocautery device according the present motion deficit.

Flexion Deficit

Adhesions and scarring are lysed and released to re-establish the suprapatellar pouch, occasionally the superior capsule needs to be incised until the vastus intermedius muscle is visible. Release continues into the lateral then the medial gutters. Hoffa's fat pad and the infrapatellar plica are excised sparing the transverse ligament between the medial and lateral menisci. The transverse ligament should glide freely over the tibia during flexion. The lateral retinaculum is released about 5 mm away from the patella, followed by releasing the medial retinaculum also about 5 mm away from the patella.

Caution: The intraarticular orientation may be very difficult due to the extensive scarring. The quadriceps tendon and the patellar ligament shouldn't be injured. The different boundaries could be easier to be palpated from outside or even marked with needles.

Retinacular release should be performed strictly close to the patella, otherwise there would be an increased risk of injury to the collateral ligaments, peroneal nerve and the popliteus tendon.

Malpositioning of the femoral tunnel of the ACL graft with marked tightness of the ACL in flexion, release up to complete excision of the graft may be indicated.

Extension Deficit

Adhesions, scar tissue and eventually cyclops lesions at the tibial insertion of the ACL are released. Analysis of notch impingement after ACL reconstruction: if the tibial tunnel is positioned too far anterior, a notchplasty and/or partial/total resection of the ACL is performed.

Malpositioning of the femoral tunnel of the ACL graft with marked tightness of the ACL in extension, release up to complete excision of the graft may be indicated.

If the PCL graft is Malpositioned with marked tightness: release/excision. Osteophytes in the notch are removed with an osteotome or shaver.

POL- release: release of the posterior oblique ligament of the medial collateral ligament: the leg is placed in 10° flexion and an arthroscopic knife (banana knife) is used to incise the capsule proximal to the meniscus at the area of transition between the posterior horn and the pars intermedia while applying a valgus stress. This results in marked widening of the medial joint space.

Posterior capsular release: the interval between the ACL and PCL and the notch roof is released and freed to allow passing the arthroscope into the posterior recess. A posteromedial portal is established for passage of instruments (using a needle). Scar tissue is removed and the capsule is sharply released at its femoral bony insertion until the gastrocnemius muscle is visible.

The light cable is rotated to visualize the entire capsular attachment. A posterolateral portal is not necessary in most cases.

Postoperative assessment and documentation of the range of motion. A good improvement in the range of motion could be usually achieved after the operation.

20.3.5 Postoperative Management

- Monitoring of peripheral circulation, motor and sensory innervation
- Use of elastic compressive bandages
- Cooling of the extremity
- Immediate placement of the leg in a continuous passive motion machine (CPM machine)
- A customized dynamic brace is recommended esp. with extension deficit

20.3.6 Follow-up Management

A dynamic knee brace is used for 6 weeks in case of extension deficit. Passive mobilization using the CPM machine during hospitalization, 6 times/day for about 20 minutes to the maximum tolerable flexion and extension as well as manual physiotherapy twice daily focusing on the passive and active assisted range of motion exercises, patellar mobility exercises and isometric quadriceps exercises.

Outpatient physiotherapy after discharge for at least 4 times/week for at least 6 weeks. Partial weight bearing for about 14 days followed by gradually increasing weight bearing (symptom-dependent).

Return to sport after restoration of the muscular balance (at least 90 % of the power of the opposite side).

20.3.7 Tips & Tricks

Arthroscopy portals should not be established close to the patella to avoid difficulties in moving the instruments.

The anatomical landmarks are not reliable for placement of the anterolateral portal in case of patella baja. The X-ray image should be always viewed before establishing the portals.

The posterior neurovascular structures are at increased risk during placement of the posteromedial portal and the working in the posterior compartment. Therefore, only the skin is incised with subsequent blunt dissection with scissors in the direction of the already placed needle. Always remain close to the bone during excision of scar and capsular tissue

Postoperative bleeding should be prevented as possible to avoid recurrent scarring. Therefore, release should be mainly performed using the electrocautery device with meticulous subtle hemostasis together with placing an intraarticular drain in the suprapatellar pouch, which is usually removed after 48 h.

Excision of malpositioned cruciate ligament graft could be generously indicated. The patient should be informed prior to surgery about subsequent possible procedures (revision ligament reconstruction in a two-step procedure after restoration of the dull range of motion).

The initial postoperative pain control to allow an early aggressive range of motion exercises is essential for success of surgery, therefore a regional anesthetic procedures is essential.

Restoration of the range of motion has the priority over muscle strengthening: Strengthening exercises should only begin after restoring the full range of motion of the opposite side.

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Ankle and Foot

Patient Positioning, Arthroscopic Portals, Diagnostic Arthroscopy

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A. B. Imhoff, M. J. Feucht (Eds.), *Surgical Atlas of Sports Orthopaedics and Sports Traumatology,*
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21.1 Patient Positioning

The patient can be positioned on a standard operating table. Supine positioning is adequate if only arthroscopy of the anterior compartment is planned. The ipsilateral buttock could be posteriorly padded to prevent spontaneous external rotation of the foot. The heel should project beyond the end of the table to allow free manipulation and movement of the ankle intraoperatively. A standard leg holder could be used if the posterior compartment in addition to the anterior compartment has to be arthroscopically accessed. The patient is positioned in prone position if only a posterior compartment arthroscopy to be done. The foot should also be positioned beyond the edge of the table so that the ankle joint could be freely moved during surgery. A tourniquet (possible with exsanguination) could be optionally used in all arthroscopic ankle interventions.

21.2 Distraction

Ankle distraction can be achieved in several ways. One possibility is to use a distraction frame mounted to the operating table that could be lengthened to create distraction of the ankle joint (e.g. Ankle Distractor Set Arthrex; ◘ Fig. 21.1). Another possibility is to use a sterile strap, which could be fixed to the ankle and passed around the waist of the surgeon like a stirrup (◘ Fig. 21.2). The desired distraction can then be achieved by moving the pelvis. If the end of the operating table is dropped, the knee flexed and the ankle is freely suspended, a gauze bandage could be applied to the ankle and the other end is provided with a loop so that the surgeon can distract the ankle through the foot. Another option is to attach the gauze bandage to a suspended weight and thereby a constant distraction can be achieved.

To address pathologies such as an anterior impingement, loose bodies, synovitis and anterior ossicle or osteophytes of the ankle, it is often advantageous not to use instrumented distraction. The anterior aspect of the joint capsule relaxes when the ankle is dorsally extended allowing optimal exploration. If more central aspects of the ankle joint needs to be explored, (e.g. in osteochondritis dissecans of the talus), forced plantar flexion is needed.

21.3 Arthroscopic Portals

All relevant anatomical landmarks should be marked before establishing the arthroscopic portals. Regarding anterior portals, these landmarks include: tendons of the tibialis anterior, extensor hallucis longus and extensor digitorum longus, the dorsalis pedis artery, the saphenous vein, the superficial perineal nerve, the medial and lateral malleoli, and the joint line. Posterior landmarks include: medial and lateral malleoli, the medial and lateral border of the achilles tendon and the course of the posterior tibial artery.

The standard portals for ankle arthroscopy are the anteromedial, the anterolateral, and the anterolateral, the posteromedial, and the posterolateral portal (◘ Figs. 21.3 and 21.4). The two posterior portals should particularly carefully created due to their close proximity to the neurovascular structures (◘ Fig. 21.4).

21.3.1 Anteromedial Portal

Medial to the tibialis anterior tendon at the level of the ankle joint line (◘ Fig. 21.3). Injury of the great saphenous vein and saphenous nerve, which are usually located medial to the portal, should be avoided.

21.3.2 Anterolateral Portal

Lateral to the tendons of peroneus tertius and extensor digitorum longus at the level of the ankle joint line (◘ Fig. 21.3). The intermediate cutaneous branch of the superficial peroneal nerve lies closely proximal to the portal site and can often be felt.

21.3.3 Posteromedial and Posterolateral Portal

Just above the tip of the lateral malleolus, directly medial or lateral to the achilles tendon (◘ Fig. 21.4). The average distance from the posterolateral portal to the sural nerve is 6.6 mm, the average distance from the posterolateral portals to the tibial nerve is 5.7 mm.

21.4 Diagnostic Arthroscopy

21.4.1 Anterior Compartment

Ankle arthroscopy could be performed using a 4 mm diameter arthroscope. However, the authors prefers to use a 2.7 mm arthroscope with a 30° oblique lens. Based on our experience, we prefer to start with placing the anteromedial portal due to its relatively easy accessibility and reproducibility. Before establishing the portals, the ankle joint has to be first distended with 10 ml of sterile saline suing a needle inserted through the anteromedial portal. The intraarticular injection is confirmed by passive dorsiflexion of the foot and back flow of the saline solution. The portal is created in the so-called "nick and spread technique", in which only the skin is incised with a scalpel and the subcutaneous layer is dissected with a mosquito clamp down to the joint capsule. The joint capsule is

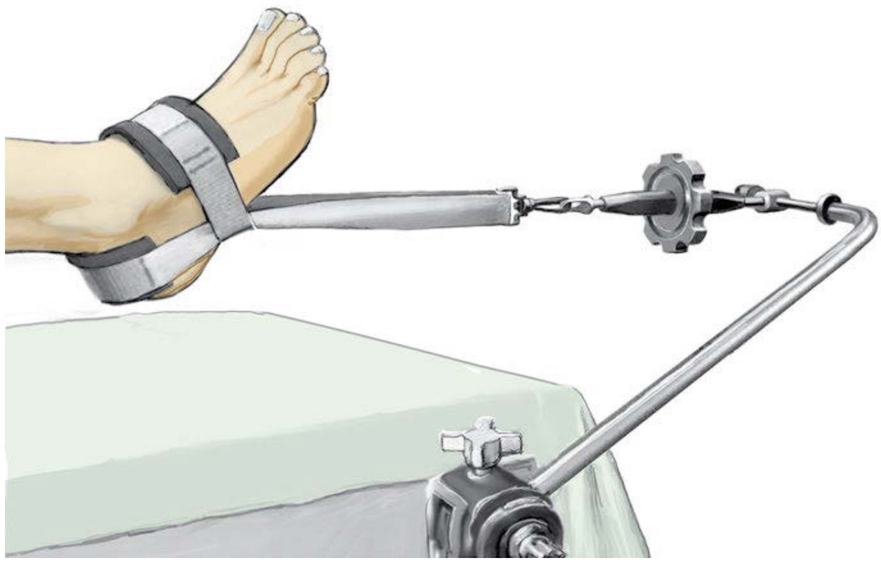

Fig. 21.1 Instrumented ankle distraction

then penetrated with a blunt trocar to avoid iatrogenic cartilage damage.

The arthroscope is inserted and the anterolateral aspect of the ankle joint is visualized. The entry point for the anterolateral portal is marked under arthroscopic trans-illumination and a needle is inserted under direct visualization (Fig. 21.5). The portal is then established using the "nick and spread" technique. Arthroscopy then begins, optionally with temporary distraction, and the relevant pathologies could be approached. The viewing and working portals could be switched according to the location of the lesion. The use of an additional inferior anteromedial portal is helpful in the treatment of synovitis in the vicinity of the deltoid ligament. In such case and to visualize the medial gutter arthroscopically, a needle is introduced under vision (usually 10 mm inferior to the anteromedial portal) and the portal is established in the correct position using the above mentioned technique.

21.4.2 Posterior Coaxial Portals

While fluid inflow is maintained through the anterolateral portal, the posterolateral portal is created directly posterior to the peroneal tendon sheaths through a vertical skin incision. Care should be taken to the close proximity to the tendon sheaths to avoid injury to the sural nerve. The trocar is inserted parallel to the bimalleolar axis while maintaining the ankle in neutral flexion. The arthroscope can be subsequently inserted through this portal. Alternatively, the posteromedial portal is established through a vertical incision directly posterior to the medial malleolus. Care should be taken here to avoid injury to the tibialis posterior tendon. The trocar is introduced parallel to the bimalleolar axis. For arthroscopic synovectomy or management of osteochondral lesions, the

Fig. 21.2 Distraction of the ankle with a strap passed around the waist of the surgeon

arthroscope is inserted via the posterolateral portal and the posteromedial portal is used as a working portal.

21.4.3 Posterior Compartment and Hind Foot

Difficulty in accessing the posterior ankle region represents a challenge for diagnosis and treatment. An excellent option to make this region accessible is to perform the posterior arthroscopy in prone position through two posterior portals. The posterior compartment of the ankle joint (intra-articular), subtalar joint, possibly os trigonum, flexor hallucis longus tendon and the posterior syndesmotic ligaments could be visualized using this approach or through hind foot endoscopy. This includes also posterior impingement of the ankle joint, a symptomatic os trigonum, tendinopathy of the flexor hallucis longus, tibialis posterior tendon or the peroneal tendons, bony avulsions, posttraumatic calcifications, loose bodies of

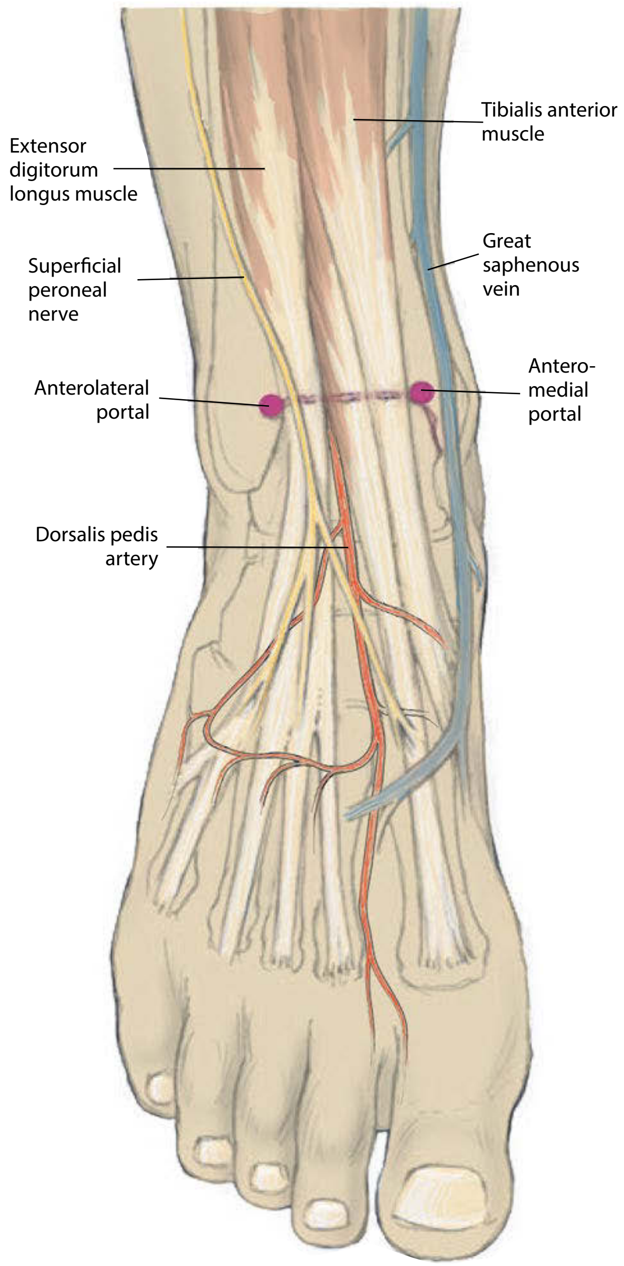

Fig. 21.3 Anterolateral and anteromedial standard portals

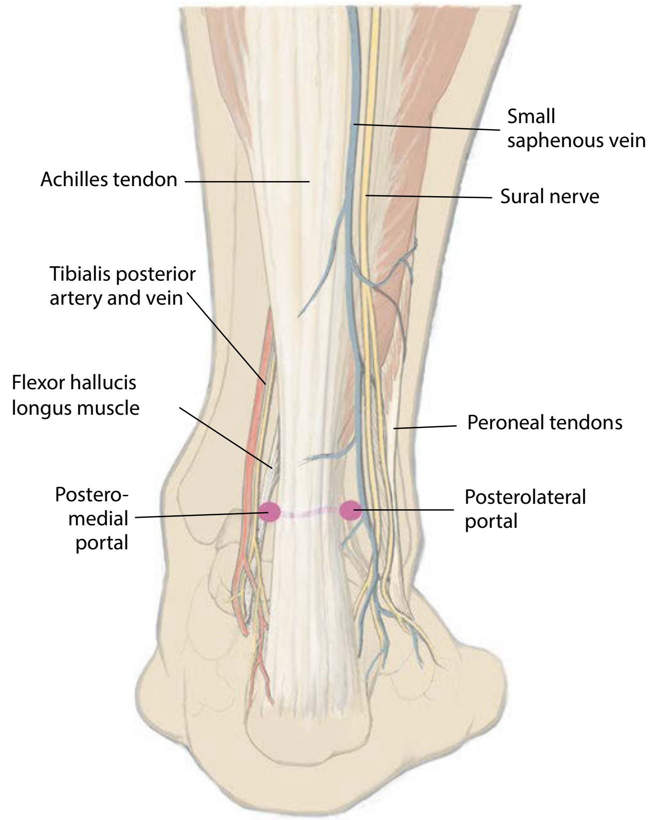

Fig. 21.4 Posteromedial and posterolateral standard portals

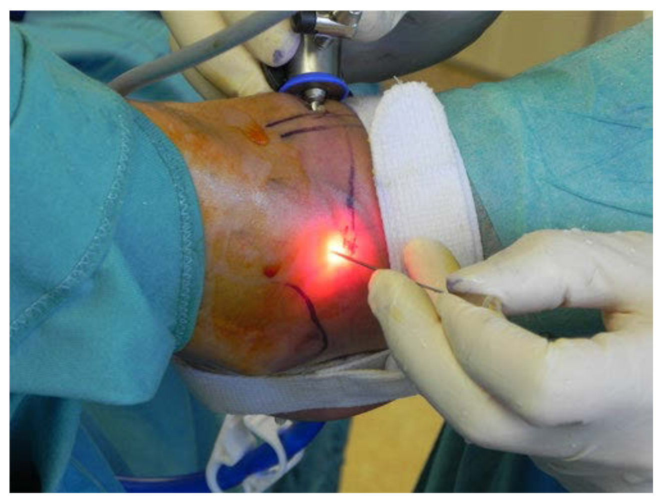

Fig. 21.5 Defining the site of the anterolateral portal with a needle under trans-illumination

the ankle and subtalar joint as well as tibiotalar and subtalar osteoarthritis, which could be arthroscopically addressed.

In prone position and to make portal placement easier, a line is drawn from the tip of the lateral malleolus to the achilles tendon, parallel to the sole of the foot, located. The posteromedial and posterolateral portal are created immediately proximal to this line, directly along the medial and lateral borders of the achilles tendon (Fig. 21.6). The posterolateral portal is then established. A vertical stab incision is made followed by splitting the subcutaneous tissue with a mosquito clamp. The mosquito clamp should be directed to the first interdigital web space between the first and second toes (Fig. 21.7). A trocar is then introduced in the same direction to be placed extraarticularly at the level of the ankle joint.

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The level could be determined by palpating the posterior talar process. The arthroscope is then introduced with the 30° angle lens laterally directed. The posteromedial portal is then made. After a stab incision, the mosquito clamp is Introduced an angle of 90° to the longitudinal axis of the arthroscope, until the shaft of the arthroscope is felt. The mosquito is then introduced along the shaft until it touches the bone.

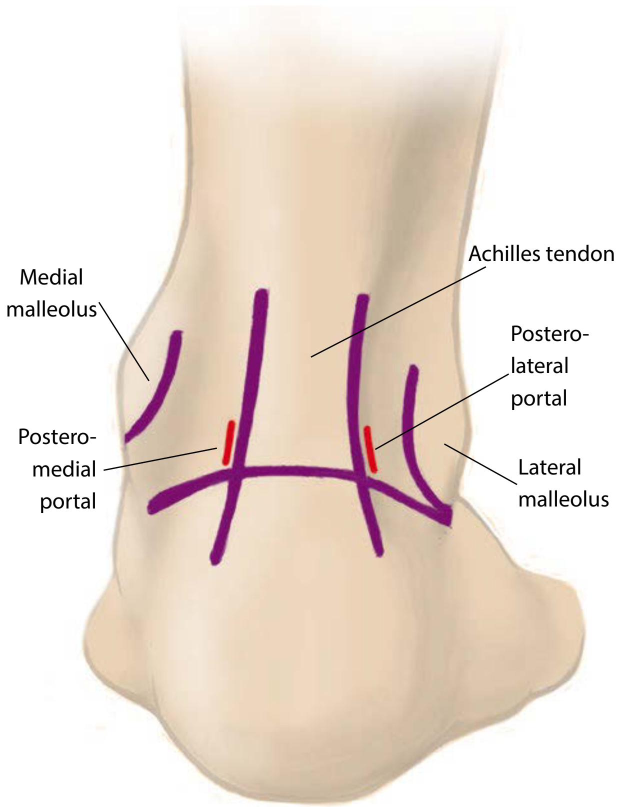

Fig. 21.6 For easier placement of the posterior portals, a line is drawn from the tip of the lateral malleolus to the Achilles tendon, parallel to the sole of the foot. The posteromedial and posterolateral portals are created immediately proximal to this line, directly along the medial and lateral borders of the achilles tendon respectively

The arthroscope is then slightly withdrawn backwards until the tip of the mosquito is visualized. The extra-articular tissue is now split with the mosquito clamp. If there is residual tissues negatively affecting the visualization, a shaver could be introduced to remove them. The tip of the shaver should be directed towards the posterolateral aspect of the subtalar joint.

The joint capsule of the subtalar joint could be then opened. The posterior talofibular ligament can be recognized. At the level of the ankle joint, the posterior ligaments as well as the posterior aspect of the tibiotalar joint could be visualized. The posterior talar process and the flexor hallucis longus tendon are now arthroscopically inspected. Due to the close proximity to the posteromedial neurovascular bundle, the shaver should never be introduced medial to the flexor hallucis longus tendon. The tendon sheath of the tibialis posterior could be explored after opening the joint capsule in an inside out technique and getting into the ankle joint.

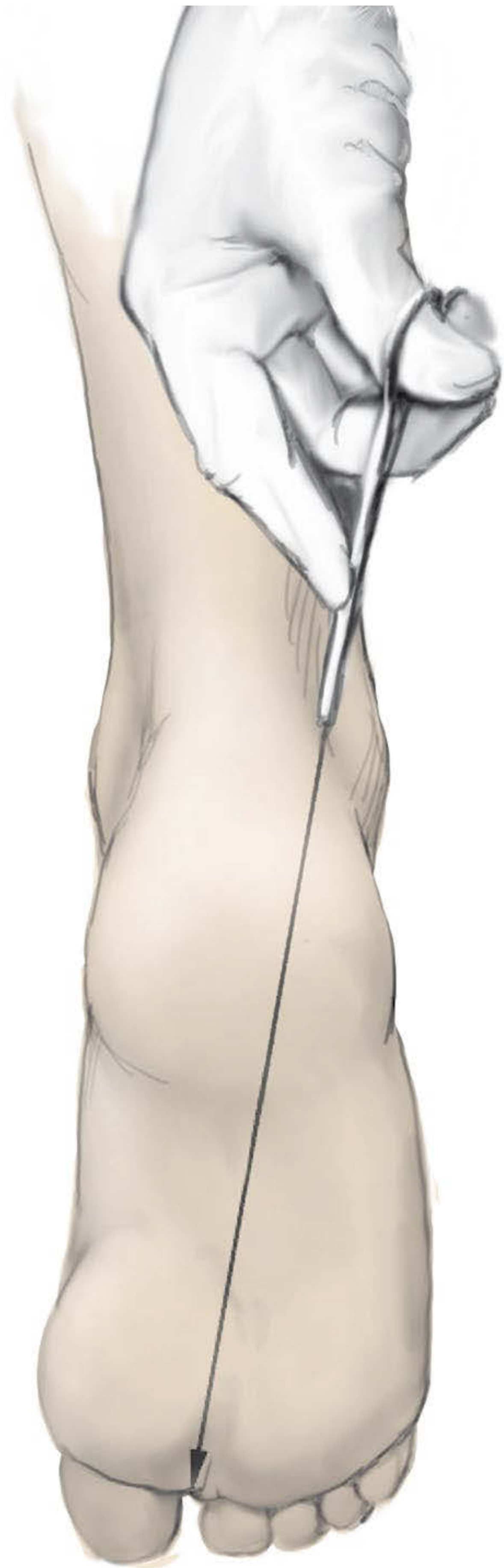

Fig. 21.7 Splitting the subcutaneous tissue with a mosquito clamp through the posterolateral portal. The mosquito clamp is directed toward the first interdigital web space between the first and second toes

21.4.4 Tips & Tricks

Neurovascular injuries are the most frequent complications of ankle arthroscopy. A detailed knowledge of the anatomy and different possible anatomic variants is therefore of great importance.

During the initial joint distension with saline solution, the shape of the tibial plafond should be considered. As the surface is curved, the needle should be introduced a little below the level of the joint line and directed posteriorly in an upward direction. The correct intraarticular injection of saline is confirmed by the initial low resistance to injection, bulging of the joint space and thereby resulting passive dorsiflexion of the foot as well as back flow of fluid through the needle. The correct position of the trocar is confirmed subsequently by back flow of the injected saline solution and the free mobility in the anterior compartment of the ankle.

