Tibial Tubercle Osteotomy for Patellar Instability: Where are we in 2018?

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Abstract

Management of recurrent lateral patellar dislocation (LPD) remains difficult and controversial, despite an expansion of knowledge. With the advancement of medicine, an understanding of known anatomical risk factors of LPD, including patella alta and increased tibial tubercle (TT)–trochlear groove distance, now guide present-day management. However, this is not without drawbacks. Current measurements of anatomical risk factors cannot be considered universal, and it is, therefore, important to consider each case individually. The focus of this article is to highlight the history of patellar instability risk factors associated with TT osteotomy, as well as present-day operative management, which aims to restore normal biomechanics. Our goal is to provide a clinical framework to help clinicians approach surgical management of LPD. Operative versus non-operative management will be discussed in another article. The included case studies will aid in the understanding of patients with patellofemoral instability, presentation, and the clinician’s approach to management, in addition to showcasing the ongoing challenges in treating patellar instability.

Keywords: patellofemoral joint; patellar instability; lateral patellar dislocation; patella alta; tibial tubercle distalization; tibial tubercle osteotomy

Introduction

The goal of this article is to discuss the role of tibial tubercle osteotomy (TTO) in our current clinical algorithm for surgical stabilization after recurrent lateral patellar dislocation (LPD). This article will describe the history of the subject to better understand our current knowledge and present-day clinical challenges. Rather than be a comprehensive review, this article hopes to provide insights to help the clinician arrive at the best surgical treatment for an individual approach to this problem. This article will focus on when to add a bony procedure to the decision to surgically stabilize the patella. Operative versus non-operative management of LPD will be discussed in other articles.

History of Patella Instability Risk Factors Associated with TTO

In 1964, Brattström described the quadriceps vector (“Q angle,” Fig. 1) as the “valgus angle formed by the quadriceps resultant + patella +ligamentum patellae,” as measured on physical examination [1]. The Q angle, along with axial radiographs, was then used in conjunction to determine the degree of “patellar malalignment,” which was ill-defined at the time. Treatment of patellar instability during this time largely followed the belief that the patella was subject to excessive lateral forces and inadequate medial forces; therefore, surgical stabilization focused on “correcting” these factors, in particular, reducing the Q angle [2, 3, 4]. The need for a more precise measurement of the Q-vector led to the TT–trochlear groove distance (TT–TG) [5], an objective measurement made on CT slice imaging. It was initially described on computed tomography (CT) scan and later adopted to magnetic resonance imaging (MRI). Using this objective measurement on CT slice imaging, a threshold >20 was defined as pathologic, and surgical correction was suggested in patellar instability populations in need of patellar stabilization [6]. TT medialization was described by Elmslie and popularized by Trillat et al. [7]. The technique was believed to correct disproportionate lateral versus medial forces, the amount medialization of the TT was noted to be strictly empirically [7]. According to the literature at this time, it is unclear if the surgeon’s methodology was for the treatment of pain, for patellar dislocations, or both, but successful stabilization of the patella was achieved through medial TT transfer [8, 9, 10].

Despite its widespread use, there remains concern with the measurement of TT–TG:

• The utility of the TT–TG distance is questioned, as the TT–TG is measured as a distance instead of a ratio [11]. Comparisons between patients with variable body build and heights may not be valid.

• The role of tibial-femoral rotation and its effect on this measurement scheme has been questioned [12].

• The TT–TG measurement does not modify or adapt to patients with high-grade trochlear dysplasia, as this could increase the TT–TG distance by medialization of the proximal measurement (medialization of the groove) [11]. Correction of a high TT–TG by medialization of a distal TT could lead to an increase in medial-sided patellofemoral (PF) and/or tibiofemoral forces creating a medial-sixed cartilage...
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Patella Alisa (Fig. 3)
In 1938, Blumensaat noted the association of patella alta with patellar instability [19]. The association of patella alta with patellar instability was subsequently discussed by numerous authors [6,20,21,22]. Since then, many authors have

wear pattern.

