Anteromedial Tibial Tubercle Osteotomy (Fulkerson Osteotomy)

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40.1 Introduction

The tibial tubercle (interchangeable with tuberosity) is the most distal anchor of the extensor mechanism and can serve as a tool in altering patellofemoral (PF) mechanics. Known collectively as distal realignment procedures, osteotomies of the tibial tubercle are a useful method to treat a variety of PF conditions by allowing coronal, axial, and sagittal plane adjustments of the patellofemoral articulation which redistribute patellar contact pressures (force and contact area) and potentially improve tracking. Numerous tibial tubercle osteotomies have been described in the literature to treat PF pain, chondrosis, and instability. The most notable include medialization, initially described by Roux and later popularized by Elmslie and Trillat, for the treatment of PF instability[30] and anteriorization of the tibial tubercle described by Maquet[18] performed to treat PF pain associated with arthritis. Each of these procedures takes advantage of important technical alterations in patellar kinematics. Anteriorization of the tubercle elevates the distal extensor mechanism and serves to shift patellar contact forces proximally, while medialization results in a decrease of the lateral force vector.

In an effort to avoid complications associated with the Maquet procedure, Fulkerson[11] designed a tubercle osteotomy known as the anteromedialization (AMZ) technique to address PF pain in conjunction with patellar maltracking. The oblique nature of the Fulkerson osteotomy allows for simultaneous anteriorization and medialization of the tibial tubercle. By varying the angle of the osteotomy, the tubercle can be biased to a more anterior or more medial position. Since his initial description, the indications for this procedure have evolved significantly and continue to be refined. This has been primarily driven by the evolution and outcomes of patellofemoral resurfacing procedures as well as improved objective measures of patellar alignment, contact area, and forces.

The tibial tuberosity to trochlear groove (TT–TG) distance, popularized by Dejour et al.[8] as an objective measure of tuberosity position, has helped quantify abnormal tuberosity position and enhanced appropriate candidate identification for all tuberosity osteotomies including the AMZ. This becomes important because patellar contact pressures are very sensitive to distal realignment.[1,17,25] In addition, combining AMZ with PF cartilage restorative procedures such as autologous chondrocyte implantation and osteoarticular grafting procedures within the PF compartment have demonstrated superior results to either procedure performed independently.[10,14,19,21,28]

40.2 Indications

When discussing the indications for AMZ it is important to note that as with most patellofemoral surgeries, it should only be performed after the patient has tried and failed nonoperative measures that include a comprehensive "core to the floor"[9] program of rehabilitation, bracing, and orthotics. Indications for AMZ are primarily based upon mechanical and chondral pathologies specific to each individual knee. Malalignment is a term that has different meanings to

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different experts, but for the purposes of this chapter it simply means alignment that is different from the average asymptomatic individual. A comprehensive review by Post et al.[23] demonstrated that the "Q" angle was inadequate to use as a measure of malalignment of the tibial tuberosity. Using the objectively measured TT–TG, asymptomatic patients have distances averaging 13 mm and those with instability symptoms have average measurements of over 15 mm.[27] A panel of patellofemoral experts agreed that TT–TG distances of over 20 mm were definitely abnormal and would be potential candidates for moving the tibial tubercle.[15] Patients with isolated chondrosis of the distal or lateral patella, who have excessive lateral patellar tilt and/or subluxation associated with an increased TT–TG distance and minimal trochlear chondrosis are optimal AMZ candidates based on a retrospective review of AMZ outcomes by Pidoriano.[22] It has been argued that rotational tuberosity abnormalities associated with subjective instability and pain may be sufficiently treated with straight medialization or derotation of the tibial tubercle,[20] although Pritsch et al.[24] found 80% of 66 patients undergoing tubercle transfer for patellar instability and pain associated with maltracking required anteriorization based on intraoperative examination. Second, patients who are undergoing PF cartilage restorative procedures have been shown to benefit from a combined AMZ procedure,[10,14,19,21,28] where optimization of the biomechanical environment and decreased stress across the restored cartilage is required. Additionally, in patients undergoing MPFL repair or reconstruction for recurrent lateral patella instability, AMZ may be indicated only in the setting of a significantly increased TT–TG distance. However, it should be noted that while this theoretically decreases the lateral vector forces on the healing MPFL tissues, there is no randomized study of AMZ plus MPFL surgery versus MPFL surgery alone published as of this writing. A summary of AMZ indications is presented in Table 40.1.