The superficial peroneal nerve which is at risk during placement of the anterolateral portal could be felt or even seen in maximal passive plantar flexion and slight supination of the foot.

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Achilles Tendon

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22.1 Achilles Tendon Repair (Acute Rupture)

S. Hofstätter R. Schuh, H.-J. Trnka

22.1.1 Indication

Fresh Achilles tendon ruptures in patients with a good physical condition. Age alone should not be a contraindication. Contraindications for open repair include peripheral arterial diseases, advanced biological age, bad skin and soft tissue conditions and poorly controlled diabetes mellitus.

22.1.2 Operation Principle

Many repair and suture techniques are described (end-to-end Bunnell suture, Krakow-type suture and modified Kirchmair-Kessler suture). Open or minimally invasive repair of the tendon could be performed.

Open Achilles tendon repair is the standard technique to achieve a secure repair with subsequent lower risk of re-rupture. The treatment of choice among the different surgical techniques (open, minimally invasive or percutaneous) should be tailored to the patients' needs and general condition.

22.1.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: Patients are usually between 30 and 50 years old, playing sport on a recreational basis and reporting a preceding intense training session. Men are affected more often than women (ratio 12 : 1). Positive history of fluoroquinolone intake or steroid injection.
- Symptom specific examination: a palpable defect could be felt in many cases and denotes a complete tear of the Achilles tendon. Reactive Thompson test: absent or very weak planter flexion of the foot with passive compression of the calf muscles in prone position. Knee flexion test: the patient lies in prone position and is asked to flex the knee to 90°. A tear of the Achilles tendon is probable if the foot spontaneously falls into neutral or slight dorsiflexion.

Imaging

- X-ray of the ankle ap and lateral views to exclude fractures
- Dynamic ultrasound could be done to evaluate the degree of gaping of the Achilles tendon in neutral position and in planter flexion. This modality has a high value to evaluate if both ends could be adapted to each other in maximum plantar flexion.

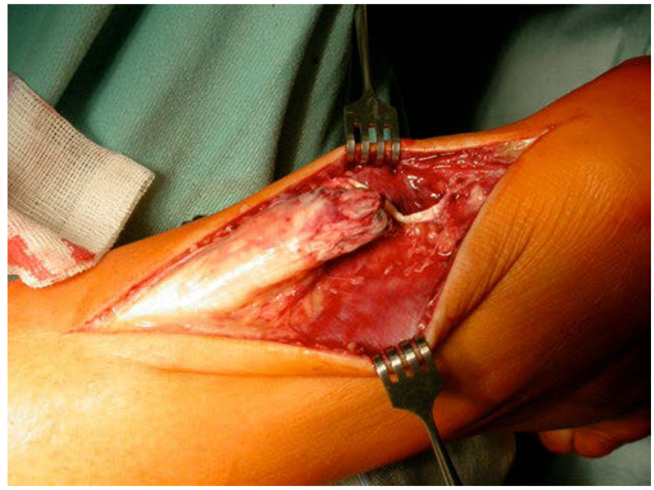


Fig. 22.1 Showing Achilles tendon rupture

- MRI represents a very good additional diagnostic tool. It provides additional information about the condition of the tendon (e. g. degeneration), the degree of the tendon retraction as well as any associated injuries.

Patient Information/Consent

Specific operative risks: impaired wound healing, adhesions, scarring, peritendinitis, particularly in elderly patient population, re-rupture (1–3 %), sural nerve injury, DVT, shortening or elongation of the repaired Achilles tendon and decreased muscle power.

22.1.4 Surgical Technique

Positioning and Preparation

The operation is performed in prone position with a small cushion (roll) between the operation table and the tibia. A thigh tourniquet is not essential (but could be applied). Some surgeons prefer to drape and prepare the other side for comparison with the normal side and thus to restore the exact tension of the Achilles tendon after repair.

Open, Direct Achilles Tendon Repair

Approach for open Achilles tendon repair is usually a longitudinal medial, central or lateral incision of about 5–8 cm length. The skin and the subcutaneous tissue should be atraumatically managed to avoid wound healing complications. The peritenon is opened and the hematoma is thus evacuated in most cases to reveal both ends of the ruptured Achilles tendon (Fig. 22.1).

The extent of gaping is measured to evaluate the possibility of direct repair. This should be possible in acute ruptures that could be approximated without excessive tension. Many repair techniques are described in the literature, e. g. Bunnell-, Kessler- and Krakow-type suture techniques (Fig. 22.2).

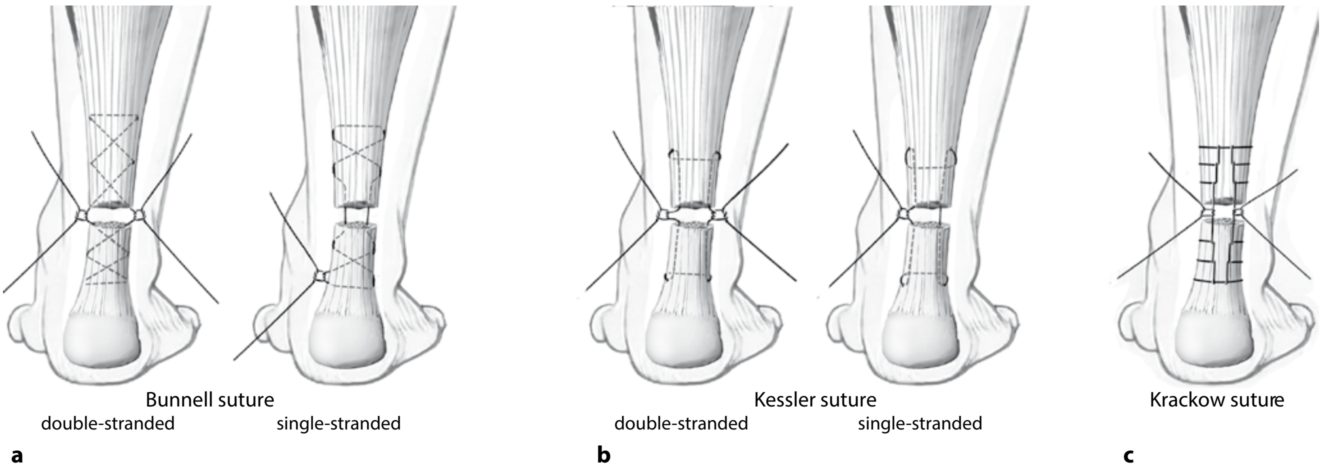


Fig. 22.2a–c Techniques of direct Achilles tendon repair: **a** Bunnell **b** Kessler **c** Krakow-type sutures

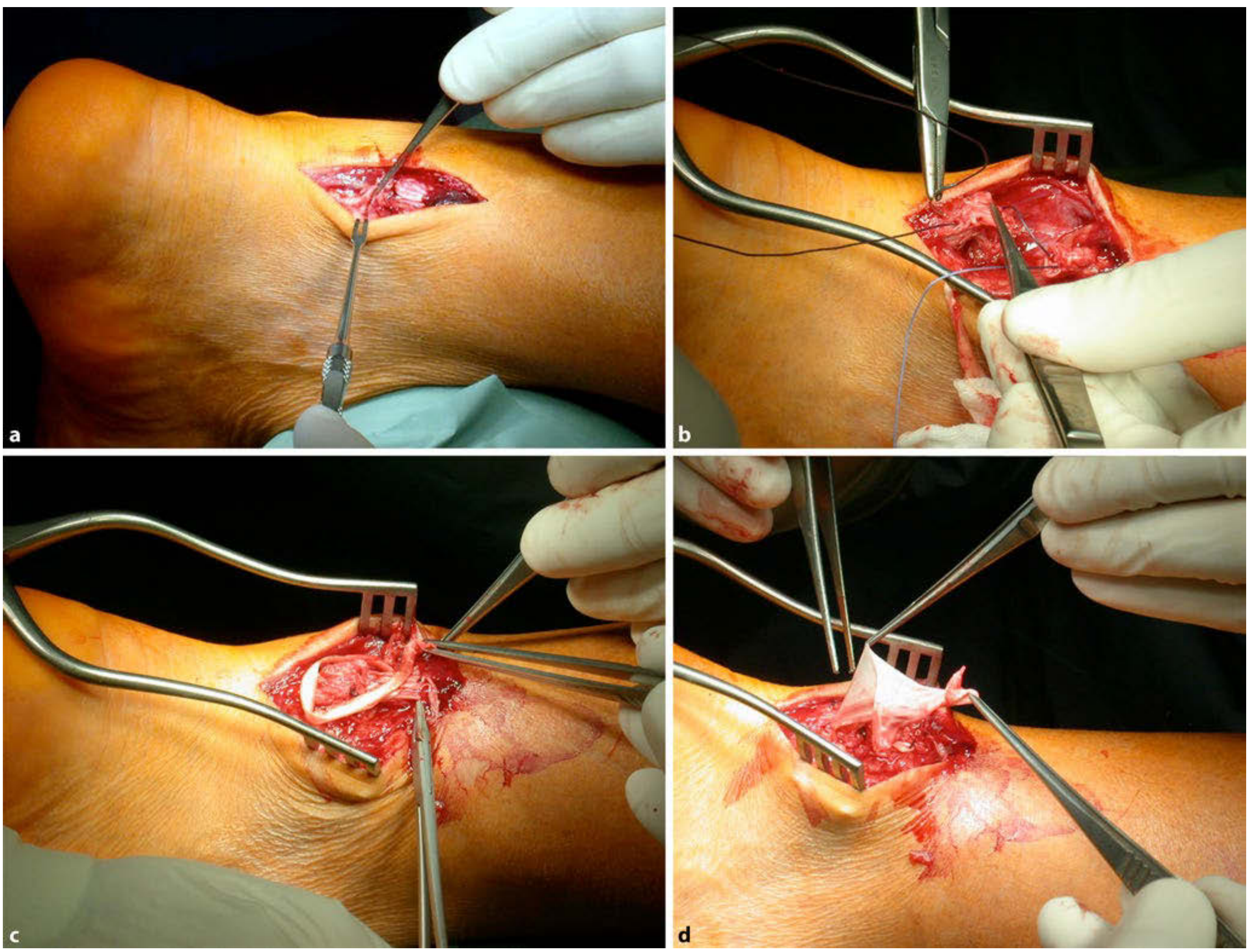


Fig. 22.3a–d Open Achilles tendon repair with plantaris tendon augmentation. **a** the Peritenon is opened to visualize the ruptured ends **b** Tendon repair using Kessler-type suture **c** Augmentation of repair with plantaris tendon in an interwoven pattern **d** closure of the peritenon

We prefer to use the Kessler-type suture technique for repairing acute Achilles tendon ruptures. After approximating both ends of the tendon, a simple Kessler suture is performed using a 2–0 Vicryl suture. Suturing begins with the proximal part of the tendon and the suture is passed through the tendon longitudinally for about 2.5 cm and then transversely and again longitudinally to exit at the ruptured end. The same is done for the distal end of the tendon. The sutures are then tied and the knot is buried within the repair site. A continuous circumferential suture using a circular 2-0 Vicryl suture helps

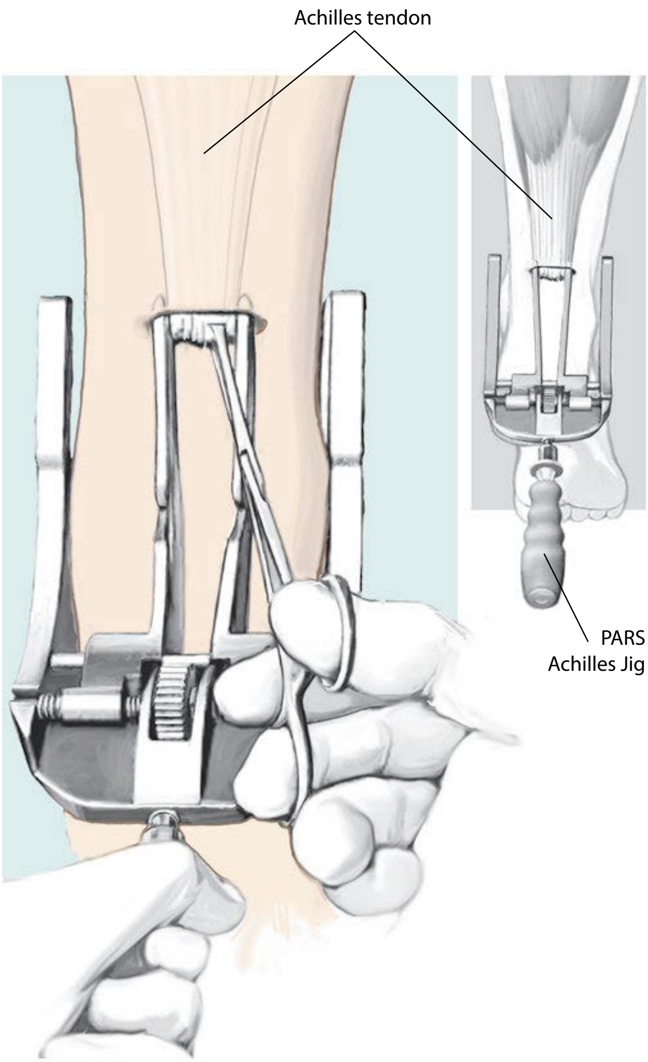


Fig. 22.4 The two inner arms of the PARS Achilles Jig (Arthrex) are inserted along both sides of the Achilles tendon within the paratenon

to improve coadaptation of the tendon ends and increases the strength of the repair by about 15 %, however, it has the potential disadvantage of disturbing blood circulation and consequently the healing.

Augmentation with the plantaris tendon is not routinely needed with good tendon quality, good repair and good primary coadaptation. This augmentation could be performed with poor quality of the tendon or if the repair is not ideal. The plantaris tendon is harvested using a tendon stripper to strip the tendon from the muscle belly proximally and used to augment the repair depending on its length by incorporating it into the proximal and distal ends of the tendon in an interwoven pattern that is then sutured with a 1-0 Vicryl suture (Fig. 22.3). However, there is no evidence that primary repair with plantaris tendon augmentation minimizes the re-rupture rate. After repair, the ankle is passively moved to check the stability of the repair. The peritenon is then closed with continuous watertight sutures.

22

Minimally Invasive Repair of the Achilles Tendon with the PARS Achilles Jig

After palpating the site of the tendon rupture, a transverse incision is made about 1 cm proximal to the site of rupture. The proximal part of the tendon is grasped with a clamp and the two inner arms of the PARS Achilles Jig (Arthrex) are placed within the paratenon alongside the Achilles tendon (Fig. 22.4). Both inner arms are then advanced until they reach the muscle belly where they could be easily mildly spread.

The blue and white FiberWire sutures are then passed through the corresponding holes in the outer arms (No. 1–5) transversely through the Achilles tendon and the corresponding holes in the inner arms. (Fig. 22.5). The PARS Jig is pulled out so that the sutures comes out through the incision from under the paratenon (Fig. 22.6).

The blue suture number 2 on both sides is then passed under number 3 and 4 looped sutures and back through the loop of the number 4 suture (or number 3 on the opposite side). The number 2 suture is pulled through the Achilles tendon to the other side by pulling the free non-looped ends of the looped sutures number 3 and 4. The stitch is then locked in place by pulling on the number 2 suture. The same steps are performed exactly for the distal part of the Achilles tendon (Fig. 22.7).

The suture ends on both sides are tied together with the foot in maximum plantar flexion, starting with the white sutures and then the blue sutures (Fig. 22.8).

22.1.5 Postoperative Management

- Monitoring of peripheral circulation, motor and sensory innervations.
- Use of elastic compressive bandages as well as a lower leg walker/boot or a plaster cast in neutral to slight planter flexion position.
- Cooling and elevation of the extremity.
- Early postoperative mobilization and motion exercises have a positive effect on the healing and repair strength.

22.1.6 Follow-Up Management

Non weight bearing for about 4–6 weeks in a brace with heel wedges. The collagen proliferation phase of tendon healing takes about 4 weeks and during this period no or very low stress should be applied to the tendon.

Physiotherapy starts after 4 weeks (passive exercises, dorsiflexion, plantar flexion, circular movements). Tensile forces (eccentric exercise) are very important here for collagen alignment and strengthening. After 6 weeks, gradual partial weight is started to reach a full weight bearing over a period of an-

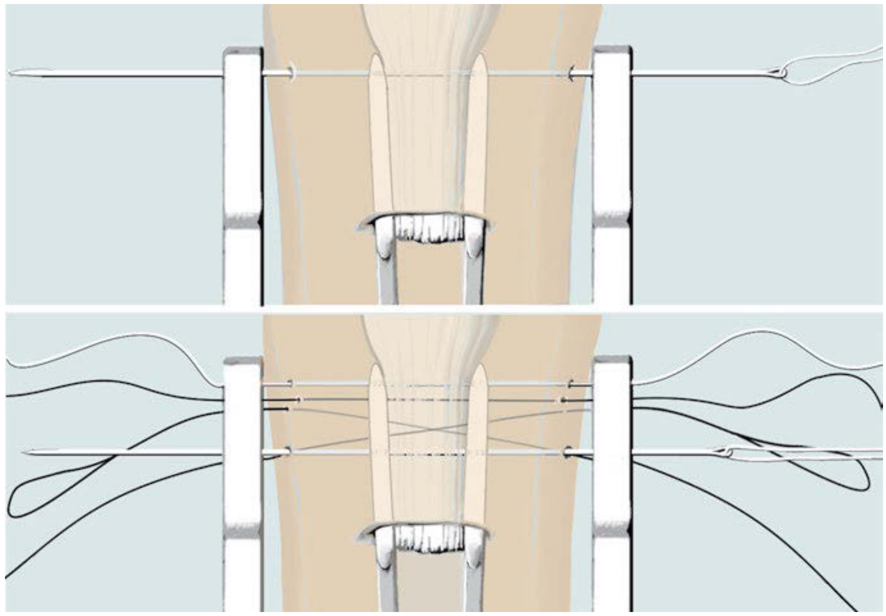


Fig. 22.5 FiberWire sutures are passed through the Achilles tendon successively through the corresponding hole marks

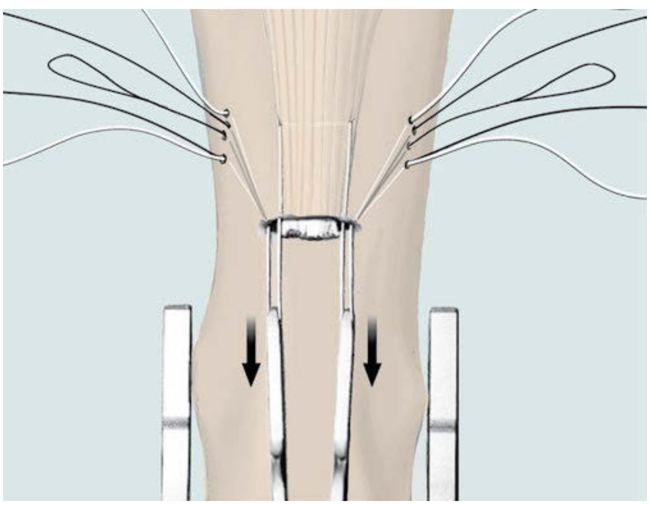


Fig. 22.6 The PARS Achilles Jig is pulled out so that the sutures come out through the incision from under the paratenon

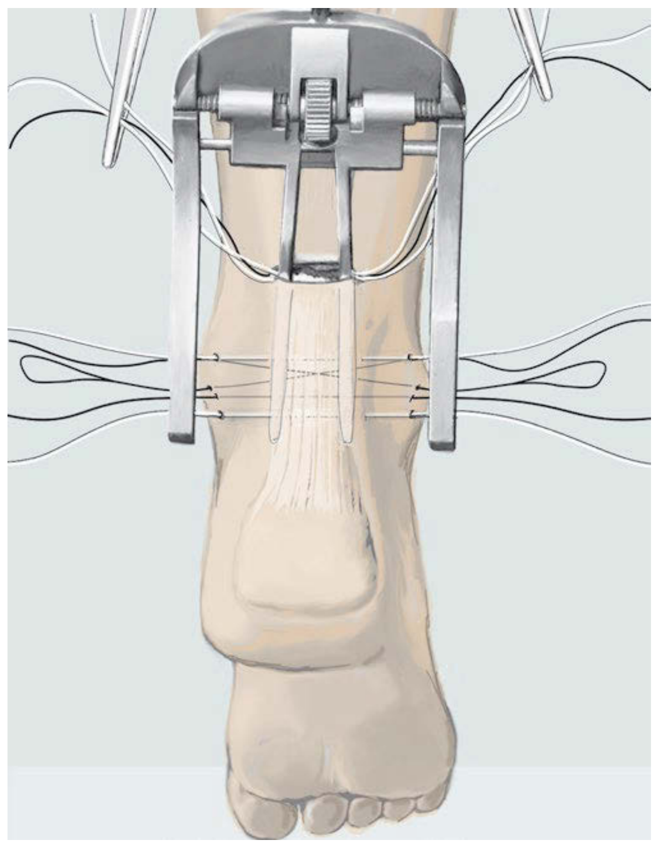


Fig. 22.7 The distal end of the tendon is sutured in the same way

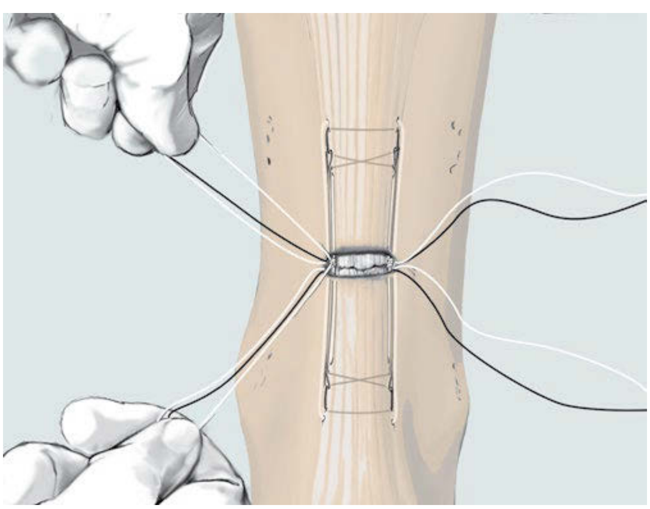


Fig. 22.8 Sutures are knotted in plantar flexion starting with the white ones

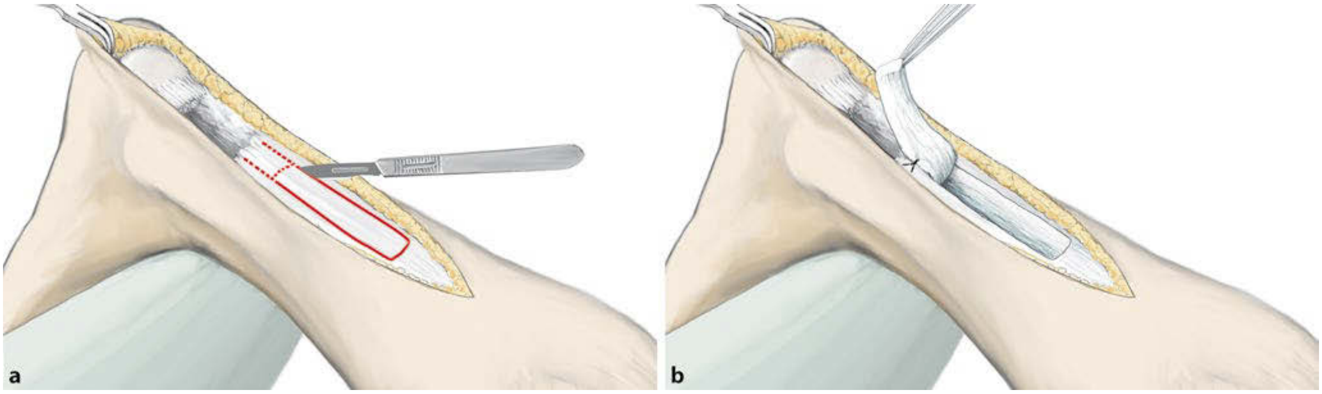


Fig. 22.9a,b Principle of turn down flap **a** a 10–15 mm wide strip of tendon is dissected from the proximal tendon. **b** the tendon strip is turned down 180° and fixed to the reflection site with stay sutures

other 6 weeks. An ultrasound follow up should be carried out after 8 weeks. Active sports are allowed at about 6 months after surgery.

22.1.7 Tips & Tricks

Partial rupture of other ankle flexors could be overlooked during clinical assessment.

Ultrasound and MRI represent here very good diagnostic tools.

Painful scar could results if a median incision is used. Lateral incision carries a higher risk of sural nerve injury.

The paratenon must be repaired if still available and not extensively damaged (placed and sutured over the tendon).

22.2 Achilles Tendon Reconstruction (Chronic Rupture)

S. Hofstätter R. Schuh, H.-J. Trnka

22.2.1 Indication

Chronic Achilles tendon ruptures in patients with good physical condition. Contraindications for surgical treatment include peripheral vascular disease with advanced biological age, poor skin and soft tissues conditions and poorly controlled diabetes mellitus.