• The TT-posterior cruciate ligament (TT-PCL) measurement (Fig. 2) [13] attempts to address some of the concerns with the TT-TG and measures the lateralization of the TT relative to a fixed point on the tibia, rather than the trochlea, to eliminate the effect of tibial rotation at the knee joint level. However, a recent study comparing the TT-PCL to TT-TG in a patella

instability population found both to have excellent interobserver reliability, but the TT-PCL measurement was less predictive of recurrent instability [14]. An increased TT-TG measurement is rarely seen without other elevated anatomic risk factors in a patient with primary LPD; it is more often seen in patients with multiple anatomic patellar instability risk factors [15,16]. Therefore, the need for its correction in isolation is rare. When associated with patella alta, correction of alta and increased TT-TG is prudent. Current surgical algorithms place less emphasis on the need for medialization of the TT in the treatment of LPD than previously [17], particularly as an isolated procedure. Its role in patellar stabilization is currently being challenged. Matsushita et al. [17] found no difference in the clinical outcomes scores nor the rate of recurrent LPD when these patients were treated with medial PF ligament (MPFL) reconstruction without a TTO, whether the TT-TG was >20 mm or <20 mm. The authors’ conclusion was that TT-TG >20 mm may not be an absolute indication for medial TTO when performing an MPFL reconstruction. The main role of TTO medialization is to reduce lateral patellar facet overload, with anterior and medial transfer of the TT for lateral PF chondrosis [18]. The indications for this surgical procedure are beyond the scope of the chapter.

Figure 1: In 1964, Brattström described the quadriceps vector (“Q angle”) which uses the “valgus angle formed by the quadriceps resultant + patella + ligamentum patellae,” as measured on physical examination. Measure knee in full extension. Reference line from anterior superior iliac spine to center of patella. Second reference line from center of patella to tibial tubercle (Copyright © 2017 Regents of the University of Minnesota). All rights reserved.

Figure 2: Patella alta. Sagittal radiograph of a knee with patella alta.

Figure 3: Tibial tubercle-posterior cruciate ligament (TT-PCL) measurement. Measure on axial view (requires three slice imaging views). Baseline (LL) across bony anatomy of dorsal tibial lateral and medial condyles tangent to the proximal tibia below the joint and above the head of the fibula. Superimpose a second image of tibia showing the most inferior slice in which the posterior cruciate ligament could still be clearly identified. Line (MM) at 90° to baseline at medial border of the PCL. Superimpose a third image of tibial tubercle; line (NN) parallel to line (MM) at midline of patellar tendon insertion onto tibia. Measure distance (OO) in millimeters between lines (MM) and (NN), parallel to baseline (LL) (Copyright © 2017 Regents of the University of Minnesota). All rights reserved.

Figure 4: Insall-Salvati index. Measure on sagittal cut with greatest patellar length. Line (B) from most superior subchondral bone to the point of tendon insertion on inferior patella; line (A) from lower point of line (B) to superior aspect of insertion of patellar tendon on tibial tuberosity. Insall-Salvati ratio = A ÷ B (Copyright © 2017 Regents of the University of Minnesota). All rights reserved.

Figure 5: Modified Insall-Salvati (I/S) ratio. Measure on sagittal cut with greatest patellar length. Line (D) measurement of cartilage articular surface; line (F) from lower point of line (D) to superior aspect of insertion of patellar tendon on tibial tuberosity. Modified Insall-Salvati ratio = F ÷ D (Copyright © 2017 Regents of the University of Minnesota). All rights reserved.
discussed and developed methods for measuring patellar height.

**Tibial-based measurements**

- Insall-Salvati (I/S) index (Fig. 4) [23]
- I/S >1.3 is indicative of patella alta
- I/S ratio is not sensitive to patellar morphology differences
  - I/S ratio does not change with distal TTO.
  - Modified I/S index (Fig. 5) [24]
  - Applied in conjunction with the original I/S index, the modified index reduces variation caused by differences in patellar shape, in particular, those with a long distal facet.
- Caton-Deschamps (C/D) ratio (Fig. 6) [25,26]
  - C/D >1.2 is indicative of patella alta
  - Has greater surgical utility as in pre-operative planning and post-operative assessment.
- Blackburne-Peel ratio (Fig. 7) [27]
  - Normal ratio = 0.8
  - Patella alta ratio >1.0.