Table 40.1 Summary of indications for anteromedialization

Summary of AMZ indications:
• Lateral or distal patella chondrosis with an increased TT–TG distance, excessive lateral tilt/subluxation, and the absence of trochlea chondrosis.
• As an adjunct procedure to patellofemoral cartilage restoration in an effort to improve the contact area and decrease PF forces to optimize the biomechanical environment of the new cartilage implant.
• Possibly, in conjunction with MPFL repair or reconstruction in patients with markedly increased TT–TG distance.

40.3 Contraindications

Several contraindications to AMZ exist and potential candidates must be assessed carefully prior to surgery. Anteromedialization is contraindicated in patients with a normal TT–TG distance and in patients who have symptoms not explained by an increased TT–TG distance. The condition of the medial PF articulation should be carefully assessed as medialization will significantly increase contact pressures between the medial patellar facet and trochlea.[25] In addition, AMZ is contraindicated for proximal patella, panpatella, and bipolar chondrosis based upon the outcomes from Pidoriano et al.[22]

Advanced chondrosis of the central trochlea has been associated with suboptimal results and is considered a contraindication to AMZ as an isolated procedure.[5,22] Standard contraindications to any osteotomy must also be considered, which includes smoking, infection, inflammatory arthropathy, marked osteoporosis inhibiting adequate fixation, complex regional pain syndrome, arthrofibrosis, inability to minimally weight-bear, and noncompliant patients. A summary of AMZ contraindications is presented in Table 40.2.

40.4 Surgical Technique

Techniques for AMZ have classically been described as an isolated procedure; however, AMZ typically includes lateral retinacular release or lengthening to untether the patella allowing the patellar medialization component, and is not uncommonly performed in conjunction with procedures such as MPFL repair/reconstruction or cartilage restorative procedures. These procedures must be taken into consideration when planning the surgical approach.

Table 40.2 Summary of contraindications to anteromedialization

Summary of contraindications to isolated AMZ:
• Normal TT–TG distance
• Medial patellofemoral chondrosis (only if not combined with cartilage restoration procedure)
• As an isolated procedure, when not combined with cartilage restoration, to treat proximal pole, panpatella, trochlear, or bipolar chondrosis
• General contraindications to osteotomy (i.e., smoking, osteoporosis, inflammatory arthropathy)

40.4.1 Preoperative Assessment and Planning

The desired amount of anteriorization and medialization (based on the objective measurement of the TT–TG distance) must be calculated preoperatively. These two components are considered separately and then basic trigonometric ratios can be used to determine the desired angle for the osteotomy. Anteriorization of between 10 and 15 mm is most commonly recommended as it decreases PF stress loads by approximately 20%[7,8] and results in minimal sagittal rotation of the patella. In regards to the medialization component, the goal of the osteotomy is to normalize the TT–TG distance, which based on the literature, is within a range of 10–15 mm. By varying the slope and the extent of anteriorization, a variety of medialization distances can be achieved. The required angle can be calculated by the inverse tangent of the desired anterior movement divided by the desired medial movement Table 40.3. For example, a 60° osteotomy with 15 mm of elevation will produce 8.7 mm of medialization, which will normalize most tuberosity positions as it is rare for TT–TG distances of over 25 mm. When more medialization is required, the slope may be decreased; a slope of 45° would move the tubercle 15 mm medially with 15 mm of elevation.

