Tibial Tubercle Osteotomies: a Review of a Treatment for Recurrent Patellar Instability

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Abstract

Purpose of Review The goal of this review is to provide an overview of current surgical treatment options for tibial tubercle osteotomies as a treatment for recurrent patellofemoral instability. As such we sought to provide the reader with the most current answers to why treatment practices have changed and how this has affected the outcome of surgical treatment for patellar instability.

Recent Findings As our understanding of patellofemoral biomechanics have grown, appropriate surgical and non-surgical treatment options have followed suit to address these findings.

Summary A clear understanding of the pathomechanics causing the patient's patellar instability is germane to choosing the most appropriate surgical intervention to address this instability. Likewise, understanding the goal of the intervention chosen—e.g., unloading, realignment—is paramount. These surgical techniques may be technically challenging and surgical specialists with experience in these techniques are recommended for optimal outcomes.

Keywords Tibial tubercle osteotomy · Patellar instability · Patellofemoral · Patellofemoral pain

Introduction

The primary anatomical culprits of lateral patellar instability include a morphologically abnormal patella, an abnormally high patella (patella alta), a dysplastic trochlea, and a more lateral position of the tibial tuberosity. In isolation or in concert, these issues can have a destabilizing effect on the patella through a flexion/extension arc [1, 2]. Elias et al. showed that in near full extension, the primary anatomic variant that contributed to patellar instability was related mostly to trochlear dysplasia [1, 2]. In contrast, at greater flexion angles, patellar instability was more related to the location of the tibial tuberosity [1, 2].

The patella is a uniquely shaped, sesamoid bone that plays an important role in extension of the knee composed of three facets—lateral, medial, and odd—that are separated by ridges. Wiberg classified patellar morphology into three distinct types

[3, 4]. Type I has a medial and lateral facet that are approximately equal in size. In type II, the medial facet is smaller than the lateral facet, and in type III, the medial facet is small, has a steep angle, and is convex compared to the lateral facet which is broad and concave [4]. Type I is the most common and types II and III are seen as dysplastic or anomalous, which is associated with patellofemoral instability [3].

Several studies have shown the importance of the trochlea for normal patellofemoral biomechanics [5]. The primary measures of a dysplastic trochlea correlated with patellar instability are the sulcus angle [6], trochlear depth [7], and asymmetry of the trochlear facets [7]. Balcarek et al. showed a significant difference in these parameters for those with patellar instability compared to those without, underscoring the important role the trochlear groove plays in patellar instability [5].

Although it is of the utmost importance to take the patient's entire anatomy into account when evaluating for patellar instability, the focus of this review will be on managing such instability with the use of tibial tubercle osteotomy techniques. Tibial tubercle osteotomies can be indicated for focal patellar chondral defects as an unloading procedure. However, our review is dedicated to the surgical options available for utilizing a tibial tubercle osteotomy in the setting of recurrent lateral patellar instability. We will focus on the three primary

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techniques for tibial tubercle osteotomy—Maquet, Elmslie-Trillat, and Fulkerson—that have been described, although there are several published modifications of each.

Indications and Technique

Anteriorizing—the Maquet Technique (Fig. 1)

First described 1963, the Maquet osteotomy is designed to decrease load in a painful patellofemoral joint by isolated anteriorization of the tibial tubercle (Fig. 1) [8, 9]. The Maquet procedure has been shown to reduce patellofemoral joint contact forces [10] and increase the joint contact area, further decreasing patellofemoral joint load. The primary indication for this surgical technique is patellofemoral pain, particularly from mild/moderate patellofemoral arthritis or post-patellectomy pain [11]. Generally, patellar malalignment is a contraindication to isolated anteriorization of the tibial tubercle.

The surgical technique originally described by Maquet [8, 9] begins with an incision medial to the tibial tubercle. An 8-mm (depth) × 15-cm (length) portion of the anterior tibial tubercle and tibial crest is then elevated using a flat osteotomy in the coronal plane, as opposed to the oblique cut utilized in other techniques. This is subsequently raised and back filled proximally with a 2-cm-thick iliac bone block; the remaining triangular defect is filled in with iliac bone graft. The result is purse anteriorization without medial translation. Careful skin closure is necessary; often, a relieving stitch is required to prevent skin necrosis.