22.2.2 Operation Principle

In old chronic ruptures with retracted tendon a combination of a V-Y tendinous flap, turn down flaps with flexor hallucis longus (FHL) or plantaris tendon augmentation should be carried out. Choosing the appropriate procedure depends mainly on the size of the defect. Defects up to 1 cm could be directly repaired (► Sect. 22.1.4). Defects between 1–3 cm could be also repaired with end to end sutures after intraoperative traction for more than 10 minutes to stretch the retracted muscle. Augmentation with the plantaris tendon is a good option to secure the repair. Defects between 3–7 cm require a V-Y flap, probably with a FHL augmentation. For defects larger than 7 cm, a turn down flap with FHL augmentation is recommended.

22.2.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: The patient could in most cases recall well the initial trauma, after which increasing weakness is described. The patients have rarely pain in this phase.
- Symptom specific examination: Inability to walk on tiptoe as well as inability to stand on tiptoe of the affected side. Thompson test and Knee flexion test. Plantar flexion of the foot is usually possible through the intact tibialis posterior, flexor hallucis longus and flexor-digitorum longus tendons. A palpable defect at the rupture site may still be present.

Imaging

- X-ray of the ankle AP and lateral views to exclude fractures
- MRI scan is a highly sensitive and specific diagnostic tool to assess the chronic Achilles tendon rupture. It provides valuable information about the condition of the tendon (e.g. degeneration), the degree of the tendon retraction as well as any associated injuries. The length of the defect is measured to better plan the operative procedure (V-Y flap, turn down flap, FHL tendon transfer)

Patient Information/Consent

Specific operative risks: impaired wound healing, adhesions, Scarring, peritendinitis, particularly in elderly Patient population, re-rupture, sural nerve injury, DVT, shortening or elongation of the repaired Achilles tendon and decreased muscle power.

22.2.4 Surgical Technique

Positioning and Preparation

The operation is performed under general anesthesia in prone position with a small cushion (roll) between the operation table and the tibia. A thigh tourniquet is not essential (but could be applied). Some surgeons prefer to drape and prepare the other side for comparison with the normal side and thus to restore the exact tension of the Achilles tendon after repair.

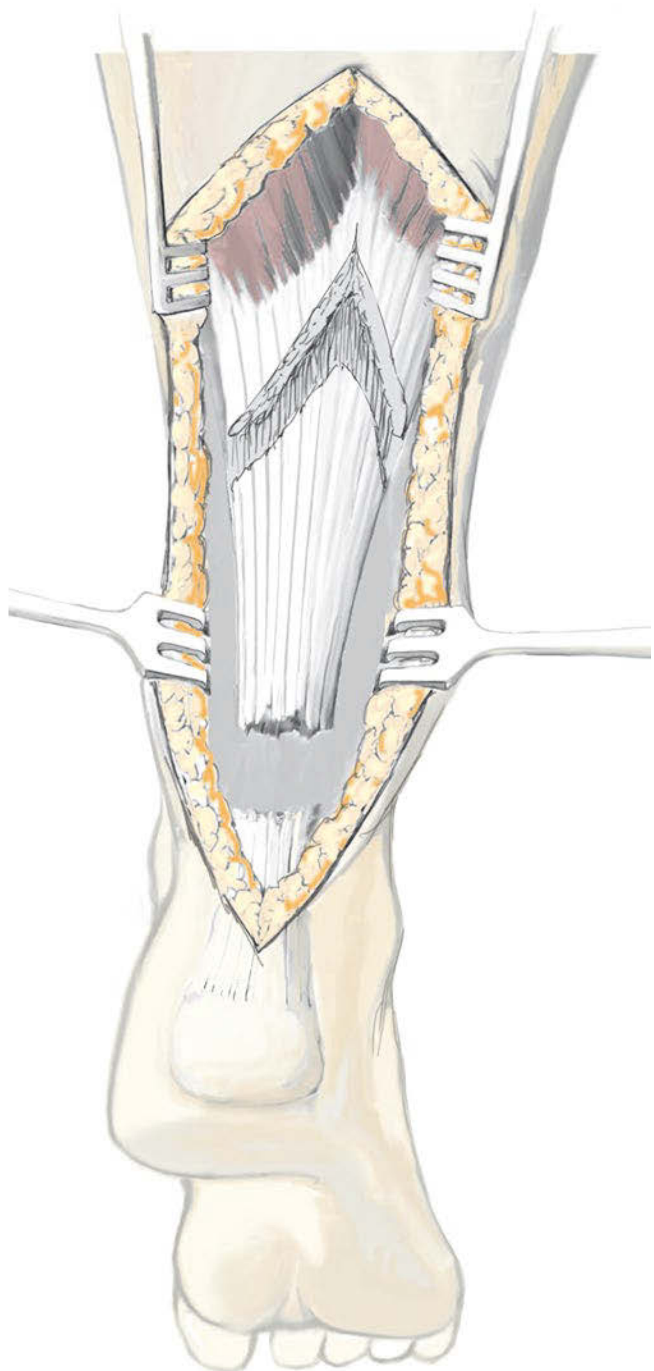
Achilles Tendon Reconstruction

A median incision centered over the Achilles tendon is used. The sural nerve must be identified and exposed. After identification of both the nerve and the ends of the ruptured Achilles tendon, the proximal and the distal stumps are debrided to a healthy and good quality tissue of the Achilles tendon. Frequently a pseudo-tendon or excessive scar tissue could be found in the defect area and should be resected. The size of the defect is then measured using a ruler with the knee in 30° flexion and the foot in 20° plantar flexion as well as in neutral position (actual defect size) to decide the most suitable operative procedure to be used (see operation principle).

Turn Down Flap with Suture Anchor Fixation at the Calcaneus

With this technique a central, 10–15 mm width flap is cut from the proximal tendon part (◘ Fig. 22.9a). Alternatively, lateral and medial flaps could also be created. The tendon flap is detached proximally and remains attached distally to the tendon over a length of about 2 cm. The tendon flap is then turned down 180° over the distal part of the tendon and fixed to the site of reflection with sutures using 1-0 Vicryl (◘ Fig. 22.9b).

Distally at the calcaneus, the Haglund's deformity is resected and cancellous bone is exposed. A suture anchor (e. g. Corkscrew, Arthrex) is then inserted into the calcaneus and used to fix the turn down flap.



◘ **Fig. 22.10** Achilles tendon aponeurosis is incised down to the underlying muscle in an inverted V shaped form

V-Y Advancement/Flap

In this procedure an inverted v shaped incision is made over the Achilles tendon aponeurosis. The v shaped incision begins proximally at the musculotendinous junction and ends distally at the Achilles aponeurosis (medial and lateral). The length of the V limb should be at least 1.5 times longer than the length of the Achilles tendon defect. The next step is to incise the tendinous aponeurosis along the marking down to the underlying muscle (◘ Fig. 22.10). The underlying muscle should be left intact at the proximal tendon stump. The proximal end of the rupture is stitched with a Krakow suture. The Achilles aponeurosis could now be brought down under tension to approach the distal end of the rupture (with the foot in plantar flexion). The two stumps could now be sutured using FiberWire suture (Arthrex). The proximal gap could now be sutured into an inverted Y with 3-0 Vicryl suture (◘ Fig. 22.11).

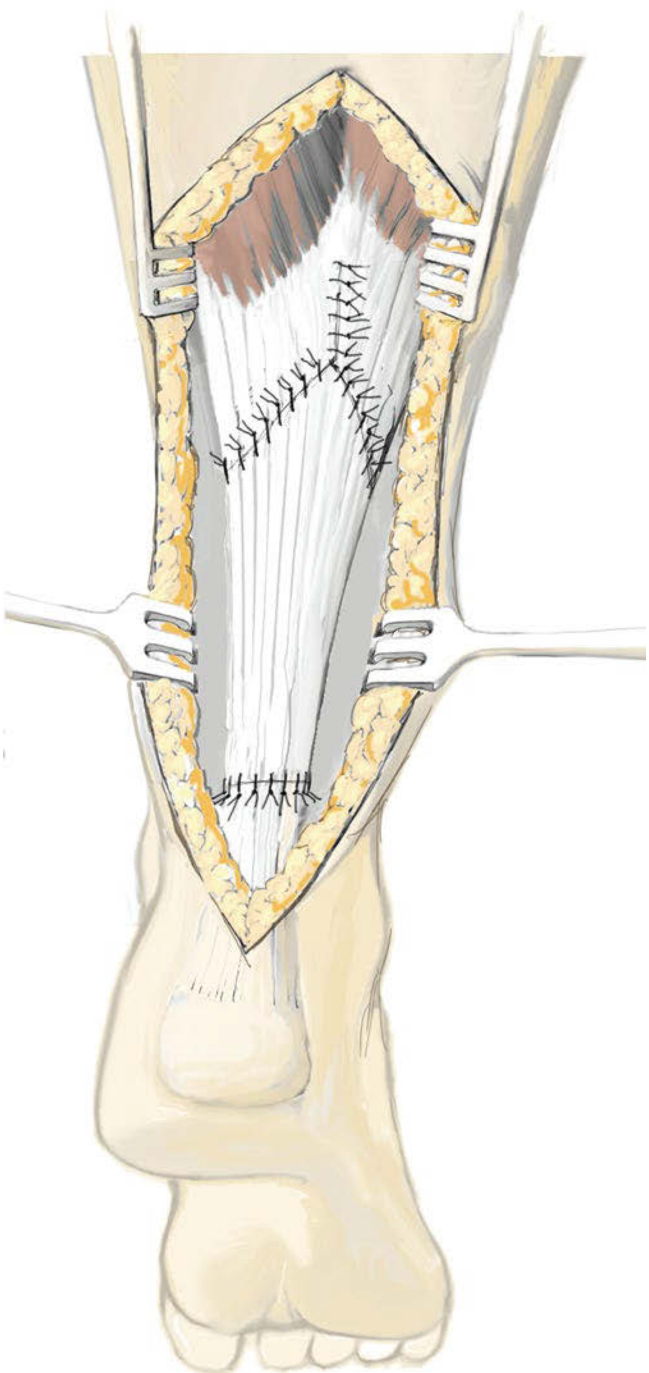


Fig. 22.11 After repairing the Achilles tendon rupture, the proximal gap is sutured into an inverted Y configuration

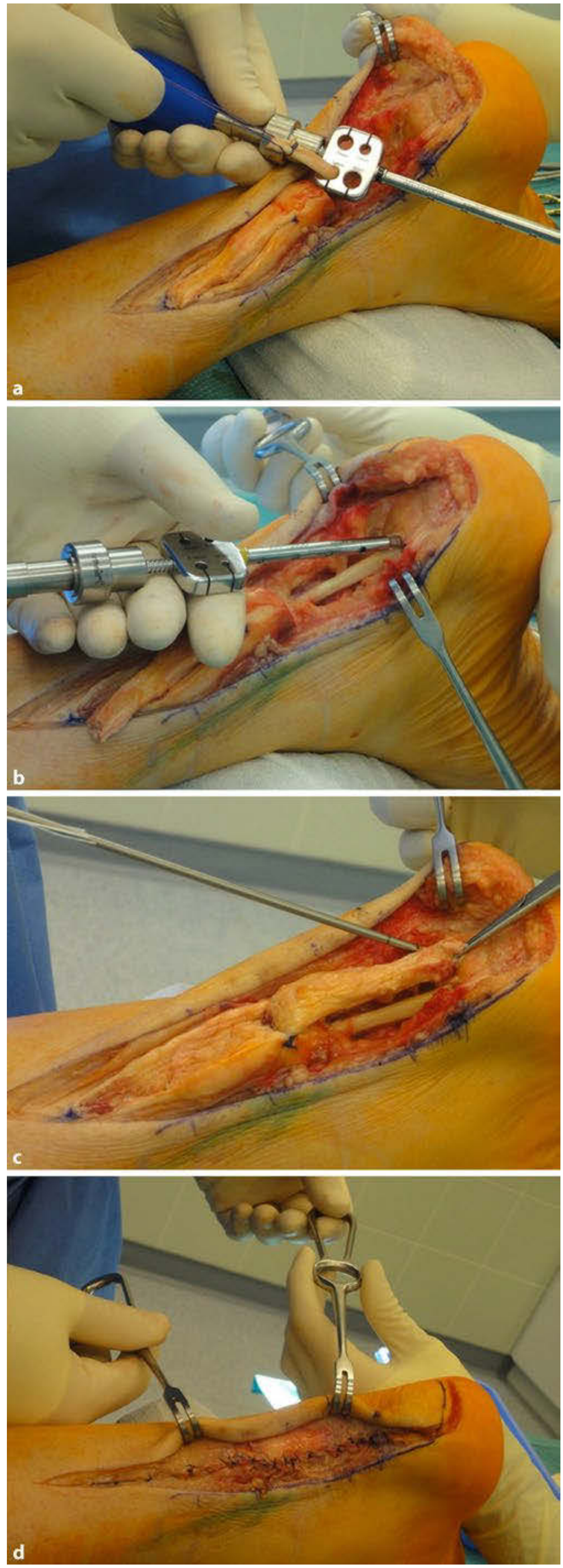


Fig. 22.12a–d Reconstruction of chronic Achilles tendon rupture by turn down flap and FHL augmentation. **a** Measuring the diameter of the distally cut FHL tendon **b** Fixation of the FHL tendon into the calcaneus bone tunnel using bio-absorbable interference screw **c** turn down flap with suture anchor fixation **d** closure of the peritenon

FHL Tendon Augmentation with Interference Screw Fixation at the Calcaneus

The FHL tendon should be first identified and exposed. The muscle belly of the FHL tendon is located in the deep posterior compartment, exactly deep to the Achilles tendon after opening the fascia. The muscle and the tendon are traced distally in the tendon canal (posterior to the tibia and talus) and the tendon is sectioned as distal as possible in maximum planter flexion of the foot and the big toe. Dissection and resection of the tendon should be carried out with great caution because of the nearby medially located neurovascular bundle. The tendon diameter is measured and a corresponding bone tunnel is drilled into the calcaneus and the tendon is fixed to it under tension using a bioabsorbable interference screw (e. g. Biotenodesis screw, Arthrex).

After checking the stability of the construct, the previously planned Achilles tendon repair/reconstruction is performed. Lastly, the peritenon is closed in a watertight fashion with continuous sutures (Fig. 22.12).

22.2.5 Postoperative Management

- Monitoring of peripheral circulation, motor and sensory innervation.
- Use of elastic compressive bandages as well as a lower leg walker/boot or a plaster cast in slight planter flexion position.
- Cooling and elevation of the extremity.

22.2.6 Follow-Up Management

A below knee plaster cast in planter flexion position is applied for 2 weeks. The foot is brought gradually into neutral position by sequentially changing the cast. Non weight bearing for 6 weeks in the cast. Wound dressing regularly until healing. Partial weight bearing is started after 6 weeks and increased gradually with the use of heel wedges in the walker until complete weight bearing is achieved. From the initially used 3 wedges, one wedge should be removed every 2 weeks. Physiotherapy should begin from the 6th postoperative week. After 3 months, increasing full weight bearing without Walker. Active sports could be allowed, earliest 6 months after surgery

22.2.7 Tips & Tricks

Wound healing complications constitutes a big problem in chronic Achilles tendon rupture. The patients need to be completely aware of this risk and the surgeon should handle the tissue with extreme care.

Painful scar could results if a median incision is used. Lateral incision carries a higher risk of sural nerve injury.

The Sural nerve should be exposed when a V-Y advancement, turn down flap or FHL augmentation are performed.

The tendon tension after repair should be compared with the opposite side. Excessive debridement can lead to shortening of the Achilles tendon.

When performing a turn down flap, the length of the tendon strip should be at least 2 cm longer than the defect length (the length of the reflection contact area).

Care should be taken while harvesting the FHL because of the close proximity of the adjacent neurovascular structures.

The paratenon must be carefully dissected, reconstructed and closed.

22.3 Achillodynia and Achilles Tendonitis

H.-J. Trnka, P. Hofstätter, R. Schuh

22.3.1 Indication

Painful thickening of the Achilles tendon, most commonly about 3 finger proximal to the insertion area and resistant to conservative treatment.

All conservative treatment attempts as eccentric stretching, Heel pad, physiotherapy and NSAIDs should have been tried for about 3–6 months without success.

22.3.2 Operation Principle

Open excision of intratendinous necrotic and tendinopathic tissues, reduction of the size of the tendon and stimulation of the local blood flow and healing with multiple longitudinal incisions of the tendon.

22.3.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: onset of pain and type of the inciting activities. Pain during and after sport.
- Symptom specific examination: painful soft tissue swelling, increased pain with dorsiflexion, positive squeeze test (compression of the swelling with the thumb and index), palpation of the medial and lateral aspects of the tendon

Imaging

- X-rays of the heel (lateral view) and the whole foot (lateral standing view)to evaluate the possibility of existing bony changes.

Fig. 22.13a,b **a** Thickened swollen Achilles tendon **b** resection of the intratendinous necrotic tissue

- The tendon itself is best assessed with ultrasound or MRI. On MRI, the intratendinous necrotic and degenerative tissue as well as partial tendon ruptures could be well identified.

Patient Information/Consent

Specific operative risks: pain improvement (50–75 %), prolonged recovery period until being able to resume sport, impaired wound healing, sural nerve injury and DVT.

22.3.4 Surgical Technique

Positioning and Preparation

- Prone position
- A tourniquet is applied to the thigh

Open Necrosectomy (Debridement and Excision of Necrotic Tissue)

About 3 cm longitudinal skin incision (medial, lateral or median) over the thickened Achilles tendon. The subcutaneous tissue and the fascia are incised and the peritenon is opened. The Achilles tendon is palpated to determine the exact location of the nodular central thickening. The Achilles tendon is incised longitudinally at the highest bulging point of the swelling. All degenerative and necrotic tissues are excised. Multiple incisions to the affected region of the Achilles tendon are performed to stimulate and improve the local blood flow. The tendon is sutured and the peritenon is closed (Fig. 22.13).

22.3.5 Postoperative Management

- Monitoring of peripheral circulation, motor and sensory innervation.
- Use of elastic compressive bandages as well as dorsal leg plaster splint.
- Cooling and elevation of the extremity.

22.3.6 Follow-Up Management

Immobilization in a dorsal lower leg splint until the stitches are removed. Protection of the leg for 6 weeks. Physiotherapy with local massage and passive ROM exercises should be started from the second week. Active training and eccentric exercises from the 6th week.

22.3.7 Tips & Tricks

The paratenon must be carefully adapted over the Achilles tendon which is mandatory for the eccentric tendon healing.

22.4 Resection of Haglund's Deformity

S. Hofstätter R. Schuh, H.-J. Trnka

22.4.1 Indication

Painful bony prominence at the posteromedial or posterolateral heel, resistance to conservative treatment measures (for 6 months), symptomatic retrocalcaneal bursitis, persistent limitation of sporting activity.

22.4.2 Operation Principle

Open resection of the Haglund's deformity through a lateral, medial or central incision. The central midline approach is

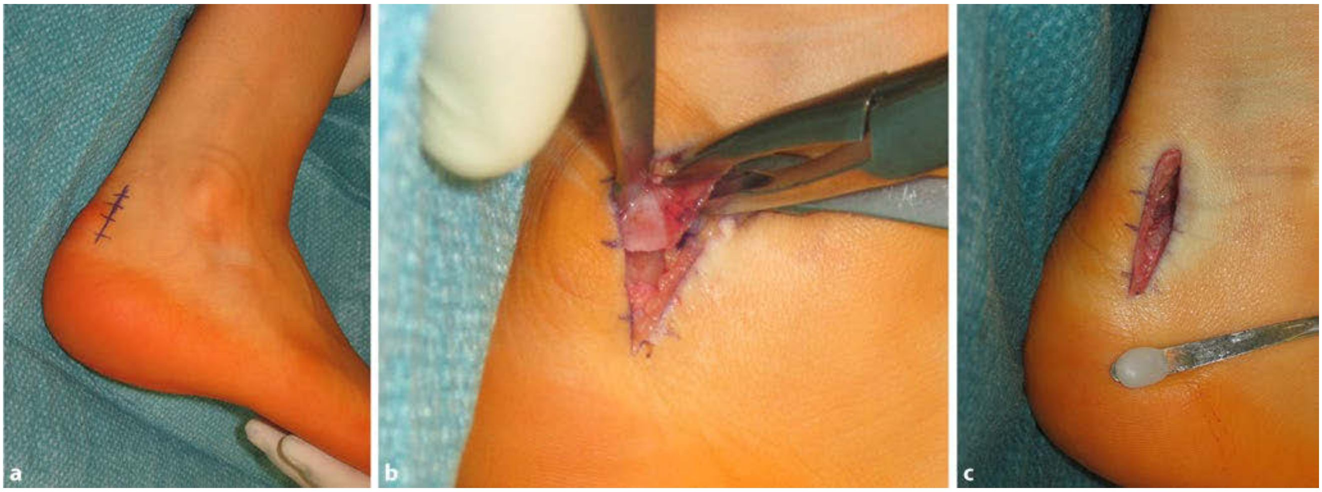


Fig. 22.14a–c Resection of Haglund's deformity via a lateral approach. a Marking the skin incision; b resection of the deformity; c sealing the osteotomy surface with bone wax

most suitable if there is an associated marked insertional tendinosis and/or calcification of the Achilles tendon insertion (posterior calcaneal spurs).Resection of the Haglund's deformity should be combined with detaching followed by reattachment of the Achilles tendon using suture anchors if detachment of more than 50 % of the Achilles tendon is necessary. Care should be taken of the sural nerve if a lateral approach is used.

22.4.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: Onset of pain and type of the triggering activities. Pain when wearing shoes with hard fixed heel countermand improvement of symptoms with walking barefoot, pain during/after sports
- Symptom specific examination: painful soft tissue swelling, pain increases with dorsiflexion, positive squeeze test (index finger and thumb), palpation of the medial and lateral aspects of the Haglund's deformity, inspection reveals a red thinned skin with hyperkeratosis, a soft mass on both sides of the Achilles tendon is palpated if there associated bursitis.

Imaging

- X-rays of the heel (lateral view) and the whole foot (lateral standing view) to evaluate the extent of the Haglund's deformity and the Kager's triangle (= radiolucent triangular area on the lateral X-ray view, bounded by the following structures: anteriorly the big toe flexor muscles and tendons, posteriorly by the Achilles tendon and inferiorly by the calcaneus).
- MRI is mostly unnecessary, except when tendinopathy, Insertional tendinosis with calcification of the Achilles tendon, bursitis, partial rupture of the Achilles tendon are suspected.

Patient Information/Consent

Specific operative risks: pain improvement (50–75 %), prolonged recovery period until being able to resume sport especially if there is insertional tendinosis together with Haglund's deformity (3–6 months), impaired wound healing, sural nerve injury when using the lateral approach.

22.4.4 Surgical Technique

Positioning and Preparation

- Lateral or prone position with the lateral or medial approach. Prone position is preferred if a central transachilles approach is planned (with posterior calcaneal spur).
- A tourniquet is applied to the thigh.

Resection of Haglund's Deformity via the Lateral Approach

About 3 cm long lateral skin incision is made over the calcaneal tuberosity. Cave: The sural nerve, which passes proximal to the wound shouldn't be injured. Sharp dissection down to the periosteum. A periosteal elevator and 2 pointed Hohmann's retractors are used to expose the Haglund's deformity, which is then resected up to the insertion of the Achilles tendon, depending on its extent and size with a broad osteotome. The bone edges should then be well inspected and palpated and any remaining bony prominence should be removed and smoothened using a bone nibbler or a chamfer (Fig. 22.14).

There should be then no further impingement between the Achilles tendon and Haglund's deformity with passive dorsiflexion of the foot. The bursa is removed with a bone nibbler.

Fig. 22.15a,b Resection of Haglund's deformity. **a** Preoperative radiograph with obvious Haglund's deformity **b** postoperative radiograph after resection

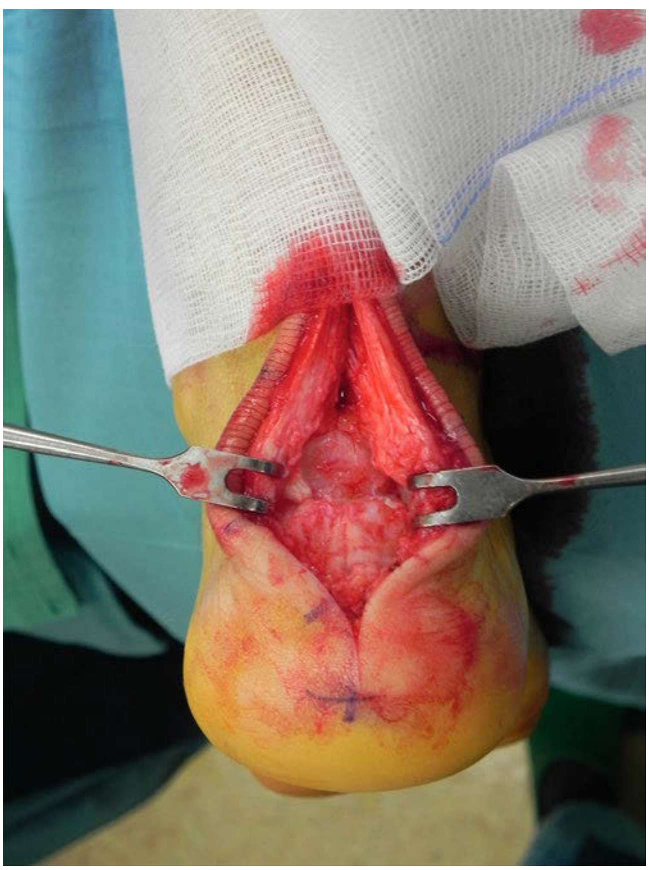


Fig. 22.16 After skin incision, the Achilles tendon is longitudinally split down to the bone, detached from the bone and reflected medially and laterally

Bone wax is applied to the raw bone surface and a drain is used (Fig. 22.15).