40.4.2 Setup and Positioning of the Patient

The patient is positioned in the supine position with a side post and a gel-pad under the ipsilateral hemipelvis. This facilitates an initial arthroscopic evaluation of the knee and limits external rotation of the limb during the osteotomy. All extremities are well padded, a tourniquet is applied, and prophylactic antibiotics are administered. General, spinal, epidural, or regional block anesthesia can be used depending upon patient and surgeon preference. A thorough examination under anesthesia includes assessment of range of motion, patella tracking, and patella displacement. The patient is then prepped and draped in standard fashion.

Table 40.3 Reference guide for osteotomy slope

Osteotomy slope (°)	Elevation (mm)	Medialization (mm)
60	15	8.7
50	15	12.5
45	15	15

40.4.3 Arthroscopic Evaluation

Initially, arthroscopic evaluation and documentation of patellofemoral chondrosis is performed. The areas of chondrosis are regionally mapped using the ICRS region knee mapping system noting that significant patellar chondrosis may lead to termination of the procedure unless concomitant cartilage restoration has been planned. Certainly other contraindications may be discovered at arthroscopy and would also halt proceeding with AMZ. At this stage, based on clinical tilt or CT/MRI documented patellar tilt, an arthroscopic lateral release may be performed if indicated. When combined with PF cartilage restoration the lateral release or lateral lengthening is performed in an open manner to allow direct access for performing the cartilage restoration procedure. Lateral release should allow neutralization of patella tilt and unrestricted central positioning of the patella relative to the trochlea; however, care must be taken to ensure that medial patella subluxation does not occur. It should be noted that lateral lengthening can maintain control not offered by lateral release.[4]

40.4.4 Incision and Exposure

The longitudinal incision runs approximately 8–10 cm distally beginning at the patellar tendon insertion to the tibial tubercle. The incision can be extended proximally to allow adequate exposure if concomitant cartilage restoration is being performed. The patella tendon is identified and released from capsule medially and laterally to allow protection with a retractor and later tubercle elevation. The lateral incision is extended distally along the lateral margin of the tibial tuberosity and tibial crest allowing subperiosteal elevation of the anterior compartment musculature and thereby exposing the lateral wall of the tibia. A custom retractor is positioned at the posterior aspect of the lateral tibia in order to protect the posterior neurovascular structures (deep peroneal nerve and anterior tibial artery) (Fig. 40.1).

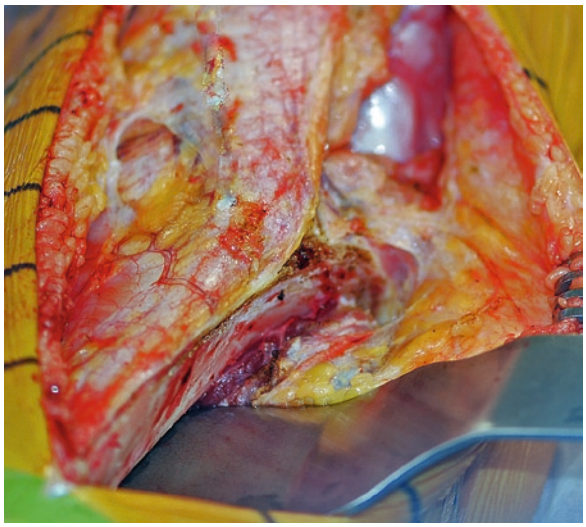

Fig. 40.1 Anterior compartment musculature is elevated from the lateral wall of the tibial with retractor protecting neurovascular structures posteriorly

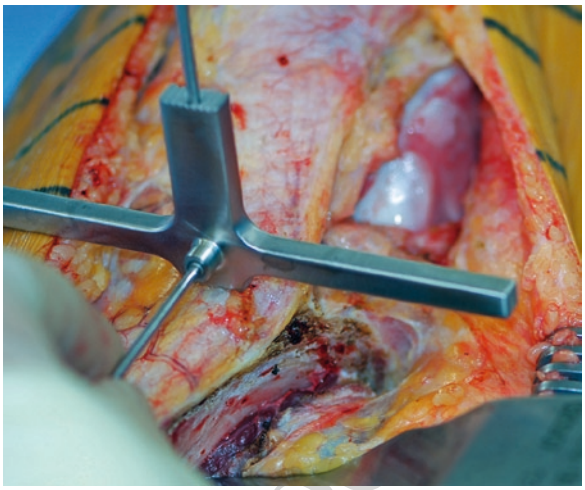

Fig. 40.2 The reference pin guide is orientated so it is perpendicular to the posterior cortex of the tibia

