21 Tibial Tubercle Anteromedialization Osteotomy

Scott Kuzma, David C. Flanigan, and Robert A. Magnussen

21.1 Introduction

Tibial tubercle osteotomies (TTOs) are procedures designed to address patellofemoral (PF) joint disorders including malalignment, instability, and articular cartilage lesions or arthritis through distal realignment of the extensor mechanism. These osteotomies are generally performed to correct excessive lateralization (external rotation) of the tibial tubercle and/or unload portions of the PF joint. Multiple osteotomy techniques have been described, including the Elmslie–Trillat [1] procedure for direct medialization, Maquet procedure for direct anteriorization [2], and the Fulkerson procedure for anteromedialization (AMZ) [3]. The tibial tubercle can also be moved proximally or distally to correct patella infera or patella alta, respectively.

Due to its ability to both realign the extensor mechanism and unload portions of the PF joint, the AMZ osteotomy is frequently utilized in the treatment of PF joint pathology. The osteotomy has indications in the treatment of articular cartilage defects, PF osteoarthritis, and instability of the PF joint and is the focus of this chapter.

S. Kuzma
Department of Orthopaedics, The Ohio State University Wexner Medical Center, Columbus, OH, USA

D. C. Flanigan · R. A. Magnussen (✉)
Department of Orthopaedics, The Ohio State University Wexner Medical Center, Columbus, OH, USA

OSU Sports Medicine Research Institute, The Ohio State University Wexner Medical Center, Columbus, OH, USA
e-mail: Robert.magnussen@osumc.edi

21.2 Biomechanics

The biomechanics of the PF joint are important to understand when considering any TTO. In the absence of significant patella alta, the inferior portion of the patella first engages within the trochlea at approximately 10°–20° of knee flexion. As knee flexion increases, the patellar contact area increases and moves proximally on the patellar articular surface. At knee flexion angles greater than 90°, the medial and lateral patellar facets are the primary areas of articulation with the femoral condyles with the quadriceps tendon sharing some of the load [4].

In full extension, there is essentially zero PF joint reaction force. As knee flexion angle increases, posteriorly directed PF joint reaction forces increase as well due to tension in the quadriceps and patellar tendon [4]. Lateralization of the tibial tubercle and an increased Q-angle have been shown to significantly increase lateral patellar facet pressures by a mean of over 40% and decrease lateral facet contact area by approximately 20% [5].

Anteriorization of the tibial tubercle will decrease PF joint reaction forces as it increases

D. Dejour et al. (eds.), *Patellofemoral Pain, Instability, and Arthritis*,
https://doi.org/10.1007/978-3-662-61097-8_21

the angle between the quadriceps and patellar tendon [2, 4]. A minimum of 12 mm of anteriorization will decrease joint reactive forces [6, 7], and 20 mm of anteriorization decreases contact pressures within the PF joint by 50% [2]. Anteriorization of the tubercle also anteriorly rotates the inferior pole of the patella and transfers the contact area proximally on the patella [6]. Medialization of the tibial tubercle similarly has been shown to decrease PF contact forces by a mean of 7 ± 4% and lateral facet contact pressure by a mean of 13 ± 5% [5].

Not surprisingly, the AMZ osteotomy is quite effective in offloading the lateral patellar facet through both medialization and anteriorization. With anteromedial translation between 8 and 15 mm, Fulkerson et al. demonstrated considerable decrease in lateral facet contact pressure at full extension and in early flexion and slight proximal translation of the patellar contact area [8]. In another biomechanical study, Beck et al. showed that the AMZ osteotomy decreased both mean contact pressure and mean lateral trochlear contact pressure and transferred the contact pressures to the medial PF joint [9]. Similarly, Ramappa et al. showed that AMZ of the TT was able to significantly decrease mean and maximum patella pressures and lateral facet pressures [5].

21.3 Evaluation

21.3.1 History

It is important to obtain a thorough history from the patient including symptoms, instability events, prior treatment, and surgical history. Attention should focus on the onset (traumatic versus insidious), chronicity (acute versus chronic), and location (lateral versus medial versus diffuse) of the patient's symptoms. Additionally, the presence of swelling or mechanical symptoms may indicate osteochondral lesions. It is critical to differentiate complaints of PF pain from PF instability. When considering instability, the mechanism of injury, number of episodes, dislocations versus subluxations, and need for reduction (self versus medical professional) are key aspects to delineate. Any prior treatment including medications, injections, physical therapy, bracing, or surgical intervention should be discussed, and operative reports and images should be evaluated.