Medializing—the Elmslie-Trillat Technique (Fig. 2)

The Elmslie-Trillat procedure consists of an isolated medialization of the tibial tubercle (Fig. 2) [12]. The primary indication for this surgical technique is for patients with patellar instability or lateral maltracking. For appropriately selected patients, a medializing tibial tubercle transfer can provide a

high rate of satisfactory results; however, in patients with degenerative changes, particularly patellar chondromalacia, this procedure has poor outcomes [13].

The surgical technique was originally described by Roux and subsequently modified and popularized by Elmslie and Trillat [12]. The technique has undergone many iterations, but is best described by Cox [13]. A medial parapatellar incision is carried out. This skin flap is elevated with visualization of the tenosynovium of the patellar tendon and bursa. These are incised and carefully elevated medially and laterally to allow full visualization of the patellar tendon. Next, attention is turned to the tibial tubercle; an osteotome is used to start a cut of 5 mm posterior to the anterior edge of the tubercle at the level of insertion of the patellar tendon. This is continued distally for 4–6 cm and gradually tapered anteriorly to elevate a shingle of bone hinged distally on periosteum. The depth of the cut depends on individual patient needs, with deeper cuts required for patients requiring greater medialization. This bone shingle is rotated medially until the patella tracks centrally in the trochlea. The osteotomy is then fixed in place with two bicortical lag screws.

Anteromedializing—the Fulkerson Technique (Fig. 3)

The Fulkerson osteotomy is an anteromedial transfer of the tibial tubercle—combining elements of both the Maquet and Elmslie-Trillat (Fig. 3). Fulkerson's indications for anteromedial tibial tubercle transfer are for patellofemoral pain failing non-operative interventions and patellar maltracking (including instability) or excessive tilt [14]. This includes isolated patellofemoral arthritis, particularly in patients with lateral and distal patellar chondral wear [15]. Bellemans et al. confirmed the utility of this procedure in patients with chronic knee pain and patellar subluxation [16]. The typical pattern of wear with lateral maltracking of the patella is lateral and distal chondral wear. Anteromedialization of the tibial tubercle helps to realign the extensor mechanism and improve patellar tracking, as well as allows the patella to make contact with the trochlea earlier in

Fig. 1 Showing anteriorization of the tibial tubercle from axial view

Fig. 2 Showing medialization of the tibial tubercle from axial view

flexion and moves the contact area off of the distal patella and more proximally [17].

The Fulkerson osteotomy was originally described in 1983 [10]. Once the tubercle is exposed, it is important to properly elevate the anterior tibialis muscle to allow complete visualization of the lateral aspect of the tubercle and posterolateral tibia for an effective osteotomy. A guide may be used to make the osteotomy, which is performed in an oblique manner from anteromedial to posterolateral, starting at the insertion of the patellar tendon and going distally for approximately 5–6 cm. Care must be taken not to make the cut too deep as this may increase the risk of fracture. The saw should aim towards the lateral cortex to minimize risk of injury to the tibial artery and deep peroneal nerve. With proper elevation of the tibialis anterior muscle, a retractor can be placed just posterior to the lateral tibial cortex to provide protection to these neurovascular structures. A transverse proximal cut should be made just deep to the patellar tendon. This cut is then connected to the main osteotomy with an oblique cut proximal-medially. The fragment is then slid along the oblique plane in an anteromedial direction and fixed with two bicortical lag screws. More vertical cuts can result in more extreme anteriorization whereas more transverse, or flat, cuts result in more medialization. The actual angle of these cuts can be quite difficult to carry out in vivo, as has been described in a study by Liu et al. of 40 knees undergoing anteromedialization osteotomies; they found that

osteotomies were rarely of the intended angle, and achieved less anterior translation, but approximately as much medial translation, as intended [2]. If the pre-operative exam demonstrated the inability to evert the patella to neutral, a lateral release may be performed to allow for adequate patellar positioning and tracking.

Post-operative Management

Post-operative rehabilitation is an important part of regaining function and range of motion. Several studies have shown that the more conditioned the extremity is prior to surgery, the better the outcome will be post-operatively. If there is obvious dynamic weakness of the knee joint prior to surgery, our recommendation is for the patient to address this with a controlled, supervised physical therapy program prior to surgery, if possible [18]. Although, to our knowledge, there are no high-level randomized controlled trials looking at the most effective rehabilitation protocol following a tibial tubercle osteotomy, the author's post-operative protocol is partially based off of the published work by Fithian et al. evaluating rehabilitative protocols following medial patellofemoral ligament (MPFL) reconstruction [19].