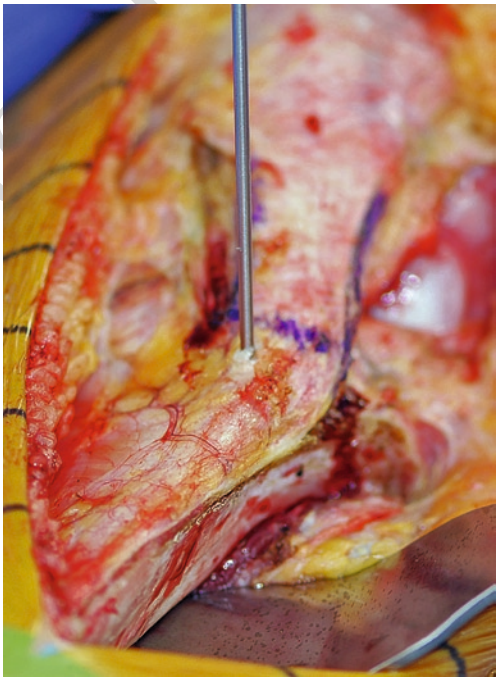

Fig. 40.3 Reference pin is inserted through the guide just distal to Gird's tubercle

40.4.5 Performing the Osteotomy

For the highly experienced surgeon the osteotomy may be performed free-hand. Fulkerson originally used an external fixator pin clamp to direct multiple pins in the osteotomy plane and then complete it with osteotomes.[11] Today, there are two commercially available AMZ osteotomy systems (Tracker, DePuy Mitek, Inc, Raynham, New Jersey and the T3 System, Arthrex, Inc, Naples, Florida). The Tracker system was available first and detailed illustrated surgical techniques using the jig system have been published by both Fulkerson and Farr. The T3 system will be used in this section to illustrate the operative technique; however the approach for each system and steps following fixation of the cutting guide are similar. For the T3 system, an initial reference pin is orientated perpendicular to the posterior cortex of the proximal tibia (Fig. 40.2). The reference pin is inserted through the pin guide into the tibial tuberosity, just distal to the patellar tendon attachment to the tibial tuberosity (Fig. 40.3). Using preoperative calculations for anteriorization and medialization, the desired slope angle guide is assembled with the cutting block and cutting block post. The cutting guide is then placed over the reference pin and the cutting block is positioned immediately medial to the tibial crest beginning directly in line with the medial border of the patella tendon, as it attaches to the tibial tuberosity (Fig. 40.4), and angled laterally to allow a lateral exit of the osteotomy distally. For emphasis, the desired osteotomy forms a triangle shape that tapers distally allowing an exit through the anterior cortex to the lateral wall of the tibia. The desired pedicle length for the osteotomy is approximately 7–10 cm. When correct positioning has been achieved and the entry and exit sites have been confirmed, two break-away pins secure