21.3.2 Physical Examination

A complete evaluation of the patient's lower extremity should be performed including gait and limb alignment and rotation, considering genu valgum, femoral anteversion, and tibial torsion. A standard general orthopedic examination of the knee should assess presence of effusion, range of motion, tenderness, ligamentous stability, and muscle strength. This exam is followed by a thorough examination of the PF joint including assessment of the *Q*-angle, presence of tenderness along the medial or lateral patella, crepitus with range of motion, patellar tracking, and patellar tilt. Patellar mobility, both medially and laterally, should be documented and the endpoint assessed. Lateral patellar tilt that is unable to be corrected indicates lateral retinacular tightness. Special tests including J-sign and patellar apprehension are critical as well. The J-sign assesses dynamic patellar tracking and is considered positive if the patella deviates laterally as the patient actively extends the knee from a flexed position and may indicate abnormal bony morphology or soft tissue structures. Patellar apprehension should initially be performed in full extension, and the examiner should manually translate the patella laterally. It is considered positive if the patient has apprehension (a sense of impending dislocation) or guarding (involuntary quadriceps contraction). The exam should be repeated with increasing degrees of knee flexion and should diminish as the patella engages the trochlea. Persistent apprehension in knee flexion beyond approximately 45° may indicate patella alta or trochlear dysplasia.

21.3.3 Imaging

21.3.3.1 Radiographs

Plain radiographs of the knee are important to obtain to evaluate the bony anatomy and presence of any pathology including osteoarthritis, abnormal patellar height or tilt, and trochlear dysplasia. Standard views include bilateral-weight bearing, anteroposterior, flexed posteroanterior, lateral, and flexed axial views of the affected knee. It is especially important to have appropriately aligned lateral views in order to evaluate the trochlea as well as assess patellar height. Evaluating patellar height is an important consideration when planning AMZ in order to determine whether any distalization is needed as well. There are multiple methods to assess patellar height including the Insall–Salvati method, Blackburn–Peele method, and Caton–Deschamps (C-D) methods. We prefer to use the C-D method, as this measurement is independent of the patellar tendon length and can still be utilized after prior TTO. The C-D ratio is calculated by dividing the distance from the inferior aspect of the patellar articular cartilage to the anterosuperior margin of the tibial plateau by the length of the patellar articular margin. A value greater than 1.3 is considered abnormal (Fig. 21.1).

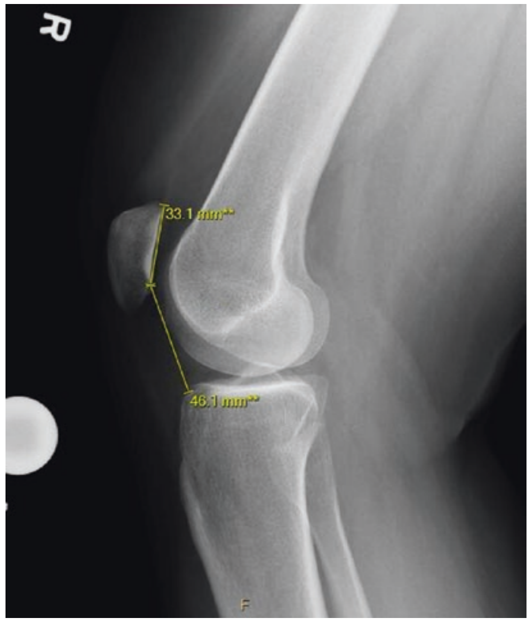

Fig. 21.1 Lateral radiograph of the right knee demonstrating elevated Caton–Deschamps ratio

21.3.3.2 Computed Tomography and Magnetic Resonance Imaging

Cross-sectional imaging including both computed tomography (CT) and magnetic resonance imaging (MRI) are important secondary imaging modalities used to evaluate the PF joint and for preoperative planning. Both modalities are comparable in showing the PF joint morphology and ability to perform additional measurements. MRI has the additional benefit of accurate localization and assessment of chondral lesions. Rotational abnormalities of the lower extremity are best evaluated using CT.

Axial CT and MRI images are useful in evaluating patellar tilt and trochlear dysplasia. Lateral patellar tilt greater than 20° are considered abnormal and may be indicative of a tight lateral retinaculum or trochlear dysplasia. Trochlear dysplasia is evaluated by measuring the sulcus angle and trochlear inclination. A sulcus angle of 145° or greater and trochlear inclination angle less than 11° are abnormal and consistent with trochlear dysplasia.

Axial imaging also allows assessment of the lateralization of the tibial tubercle relative to the trochlear groove or PCL. Originally described by Goutallier et al. [10], the tibial tubercle to trochlear groove (TT-TG) distance is measured as the distance between the center of the tibial tubercle and the deepest portion of the trochlear groove on a line parallel to the posterior condylar axis (Fig. 21.2). 10–15 mm is considered normal, and greater than 20 mm is deemed abnormal. The classic modality to measure the TT-TG distance is CT, but MRI is also accurate and reliable in measuring the TT-TG distance. One must consider that MRI typically underestimates the TT-TG distance relative to measures made on CT due to the required flexion of the knee to position it in a coil. The average difference in values