Resection of Haglund's Deformity via a Midline (Transachilles) Approach and Reattachment of the Achilles Tendon with the Speed Bridge Technique

It is recommended if the Haglund's deformity is associated with insertional tendinosis (with or without calcification in the Achilles tendon) to use the posterior midline approach in the prone position. Skin incision is followed by a longitudinal midline incision of the Achilles tendon down to the bone. The distal insertion of the tendon is split and released from the bone and then reflected medially and laterally (Fig. 22.16). Intratendinous calcifications are debrided and removed. The calcaneal tuberosity is exposed using 2 Hohmann retractors (medially and laterally). The Haglund's prominence is removed using a broad osteotome. Image intensifier could be used for a better localization of the level. Reattachment of the tendon is done using the Achilles SpeedBridge (Arthrex). For that, 2 holes for the 4.75 mm BioComposite SwiveLocks are drilled (at the osteotomy surface) about 1 cm proximal to the insertion of the Achilles tendon and prepared with the tap. The two BioComposite SwiveLocks, one preloaded with a blue and the other with a white/black FiberTape are inserted into the holes (Fig. 22.17). The FiberTapes are then passed through the tendon on both sides using the attached needles (Fig. 22.18). Two other bone holes are drilled and prepared distal to the Achilles tendon insertion in the same way. Two additional 4.75 mm BioComposite SwiveLocks are loaded, each with a FiberTape and inserted into the corresponding bone hole (Fig. 22.19) resulting in a crossing (hourglass) configuration compressing the Achilles tendon on the calcaneus (Fig. 22.20).

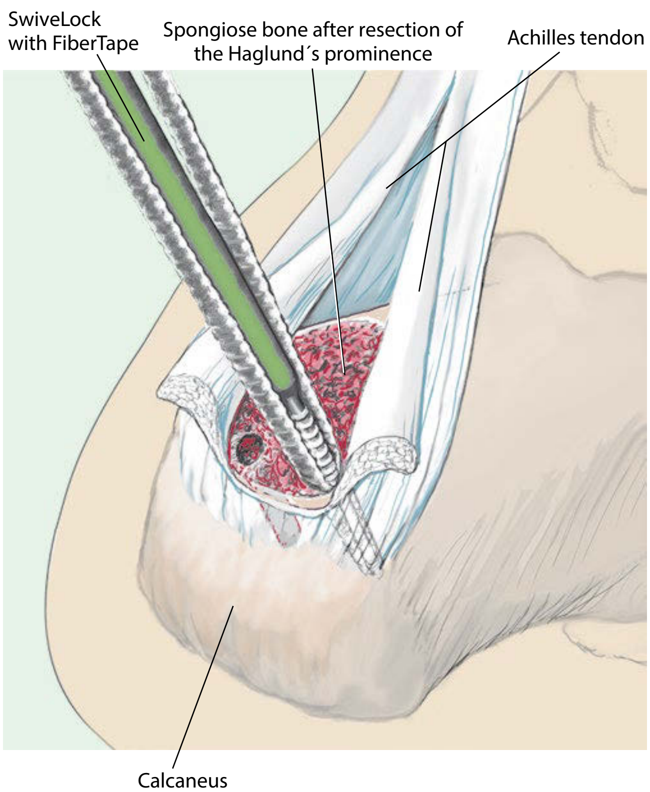


Fig. 22.17 Insertion of the BioComposite SwiveLocks preloaded with FiberTape

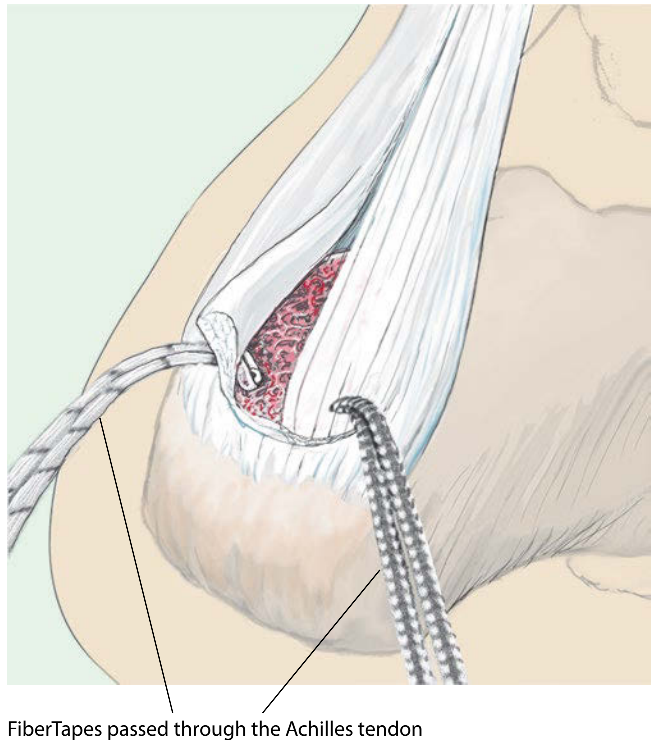


Fig. 22.18 Passing the ends of both FiberTape sutures through the Achilles tendon

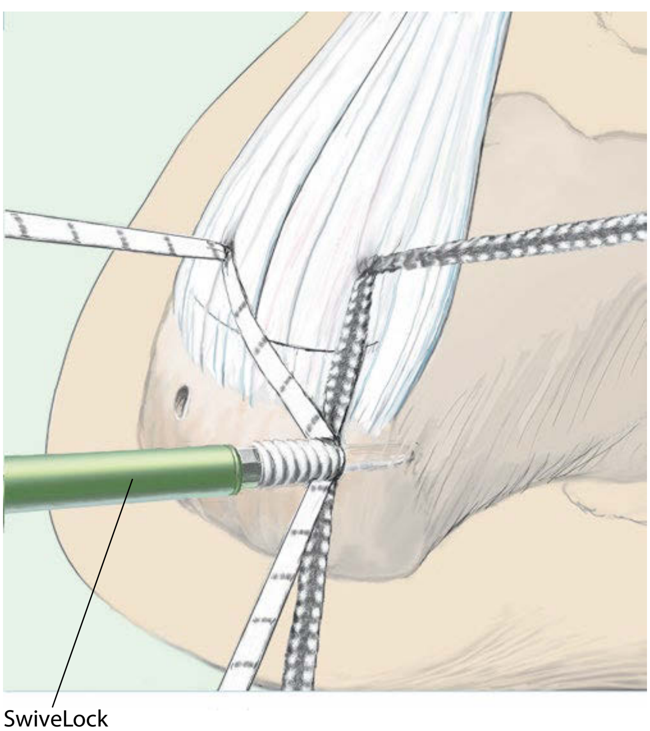


Fig. 22.19 Loading a further SwiveLocks with one FiberTape from each anchor and inserting it into the distally prepared hole

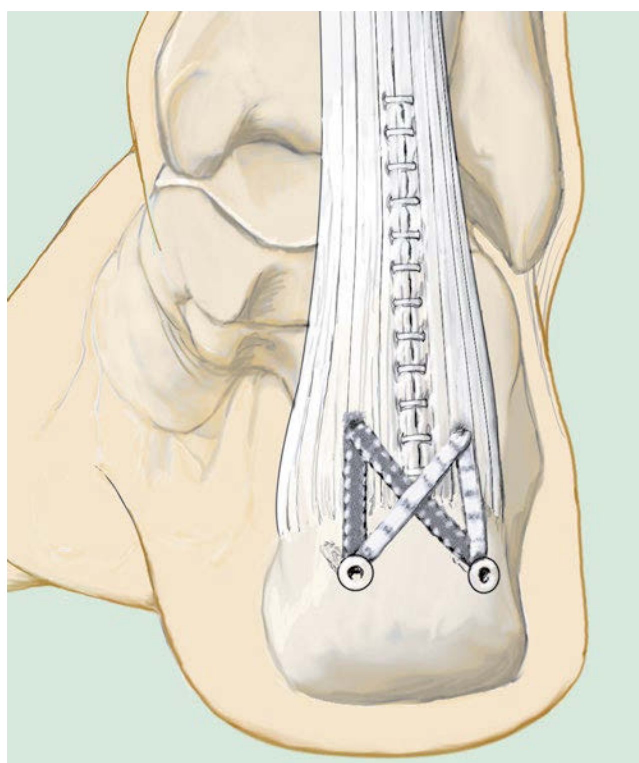


Fig. 22.20 Completed Reattachment of the Achilles tendon with crossed Tapes

22.4.5 Postoperative Management

- Monitoring of peripheral circulation, motor and sensory innervation.
- Use of elastic compressive bandages
- A below knee plaster splint or cast in planter flexion if the Achilles tendon is reattached.
- Cooling and elevation of the extremity.

22.4.6 Follow-Up Management

Resection of the Haglund's deformity without reattachment of the Achilles tendon: immobilization of the ankle until stitches are removed with partial weight bearing for 14 days.

Resection of the Haglund's deformity with reattachment of the Achilles tendon: A below knee plaster splint or cast in planter flexion for 2 weeks. In the 2–5. weeks cast (in 5–10° of plantar flexion), in the 5th–8th weeks Aircast Walker/Boot with a heel wedge (5–10°), in the 8–12. weeks normal high shoes with heel wedge could be worn and physiotherapy with eccentric exercises is started.

22.4.7 Tips & Tricks

Resection of the Haglund's deformity only is suitable if there is only associated bursitis. If this deformity is associated with insertional tendinosis, additional debridement and excision of the necrotic and tendinopathic tissues as well as detachment and reattachment of the Achilles tendon depending on the extent of the pathology should be considered. Although a FHL tendon transfer is rarely needed, it should be however previously planned. If there is a markedly prominent posterior calcaneal spur, a posterior midline (transachilles) approach with partial or complete detachment of the Achilles tendon are recommended with subsequent reattachment using suture anchors (if more than 50 % of the tendon is detached). The peritenon should be well adapted over the Achilles tendon to allow for optimal eccentric tendon healing to occur. Physiotherapy with eccentric exercises is ideally started after the 8th week if the Achilles tendon has been detached or if a tendon transfer was needed.

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Instability

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DOI 10.1007/978-3-662-43776-6_23,

23.1 Lateral Ligament Reconstruction

H.-J. Trnka, M. Feucht

23.1.1 Indication

Ankle supination trauma result in injury to the lateral ligament complex in up to 90 % of cases, with up to 30 % of these injuries resulting in chronic lateral ankle instability.

Surgical reconstruction is indicated if the sporting and daily life activities are still limited due to recurrent supination trauma despite functional rehabilitation with muscle-strengthening, and proprioceptive physiotherapy.

23.1.2 Operation Principle

Augmentation and/or reconstruction of one or more ligaments of the lateral ligament complex (anterior talofibular ligament, calcaneofibular ligament, posterior talofibular ligament) to restore the ankle joint stability. Surgical reconstruction can be either anatomical or non-anatomical. With anatomical reconstruction techniques, the torn ligament is anatomically augmented or replaced. Examples are the Broström-Gould technique using local structures (extensor retinaculum) or by using tendon grafts (free or local) take place

23.1.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: History of trauma, history of conducted treatment, exercise capacity, walking distance, symptomatology (instability, pain), Footwear.
- Symptom specific examination: anterior drawer test, talar tilt test.

Imaging

- X-ray of the ankle AP and lateral views (standing)
- MRI of the ankle joint.

Patient Information/Consent

Specific operative risks: impaired wound healing, infection, nerve injury, thrombosis, recurrent instability (supination trauma).

23.1.4 Surgical Technique

Positioning and Preparation

- Lateral decubitus position.
- A tourniquet is applied to the thigh

Modified Broström–Gould Technique

A curved incision is performed anterior to the anterior border of the distal fibula over the anterior part of the ligament complex. The extensor retinaculum is dissected and retracted distally with a Langenbeck retractor. The insufficient anterior talofibular ligament is exposed and sharply incised a few millimeters anterior to the tip of the fibula and the proximal part together with the periosteum are raised off the bone. The anterior fibula is freshened with a chisel/burr. The calcaneofibular ligament is evaluated and if found to be overstretched, it must be divided and reefed (overlapped and sutured).

The distal part of the ligament is stitched with 3 sutures in a u-shaped manner (◘ Fig. 23.1). The ligament is then fixed over the freshened anterior distal fibula using three 2.5 -mm PushLock anchors (Arthrex) each threaded with one of the already placed sutures while the ankle joint is fixed in pronation (◘ Fig. 23.2).

The periosteum and the proximal portion of the divided anterior talofibular ligament are then sutured over this reconstruction. Finally, the extensor retinaculum is mobilized proximally and sutured over the proximal portion of the divided anterior talofibular ligament to augment the reconstruction (◘ Fig. 23.3).

Watson–Jones Technique

The skin incision begins from the base of the 5th metatarsal and extends proximally over the course of the peroneal tendons and posterior to the fibula for approximately 12 cm. The sural nerve is dissected and retracted bluntly and the peroneal tendons sheath is opened and the peroneus brevis tendon exposed. The peroneus brevis tendon is longitudinally split from its insertion at the base of the 5th MTB up to the musculotendinous junction and the anterior part is cut proximally.

A hole is drilled with a 4.5 mm drill pit about 2 cm proximal to the tip of the fibula in a postero-anterior direction in the line of extension of the anterior talofibular ligament. A second hole is drilled anterior to the fibula through the talar neck in a dorsoplantar direction. The graft is then passed through the fibula from posterior to anterior and then passed and pulled under optimized tension through the talar neck in a dorsoplantar direction. Depending on the length of the graft, it could be either sutured to itself or passed posteriorly through another drill hole in the distal fibula (◘ Fig. 23.4).

Chrisman–Snook Technique

The approach and exposure of the peroneus brevis tendon is performed as described above followed by dividing the tendon at the musculotendinous junction. A hole is drilled with a 4.5 mm drill pit anterior to the fibula after exposure of the talar neck at the level of insertion of the anterior talofibular ligament from the plantar surface towards dorsal.

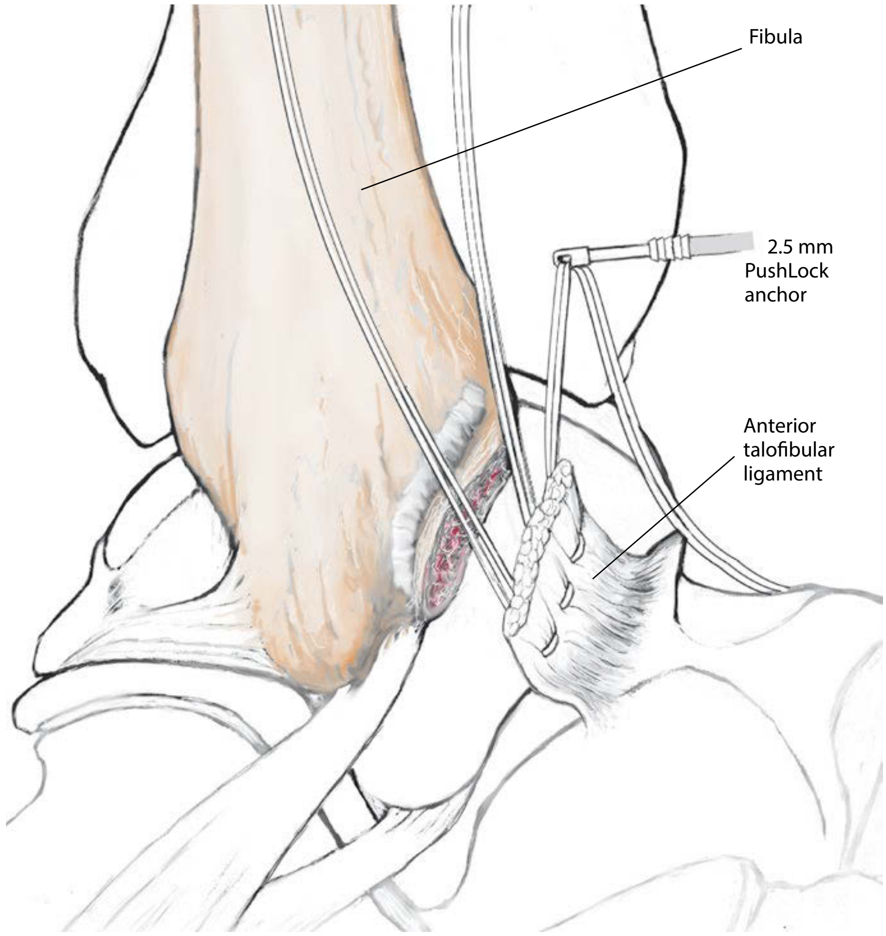


Fig. 23.1 U-shaped stitching of the distal part of the anterior talofibular ligament and threading the corresponding suture limbs each in a 2.5 mm PushLock anchor (Arthrex)

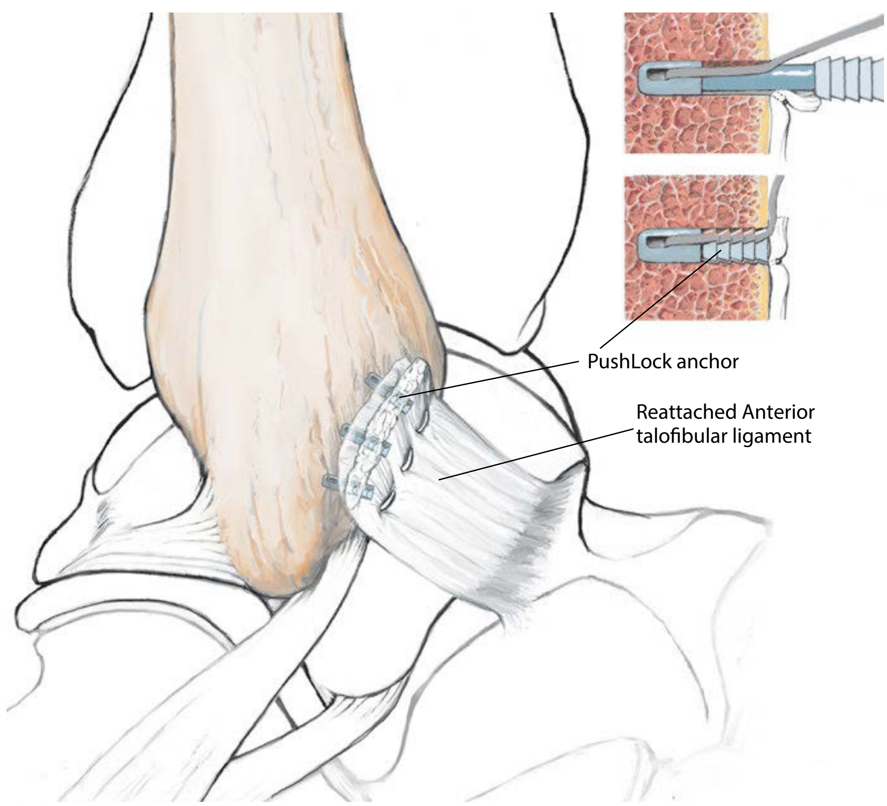
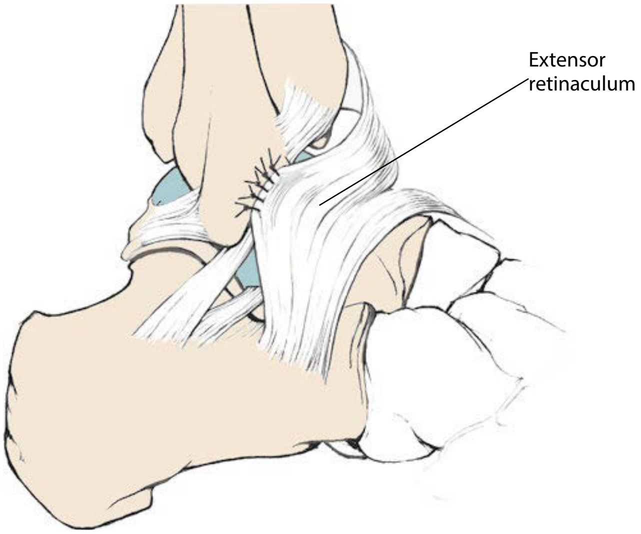
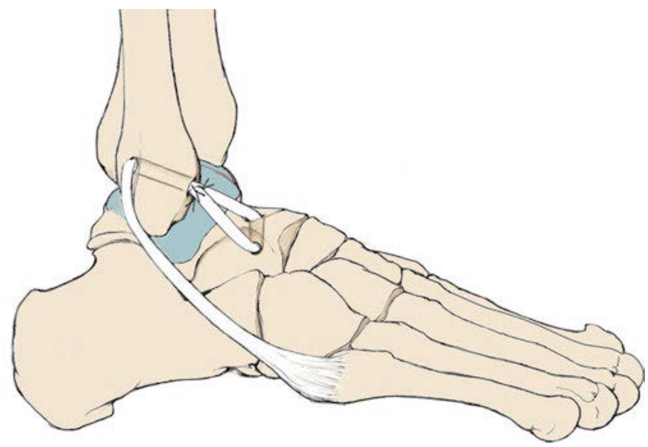


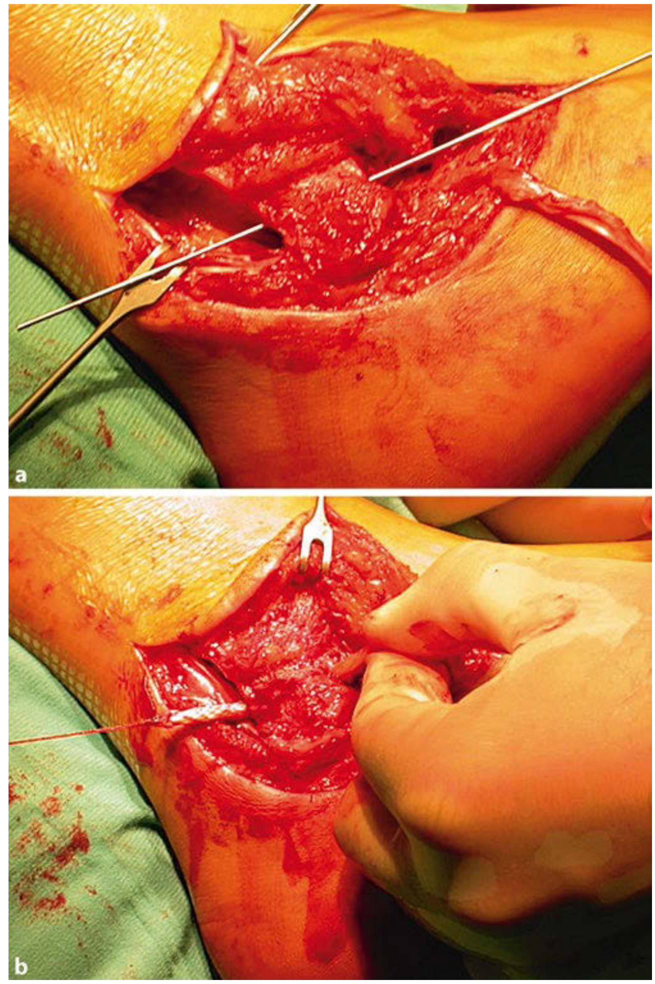
Fig. 23.2 Refixation of the anterior talofibular ligament to the freshened anterior distal fibular using three 2.5 mm PushLock anchors (Arthrex) while the ankle is in pronation



■ **Fig. 23.3** Suturing the extensor retinaculum to the proximal part of the anterior talofibular ligament



■ **Fig. 23.4** Schematic illustration of the Watson-Jones technique



■ **Fig. 23.5a,b** **a** guide wire is introduced into the fibular drill hole; **b** pulling the peroneus brevis tendon through the tunnel

If the distal part of the talofibular ligament is still well-preserved, the graft can be alternatively passed through this part. A second hole is drilled horizontally through the fibula in an anteroposterior direction. The free end of the tendon is then pulled through the drill holes in the talus and the fibula (■ Fig. 23.5). The graft is finally passed over the peroneus longus tendon and fixed to the calcaneus with a suture anchor (e.g. Corkscrew, Arthrex) (■ Fig. 23.6).

Anatomical Reconstruction of the Lateral ligaments with Free Peroneus Brevis Tendon Graft (Gold Technique)

Curved skin incision along the distal fibula. The peroneus brevis tendon is exposed proximal and distal to the extensor retinaculum. The tendon is split longitudinally into two equal halves along its entire course starting proximally. Short incision at the base of the 5th MTB to expose the insertion of the peroneus brevis tendon. The anterior part of the split tendon is stripped with a small tendon stripper starting proximally after dividing the tendon at the musculotendinous junction (■ Fig. 23.7a). The tendon is stripped and sharply released from its distal bony insertion.