Regardless of the protocol employed, restoration of vastus medialis obliquus (VMO) strength is of critical importance.

Fig. 3 Showing anteromedialization of the tibial tubercle from axial view

The VMO is a dynamic stabilizer and medial restraint for the patella. A weak VMO has been demonstrated to be contributory to patellar maltracking and anterior knee pain [13, 20, 21]. Therapy, both pre-operatively and post-operatively, should target this important stabilizer of the patella.

The authors recommend a multi-phase rehabilitation protocol. In the setting of an osteotomy, the first phase of rehabilitation must treat this injury as a fracture, conceptually. That is, in phase I, we recommend non-weight bearing with supervised physical therapy working on patellar manual mobilization and hip strengthening/control. Pain can be treated with electrical stimulation, cold therapy, compression, or other modalities [19]. During this initial 4–6 weeks, the patient is locked in extension and non-weight bearing. It should be noted that some surgeons allow limited range of motion during phase I; early mobilization, or even use of CPM, may be beneficial in larger surgeries, particularly TTOs combined with further intra-articular cartilage work or associated MPFL reconstruction. Phase II is a progression to gentle passive range of motion (ROM) and quad sets for reinitiating quadriceps muscle firing to regain voluntary control of the musculature. During this phase, the patient progresses to short-arc quadriceps firing and straight leg raise exercises as part of the beginning, muscle strengthening phase. This phase is 2–4 weeks in length. Phase III is initiated once ROM goals and muscle firing control have been achieved. This is the intermediate phase of muscle strengthening rehabilitation where closed chain exercises are initiated (e.g., leg press machine, partial squats). These exercises focus on regaining eccentric control [18]. This phase is 2–4 weeks in length. Phase IV focuses on muscle endurance and neuromuscular control. If the patient is an athlete, at this point, the physical therapist will initiate sport-specific functional exercises to begin reintegrating the athlete back to their respective sport. Running or jogging is initiated during this phase. This phase may be 4–6 weeks in length, depending on the sport and level of competition.

Complications

While this is a generalized discussion of the complications of tibial tubercle osteotomies, it should be noted that complications from tibial tubercle transfer depend largely on the surgical approach, method, and direction of tibial tubercle transfer.

The Maquet technique, which has largely been abandoned for less morbid transfers, was plagued by high complication rates, most notable for skin necrosis, compartment syndrome, and nonunion [22]. While not as morbid as the Maquet technique, other methods of tibial tubercle transfer demonstrate similar types of complication. In a review by Payne et al. [23], which excluded the Maquet technique, the overall complication rate of tibial tubercle transfer was 4.6%. This rate

was found to be highest when the tubercle was completely detached from the tibia. The most common complication was prominent hardware, though there was also a 0.8% risk of nonunion and 1% risk of tibial fracture.

Nonunion is a recognized risk after tibial tubercle transfer [23]. It is hypothesized that distalization may be a contributing factor to tibial tubercle nonunion owing to increased stresses on the osteotomy site once fixed. Technique is an important consideration for minimizing risk of nonunion. When creating osteotomies, thin bone shingles can compromise union rates by decreasing cancellous bone available to contribute to healing; another consideration is to utilize screws that are perpendicular to the osteotomy site that can ensure maximal compression of the two surfaces [24]. Intraoperatively, it is important to make efforts to preserve the blood supply by avoiding periosteal stripping and thermal necrosis can also improve chances of union. Similarly, certain patient factors such as obesity and smoking may predispose to nonunion [25].

A real and recognized risk of tibial tubercle transfer is the fracture of the proximal tibia. Both Stetson et al. [26] and Bellemans et al. [16] discussed fracture as a complication of the Fulkerson osteotomy and concluded that prolonged protected weight bearing with crutches, and even complete non-weight bearing, is required to mitigate this risk. A systematic review of tibial tubercle osteotomies suggested rate of fracture is increased when the tibial tubercle is completely detached from its hinge [23]. Risk of fracture has been related to surgical technique, such as size of osteotomy or tools used to perform the osteotomy. Thick osteotomized fragments may create a stress riser that could increase risk of fracture [27]. There have also been studies suggesting that use of an osteotome, rather than an oscillating saw, may increase risk of fracture [28]. Finally, rapid and aggressive advancement of therapy may put an osteotomy at risk.