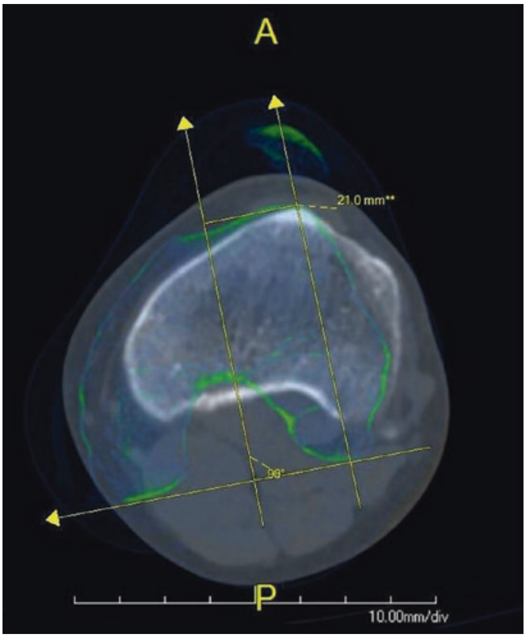

Fig. 21.2 Superimposed axial CT scan images demonstrating proper measurement technique and elevated tibial tubercle to trochlear groove distance

obtained from CT and MRI is about 2 mm but may be larger in knees with a high TT-TG distance [11]. Assessing TT-TG on an MRI can also be more challenging as most imaging software is unable to superimpose images. Camp et al. demonstrated accuracy and reliability of a simple alternative utilizing an external alignment method that any practitioner may employ [12].

21.4 Indications

There are two distinct and yet frequently overlapping indications of AMZ osteotomy. The first indication is to unload specific portions of the PF joint—particularly the lateral and distal aspects of the patella. Numerous pathologic processes may result in cartilage damage in these areas that require unloading as part of their treatment, including PF osteoarthritis and focal articular cartilage defects.

The second indication for AMZ osteotomy is the correction of an increased TT-TG distance and lateral patellar tracking in the setting of patellar instability. While addressing damage to the medial PF complex through reconstruction of the medial patellofemoral ligament (MPFL) has become the mainstay of treatment of recurrent lateral patellar instability, distal realignment still plays an important role as an adjunct procedure in patients with abnormal patellar tracking and tibial tubercle position. A recent biomechanical study by Stephen et al. demonstrated poor correction of patellar tracking with isolated MPFL reconstruction in patients with a TT-TG distance greater than 15 mm [13]. The addition of an AMZ osteotomy to MPFL reconstruction may improve patellar tracking and decrease recurrence risk in this population. Patients with both patellar instability and cartilage damage in the lateral and/or distal aspects of the PF joint are an ideal population for AMZ osteotomy.

While AMZ osteotomies are sometimes performed in isolation, it is commonly performed in conjunction with other procedures depending on the underlying pathology. Patients with lateral overload in the absence of instability may benefit from a lateral procedure such as lateral release or lengthening. Patients with focal cartilage defects of the lateral or distal PF joint may benefit from concomitant cartilage treatment. Finally, as discussed above, patients with instability will likely benefit from MPFL reconstruction in most cases, with osteotomy as an adjunct.

21.5 Contraindications

Contraindications to AMZ osteotomy include patients with significant medial PF chondral damage as AMZ will increase medial patellar fact forces and could lead to further damage in this area. Work by Pidoriano et al. also demonstrated relatively poor outcomes of AMZ osteotomy for the treatment of diffuse PF osteoarthritis [14]. A further contraindication to AMZ osteotomy is the treatment of patients with patellar instability who lack a pathologically increased TT-TG distance. Further tibial tubercle medialization in these patients could lead to iatrogenic medial patellar instability—particularly when a lateral release is also performed. Additionally, relative contraindications to any lower extremity osteotomy apply to TTO as well, including tobacco use, poor bone quality that would prevent adequate fixation, and the inability to follow postoperative protocols.

21.6 Surgical Technique

21.6.1 Preoperative Planning

Key to the versatility of the AMZ osteotomy is the ability to vary the relative degree of anteriorization and medialization achieved based on the angle at which the primary cut is made (Fig. 21.3). An increased obliquity of the cut allows for more anteriorization than medialization. Conversely, a flatter cut allows for more medialization than anteriorization. The TT-TG distance as described above provides useful insight into the degree of medialization that is needed. As above, cases with more PF chondral damage may benefit from more anteriorization. Examples of common osteotomy angles and the resulting displacement after a 10 mm anteromedialization are provided in Table 21.1.

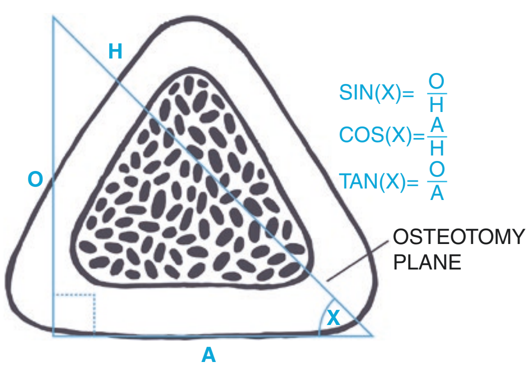

Fig. 21.3 Illustration of axial tibia demonstrating right angle trigonometry to calculate translation amount. Reprinted from Arthroscopy Techniques, Ridley TJ, Baer M, Macalena JA, Revisiting Fulkerson's Original Technique for Tibial Tubercle Transfer: Easing Technical Demand and Improving Versatility, e1211–e1224, 2017, with permission from Elsevier