The free tendon graft is prepared at a side table and stitched at both ends. The insertion of the anterior talofibular ligament (ATFL) and the calcaneofibular ligament (CFL) at the distal fibula, talar neck and calcaneus are exposed. A guide wire is then inserted at the talar insertion of the ATFL and overdrilled with a 4 mm drill pit. Two transfibular tunnels are drilled under protection of the peroneal tendons with a Hohmann retractor. A guide wire is inserted at the fibular insertion of the ATFL in a slightly ascending direction towards posterior and overdrilled with a 4 mm drill pit (■ Fig. 23.7b). A second guide wire is inserted from the fibular insertion of the CFL in an ascending direction towards posterior (■ Fig. 23.7c), so that it exits just below the outlet of the previously drilled tunnel resulting in a V-shaped course formed by the two trans-fibular tunnels. The wire is overdrilled with a 4 mm drill pit and shuttle sutures are passed through both drill holes (■ Fig. 23.7d). One end of the tendon graft is fixed into the talar hole using a 4,75 Bio-SwiveLock (Arthrex)

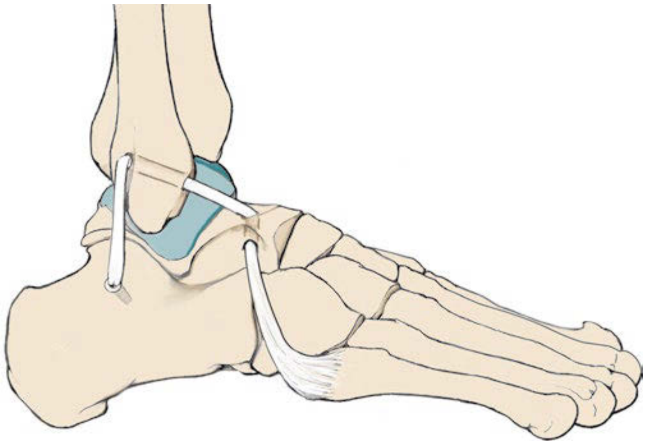


Fig. 23.6 Schematic illustration of the Chrisman-Snook technique

(Fig. 23.7e). The other free end of the graft is passed through the anterior end of the ATFL tunnel using the shuttle suture and pulled posteriorly (Fig. 23.7f) and subsequently though the posterior end of the CFL tunnel to be pulled out anteriorly (Fig. 23.7g).

The ankle joint is reduced, the graft is tensioned and the first part is fixed to the fibular ATFL tunnel with 3,0 mm Bio-FASTak (Arthrex). The free end of the graft is then pulled distal to the retinaculum to be inserted into the calcaneus. A guide wire id drilled into the calcaneus at the insertion site of the CFL below the peroneal tendons, over-drilling with a 4 mm drill pit and pulling the graft over the guide wire. The subtalar joint is reduced, the graft is tensioned and fixed with a 4,75 Bio-SwiveLock (Fig. 23.7h). Lastly, the stability and the full range of motion should be verified.

23.1.5 Postoperative Management

- Monitoring of peripheral circulation, motor and sensory innervation.
- A split short leg plaster cast is applied.
- postoperative radiographs.

23.1.6 Follow-up Management

A split short leg plaster cast is used for one week. This is followed by non-weight bearing for another 5 weeks in a complete short leg plaster cast. After removal of the cast, progressive training and muscle strengthening with the use of stabilizing ankle brace for about 6 weeks.

23.1.7 Tips & Tricks

A vacuum mattress is recommended with the lateral position. A blunt dissection with a small towel after skin incision to expose the extensor retinaculum. The subcutaneous fat can be well separated from the retinaculum by this method. With insufficient graft length in the Watson–Jones technique, the tendon graft can be fixed into the talar neck with an anchor.

23.2 Syndesmosis Reconstruction

P Hofstätter , R. Schuh, H.-J. Trnka

23.2.1 Indication

Painful acute or chronic insufficiency of the distal tibiofibular syndesmosis resistant to treatment.

23.2.2 Operation Principle

Dynamic, semi-rigid stabilization of the distal tibiofibular syndesmosis with one or two pulley systems (TightRope, Arthrex). The TightRope system is based on a Suture- Button principle and consists of a #5 FiberWire suture that forms a loop between a round and a longitudinally oval buttons. This fixation is a good alternative to the temporary syndesmotic screw, which has the disadvantage of the required secondary screw removal and inability to perform early postoperative functional treatment.

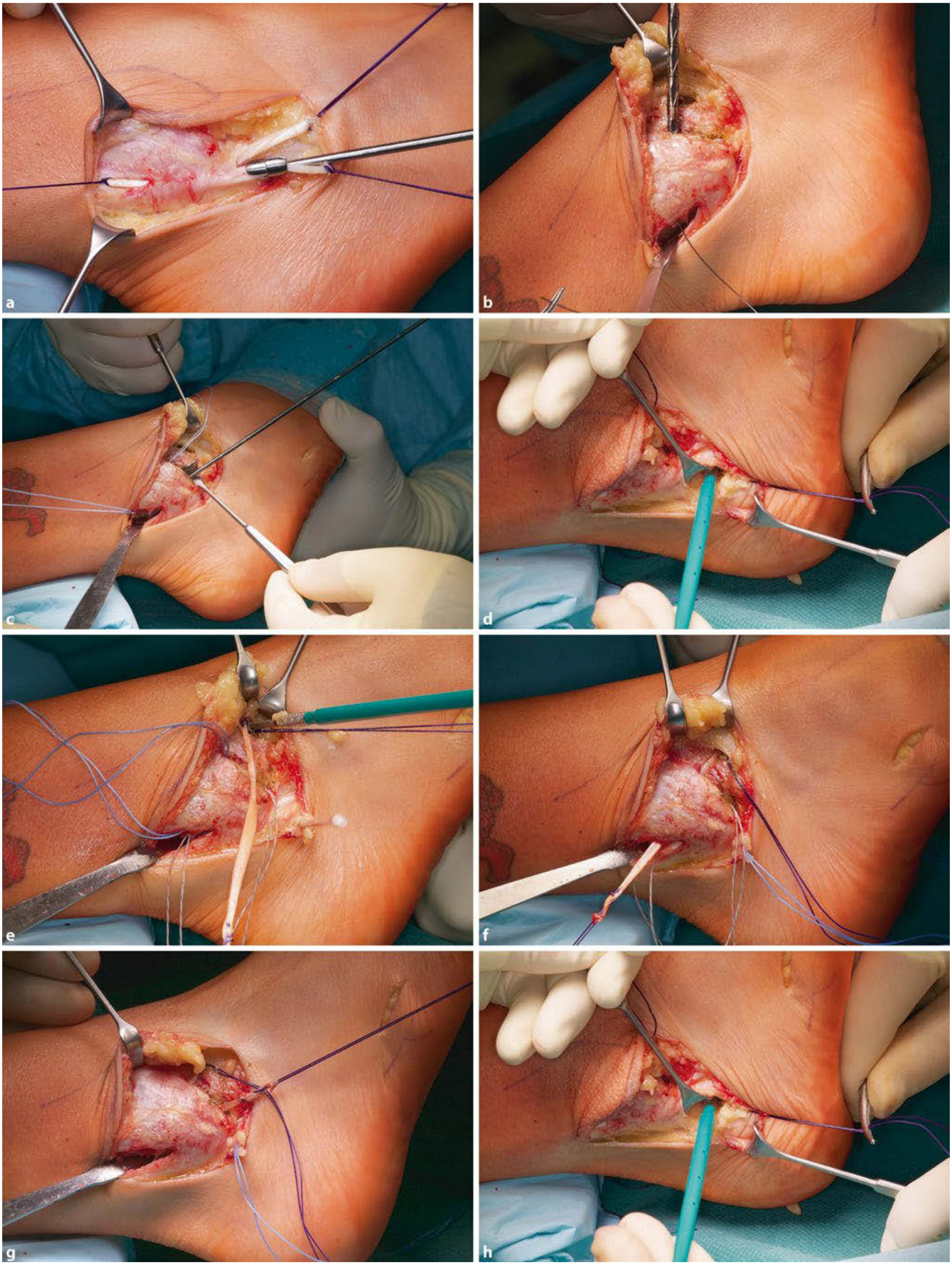
The double TightRope fixation is recommended with sever Maisonneuve Injuries, while the single fixation is done with isolated chronic syndesmotic instability. This dynamic semi-rigid fixation is also possible in cases of ankle fractures of the AO type B or C.

23.2.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: mechanism of trauma, Symptomatology, intractable pain after supination in anterior or the lateral aspect of the ankle joint, intractable pain after Immobilization/infiltration, duration of symptoms.
- Symptom specific examination: Pain and sensation of tenseness in the region of the anterior inferior tibiofibular ligament. Pain on passive dorsiflexion with widening of the ankle mortise. Positive external rotation stress test, in which the talus is rotated laterally relative to the fibula resulting in painful stressing of the syndesmotic ligaments. Positive squeeze test: The squeeze test assesses if pain results from manual compression of the ankle mortise (by hand) while the ankle is dorsiflexed. Instability can be present if the pain is reduced through manual compression of the ankle mortise in dorsiflexion.


a
b
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Imaging

- X-ray of the ankle joint in two views to exclude fractures (Mortise view of both sides and a lateral view.
- MRI and CT scans of the ankle joint may be needed to assess the condition of the ligaments and possible concomitant lesions.

Absent widening of the ankle mortise on radiographs (Mortise-view) or absence of lesions of the anterior or posterior syndesmosis on MRI does not exclude the presence of chronic Instability.

Patient Information/Consent

Specific operative risks: irritation of the peroneal brevis und peroneus longus tendons, injury of the superficial peroneal nerve, osteolysis, restriction of the ankle joint movement, pain, possible implant removal, instability, secondary dislocation, malpositioning.

23.2.4 Surgical Technique

Positioning and Preparation

We recommend performing an ankle arthroscopy before treating the chronic syndesmotic instability to assess the articular cartilage, synovial membrane (possible synovial fringes) and the syndesmotic space.

- Patient in the supine position
- A roll is placed under the ipsilateral buttock to rotate the lower extremity inward, allowing for easier fixation from the lateral side.
- A tourniquet is applied to the thigh
- The image intensifier should come from the other side to allow easier intraoperative use.

Syndesmosis Stabilization with a Single TightRope System

Following disinfection and draping, the level of the guide wire is localized. A skin incision is performed over the lateral aspect of the fibula about 2 cm above the joint line.

For fixation using a single TightrRope, a guide wire is inserted from the lateral cortex of the fibula and directed anteromedially at about 30° to the frontal plane (Fig. 23.8). The wire is overdrilled with a cannulated 3.5 mm drill pit.

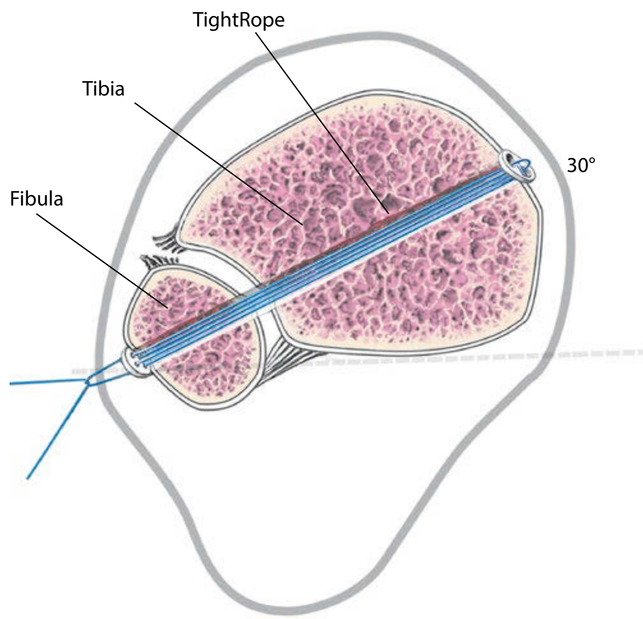

Fig. 23.8 Placement of the TightRope system

The TightRope needle is passed along the drill hole from the lateral side (Fig. 23.9) and out the medial intact skin. The white 2-0 FiberWire pull-through suture is pulled to advance the oblong button through the drill hole until the button exits the medial tibial cortex. The green/white suture (facilitates flipping the button) should be slack during pulling the white suture. This is achieved by pulling the white and green/white sutures in opposite directions until the button can be easily seated along the medial cortex (using image intensifier). Toggling the two # 5 FiberWire sutures on the lateral side helps to set the medial button on the cortex. With correct positioning of the button, the medial sutures can be cut and removed. The syndesmosis is reduced before tying the sutures laterally using a Weber reduction forceps (Fig. 23.9).

Under compression of the syndesmosis, the sutures of the TightRope system are tied and then cut 1 cm from the knot. The knot is buried below the periosteum posterior to the fibula.

Syndesmosis stabilization with two TightRope systems

This is analogous to the technique described above but a second TightRope is added. The second construct is placed about 1 cm proximal to the first and 3 cm proximal to the ankle joint line. Here the direction is about 45° to the frontal plane and slightly ascending from lateral to medial (Fig. 23.10).

◄

Fig. 23.7a–h Anatomical lateral ligament reconstruction with free peroneus brevis graft. **a** harvesting the already split peroneus brevis tendon with a tendon stripper; **b** Drilling the first trans-fibular tunnel at the insertion site of the ATFL; **c** Drilling the second trans-fibular tunnel at the insertion site of the CFL; **d** shuttle sutures are passed through both tunnels; **e** fixation of one end of the graft into the talar neck at the insertion site of the ATFL using a 4,75-Bio-SwiveLock (Arthrex); **f** the graft is pulled through fibular ATFL tunnel from anterior to posterior; **g** the graft is then pulled through the fibular CFL tunnel from posterior to anterior; **h** fixation of the graft to the calcaneal insertion of the CFL using a 4,75-Bio-SwiveLock (Arthrex)

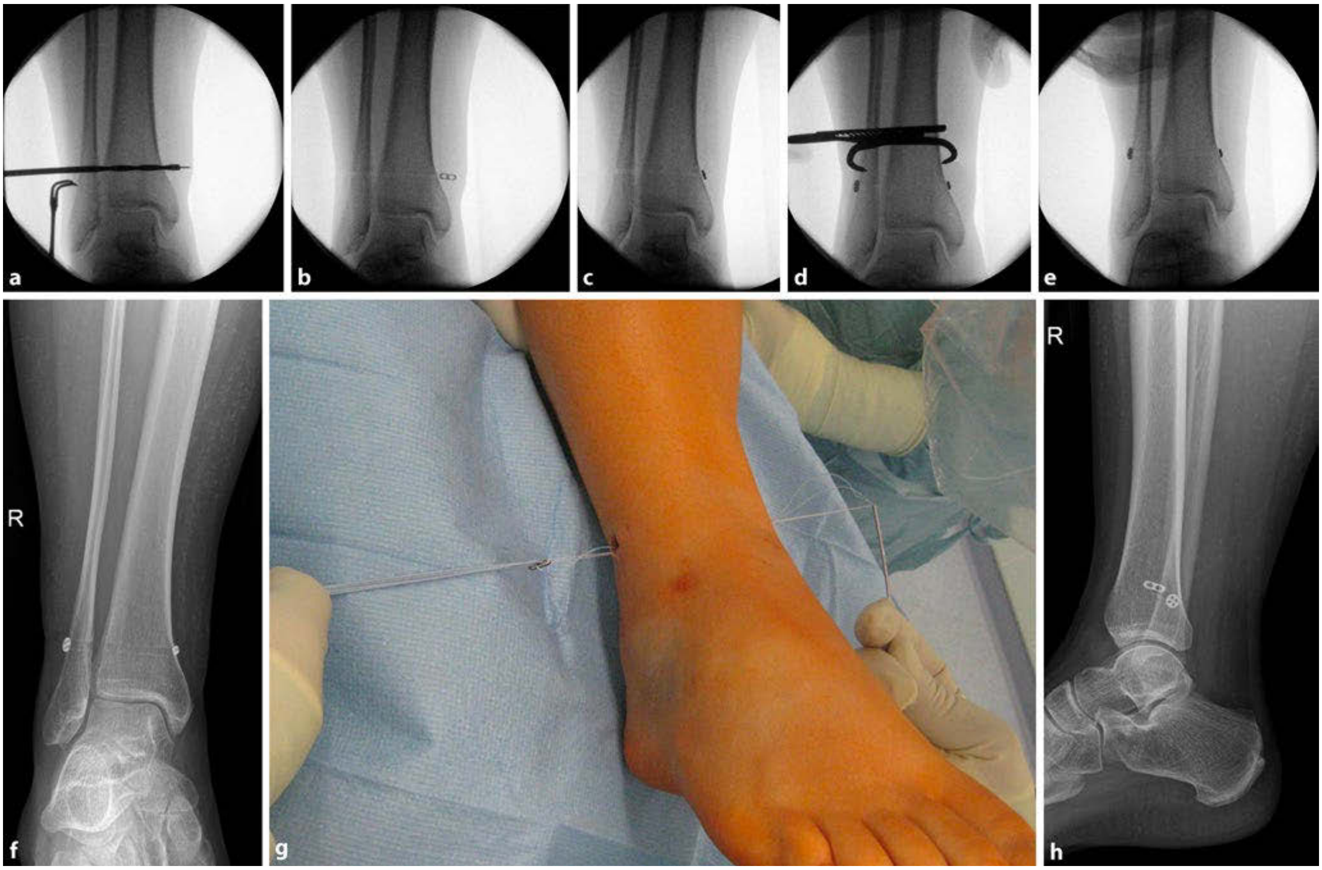

Fig. 23.9a–h Syndesmosis repair with a TightRope (Arthrex). **a** overdrilling of the guide wire with a 3.5 mm drill bit; **b** pulling the TightRope system up to the medial tibial cortex; **c** Flipping the button; **d** reduction of the syndesmosis with a Weber clamp; **e** end result after tying the sutures laterally; **f** postoperative radiographs (mortise view); **g** intraoperative photo during pulling the TightRope; **h** postoperative radiograph (lateral view)

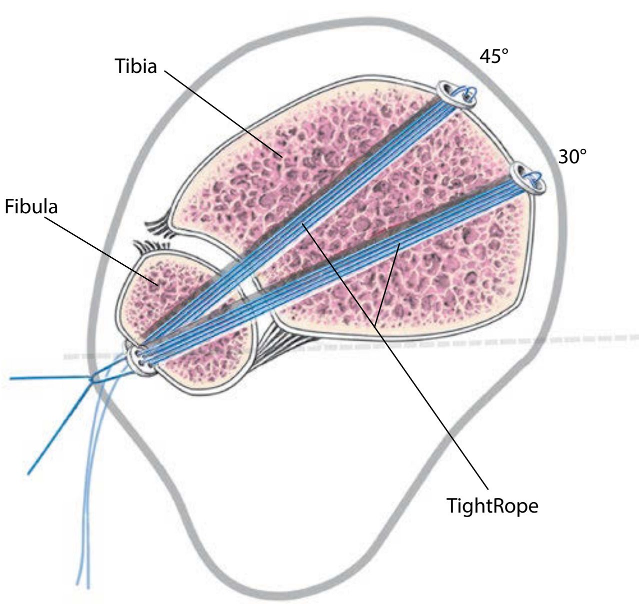

Fig. 23.10 Placement of double TightRope systems

23.2.5 Postoperative Management

- Monitoring of peripheral circulation, motor and sensory innervation.
- Use of elastic compressive bandages as well as a short leg splint.
- Cooling and elevation of the extremity.
- Postoperative radiographs

23.2.6 Follow-Up Management

Postoperative non weight-bearing in a plaster cast for 2 weeks. Gradual weight-bearing in the 3rd–5th weeks not exceeding the pain limits and starting the physiotherapy. Full weight bearing from the 5th–8th week.

23.3 Stabilization of the Peroneal Tendons

H.-J. Trnka, P. Hofstätter, R. Schuh

23.3.1 Indication

Chronic recurrent painful peroneal tendons dislocation.

23.3.2 Operation Principle

Numerous operations can be performed depending on the local situation. Eckert and Davis have classified the peroneal tendons instability into 3 grades. Grade 1 corresponds to injury of the superior peroneal retinaculum, grade 2 a detachment of the fibrocartilagenous ridge from the fibula together with elevation of the retinaculum and grade 3 with a complex bony avulsion of the retinaculum.

An acute rupture or bony avulsion of the retinaculum can be managed with refixation and augmentation of the retinaculum. In a very shallow fibular groove or a very thin and distorted retinaculum, an additional bony deepening of the sliding groove is necessary. Reconstruction of the bony roof is very rarely necessary.

23.3.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: detailed symptomatology (pain and/or recurrent peroneal tendon dislocation/subluxation), onset and duration of symptoms, activities provoking the symptoms, previous treatment.
- Symptom specific examination: painful soft tissue swelling over the lateral malleolus, audible and/or palpable snapping of the peroneal tendons, worsening of the pain with dorsiflexion and inversion, eventual eliciting of subluxation of the peroneal tendons.

Imaging

- X-rays of the heel (lateral view) and the whole foot (lateral standing view) to assess bony changes.
- The tendon itself is best assessed with ultrasound or MRI. Intratendinous necrotic areas, partial tendon ruptures as well as the integrity of the retinaculum can be assessed on MRI.

Patient Information/Consent

Specific operative risks: sural nerve injury, recurrent dislocation.

23.3.4 Surgical Technique

Positioning and Preparation

- Supine or lateral position
- A tourniquet is applied to the thigh

Repair of the Retinaculum

J-shaped skin incision posterior to the course of the peroneal tendons behind the lateral malleolus (◘ Fig. 23.11). Care should be taken for the posterior intermediate cutaneous nerve anteriorly and the sural nerve posteriorly. Dissection for the peroneal tendons and exposure of the retinaculum.

If the fibular groove and its roof are sufficient for secure sliding of the tendons, an isolated soft tissue reconstruction can be performed. The superior peroneal retinaculum (that is usually torn from the fibula) is reattached either with transosseous sutures or using suture anchors (e. g. PushLock, Arthrex).

Deepening of the Fibular Groove

Skin incision as described above. The peroneal tendons are dissected and the retinaculum is exposed. The tendons are dislocated anteriorly over the fibula to evaluate the extent and degree of dislocation.

The periosteum elevated from the fibula is further dissected with the attached retinaculum from the fibula to prepare about 5 cm long posteriorly based periosteal-retinaculum flap (◘ Fig. 23.12). Then the peroneal tendon were pulled away.

Direct Deepening

A longitudinal cortical osteotomy is made with an oscillating saw at the anterior margin of the groove (the posterolateral edge of the distal fibula). A transverse cortical osteotomy is then performed both proximally and distally along the whole width of the fibular groove. Subsequently, the cortical bone at the posteromedial edge of the groove is weakened using an oscillating saw. A cortico-cancellous bony chip is elevated posteriorly. The groove is then deepened by reducing the underlying cancellous bone using a rounded burr (◘ Fig. 23.13). After sufficient deepening of the groove, the elevated bony chip is reduced and impacted into the fibula using a bone tamp. Finally, the peroneal tendons are reduced and the previously prepared periosteal-retinaculum flap is tightly reattached to the fibula (◘ Fig. 23.14).

Indirect Deepening

A 4-mm drill is inserted at the distal tip of the fibula parallel to the groove for the peroneal tendons and hereby and used to reduce the cancellous bone. A bone tamp is then used to impact and deepen the groove. The peroneal tendons are reduced and the periosteal-retinaculum flap is tightly reattached anteriorly to the fibular periosteum.

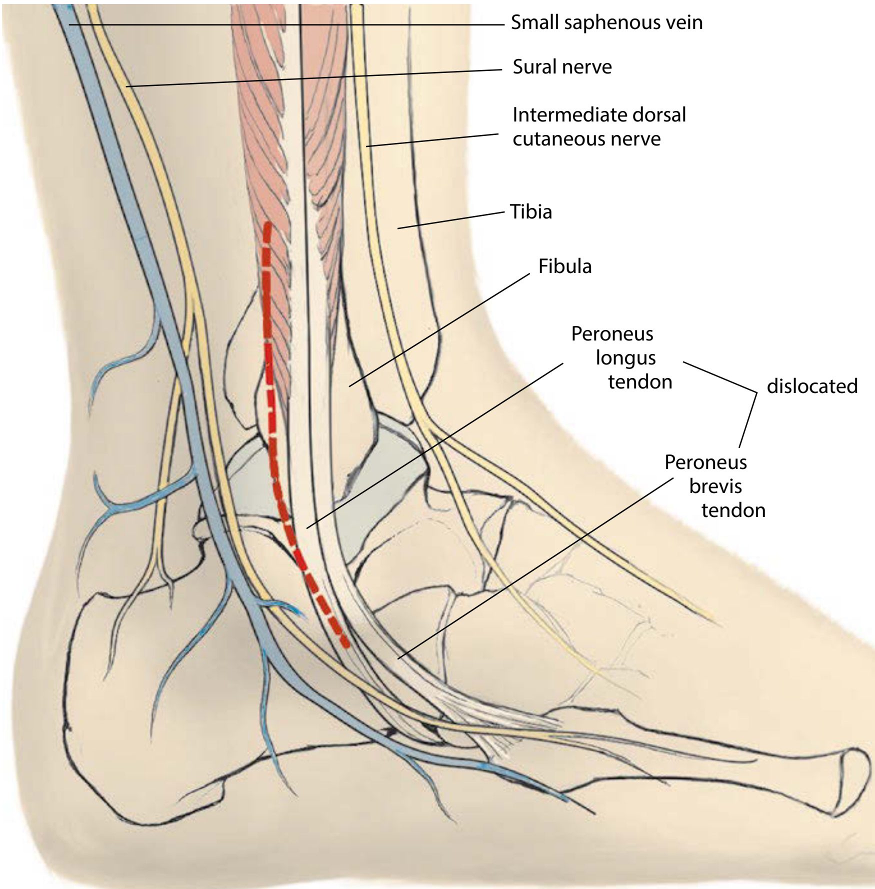

Fig. 23.11 J-shaped skin incision posterior to the course of the peroneal tendons

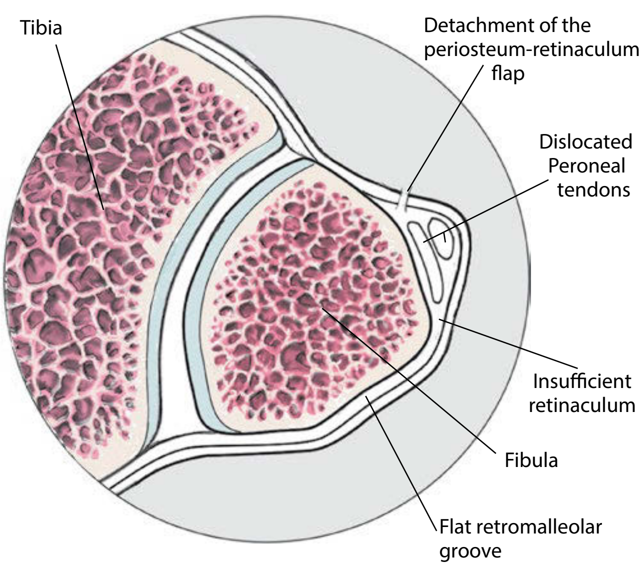

Fig. 23.12 preparing a posterior based periosteal retinaculum flap

23.3.5 Postoperative Management

- Monitoring of peripheral circulation, motor and sensory innervation.
- A short leg plaster cast is applied.
- Cooling and elevation of the extremity.
- Postoperative radiographs

23.3.6 Follow-up Management

Immobilization in a short leg plaster cast for 6 weeks, partial weight bearing until the stitches are removed. Physiotherapy is started after removal of the cast planter flexion, inversion and adduction exercises. Dorsiflexion, abduction and eversion are allowed from the 9th week.