**Femoral-based measurements**

- Patella-Trochlear index (Fig. 8) [28]
  - Inspired by Bernageau’s “engagement index” [29] defining the relative position of the patella to the TG on lateral radiograph, the patella-trochlea index analyzes sagittal MRI to establish the true articular cartilage patellotrochlear relationship [28].
  - Controls: 0.45 ± 0.05 [30]
  - Patella alta: < 0.0128 [28].

**Evolution of Operative Management of Patella Alta**

Although there is ample evidence that the presence of patella alta places one at a higher risk for primary and recurrent patella dislocations [15,16], it is important to recognize there are limitations with each measurement, and therefore, none are universal. For patella alta, C/D is used most among PF surgeons; however, most PF surgeons look at more than one measurement before surgically treating for alta (Personal Communication, International PF study Group, Munich 2017). Clinical interpretation of patella height, along with patellotrochlear engagement, remains an “evolving” clinical entity after nearly a century of recognition of patella alta as a risk factor for patella dislocation. In the 1980s, CD, who described the C/D ratio, also described the first surgical correction of patella alta, with distalization of the tubial tubercle [25,31]. The main goal of TTO distalization is to have earlier engagement of the patella in the groove, where the bony walls of the trochlea provide protection of the patella against lateral translation. With a high-riding patella, PF contact area is reduced, concentrating forces on the inferior lateral patella. By surgically decreasing the patellar height, there is an increase in surface contact which also distributes PF contact pressure over a greater area, which can be an additional benefit. A factor in the “menu a la carte,” when patella alta measured by C/D >1.2 mm was normalized to C/D = 1, good outcomes and improved patellar stability resulted [6]. More recently, the role of the MPFL has proven to play a major role in patellar stabilization [32,33], with reconstruction of the MPFL becoming a foundation in the management of recurrent LPD [11]. The clinical challenges that remain are defining the anatomic thresholds for surgical correction of patella height, combined with patellotrochlear engagement, that results in optimal outcomes. This would allow for better clinical algorithms of when (at what threshold) and how (what surgical procedure) to normalize this risk factor.
TTO Case

A 15-year-old female dancer was referred for the evaluation of the left patellar instability. She describes two specific episodes of frank lateral patella dislocation (LPD), one many years ago and one just before presentation. Each required manual manipulation. In addition to these two frank LPD, she has had many episodes of subluxation defined as a sense of patellar motion which necessitates her stopping her activity and straightening her knee. These are painful and associated with knee swelling. Non-operative management has included physical therapy and McConnell taping which has helped her symptoms; however, the most recent dislocation occurred while her knee was taped. She does not have confidence in her knee. On examination, her BMI is 23. With single leg squatting, she demonstrates a “dynamic” valgus of her left knee with single leg squat left > right. The left knee motion is 0–140°; mild effusion is present. Marked (+) lateral patellar apprehension is present which limits the assessment of patellar translation; it is three quadrants lateral with a soft endpoint.

Neutral medial patella tilt test. (+) J-sing left side only. Anatomic patella instability factors (APIFs): Lateral radiographs reveal a C/D ratio of 1.46. MRI evaluation showed patellar-trochlear index of 0.3, TT–TG of 19, and a lateral patellar tilt of 27° (+) trochlear dysplasia. Diagnosis: Recurrent LPD, patella alta under rehabilitation at relevant body movement patterns.