Table 21.1 Degree of obliquity of the osteotomy and approximate resulting amount of anteriorization and medialization of a 10 mm tibial tubercle anteromedialization

Osteotomy slope (°)	Anteriorization (mm)	Medialization (mm)
30	5	8.6
45	7.1	7.1
60	8.6	5

21.6.2 Positioning

The patient is placed supine on the operating room table with all extremities and bony prominences well padded. A small padded bump is placed under the ipsilateral hip to position the lower extremity in neutral rotation. A lateral thigh post is used in order to facilitate arthroscopic evaluation and provide lateral positioning support during the remainder of the procedure. A tourniquet is placed high on the thigh, and standard preoperative antibiotics are administered. Examination under anesthesia is performed including evaluation of range of motion, ligamentous stability, patellar tracking, patellar tilt, and patellar translation and ability to dislocate in through the full range of motion. The lower extremity is then prepped and draped in standard sterile fashion, and a preoperative timeout is performed. Planned skin incisions are marked, taking into account all potential concomitant procedures and ensuring appropriate skin bridges (Fig. 21.4).

21.6.3 Arthroscopy

Diagnostic arthroscopy is performed through standard inferolateral and inferomedial portals. The entire joint is inspected, taking particular care to inspect the PF joint. The articular surfaces are inspected, and areas of chondral wear and damage are documented. The creation of a superolateral portal may also be useful to provide a proximal view of patellar tracking as the knee is brought through range of motion. The arthroscopic evaluation may identify severe PF cartilage damage or chondrosis or other contraindications that precludes proceeding with the

Fig. 21.4 Intraoperative photograph of planned skin incision for tibial tubercle osteotomy and potential concomitant procedures

AMZ osteotomy. If concomitant procedures are planned, arthroscopic preparation for these is performed, and any additional intra-articular pathology (meniscal tears, loose bodies, plicae, etc.) is addressed at this time as well.

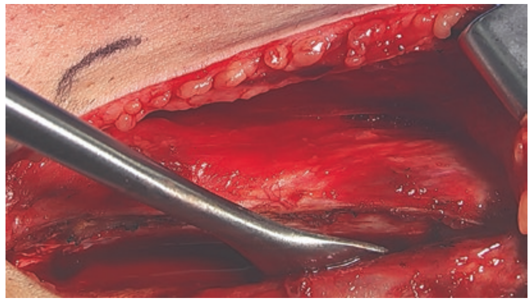

Fig. 21.5 Intraoperative photograph of subperiosteal elevation of anterior compartment

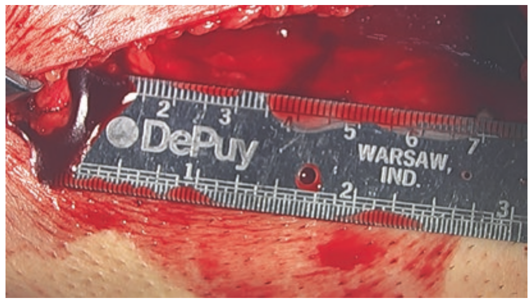

Fig. 21.6 Intraoperative photograph demonstrating measurement of osteotomy length

21.6.4 Open Procedure

21.6.4.1 Exposure

An approximately 10 cm incision is made from Gerdy's tubercle and carried distally and medially along the lateral aspect of the tibial tubercle and tibial crest. Dissection is carried through the skin and subcutaneous tissue until the anterior compartment fascia is identified. The fascia is incised longitudinally just lateral to the tibial crest, maintaining a small cuff of tissue for closure, and the anterior compartment musculature is elevated off the tibia in a subperiosteal fashion (Fig. 21.5). Both edges of the patellar tendon are identified and cleared of tissue. A blunt retractor is placed behind the patellar tendon for protection and to identify the insertion point on the tibia.

21.6.4.2 Osteotomy

The osteotomy is then marked out. The distal aspect of the osteotomy is measured 7 cm distally from the patellar tendon insertion, and the anterior tibia is marked at this point (Fig. 21.6). Two parallel K-wires are inserted in the tibia as a guide for the oblique osteotomy at the pre-determined angle as described above. One K-wire is placed at the distal aspect that was previously marked and the second at the patellar tendon insertion on the tibia. The K-wires are inserted from medial to lateral starting 1–2 mm medial to the tibial crest, aimed at the angle of the planned osteotomy and passed just through the lateral cortex (Fig. 21.7). Using a handheld oscillating saw, the medial tibial cortex is scored (Fig. 21.8). The tibia is then cut in plane with the K-wires starting centrally between the K-wires (Fig. 21.9). The cut is carried through the far (lateral) cortex and extended proximally and distally, taking care to protect the lateral structures with retractors. The K-wires are removed once the plane of the cut has been established to prevent interference with the oscillating saw. It is important to taper the distal aspect of the osteotomy anteriorly so that the bone is about 1–2 mm thick at the most distal aspect to minimize fracture risk. The distal 1–2 mm of the anterior tibial cor-