23.3.7 Tips & Tricks

The retinaculum must be sufficiently and tightly reconstructed in every case, even if deepening of the groove is performed. Part of the tendon must be resected if it is hypertrophied to prevent overstuffing of the canal.

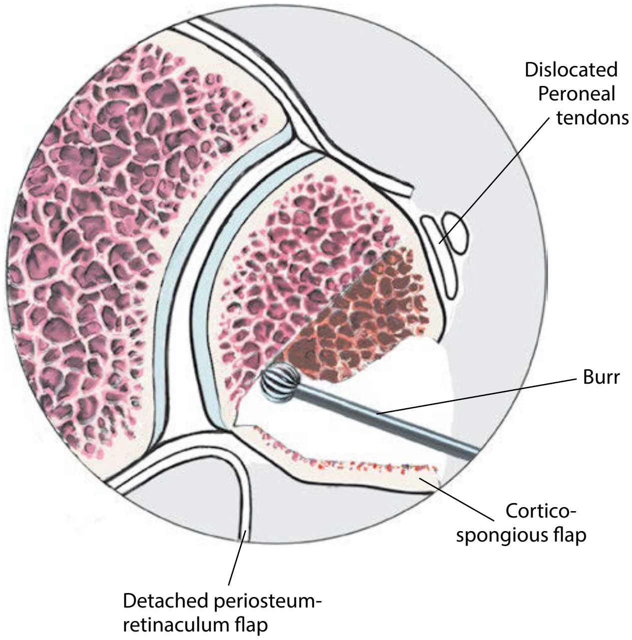

Fig. 23.13 Deepening of the fibular groove by removing the underlying cancellous bone after elevation of a cortico-cancellous bone chip

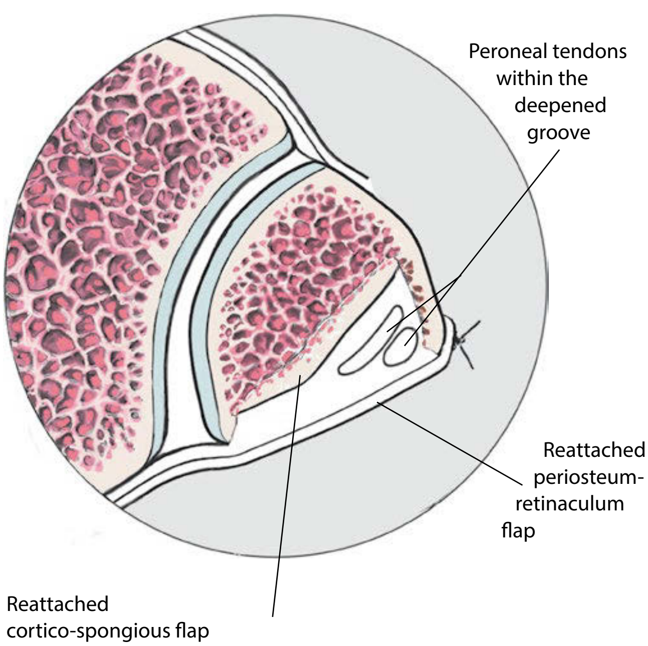

Fig. 23.14 After deepening of the fibular groove, the bone chip is reduced and impacted with a bone tamp and the periosteum-retinaculum flap is tightly reattached to the fibula

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Chondral and Osteochondral Lesions

A. Schmitt, S. Vogt

A. B. Imhoff, M. J. Feucht (Eds.), *Surgical Atlas of Sports Orthopaedics and Sports Traumatology*,
DOI 10.1007/978-3-662-43776-6_24,

24.1 Microfracture

A. Schmitt, S. Vogt

24.1.1 Indication

Symptomatic focal cartilage lesions between 1–2 cm^2 in size, ICRS grade 3–4. Strict indication includes corresponding cartilage lesions.

Specific contraindications: osteoarthritis, osteonecrosis, osteochondral defects (relative).

24.1.2 Operation Principle

Induction of regenerative cartilage tissue formation through releasing mesenchymal stem cells after penetration of the subchondral lamella.

24.1.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: pain character, limited range of motion, locking, instability, trauma
- Symptom specific examination: Malalignment, foot deformity, tenderness, pain on motion, range of motion, crepitation, locking, and instability.

Neurological and Vascular Evaluation

Examination and documentation of peripheral neurological and vascular condition (particularly the superficial peroneal nerve, intermediate and medial dorsal cutaneous nerves, peroneal nerve, tibial nerve, dorsalis pedis, anterior and posterior tibial arteries.

Imaging

- Conventional X-ray of the ankle in 2 planes (AP in 18° of internal rotation [Mortise-view] and lateral) for evaluation of deformities, calcification, necrosis, cysts and arthritic changes
- MRI to assess the extension of the cartilage damage, subchondral cysts and associated reactions, osteoarthritic changes and the presence of loose bodies
- CT with intraarticular contrast agent injection, when MRI is not possible e.g. presence of metallic implants
- Special radiological studies could be helpful (e.g. MRI T2-Mapping)

Patient Information/Consent

Specific operative risks: insufficient regenerative tissue, subsequent failure of regenerative tissue, induction of osteonecrosis, non-weight bearing for 6 weeks, progressive cartilage damage, osteoarthritis and revision with possible shift to other cartilage restorative procedures.

24.1.4 Surgical Technique

Positioning and Preparation

- Supine position with freely movable legs, the feet of the patients should be positioned at the distal end of the table to allow distraction of the ankle
- A tourniquet is applied to the thigh

Arthroscopic Microfracture of the Ankle Joint

An anterolateral arthroscopic portal is established followed by the anteromedial portal in an outside-in technique under trans-illumination (Diaphanoscopy). Attention should be paid for the course of the superficial peroneal nerve. Debridement of the hypertrophied synovium with a soft tissue shaver for a good visualization. The anterolateral portal could be used as a working portal (for instruments) or an additional portal may be created (e.g. superomedial or posterolateral portal) according to the location of the cartilage lesion.

After arthroscopic evaluation and documentation of the cartilage lesion, a curette or sharp spoon is used to create stable margins of the surrounding normal cartilage (◘ Fig. 24.1a). The defect area is debrided down to the subchondral bone and the calcified layer and sclerotic herds are removed (◘ Fig. 24.1b). This could result in spotty bleeding. The subchondral bone is then opened using microfracture awl (◘ Fig. 24.1c). Awls of different curvatures are available and the most suitable one depending on the location of the cartilage lesion should be used so that the penetration is as perpendicular as possible to the subchondral lamella. The depth of perforation should be about 3 mm. Successful penetration is evidence by flow of blood or bone marrow substance from the holes. The microfracture holes should be 3–4 mm apart (◘ Figs. 24.2 and 24.3).

24.1.5 Postoperative Management

- Monitoring of peripheral circulation, motor and sensory innervation.
- Use of elastic compressive bandages
- Cooling and elevation of the extremity.

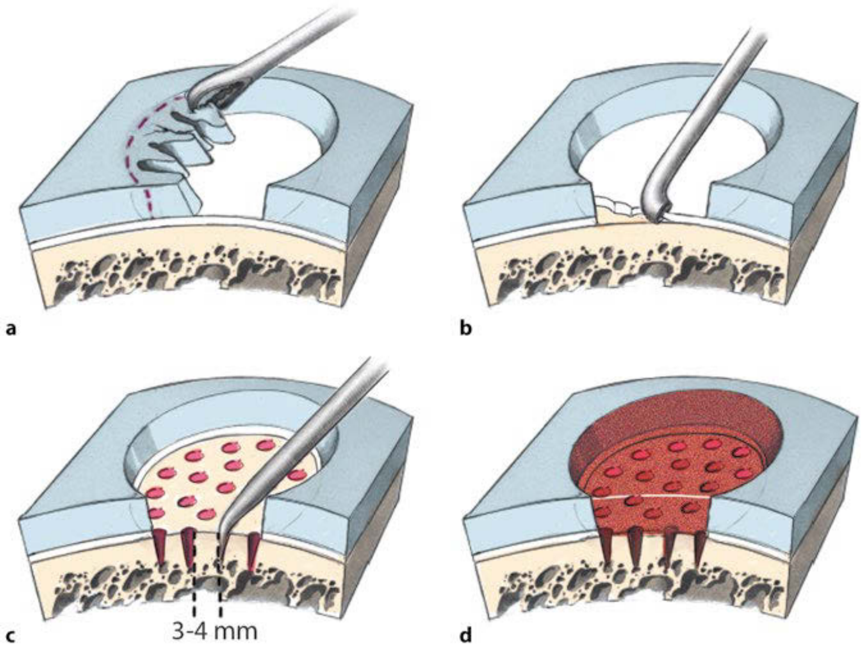

Fig. 24.1a–d Schematic representation of microfracture: **a** creating a stable margin in the healthy surrounding cartilage using ring curette; **b** removal of the calcified cartilage layer with a sharp spoon curette, **c** perforation of the subchondral bone with the microfracture awl e; **d** defect filled with blood clot

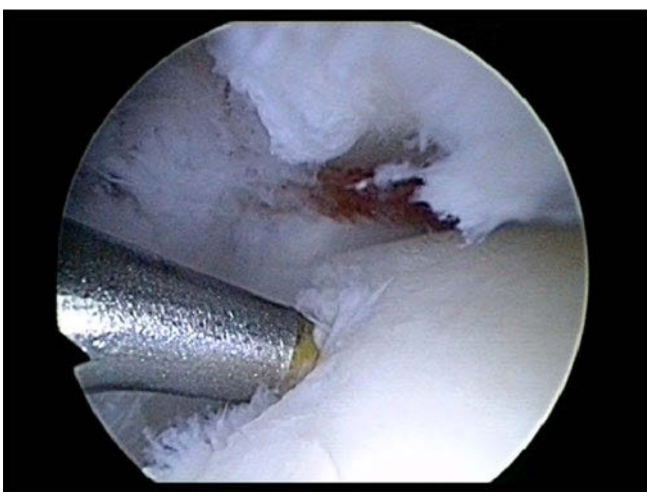

Fig. 24.2 Microfracture of cartilage lesion at the medial talar dome

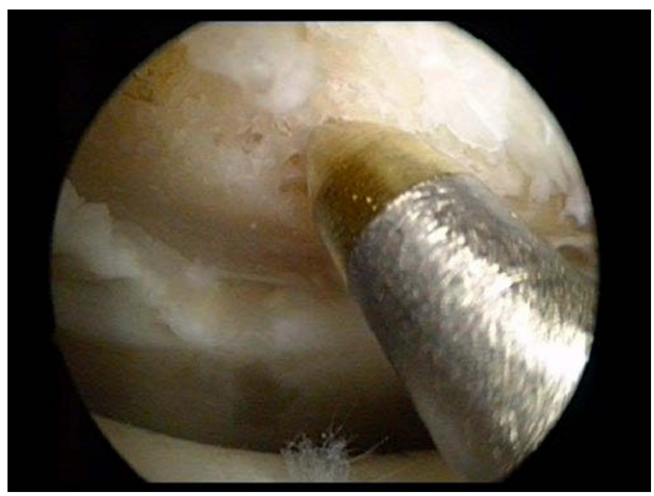

Fig. 24.3 Microfracture of a cartilage lesion at the distal tibia

24.1.6 Follow-Up Management

Free range of motion of the ankle joint starting from the 2nd postoperative day without weight bearing. Non weight bearing on the affected leg for 6 weeks using crutches. Progressively increasing weight bearing from the 7th postoperative week.

24.1.7 Tips & Tricks

Good preparation of the defect area (debridement of sclerosis, creation of stable cartilage margins) before performing microfracture!

Creating a stable defect margin is of particular importance because at the beginning of regeneration process, the newly formed tissue is still weak and unstable and requires protection from the surrounding normal cartilage.

Microfracture is sometimes difficult to be performed in cases of chronic cartilage defects with markedly hard or sclerotic layer over the subchondral bone. In such cases, preliminary few perforations to evaluate the thickness of the hardened bone are followed removal of this bony layer down to the subchondral bone and finally microfracture.

Perforations should be as close as possible to the surrounding healthy cartilage in the transitional zone.

Preservation of adequate bone bridges between the perforations should be kept in mind to maintain the stability of the subchondral plate. Moreover, the perforations should be orthograde (perpendicular) to the subchondral bone, otherwise the holes may converge towards each other with the risk of collapse of the subchondral bone.

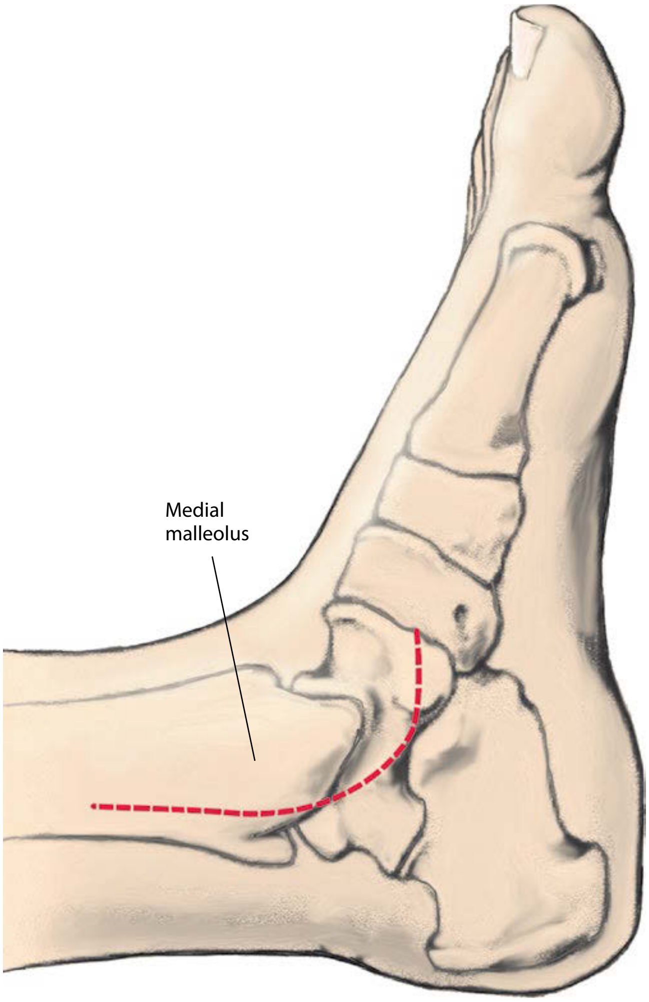

Fig. 24.4 The skin incision begins approximately 3 finger breadth above the medial malleolus and extends distally and anteriorly, just posterior and below the medial malleolus

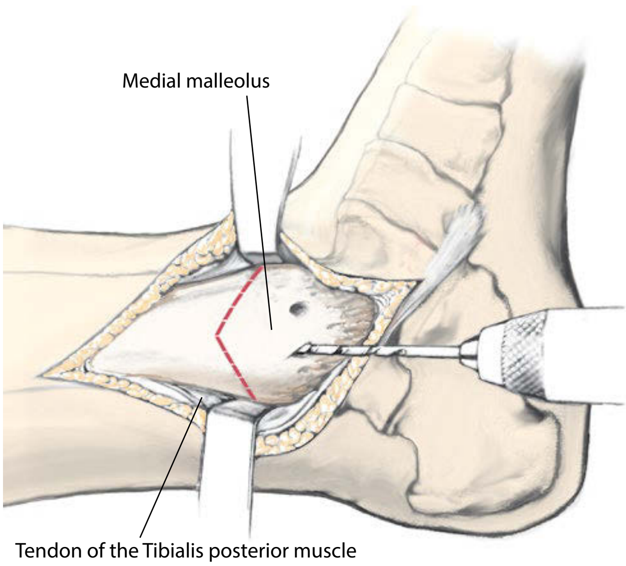

Fig. 24.5 Pre-drilling of the two holes in the medial malleolus for the lag screws that would be used later (about 5 cm depth and in 70° ascending direction)

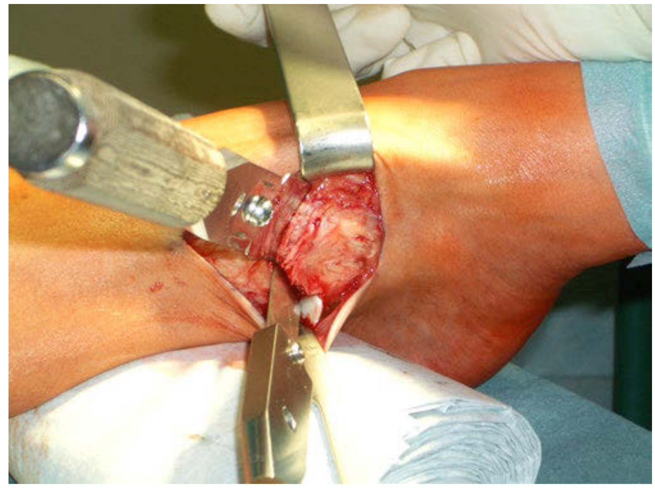

Fig. 24.6 V-shaped medial malleolar osteotomy with a flat osteotome

To ensure sufficient opening of the subchondral lamella, the inflow of arthroscopy medium is stopped or the tourniquet is released, which should result in outflow of blood, bone marrow and fat cells from the perforation holes.

Strict avoidance of intraarticular drains to avoid unintended disruption of the newly formed blood clot. If a drain is necessary, it should be without vacuum suction!

24.2 Autologous Osteochondral Transplantation

24.2.1 Indication

Focal osteochondral defect up to about 2 cm^2 in size. Localized osteonecrosis or cysts up to 2 cm^2.

24.2.2 Operation Principle

Replacement of osteochondral defects of the talar articular surface through transplantation of autologous osteochondral cylinders from low weight bearing area of the knee joint.

24.2.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: pain character, limitation of motion, locking of the joint, instability, trauma
- Symptom specific examination: Malalignment, foot deformity, tenderness, painful motion, range of motion, crepitation, locking, instability.

Imaging

- Plain radiographs of the ankle in 2 views (AP with 18° of internal rotation [Mortise-view] and lateral) for assessment of osteoarthritic changes, osteonecrosis and cysts.
- MRI (with intraarticular/intravenous contrast agent) to assess the extent of osteochondral lesion, associated subchondral reaction, degenerative changes, presence of loose bodies and to exclude concomitant pathologies
- CT with intraarticular contrast agent injection, when MRI is not possible e.g. presence of metallic implants
- Special radiological studies could be helpful (e. g. MRI T2-Mapping)
- Plain radiographs of the donor knee joint in 3 views (AP, lateral and patella tangential) to assess the osseous condition and to exclude osteoarthritic changes.

Planning

The incision and the necessity of a malleolar osteotomy (required fixation instruments should be prepared) should be planned according to the location of the lesion.

Patient Information/Consent

Specific operative risks: possibility of malleolar osteotomy if needed with its associated risks such as delayed bone healing, non-union, fixation failure, re-fracture, secondary dislocation, necrosis of the graft, lack of bony integration, cyst formation, cartilage incongruity with step formation, non-weight bearing for 6 weeks postoperatively; donor site morbidity at the knee.

24.2.4 Surgical Technique

Positioning and Preparation

- Supine positioning of the patient with freely movable leg
- applying a thigh tourniquet

Autologous Osteochondral Transplantation for Osteochondral Defects of the Medial Talar Dome

Approximately 10 cm long, curved incision beginning 3 fingerbreadths proximal and posterior to the medial malleolus and extending along the tip of the medial malleolus distally and anteriorly (Fig. 24.4). Sharp dissection down to the deep leg (crural) fascia which is incised anterior to the medial malleolus and the joint is opened.

A medial malleolar osteotomy is needed if the osteochondral defect couldn't be exposed completely. This requires also exposure and incision of the crural fascia posterior to the medial malleolus, opening the tibialis posterior compartment and retracting the tendon posteriorly with a Langenbeck retractors. The joint is then opened posterior to the medial malleolus. Before the osteotomy, the two holes for the lag screws that would be inserted later for fixation are pre-drilled (approximately 5 cm depth and in a 70° ascending direction: Fig. 24.5). Two

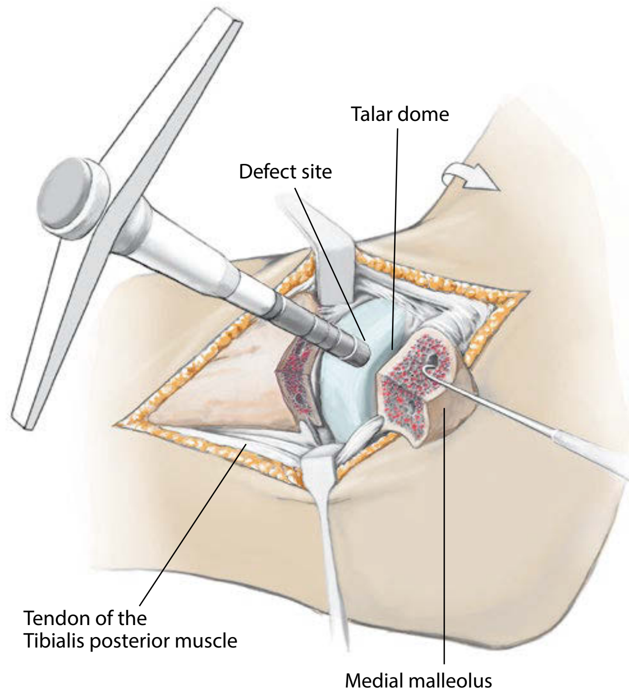

Fig. 24.7 Removal of the defect with the "recipient harvester" (OATS Instruments, Arthrex)

Hohmann retractors are then inserted, one anterior and the other posterior to the medial malleolus at the level of the osteotomy to protect soft tissues. A V-shaped osteotomy is then performed using flat osteotomes (Fig. 24.6). The medial malleolar fragment is then retracted to expose the medial talar dome.

The size of the defect and subsequently the size of the required harvester are determined using a sizer/tamp. The defect is then removed using the "recipient harvester" (OATS instruments, Arthrex) to a depth of about 12–15 mm (Figs. 24.7 and 24.8). If the defect is very close to the edge of the articular surface, the defect cylinder should be obliquely removed to ensure sufficient stability of the subsequently inserted graft. The cancellous bone of the recipient site is impacted using the tamp (plunger).

The donor cylinder is harvested using the appropriately matching "donor harvester" (about 0.3 mm larger in diameter than the "recipient harvester") from the superolateral area of the trochlea of the ipsilateral knee through a mini arthrotomy (► Sect. 18.3). If the recipient socket is prepared obliquely, identical angulation of the cartilage surface relative to the donor cylinder axis must be considered to avoid step formation of the reconstructed cartilage surface.

The length of the donor cylinder should be matched to the depth of the recipient socket and the cylinder is then advanced into the socket with press-fit technique using a special delivering tube and a tamp (Fig. 24.9). With large sized defects a combination of multiple cylinders of different sizes is possible (mosaicplasty).