Surgical plan

1. Distal/medial TTO: About 12 mm distalization would result in a C/D ratio of 1.1 (Fig. 9). Intraoperatively, lateral fluoroscopic images are also used to confirm appropriate patellar height with @ 1/3 patella/groove engagement on fluoroscopic examination with knee in full extension or as the tip of the inferior pole of the patella should intersect the anterior projection of Blumensaat’s line at 30° of flexion. The TT was also translated 7 mm medially based on a tubercle sulcus angle (TSA) of zero (Fig. 10).
2. MPFL reconstruction with gracilis allograft.
3. No lateral lengthening was left necessary based on intraoperative tilt test.
4. Although (+) J-sign is present on injured side only, with (+) trochlear dysplasia, no significant supratrochlear bump is present. It was felt that distalization alone combined with medial stabilization would eliminate the J-sign.

Post-operative: Followed routine protocol discussed elsewhere in this journal. TT healed by 6 months post-operative. From is present, no J-sign. She was allowed to return to dance at 6 months after functional testing revealed limb symmetry index of >85%, with the exception of leaping and pounding activities which she returned to a year later. Functional testing at 1 year showed symmetric strength and balance in her operative and non-operative legs, with good core strength and endurance. She returned to competitive dance doing different types of dance. She is very confident in her knee, and it feels very stable with no episodes of instability postoperatively.

TTO Case Complication

A 17-year-old female tennis player who had previous undergone arthroscopic debridement of her right knee was referred for continued anterior knee pain. She has suffered from anterior knee pain for over a year which has gradually worsened with tennis to the point she had to stop playing. Her pain is worse with stair climbing, flexion, and running/cutting activities. She describes “locking” of her patella in extension and early flexion. She endorses the feeling of patellar instability though she has not had a frank dislocation event. She does not have confidence in her knees when she tries to be active. On examination,
she has a BMI of 25. The right knee motion is 0–145° with mild crepitus. She has four quadrants lateral and two quadrants of mediolateral translation. She has no apprehension but does have a J-sign with palpable and visual trochlear engagement at approximately 15° of flexion.

Further, examination is notable for “dynamic” valgus of her knee with single stance squat and poor core stability. AP IF (Fig. 11): Lateral radiographs: C/D ratio of 1.4. MRI: A patellar-trochlear index of 0.08. TT–TG: 18 mm, lateral patellar tilt: 13°. Her cartilage is well preserved on MRI. APIF (Fig. 11): Lateral radiographs:C/D ratio of 1.4. MRI: A patellar-trochlear index of 0.08. TT–TG: 18 mm, lateral patellar tilt: 13°. Her cartilage is well preserved on MRI. TT–TG: 18 mm, lateral patellar tilt: 13°. Her cartilage is well preserved on MRI.

Diagnosis: PF a pain in the setting of significant patella alta, with (+) patellar subluxation without frank instability. She underwent physical therapy for 4 months to include core strengthening, lower extremity stretching, improvement in body kinematics, and medial patellar taping. Taping improved her symptoms; however, she did have some aching in the knee after extended periods of taping. Modest strength gains were made with no change in symptoms of catching and locking.

Surgical plan

This patient was indicated for a distal TTO to address her symptoms of locking in full extension to early flexion, and to improve her ability to perform activities without pain and swelling. She has not had frank patellar instability despite her patellar mobility in full extension, given this, no MPFL reconstruction was not performed. Based on pre-operative and intraoperative imaging, distalization of 15 mm was planned and executed with a post-operative C/D ratio of 1.1. Her tubercle was also moved medially 7 mm to a TSA of zero. She progressed to full ambulation from 6 to 8 weeks without pain at the osteotomy site. At 2 months postoperatively, she was allowed to ambulate without crutches. Her osteotomy had not fully healed, and she was having a small amount of resorption at the distal aspect of her osteotomy (Fig. 12). At 3 months, the patient had a fall onto her knee. She was able to ambulate and carry on with her activities until she had significant worsening during activity in gym class a few days later. She was found to have a proximal tibia fracture at the distal aspect of her osteotomy (Fig. 13). She was treated with open reduction internal fixation with a tibial plate (Fig. 14). Postoperatively, she did well on to complete healing with full motion with improvement in her symptoms of catching and pain.

References


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