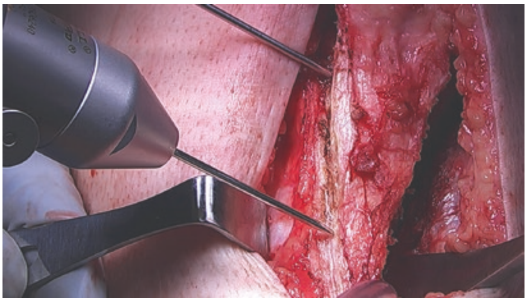

Fig. 21.7 Intraoperative photograph of insertion of parallel K-wires at planned osteotomy slope

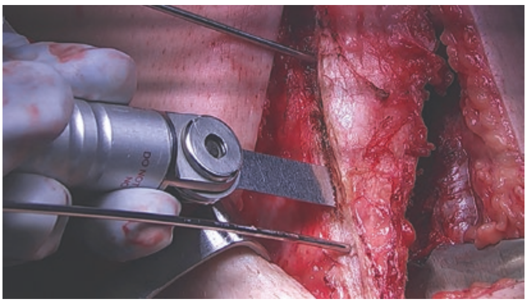

Fig. 21.8 Intraoperative photograph of oscillating saw scoring the medial cortex of the tibia

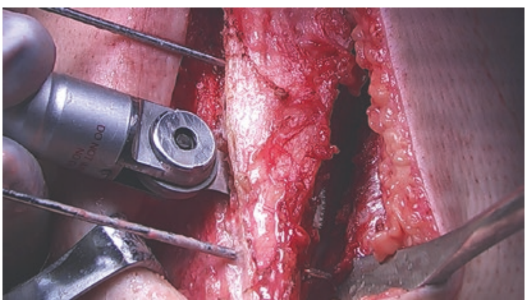

Fig. 21.9 Intraoperative photograph of osteotomy cut in plane with the previously placed K-wires and carried through the lateral cortex

tex of the osteotomy is left intact to act as a hinge (Fig. 21.10). Proximally, osteotomes are used to complete the osteotomy through the lateral cortex in order to prevent damage to the lateral neurovascular structures (Fig. 21.11). The transverse portion of the proximal osteotomy is made with an osteotome (Fig. 21.12), and a small back cut may be made with the oscillating saw (Fig. 21.13) or an osteotome. This results in a triangular shape to the osteotomy. Alternatively, commercially available jigs and cutting guides may be used for this portion.

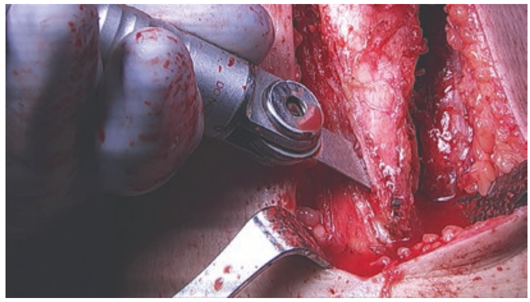

Fig. 21.10 Intraoperative photograph of distal aspect of osteotomy, leaving 1–2 mm of cortex intact to act as a hinge for the osteotomy

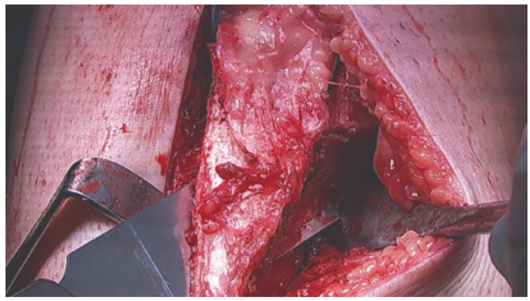

Fig. 21.11 Intraoperative photograph demonstrating the use of an osteotome for completing the proximal aspect of the osteotomy through the lateral cortex

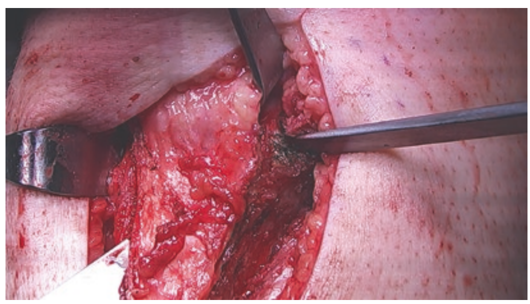

Fig. 21.12 Intraoperative photograph demonstrating the transverse osteotomy posterior to the patellar tendon. Note the retractor behind the patellar tendon

At this point in the case, any required cartilage procedures can be performed by extending the incision proximally and utilizing the osteotomy to provide excellent exposure and visualization prior to osteotomy fixation.