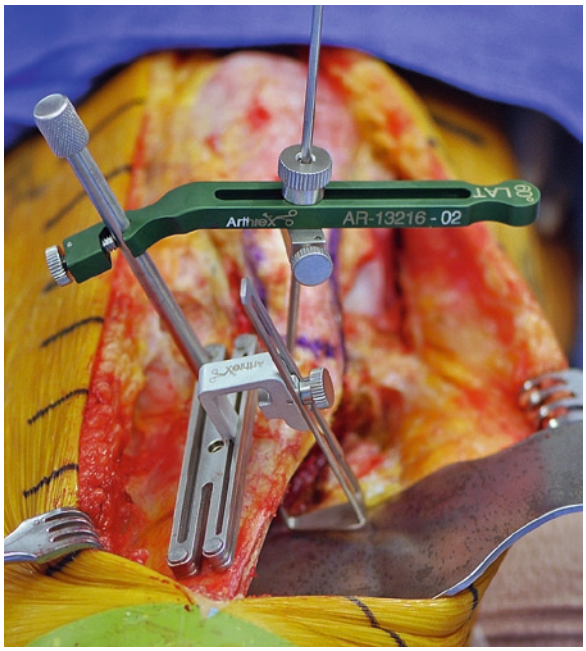

Fig. 40.4 The cutting guide is placed over the reference pin and the cutting block is positioned medial to the patella tendon

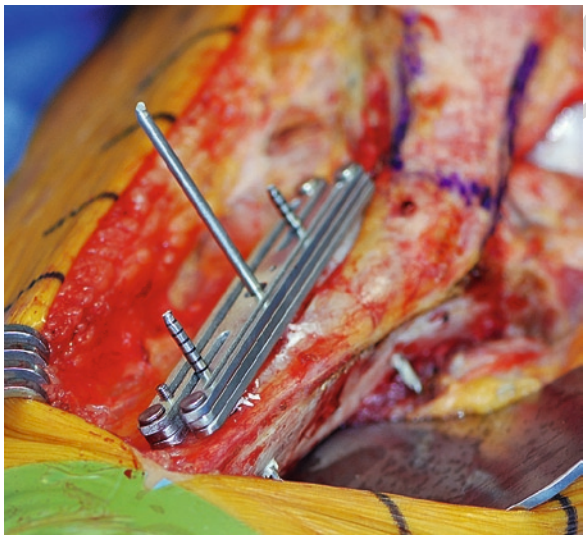

Fig. 40.5 Break-away pins secure the cutting block after positioning is confirmed

the cutting block in position (Fig. 40.5). With the retractor still protecting neurovascular structures posteriorly, the cut is made with an oscillating saw which is simultaneously cooled with saline (Fig. 40.6). The cutting block is removed and the oscillating saw is directed toward the distal exit of the osteotomy to finish the distal cut. A small osteotome is used to complete the

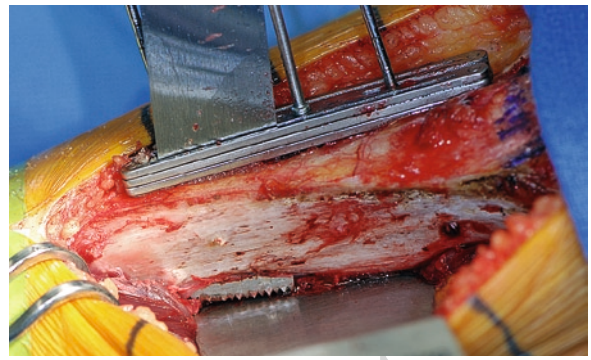

Fig. 40.6 Oscillating saw cooled with saline creates the initial sloped osteotomy, exiting on the protective retractor

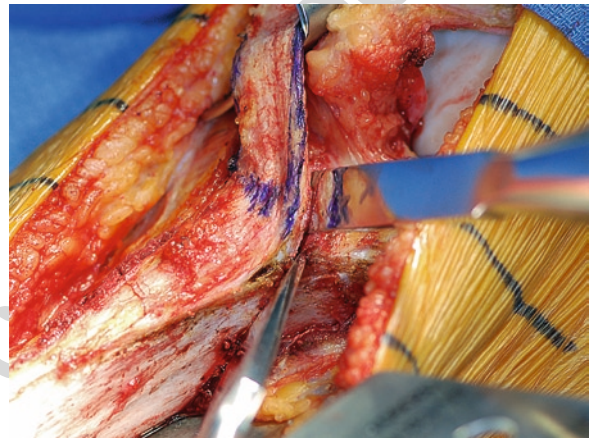

Fig. 40.7 Proximal cuts are completed with small osteotome

proximal osteotomy, approaching the tibial tuberosity medially and laterally at the level of the patella tendon insertion (Fig. 40.7). The tuberosity is now free.