Fig. 24.8a–c Removal the defect zone. **a** Osteochondral lesion of the medial talar dome **b** removal of the defect with the "recipient harvester"; **c** recipient socket at the site of the previous lesion

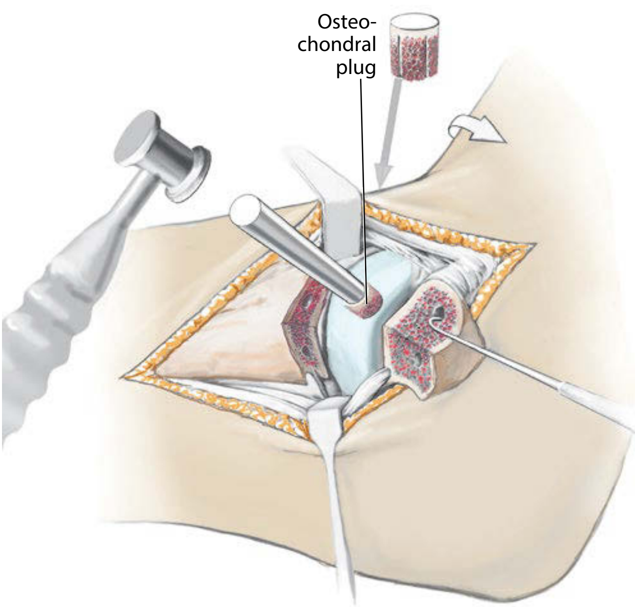

Fig. 24.9 Introducing the donor cylinder into the recipient socket. (osteochondral cylinder)

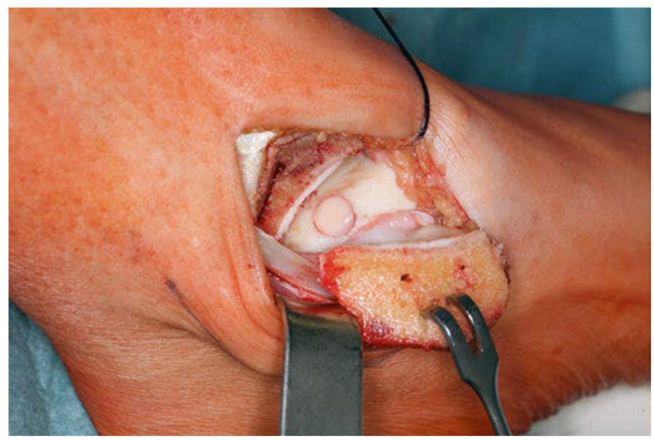

Fig. 24.10 End result after insertion of the donor cylinder

After flush insertion of the cylinder (Fig. 24.10), the medial malleolar osteotomy fragment is reduced and fixed using cancellous screws into the pre-drilled holes as lag screws.

Autologous Osteochondral Transplantation for Osteochondral Defects of the Lateral Talar Dome

Skin incision is about 10 cm long, lateral to the tendon of the extensor digitorum longus and anterior to the tibiofibular syndesmosis (Fig. 24.11). Sharp dissection down to the crural fascia with care to protect the superficial peroneal nerve followed by splitting the inferior extensor retinaculum and opening the joint capsule with care here to protect the anterior lateral malleolar artery.

A lateral malleolar osteotomy together with osteotomy of the Chaput's tubercle are needed if the osteochondral defect couldn't be exposed completely. An obliquely ascending osteotomy of the distal fibula from anterior to posterior is performed above the level of the syndesmosis with a blade osteotome. Two holes for lag screws are predrilled through the Chaput's tubercle followed by osteotomy using the blade chisel. Osteotomy of the Chaput's tubercle only is often adequate (Fig. 24.12). The osteochondral defect is then exposed with forced plantar flexion and supination of the foot.

The osteochondral defect is then removed using the recipient's harvester and one or more osteochondral cylinders are transplanted as described above. After flush insertion of the cylinder, the Chaput's tubercle is refixed using lag cancellous screws with short threads through the pre-drilled holes and the fibula is fixed with an interfragmentary lag screw and one third tubular plate.

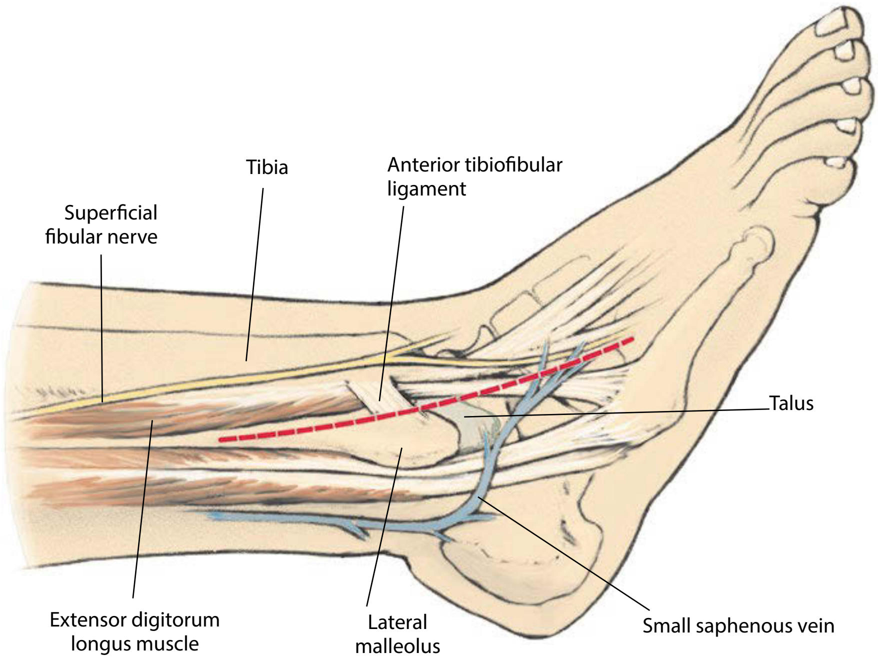

Fig. 24.11 Skin incision lateral to the tendon of the extensor digitorum longus anterior to the tibiofibular syndesmosis

Fig. 24.12a,b Radiograph after osteotomy of the Chaput's tubercle. **a** AP view **b** lateral view

24.2.5 Postoperative Management

- Monitoring of the peripheral circulation, motor and sensory innervation.
- Use of elastic compressive bandages
- Immobilization of the ankle joint in a lower leg plaster cast or a similar orthosis.
- Cooling and elevation of the extremity.
- Postoperative radiographic evaluation

24.2.6 Follow-Up Management

Immobilization of the ankle joint in a lower leg cast or a similar orthosis in the 1st 6 weeks with strict non weight bearing. No pronation or supination is allowed. Dorsiflexion and plantar flexion could be started from the 2nd postoperative day outside the splint. Progressive weight bearing from the 7th week. Removal of the metallic implants is optional after consolidation of the osteotomy.

The donor knee could be loaded, as pain and swelling could be tolerated, in full range of motion immediately after surgery.

24.2.7 Tips & Tricks

Pre-drilling the lag screw holes for subsequent fixation simplifies the step-free fixation.

The extra-articular location of the drill holes for lag screws should be verified after performing the medial malleolar osteotomy.

A too short donor cylinder could be compensated by reducing the depth of the recipient socket with cancellous bone. Cave: necrotic bone removed from the defect zone shouldn't be used even for filling the donor cylinder socket.

Tendentially, a deeply seated cylinder is preferred over a protruding cylinder.

If the grafted cylinder is too deeply seated, a corkscrew or chisel inserted below the cylinder in case of marginal defects could be used to remove it. The bed of the socket is then grafted with sufficient cancellous bone to achieve a new flush and congruent position of the graft.

The harvester should be left about 60 seconds in the bone after insertion to allow swelling of the bone inside and subsequently secured removal of the cylinder.

The graft should be always kept moist with a physiological saline solution to prevent apoptosis (in a wet towel) and not immersed in fluid (cartilage swells and results in more difficult implantation).

Minimal force should be used during implantation of the cylinder to avoid cartilage damage.

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Arthrosis

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A. B. Imhoff, M. J. Feucht (Eds.), *Surgical Atlas of Sports Orthopaedics and Sports Traumatology,*
DOI 10.1007/978-3-662-43776-6_25,

25.1 Anterior Ankle Impingement "Soccer's Ankle"

R. Schuh, S. Hofstätter , H.-J. Trnka

25.1.1 Indication

Chronic activity related ankle pain due to tibiotalar osteophytes at the anterior aspect of the ankle joint, which results in anterior impingement syndrome (so-called "soccer's ankle" or "athletes ankle").

Repetitive mechanical stress is believed to be the cause of this pathological condition. This occurs mainly with repetitive distraction of the capsuloligamentous structures, as for example in shooting the ball in soccer (with plantar flexion of the ankle) and represents the basic factor behind the formation of tibiotalar osteophytes. The definitive cause for the formation of osteophytes is however controversial.

The pain seems to result from irritation and inflammation of the soft tissues surrounding the osteophytes, but not the osteophytes themselves. Repetitive trauma to the soft tissue by the osteophytes leads to synovial hypertrophy and inflammatory cell infiltration.

Theoretically, removal of the soft tissue should eliminate the pain. However, the pathomechanical process will not be interrupted if the osteophytes are not addressed.

25.1.2 Operation Principle

Resection of the anterior tibial osteophytes and those on the talar neck as well as removal of the synovial villi.

Resection of the osteophytes can be open or arthroscopically performed. The open approach has the disadvantage of possible injury to the cutaneous braches of the superficial peroneal nerve, wound healing problems, hypertrophied scar tissue, and injury to the long extensor tendons, which is why the authors prefer the arthroscopic approach.

25.1.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: patients complain often from diffuse pain at the anterior aspect of the ankle joint, often a history of repetitive inversion trauma and recurrent local swelling after mechanical activity.
- Symptom specific examination: limited dorsiflexion of the ankle with terminal degrees pain, tenderness over the anterior joint space (mainly medial to the tibialis anterior tendon and lateral to the tendon of the extensor hallucis longus). Osteophytes can be often palpated in mild plantar flexion.

Imaging

The extent of the radiological changes detectable in X-ray are related to the duration of symptoms. In the early stages there is detectable cortical erosion of the distal tibia while in the advanced stages a typical bony spur can be seen in the lateral view. Additionally, a bony spur at the head-neck junction of the talus can be seen.

Often the anteromedial osteophytes are not detectable in the standard a.-p. and lateral views. Therefore, an oblique view of the ankle should be obtained when there is a high clinical suspicion. In the so called anteromedial impingement view the central ray is directed about 45° caudally, the leg is externally rotated 30° and the ankle in plantar flexion

Patient Information/Consent

Specific operative risks: impaired wound healing, infection, nerve injury, thrombosis, recurrence of osteophytes, progression of the osteoarthritis and limitation of the ROM.

25.1.4 Surgical Technique

Positioning and Preparation

- Supine
- The leg is positioned at the edge of the operating table, so that the surgeon can move the ankle intraoperative into dorsiflexion.
- Optionally, a tourniquet can be applied

Arthroscopic Removal of the Tibiotalar Osteophytes

Anteromedial and anterolateral portals are established as described in ► Sect. 21.1. Additional portals are only required in exceptional cases. Synovectomy is performed first after a systematic arthroscopic examination of the joint to allow adequate exposure of the anterior border of the tibia.

A shaver is used to remove the soft tissue proximal to the osteophytes and thus exposing the anterior border of the distal tibia. These osteophytes can be intraoperatively optimally visualized by dorsiflexion of the ankle (◘ Fig. 25.1a). The use of distraction devices can increase the tension of the anterior capsule and make it more difficult to visualize the osteophytes.

The osteophytes at the tibial side can be removed using a 4-mm chisel and a shaver ("bone cutter" or "acromionizer") (◘ Fig. 25.1b–e) with great care to avoid injuring the talar cartilage. Osteophytes at the talar neck are then removed. Under arthroscopic visualization, success of the procedure is confirmed by assessing the passive dorsiflexion and if needed, more resection is performed (◘ Fig. 25.1f).

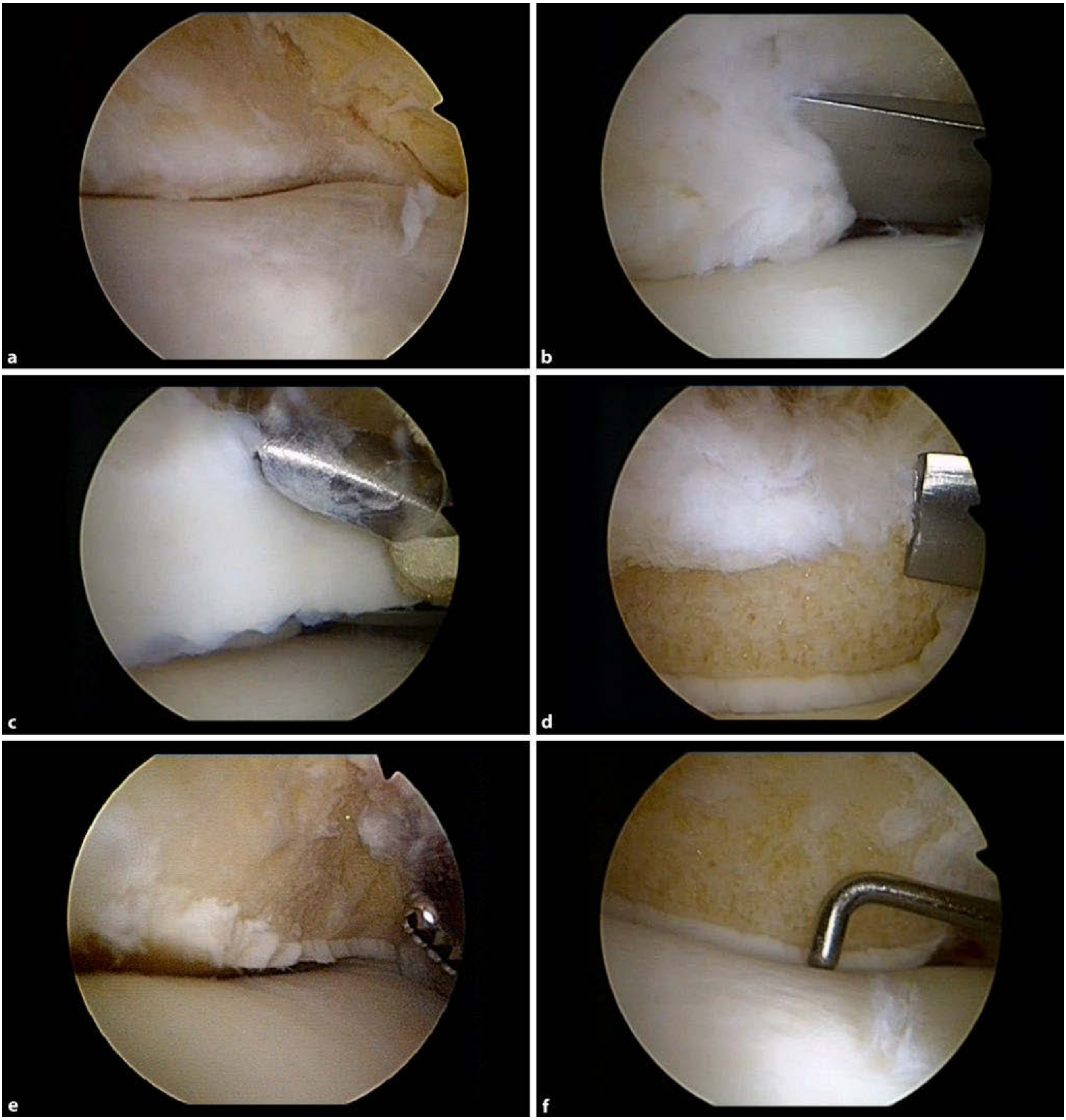


Fig. 25.1a–f Arthroscopic removal of osteophytes on the anterior edge of the tibia. **a** Exposure of the osteophytes; **b** resection of the osteophytes with a 4-mm osteotome; **c** Removal of the resected material with an arthroscopic grasper; **d** completing the resection using the osteotome; **e** smoothing the resection margins with a shaver; **f** final result after resection

25.1.5 Postoperative Management

- Monitoring of peripheral circulation, motor and sensory innervation
- Use of elastic compressive bandages
- Cooling and elevation of the extremity
- Postoperative radiographs (Fig. 25.2)

25.1.6 Follow-up Management

Postoperative rehabilitation includes the use of elastic compression bandages and partial weight bearing (four point gait) with two crutches for 3–5 days. The patient is instructed to practice passive range of motion exercises of the ankle in dorsiflexion. Physiotherapy is started after healing of the portals with gait training.

Fig. 25.2a,b **a** Preoperative radiograph showing prominent osteophytes at the anterior distal tibial edge; **b** postoperative radiograph following osteophytes resection

25.1.7 Tips & Tricks

Repeated intraoperative assessment using the C-arm is recommended as the osteophytes are often arthroscopically underestimated.

25.2 Cheilectomy and MTP Arthrodesis for Hallux Rigidus

H.-J. Trnka, S. Hofstätter, R. Schuh

25.2.1 Indication

Cheilectomy is indicated for grade 1 or 2 osteoarthritis of the 1st MTP joint resulting in decreased ROM with partially preserved articular surface.

Metatarsophalangeal (MTP) arthrodesis is indicated for osteoarthritis of the MTP joint grade 3 with completely destroyed articular surface and painful limitation of the ROM.

25.2.2 Operative Principle

- **Cheilectomy:** restoration of the functional range of motion with partial resection of the dorsal part of the base of the proximal phalanx and the metatarsal head
- **MTP arthrodesis:** arthrodesis of the MTP joint in a functional position that allows rolling movements in the normal shoes with a maximum heel height of 5 cm.

25.2.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: complaints (pain, limitation of motion), exercise capacity, pain-free walking distance, footwear.
- Symptom specific examination: maximal planter flexion and dorsiflexion, tenderness at the 1st MTP joint.

Imaging

Radiographs of the forefoot in standing dorsoplantar and lateral views are basic requirements for the operative indication.

Patient Information/Consent

Specific operative risks: impaired wound healing, infection, nerve injury, thrombosis, progression of osteoarthritis and limitation of motion, hallux valgus deformity, non-union at the site of arthrodesis.

25.2.4 Surgical Technique

Positioning and Preparation

- Supine position
- Operation is performed under local anesthesia (ankle block) with initial sedation.
- A tourniquet at the ankle can be optionally used

Cheilectomy

Dorsal longitudinal skin incision medial to the tendon of the extensor hallucis longus (Fig. 25.3). The extensor tendon is retracted laterally after incising the subcutaneous tissue

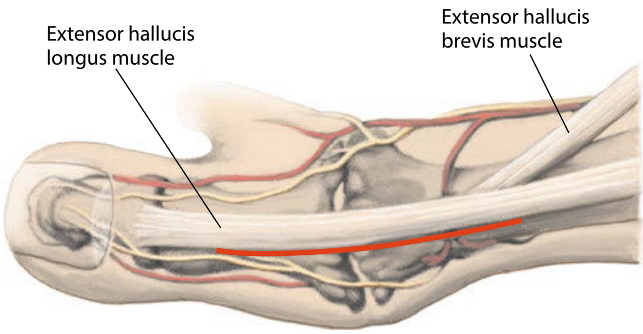


Fig. 25.3 Dorsal skin incision medial to the tendon of the extensor hallucis longus

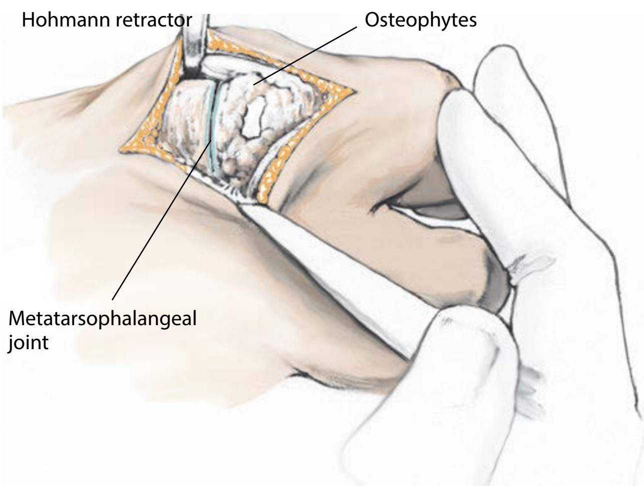


Fig. 25.4 Exposure of the metatarsophalangeal joint with 2 Hohmann retractors

and the joint capsule is opened longitudinally. The base of the proximal phalanx and the 1st metatarsal head are gently exposed using 2 Hohmann retractors (Fig. 25.4). The joint is inspected in maximal planter flexion and loose bodies and synovial villi are removed with a rongeur. The blade of the osteotome is placed at the beginning of the dorsal osteophyte at the base of the proximal phalanx and removal of osteophytes (Fig. 25.5).

The two Hohmann retractors are placed proximal to the metatarsal head. The blade of the osteotome is placed at the metatarsal head at the transition zone from the intact to the damaged articular cartilage (Fig. 25.6). This site should be more planter to the line of extension of the diaphysis of the first metatarsal bone and not along it. This corresponds approximately to the dorsal third of the metatarsal head. A hammer is used to cut off the bone wedge.

After removal of the osteophyte, the edges of the osteotomy are smoothed with the rongeur. A possibly existing medial osteophyte should not be removed, otherwise there would be increased risk of hallux valgus due to attenuation of the medial ligament.

It should be then possible to move the big toe to at least 60° dorsiflexion. If this is not possible, an additional dorsal

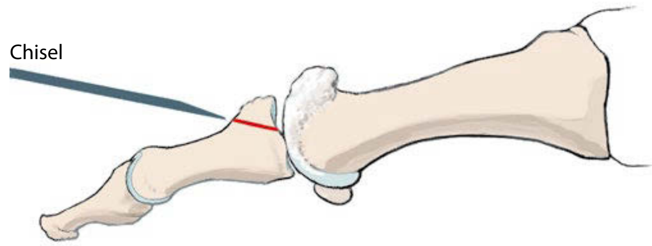


Fig. 25.5 Resection of dorsal osteophytes at the base of the proximal phalanx with osteotome

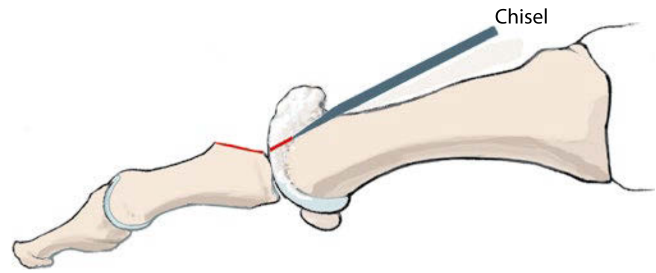


Fig. 25.6 Resection of the dorsal third of the metatarsal head with osteotome

Fig. 25.7 Schematic representation of the bone wedge to be removed in the dorsal "closing-wedge" osteotomy described by Moberg

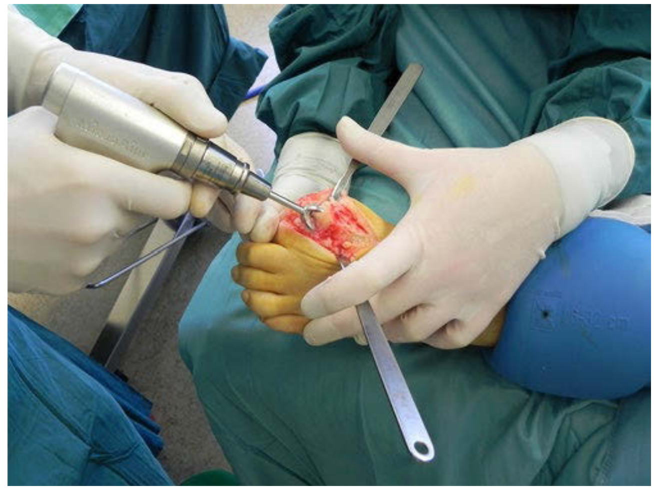
"closing-wedge osteotomy" as described by Moberg is recommended to achieve the required dorsiflexion (Fig. 25.7).

The dorsal wedge osteotomy is performed at approximately 5 mm distal to the articular surface of the base of the proximal phalanx. The wedge is removed cautiously without violating the inferior cortex which is then broken similar to a green stick fracture. The osteotomy is fixed either with a staple, a screw, Kirschner wires or 2 stitches.

1st MTP arthrodesis

Approach and exposure of the 1st MTP joint as described above. Different techniques are described for preparation of the joint surfaces. In one of these techniques, the base of the proximal phalanx and the metatarsal head are sawn off to have flat surfaces. With this method it is very difficult to control the joint position accurately and readjustment is often required which may be associated with further loss of bone length. Another possibility is to anatomically denude the articular cartilage using a burr. The most recent technique is to remove the articular cartilage using reamers.

■ **Fig. 25.8** Insertion of a guide wire into the metatarsal heads



■ **Fig. 25.9** Removal of the cartilage with a bone cutter/reamer down to the subchondral bone

■ **Fig. 25.10** Positioning the MTP joint in the desired position using an instrument set cover

As a first step, a guide wire is drilled into the 1st metatarsal head (■ Fig. 25.8). A circular reamer corresponding the size of the head is inserted over this guide wire to remove the articular cartilage down to the subchondral bone (■ Fig. 25.9). Prominent osteophytes are manually removed with a bone nibbler. Multiple drill holes are made to improve the blood supply through the exposed bone surface. The articulating surface for the sesamoid bone is usually not affected. The

■ **Fig. 25.11** Temporary fixation of the locked plate with pins

articular cartilage of the base of the proximal phalanx is removed in the same way.

The position of the 1st MTP joint is a crucial factor for the success of this operation. A position of 10–15° dorsiflexion relative to the ground plane is recommended (corresponding to the desired heel height). This is achieved intraoperatively by placing the foot over on a flat surface (e. g. the cover of the instrument set) (■ Fig. 25.10). The optimal position is mostly achieved if the index finger can be inserted between the flat surface and the big toe. Any contact between the big toe and the 2nd toe should be avoided.