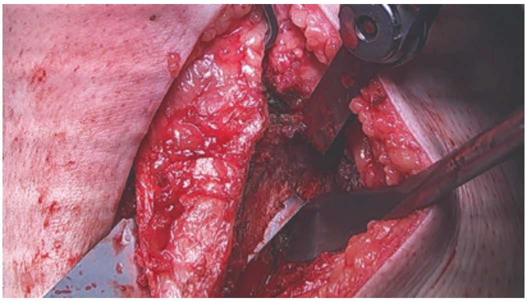

Fig. 21.13 Intraoperative photograph of use of an oscillating saw to make a back cut to connect the transverse and lateral aspects of the tibial tubercle osteotomy

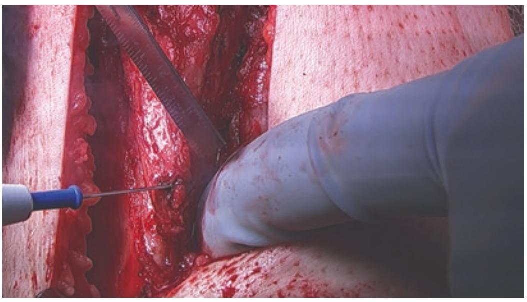

Fig. 21.14 Intraoperative photograph demonstrating measurement of translation of tibial tubercle

21.6.4.3 Fixation

Using the preoperatively calculated distances, the amount of anteromedialization is measured, and the tubercle is moved along the cut and held in the appropriate position (Fig. 21.14). The tubercle may also be moved distally or proximally to account for pre-existing alta or infera respectively if necessary, but this does require completion of the cut distally. The tubercle is then drilled perpendicular to the osteotomy (anterolateral to posteromedial) using a lag technique and fixed in place using two 4.5 mm cortical screws in a bicortical fashion (Fig. 21.15). It is important to countersink the anterior cortex to minimize postoperative irritation and the need for hardware removal. Depending on the amount of anteriorization and medialization, there may be prominence of the medial aspect of the tubercle, which may be removed to prevent skin and soft tissue irritation. Final fluoroscopic images are obtained ensuring appropriate position and fixation. The incision is then closed in standard layered fashion.

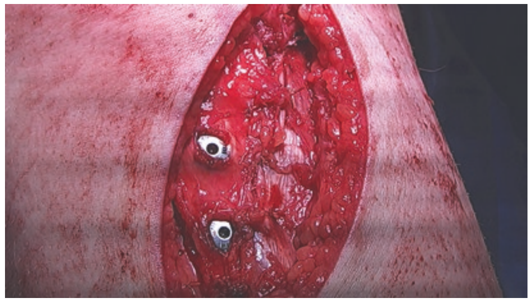

Fig. 21.15 Intraoperative photograph demonstrating final screw fixation of tibial tubercle

21.6.4.4 Additional Procedures for Instability

If a lateral lengthening or release or MPFL reconstruction is to be performed in addition to the AMZ osteotomy, it is important to complete osteotomy first. The osteotomy may change patellar tracking, particularly if distalization is involved. This change may obviate the need for or possibly necessitate a lateral procedure. Further it may change the isometry of the graft if the MPFL reconstruction is done first, resulting an anisometry and associated complications.

21.7 Postoperative Management

Postoperatively, patients are placed in a hinged knee brace. They are kept non-weight bearing for the first 2 weeks to allow for healing of the osteotomy site. If the distal hinge was maintained intra-op, patients begin a progressive weight-bearing program after 2 weeks, beginning with increasing 25% body weight weekly until they are full weight bearing at 6 weeks. Patients without an intact distal cortical hinge (distalization or loss of the hinge intra-op) are kept non-weight bearing for the entire 6 weeks. Patients are allowed full range of motion immediately postoperatively. Patients are taught home exercises before discharge and start physical therapy within the first week postoperatively to work on range of motion and quadriceps strengthening. All patients are placed on venous thromboembolism (VTE) prophylaxis (our preference is apixaban 2.5 mg twice daily) until they are full weight bearing and are then transitioned to aspirin 325 mg daily for an additional 4 weeks.

Radiographs are obtained at 2, 6, and 12 weeks postoperatively and then at 3-month intervals until osteotomy healing is complete. No impact activities are allowed until complete osteotomy healing is noted radiographically. Patients are allowed to return to sport once they have met the following additional goals: (1) single-leg and three crossover hop test for distance within 15% of uninvolved limb; (2) ≤10% deficit in isokinetic peak torque with knee extension and knee flexion (60°/sec and 300°/sec) compared to uninvolved limb; and (3) able to complete sport-specific drills without compensatory movements, exacerbation of symptoms, or reactive effusion. Patients typically meet these goals between 6 and 9 months postoperatively.

21.8 Complications and Prevention

Complications of AMZ osteotomy include common complications associated with any surgical intervention and those lower extremity osteotomies including infection, excess bleeding, compartment syndrome, VTE, incision breakdown or delayed wound healing, persistent pain, complex regional pain syndrome, loss of fixation, malunion, delayed union, nonunion, or tibia fracture [15, 16]. Additional AMZ procedure-specific complications include pain associated with the hardware requiring future removal, arthrofibrosis or stiffness, progressive PF joint articular cartilage degeneration, nonunion of the osteotomy site, fracture of the tibia or osteotomy shingle, and intraoperative neurovascular injury to the popliteal or anterior tibial arteries and deep peroneal nerve. In a systematic review of complications associated with TTO, Payne et al. found an overall complication rate of 3.7% associated with AMZ with hardware removal being the most common complication with a rate of 49% [17]. Complications related to nonunion and fracture were decreased in cases where an intact distal cortical hinge was maintained.