40.4.6 Positioning and Fixation

A ruler is used to measure the required amount of anteriorization and medialization based on preoperative calculations and the pedicle position is adjusted along the osteotomy slope. If required, the pedicles can be moved proximally or distally to address any underlying patella alta or infra. A Kirschner wire is used to temporarily secure the pedicle when correct positioning has been achieved. The tuberosity fragment is then drilled using interfragmentary lag technique and secured using two countersunk 4.5 mm cortical screws (Fig. 40.8). The screws are positioned perpendicular to the osteotomy (angled from the anteriolateral aspect of the pedicle to

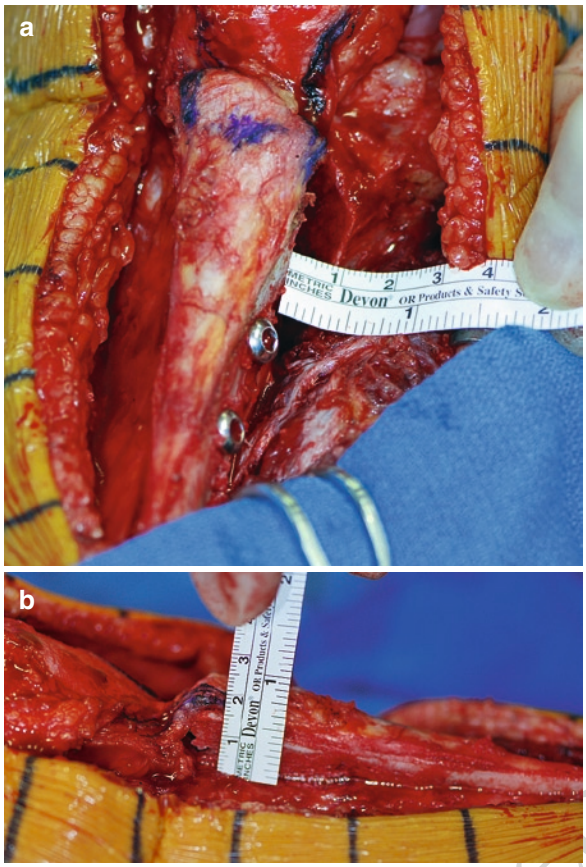

Fig. 40.8 The distance of medialization and anteriorization is measured directly and the pedicle is secured with 2–4.5 mm screws [AU3]

posteromedial tibia) so they are directed away from posterior neurovascular structures. The surgical site is closed in a standard fashion.

40.5 Pearls and Pitfalls

40.5.1 Pearls

- Preoperative rehabilitation and expectation counseling is extremely important to prepare the patient for surgery and recovery.
- The TT–TG measurement is an objective alternative to the Q-angle, quantifying the concept of tibial tuberosity malalignment.
- The mean TT–TG distance is 13 mm in asymptomatic patients and is considered excessive when above 20 mm.
- The goal is to "normalize" the tibial tubercle position that is keeping within a range of 10–15 mm.
- The required amount of anteriorization and medialization needed for normalization should be considered independently. The required osteotomy angle is determined based upon these values. [AU4]
- The osteotomy angle is equal to $\tan^{-1}$ of the desired anterior movement (y) divided by the desired medial movement (x), e.g., Angle = $\tan^{-1}$ (y/x) (For simplicity, see Table 40.3)
- Assessment for patella alta using the Caton–Deschamps ratio (normal range 0.8–1.2) is required to determine if distalization is required.
- Strengthening of proximal core muscles must be a focus of rehabilitation in conjunction with local musculature.
- Anteromedialization can be performed in conjunction with other procedures including lateral release/lateral lengthening, MPFL repair or reconstruction, or cartilage restoration procedures.