While the rate of major complication is generally low, surgical technique can undoubtedly help to improve outcomes. Care should be taken in surgical planning, approach, and fixation to minimize these risks.

Outcomes

Similar to complications of tibial tubercle osteotomies, outcomes depend on the direction and method of tibial tubercle transfer. In his initial study, Maquet demonstrated 95% of patients had improvement in symptoms [9]. Subsequent studies similarly demonstrated the potential utility of this procedure [11]. As mentioned above, this technique has lost favor owing to the high complication rates [22].

Nakagawa et al. examined 45 knees that had undergone medialization (Elmslie-Trillat) at an average follow-up of 161 months [29]. Sixty-four percent of patients at long-term follow-up had good or excellent outcomes; patients with

poorer outcomes tended to have patellofemoral pain rather than patellar instability. Additionally, poorer initial outcomes were reported for patients with degenerative changes as noted on radiographs. Carney et al. similarly reported long-term outcomes of the Elmslie-Trillat medialization procedure in 15 knees with a mean follow-up of 26 years [30]. Only 54% of patients demonstrated good and excellent outcomes at this long-term follow-up; additionally, there was a trend towards diminishing functional status in the long term.

The original article by Fulkerson et al. found good subjective results for 28 of 30 patients undergoing anteromedial tibial tubercle transfer [14]. The average age of these patients was 28 years and all patients had evidence of patellofemoral wear from patellofemoral malalignment with patellofemoral pain. They demonstrated a 93% rate of good to excellent outcomes with no evidence of serious complications such as skin necrosis or compartment syndrome. These findings were confirmed in a study by Bellemans et al. who prospectively examined 29 patients with a mean age of 26 years with chronic anterior knee pain [16]. Of these patients, 97% demonstrated improvement in patellar congruence angle and subluxation, as well as improved functional outcomes. At 4- to 12-year follow-up, Buuck et al. found that 86.4% of patients maintained good results, defined as near-normal range of motion, minimal pain and no limp, after an anteromedializing tibial tubercle osteotomy [31].

Pidoriano et al. sought to correlate outcomes with location of patellar cartilage lesions in patients undergoing an anteromedial tibial tubercle transfer [15]. Patients with distal and lateral patellar lesions had higher rates of satisfactory outcomes compared to patients with proximal or medial lesions, who tended to have poorer outcomes overall.

Debate exists as to the benefit of medialization versus anteromedialization in both patellar maltracking and patellar arthrosis. A study by Ramappa et al. examined the biomechanical effects of medial and anteromedial tibial tubercle transfer in cadaveric specimens [32]. They found that neither technique was superior to the other with addressing an increased Q angle; both techniques partially corrected for elevated patellofemoral contact pressures and patellar maltracking.

Conclusions

Although the incidence of patellar instability, as reported by Nietosvaara et al. [33], is not particularly high (43/100,000), the recurrence rate can be extremely high, between 49 and 69% [34], with each episode putting the athlete at risk for further chondral and soft tissue damage. Prompt diagnosis and treatment of this injury can decrease the risk of recurrence and risk of further cartilage and soft tissue injuries. The appropriate use of a tibial tubercle osteotomy can appropriately change the course of the natural history of lateral patellar instability, keep the athlete active, and potentially decrease

the development of osteoarthritis of the patellofemoral joint through mitigation of an otherwise abnormal and unstable patellofemoral joint.

Although excellent outcomes can be achieved, this procedure is not without complications and these range from delayed healing and nonunion to anterior skin necrosis, infection, and hardware complications/irritation [35•]. Pre-operative planning for a tibial tubercle osteotomy must focus on the goal of the procedure. As this procedure is indicated for off-loading the patellofemoral joint in the setting of chondral injury or osteoarthritic changes, frequently, this procedure is used for realignment for patellar maltracking and subsequent patellar instability—or a combination of both. With this, appropriate patient selection becomes paramount.

Compliance with ethical standards

Conflict of Interest All authors declare that they have no conflict of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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