Risk of complication can be mitigated with careful planning. Utilizing anticoagulation postoperatively and early motion can help reduce the risk of VTE. Early non-weight bearing with gradual progression can help prevent tibial fracture or loss of fixation [15]. Arthrofibrosis can be avoided with early range of motion exercises and consideration of a continuous passive motion (CPM) device [8].

21.9 Pearls and Pitfalls

21.9.1 Pearls

- A thorough diagnostic arthroscopy is imperative to ensure no chondral damage could compromise outcomes.
- A uniform osteotomy plane is important to ensure good bony contact after transfer.
- Do not over-medialize the tibial tubercle. Restoring the TT-TG distance to between 10 and 15 mm is the goal, never less than 10 mm.
- Hardware-related pain is not uncommon and may require a second surgery for removal.
- Many patients require concomitant procedures such as lateral release/lengthening, MPFL reconstruction, or cartilage restoration procedures. These should be performed simultaneously with the osteotomy.

21.9.2 Pitfalls

- A deep cut or cortical notch distally increases the risk of tibia fracture.
- Loss of the distal cortical hinge should be avoided unless distalization is planned.
- Appropriate screw length is critical as over-protrusion of the screws may result in neurovascular injury while an undersized screw may result in loss of fixation.

21.10 Outcomes

AMZ of the TT has proven to be a successful operation for PF chondral disease as well as instability. In a series of patients treated for patellar articular degeneration, Fulkerson et al.

reported 93% good to excellent subjective outcomes and 89% good to excellent objective outcomes at a mean of 35 months postoperatively [8]. In an analysis of 42 knees undergoing AMZ for patellar malalignment or cartilage breakdown, Buuck and Fulkerson reported 86% good to excellent subjective outcomes and 86% good to excellent results on physical examination with 95% of patients willing to undergo the procedure again [18]. Rosso et al. demonstrated longevity of the procedure with 77% survivorship at 108 months [19]. Outcomes are dependent on the location of cartilage damage. Pidoriano demonstrated 87% good to excellent outcomes for distal or lateral patellar chondral lesions but only 55% good to excellent results for medial facet lesions and 20% good to excellent results for proximal or diffuse lesions [14].

AMZ osteotomy can be very effective when performed with additional procedures to address concomitant cartilage pathology. Gillogly and Arnold reported significant improvement in IKDC, Lysholm, Cincinnati Knee Score, and SF-12 scores for patients undergoing concomitant PF ACI and AMZ, with 83% good or excellent outcomes [20]. Farr evaluated patients undergoing ACI for grade III and IV PF chondral lesions with concomitant ACI with 75% good to excellent outcomes on the modified Lysholm scale [21]. When he compared his outcomes to those reported by Pidoriano [14], he noted improved outcomes with ACI with AMZ compared to AMZ alone. Similarly, in a systematic review, Trinh et al. found that in studies comparing ACI to ACI with TTO for treatment of PF chondral pathology, those undergoing TTO had significantly greater improvement [22].

While most cases with patellar instability today are treated with MPFL reconstruction with the possible additional of a tibial tubercle osteotomy depending on anatomy and patellar tracking, AMZ osteotomy in isolation has also been reported with relatively good outcomes. In an evaluation of 107 knees treated with AMZ for patellar maltracking or dislocation, Palmer et al. reported 79% had good to excellent outcomes at a mean of 5.6 years follow-up [23]. Tjoumakaris et al. reported good outcomes of 44 patients treated with isolated AMZ osteotomy and lateral release for patellar instability and lateral maltracking [24]. In patients undergoing combined MPFL reconstruction with AMZ, Allen et al. found good subjective outcomes, a low rate of recurrent instability (6.7%), and that 87% of patients were able to return to sport. Several other authors have confirmed the ability to return to sports at the same or higher level than pre-op following AMZ osteotomy performed for PF pain or arthritis [25] as well as instability [24].

21.11 Conclusions

AMZ osteotomy is a reliable and useful procedure that allows for patellofemoral realignment as well as unloading of portions of the patellofemoral joint. Careful evaluation and consideration of the patient's pathology with diligent preoperatively planning allow the surgeon to perform this procedure with relatively low complication risk.