40.5.2 Pitfalls

- Over medialization of the tibial tubercle can be detrimental secondary to increased medial patellofemoral and tibiofemoral stress.
- Patients should be aware that pain over the screw site is common and they may need removal at a future date.
- Weight bearing too early can lead to a fracture of the proximal tibia if the patient is returned to full weight bearing prior to radiographic healing.[2,12,29]
- The MPFL is recognized as the key restraint to lateral patella dislocation. Isolated tibial tuberosity AMZ is not a substitute for MPFL repair or reconstruction.
- Excessive anteriorization of the tuberosity can lead to skin healing problems and can cause clinically significant sagittal plane rotation of the patella altering contact areas.
- Isolated AMZ performed in the presence of chondrosis will yield poor results when the wear patterns are located in the: proximal patella, panpatella, or trochlea. However, AMZ in conjunction with cartilage restoration procedures in these regions can achieve good results.

40.6 Complications

Potential complications include those generally associated with osteotomies of the lower limb. General complications include malunion, nonunion, fracture at the osteotomy site,[12,29] venous-thromboembolism, compartment syndrome, infection, and loss of fixation. Complications specific to AMZ include persistent pain, arthrofibrosis and stiffness, progressive chondral deterioration, symptomatic hardware, complex regional pain syndrome, and intraoperative injury to the neurovascular structures including the popliteal artery and its trifurcation[16] and the deep peroneal nerve.

40.7 Postoperative Management

To improve postoperative recovery and prepare for surgery, the patient should undergo a preoperative proximal core and kinetic chain strengthening program (lower back, pelvis, hip thigh, and leg). Postoperatively the patient is treated with standard compression dressings, protective bracing, and cryotherapy, and is monitored for immediate complications. For the first 6 weeks the patient is limited to touch weight bearing with crutches and begins transitioning to full weight bearing after radiographs are noted to be acceptable at 6 weeks. The knee is protected with a hinged knee brace in extension which is unlocked at 2 weeks and discontinued when there is adequate lower extremity control (usually by 8 weeks). Early core proximal strengthening, quadriceps strengthening, and knee range of motion exercises are essential and a close relationship with an experienced physical therapist is key to optimizing the final results. The safe range of motion may need to be modified throughout the rehabilitation process to accommodate for concomitant cartilage restorative procedures.

40.8 Conclusions

Multiple case series have reported outcomes of the AMZ procedures (Table 40.4). Despite the heterogeneity in outcome measurements, results demonstrate high percentages of excellent and good results and improvements in objective, subjective, and functional measures. Attention to details related to surgical planning and properly managing patient expectations is most likely to lead to good or excellent results. Newer techniques (i.e., the T3 system) allow the surgeon to objectively determine the inclination of the osteotomy to properly restore patellofemoral mechanics based upon the preoperative planning.

Table 40.4 Anteromedialization outcomes

Author, year	Patient number	Mean follow-up (range)	Reported outcomes
Fulkerson[11]	8	n/a	Substantial relief of pain and disability for all patients
Cameron et al.[6]	53	>12 months	66% Excellent, 16% good, 11% fair, 7% poor
Fulkerson et al.[13]	30	35 months (26–50)	35% Excellent, 54% good or very good, 4% fair, 7% poor
Sakai et al.[26]	21	5 years (2–13)	Pain relief in ascending and descending stairs for 20/21
Pidoriano et al.[22]	37	47 months (12–96)	87% Good to excellent results with lateral or distal lesions, 55% good to excellent results with medial lesions, 20% good to excellent results with proximal or diffuse lesions
Bellemans et al.[3]	29	32 months (25–44)	Significant improvements in mean Lysholm (62 preoperative, 92 postoperative, $p<0.001$) and Kujala scores (43 preoperative, 89 postoperative, $p<0.001$)
Buuck and Fulkerson[5]	42	8.2 years (4–12)	86% Good to excellent subjectively, 86% good to excellent on clinical examination

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