A dorsal placed locking plate and compression screws are used for fixation of the arthrodesis. A guide wire for the cannulated compression screw is inserted across the joint after confirming the correct position of the arthrodesis. The screw is then tightened after a second clinical and radiological confirmation of the position. The locking plate is placed dorsally across the joint and is temporarily fixed with 2 special pins (■ Fig. 25.11).

The plate holes over the proximal phalanx are used first followed by those over the metatarsal (■ Fig. 25.12).

Fig. 25.12a,b Postoperative radiographs after MTP arthrodesis with dorsal locked plate and compression screw. **a** dorsoplantar **b** lateral view

25.2.5 Postoperative Management

- Monitoring of peripheral circulation, motor and sensory innervation.
- Use of elastic compressive bandages
- Immobilization in a cast after MTP joint arthrodesis in case of revision procedures or when the bone is osteoporotic.
- Postoperative radiograph

25.2.6 Follow-up Management

Cheilectomy

Full weight bearing is allowed immediately after the operation. A simple Sandal with a Velcro fastener or a hallux valgus shoes should be used for protection of the foot. From the 5th postoperative day, the patient should begin with slight passive movements of the big toe independently. After removal of the stitches (12–14 days) physiotherapy with gait training, strengthening the intrinsic muscles and ROM exercises of the big toe.

MTP Arthrodesis

Full weight bearing is allowed immediately after the operation if the bone quality is normal. Hallux valgus shoes should be used for protection of the foot for about 6 weeks after the operation. Immobilization in a plaster cast if the bone is osteoporotic as well as with revision procedures. After the immobilization period, physiotherapy is started with gait training, strengthening the intrinsic muscles and ROM exercises of the interphalangeal joint.

25.2.7 Tips & Tricks

The posterior approach is preferable to the medial one as it allows a better overview of the joint. Also it can be used to perform arthrodesis as a revision procedure with marked advancement of the osteoarthritis.

The medial capsule should be plicated if a big medial osteophyte is removed during the cheilectomy to prevent occurrence of postoperative hallux valgus deformity.

25.3 Arthrodesis

A. Schmitt, S. Vogt

25.3.1 Indication

Symptomatic primary or secondary osteoarthritis of the ankle or the ankle and subtalar joints after failed conservative treatment with marked limitation of the patient’s activities.

Paralytic conditions, instability or marked malalignment (> 10°), which can’t be improved with the joint-preserving procedures. Revision surgery after failed endprosthesis arthroplasty.

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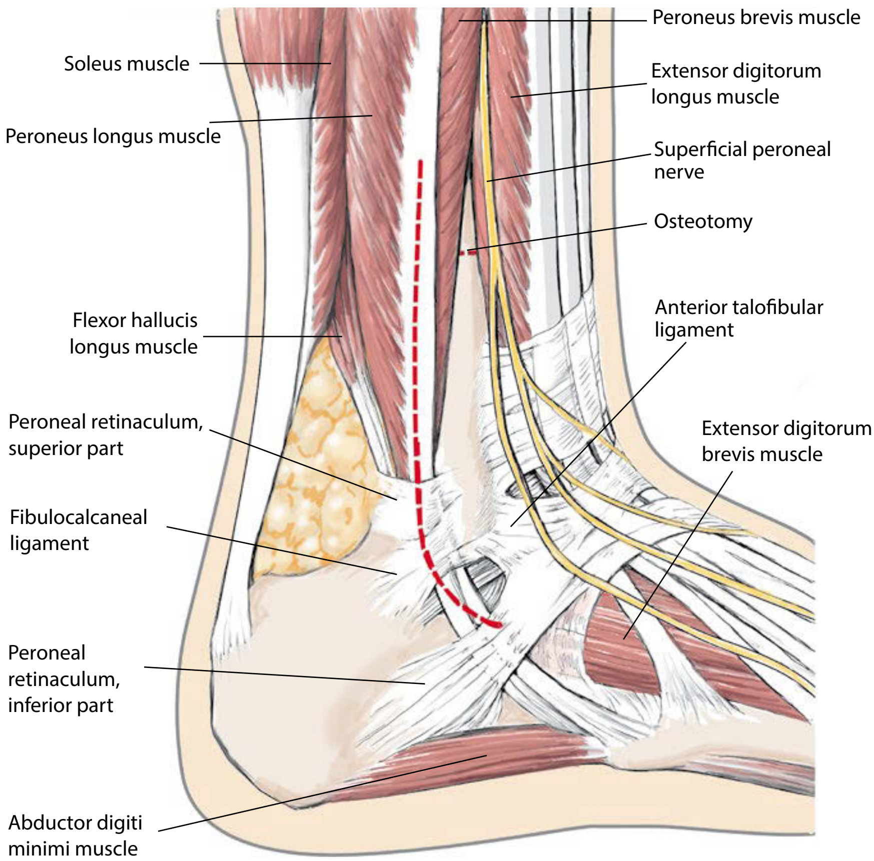

Fig. 25.13 Schematic drawing of the lateral approach and the fibular osteotomy

25.3.2 Operation Principle

Fusion of the ankle or the ankle and subtalar joints in the neutral position (0° dorsiflexion/plantar flexion) to restore the pain-free function and correct pre-existing malalignment.

25.3.3 Preoperative Assessment

Diagnosis

Clinical

- Symptom specific history: complaints (pain, recurrent swelling/effusion, limitation of motion, locking, instability), pain-free walking distance, previous trauma, previous operations, improvement of symptoms with wearing an arthrodesis brace.
- Symptom specific examination: inspection for malalignment and foot deformities, tenderness, painful motion, ROM, crepitation and instability.

Neurological/Vascular Status

Examination and documentation of the peripheral neurological and vascular status (especially the superficial peroneal nerve, medial and intermediate posterior cutaneous nerves, deep peroneal and tibial nerves; dorsalis pedis, tibialis anterior and tibialis posterior arteries).

Imaging

- standing radiograph of the ankle in two views: AP with 18° internal rotation (Mortise –view) and lateral views.
- CT scan to evaluate the osteoarthritic changes of the adjacent joints (subtalar & Chopart Joints) and bone loss.
- Alignment analysis (long leg standing anteroposterior, Saltzman view for both sides, foot in 2 views on both sides.

Planning

Determination of the technique of arthrodesis (using old incisions; arthrodesis using screws if only the ankle joint is affected; arthrodesis using nail if both the ankle and subtalar joints are affected; additional iliac crest bone graft must be planned if there is marked bone loss

Patient Information/Consent

Specific operative risks: failure of osseous consolidation with development of non-union, eventual need for dynamization with the use of nail for arthrodesis, failure of the fixation implants, secondary dislocation, early osteoarthritis of the adjacent joints, postoperative worsening of function (shoes with high heels can no longer be used), eventual need for iliac crest bone graft with its associated complications (pain, bleeding, nerve damage).

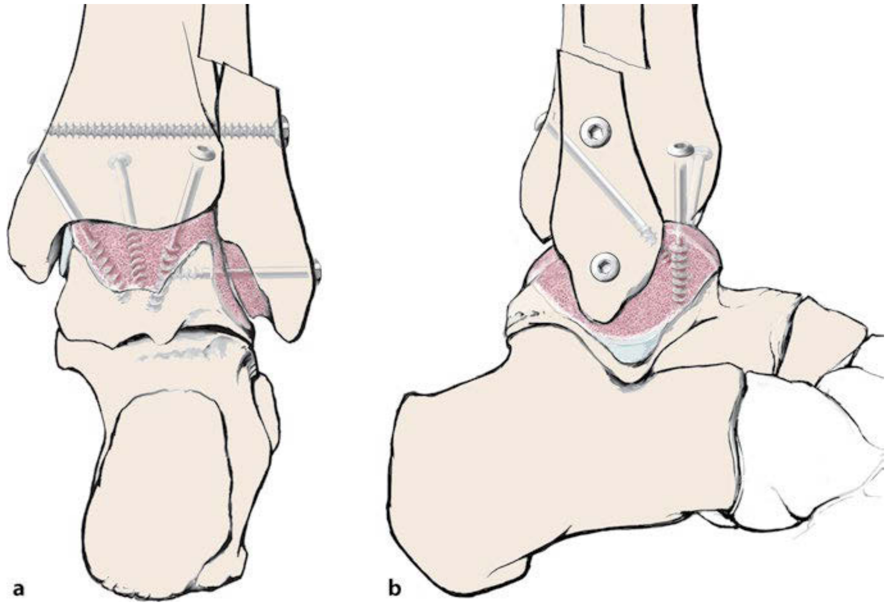

Fig. 25.14a,b Ankle arthrodesis using screws with fibular osteotomy. **a** posterior view, **b** lateral view of

25.3.4 Surgical Technique

Positioning and Preparation

- Arthrodesis using screws: supine position with freely movable leg
- Contralateral leg is lowered about 20 cm to allow taking a lateral view with the image intensifier.
- Arthrodesis of both the ankle and subtalar joints using nail: recumbent position with freely movable leg.
- The ipsilateral iliac crest is draped if necessary.

Ankle Arthrodesis Using Screws with Fibular Osteotomy

Lateral incision of about 10 cm length over the posterior fibula, beginning about 8 cm proximal to the tip of the fibula and extending distally over the lateral malleolus. After dissection and exposure of the fibula, a 1 cm shortening osteotomy of the fibula is performed about 4 cm proximal to the joint line (Fig. 25.13).

The syndesmosis is mobilized, the interosseous membrane is cut and the distal fibula is then tilted distally to view the entire articular surface of the ankle joint. Gentle and complete decortication of the entire articular surface of the ankle joint with a chisel and a sharp spoon curette. The position of the ankle joint arthrodesis is attained by displacing the talus dorsally and medially (the axis of the tibia should be in line with the second ray, the foot is positioned in 0–5° valgus, 5–10° external rotation and 0° plantar flexion/dorsiflexion).

Temporary arthrodesis with three Kirschner wires. Two wires are inserted in a converging manner in the frontal plane from inferolateral and inferomedial. The third wire is inserted from the dorsal aspect and should be directed superiorly about 40° in the sagittal plane.

The position and direction of the wires are checked with the image intensifier. The intraosseous lengths of the wires are measured followed by overdrilling with a 6 mm drill bit. Finally, the 6.5 mm small thread cancellous screws are inserted (all serration should be sunk in the talus to function as a lag screw).

Decortication of the medial surface of the distal fibular fragment as well as the corresponding lateral contact surface of the tibia and talus. Screw fixation of the fibular fragment to the tibia and talus with two 6.5 mm cancellous screws and washers. Final fluoroscopic control with the image intensifier (Fig. 25.14).

Arthrodesis of the Ankle and Subtalar Joint Using Distal Femoral Nail

About 10 cm long posterolateral skin incision between the posterior aspect of the fibula and the lateral margin of the Achilles tendon (Fig. 25.15). Dissection down to the fascia taking care of the small saphenous vein and the sural nerve. The deep fascia is split over the muscle belly of the flexor hallucis longus and then further dissection in the interval between the flexor hallucis longus and the peroneal tendons down to the subtalar joint taking care of the peroneal artery. The subtalar joint is opened between the posterior process of the talus and the posterior articular facet of the calcaneus.

Distraction of the subtalar joint using a specific arthrodesis spreader followed by decortication of the entire part of the joint that could be reached from posterior with a bur and sharp spoon curette (Fig. 25.16). The ankle joint is opened after resecting the posterior talofibular ligament and the articular surface is decorticated. The ankle joint is positioned as described above.

The entry point of the nail at the calcaneus is accurately determined using the image intensifier. A stab incision is

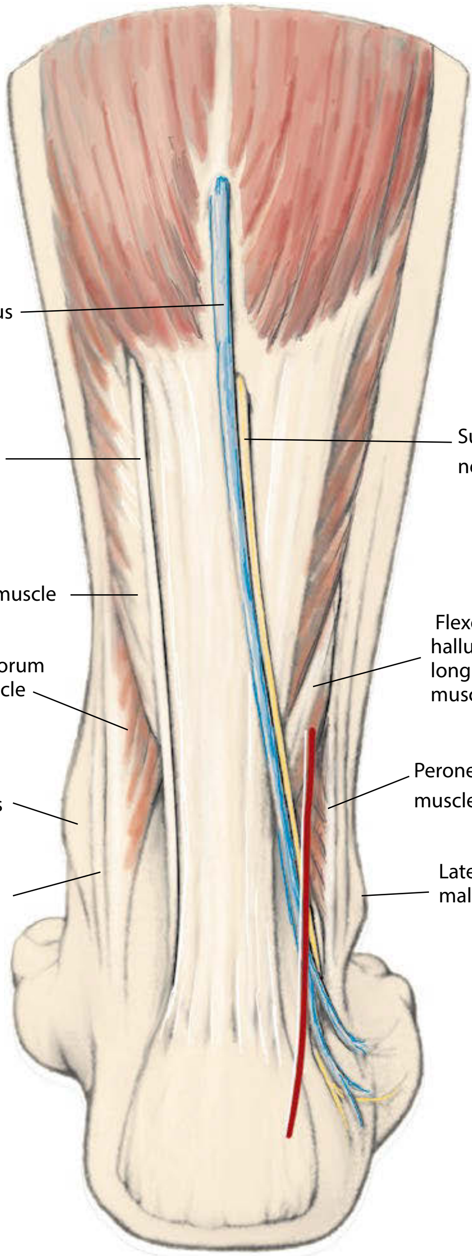

Fig. 25.15 Schematic drawing of the posterolateral approach

made followed by insertion of a 3.2- mm Kirschner wire that should pass central through the talar trochlea and the weight bearing tibial plafond (Fig. 25.17). A 17 -mm drill sleeve is inserted through the plantar incision followed by gradual reaming, starting with a 13-mm cannulated reamer.

The Kirschner wire is removed followed by insertion of the distal femoral nail (DFN, Synthes) with the attached insertion handle until it is flush with the calcaneal tuberosity. The aiming device is directed posteromedially, so that the distal locking screw can be inserted along the longitudinal axis of the calcaneus (Fig. 25.18).

A 4.9-mm hole is drilled for the insertion of a 6 mm locking screw. The distal DFN locking can be alternatively carried out using a spiral blade. Compression at the arthrodesis site is achieved with hammer blows over the insertion handle.

The insertion handle is removed and the end cap is inserted. The proximal locking is done freehand and percutaneously using two 4.9-mm locking bolts. Final radiographic assessment with the image intensifier (Fig. 25.19).

25.3.5 Postoperative Management

- Monitoring of peripheral circulation, motor and sensory innervation.
- Use of elastic compressive bandages
- Cooling and elevation of the extremity.
- Immobilization of the ankle joint in a short leg plaster splint or a similar orthosis.
- Postoperative radiographs

25.3.6 Follow-up Management

Immobilization of the ankle joint in a short leg plaster splint or a similar orthosis for 6 weeks postoperatively with total non-weight bearing. From the 7th Week (after radiological assessment) progressively increased weight bearing at a rate of about 20 kg per week in an arthrodesis boot or a similar orthosis. The orthosis can be discarded from the 13th week postoperatively according to radiological findings.

25.3.7 Tips & Tricks

In case of insufficient bone quality, washers should be used when arthrodesis is planned to be performed using screws.

Special attention should be given to the tip of the lateral malleolus. It should not be protruding beyond the subtalar joint level after decortication of the ankle joint to avoid postoperative impingement.

Patients with low compliance should be immobilized postoperatively in a complete short leg plaster cast until complete consolidation and not in a simple orthosis. Exact axial alignment must be insured to avoid early 2ry osteoarthritis.

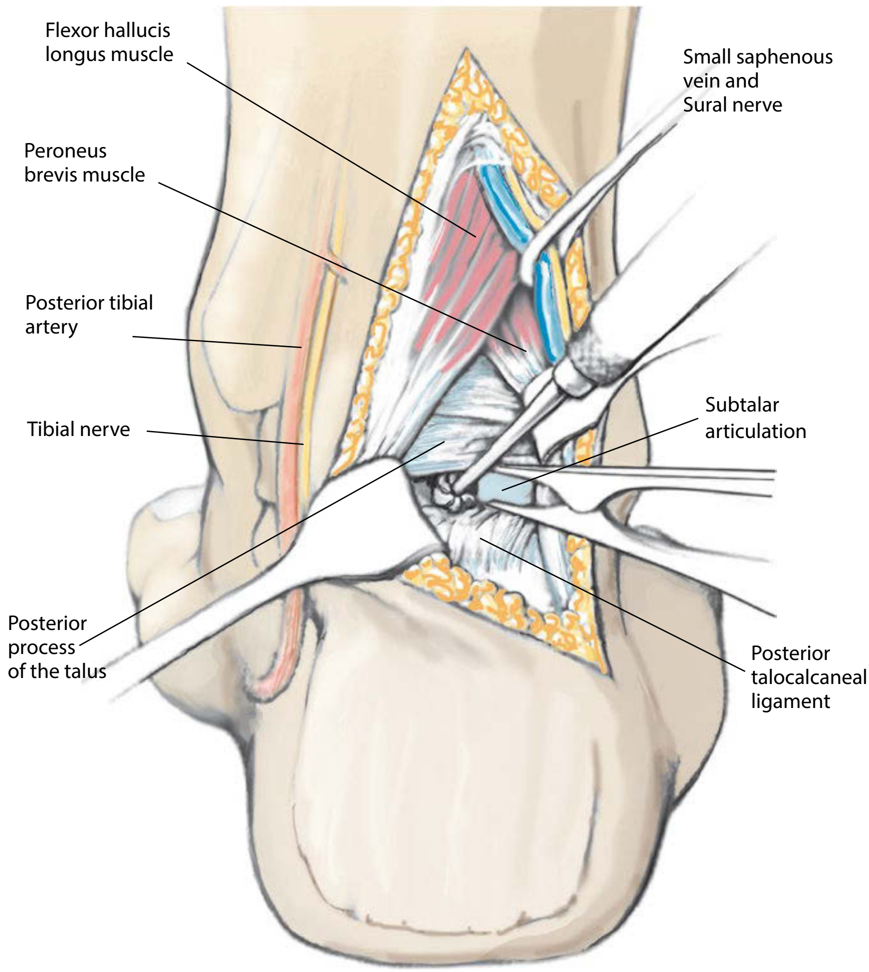

Fig. 25.16 Distraction of the subtalar joint with an arthrodesis spreader and decortication of the whole articular surface that could be accessed from posterior with a burr

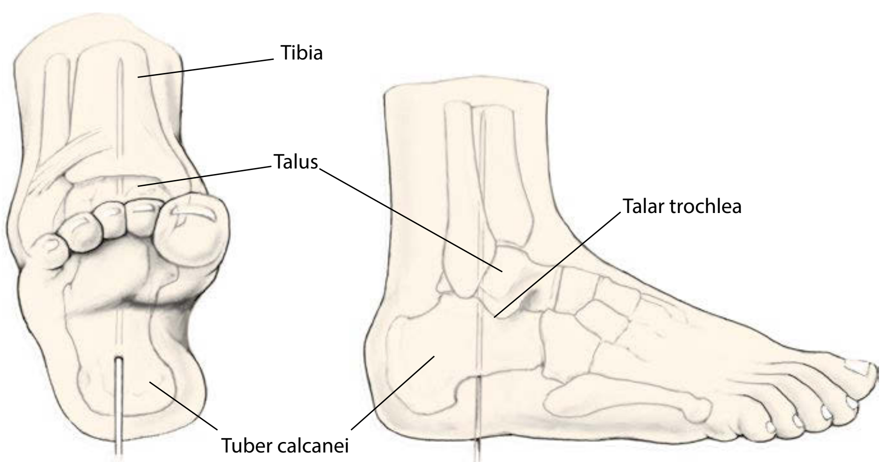

Fig. 25.17 Insertion of a 3.2-mm Kirschner wire through the center of the talar trochlea and the weight bearing surface of the tibial plafond

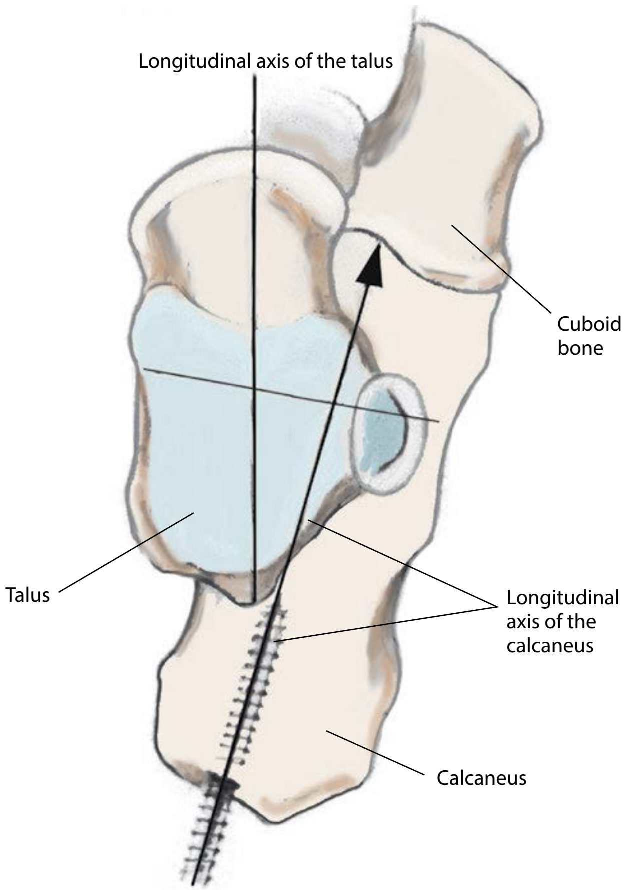

Fig. 25.18 The distal locking screw inserted along the longitudinal axis of the calcaneus

Fig. 25.19 Completed ankle and subtalar arthrodesis using a retrograde DFN

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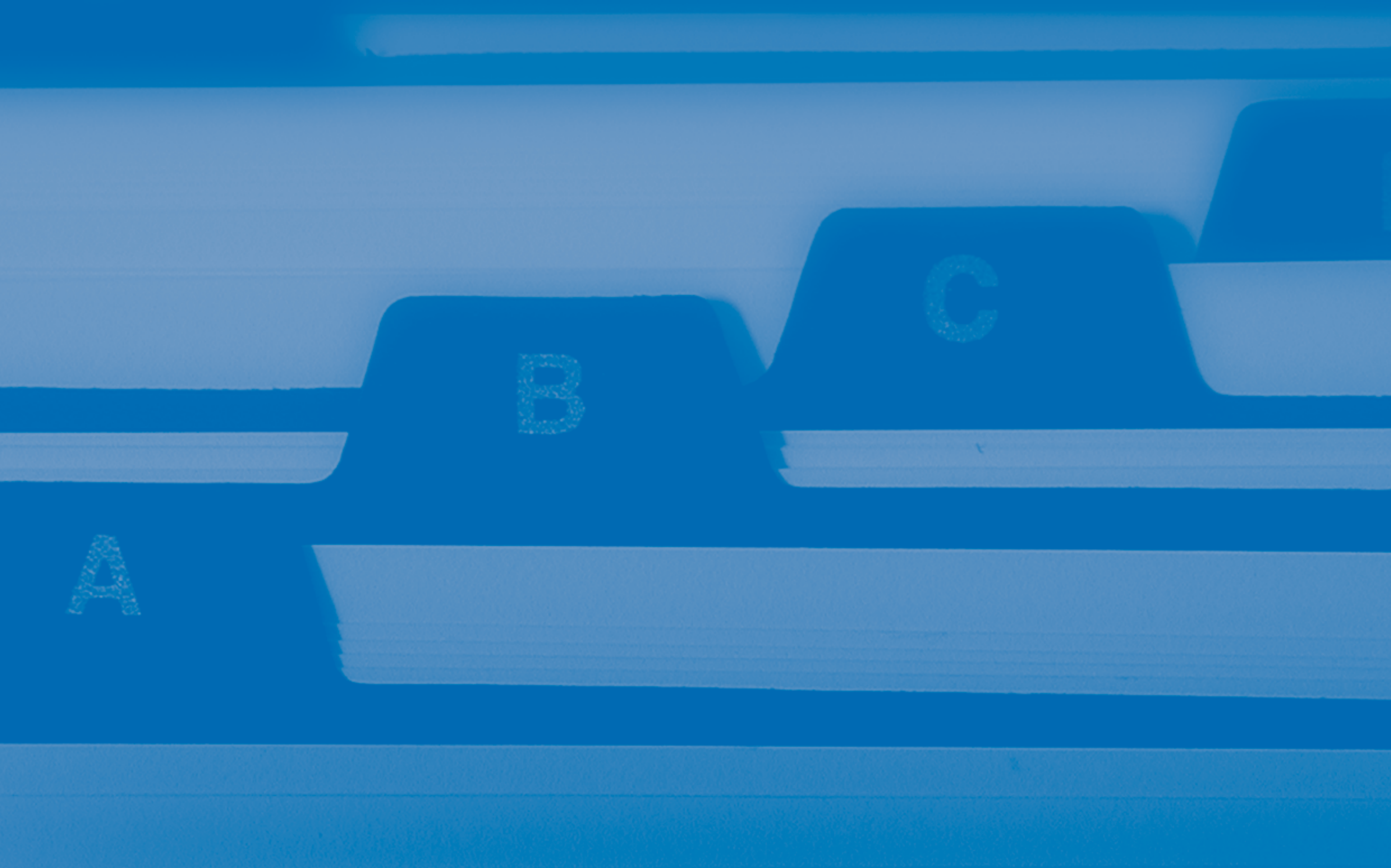

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