References

1. Trillat A, Dejour H, Couette A. Diagnosis and treatment of recurrent dislocations of the patella. Rev Chir Orthop Reparatrice Appar Mot. 1964;50:813–24.
2. Maquet P. Advancement of the tibial tuberosity. Clin Orthop Relat Res. 1976;115:225–30.
3. Fulkerson JP. Anteromedialization of the tibial tuberosity for patellofemoral malalignment. Clin Orthop Relat Res. 1983;177:176–81.
4. Hungerford DS, Barry M. Biomechanics of the patellofemoral joint. Clin Orthop. 1979;144:9–15.
5. Ramappa AJ, Apreleva M, Harrold FR, Fitzgibbons PG, Wilson DR, Gill TJ. The effects of medialization and anteromedialization of the tibial tubercle on patellofemoral mechanics and kinematics. Am J Sports Med. 2006;34(5):749–56.
6. Lewallen DG, Riegger CL, Myers ER, Hayes WC. Effects of retinacular release and tibial tubercle elevation in patellofemoral degenerative joint disease. J Orthop Res. 1990;8(6):856–62.
7. Ferguson AB, Brown TD, Fu FH, Rutkowski R. Relief of patellofemoral contact stress by anterior displacement of the tibial tubercle. J Bone Joint Surg. 1979;61(2):159–66.
8. Fulkerson JP, Becker GJ, Meaney JA, Miranda M, Folcik MA. Anteromedial tibial tubercle transfer without bone graft. Am J Sports Med. 1990;18(5):490–7.

9. Beck PR, Thomas AL, Farr J, Lewis PB, Cole BJ. Trochlear contact pressures after anteromedialization of the tibial tubercle. Am J Sports Med. 2005;33(11):1710–5.
10. Goutallier D, Bernageau J, Lecudonnec B. The measurement of the tibial tuberosity. Patella groove distanced technique and results (author's transl). Rev Chir Orthop Reparatrice Appar Mot. 1978;64(5):423–8.
11. Camp CL, Stuart MJ, Krych AJ, Levy BA, Bond JR, Collins MS, et al. CT and MRI measurements of tibial tubercle-trochlear groove distances are not equivalent in patients with patellar instability. Am J Sports Med. 2013;41(8):1835–40.
12. Camp CL, Heidenreich MJ, Dahm DL, Bond JR, Collins MS, Krych AJ. A simple method of measuring tibial tubercle to trochlear groove distance on MRI: description of a novel and reliable technique. Knee Surg Sports Traumatol Arthrosc. 2016;24(3):879–84.
13. Stephen JM, Dodds AL, Lumpaopong P, Kader D, Williams A, Amis AA. The ability of medial patellofemoral ligament reconstruction to correct patellar kinematics and contact mechanics in the presence of a lateralized tibial tubercle. Am J Sports Med. 2015;43(9):2198–207.
14. Pidoriano AJ, Weinstein RN, Buuck DA, Fulkerson JP. Correlation of patellar articular lesions with results from anteromedial tibial tubercle transfer. Am J Sports Med. 1997;25(4):533–7.
15. Stetson WB, Friedman MJ, Fulkerson JP, Cheng M, Buuck D. Fracture of the proximal tibia with immediate weightbearing after a Fulkerson osteotomy. Am J Sports Med. 1997;25(4):570–4.
16. Bellemans J, Cauwenberghs F, Brys P, Victor J, Fabry G. Fracture of the proximal tibia after Fulkerson anteromedial tibial tubercle transfer: a report of four cases. Am J Sports Med. 1998;26(2):300–2.
17. Payne J, Rimmke N, Schmitt LC, Flanigan DC, Magnussen RA. The incidence of complications of tibial tubercle osteotomy: a systematic review. Arthroscopy. 2015;31(9):1819–25.
18. Buuck DA, Fulkerson JP. Anteromedialization of the tibial tubercle: a 4- to 12-year follow-up. Oper Tech Sports Med. 2000;8(2):131–7.
19. Rosso F, Rossi R, Governale G, Marmotti A, Cherubini V, Cottino U, et al. Tibial tuberosity anteromedialization for patellofemoral chondral disease: prognostic factors. Am J Sports Med. 2017;45(7):1589–98.
20. Gillogly SD, Arnold RM. Autologous chondrocyte implantation and anteromedialization for isolated patellar articular cartilage lesions: 5- to 11-year follow-up. Am J Sports Med. 2014;42(4):912–20.
21. Farr J. Autologous chondrocyte implantation improves patellofemoral cartilage treatment outcomes. Clin Orthop Relat Res. 2007;463:187–94.
22. Trinh TQ, Harris JD, Siston RA, Flanigan DC. Improved outcomes with combined autologous chondrocyte implantation and patellofemoral osteotomy versus isolated autologous chondrocyte implantation. Arthroscopy. 2013;29(3):566–74.
23. Palmer SH, Servant CTJ, Maguire J, Machan S, Parish EN, Cross MJ. Surgical reconstruction of severe patellofemoral maltracking. Clin Orthop Relat Res. 2004;419:144–8.
24. Tjoumakaris FP, Forsythe B, Bradley JP. Patellofemoral instability in athletes: treatment via modified Fulkerson osteotomy and lateral release. Am J Sports Med. 2010;38(5):992–9.
25. Liu JN, Wu HH, Garcia GH, Kalbian IL, Strickland SM, Shubin Stein BE. Return to sports after tibial tubercle osteotomy for patellofemoral pain and osteoarthritis. Arthroscopy. 2018;34(4):1022–9.