The role of Tibial Tubercle Osteotomies in 2017

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Medial Tibial-Tubercle Osteotomy (TTO)

Treatment of patellar instability historically largely followed the belief that the patella was subject to excessive lateral forces and inadequate medial forces, therefore surgical correction focused on "correcting" these factors, in particular, reducing the valgus Q angle.[1-3]

The original technique of tibial tubercle medialization was described by Elmslie and popularized by Albert Trillat.[4] The goal of this procedure was to diminish the "baïonnette" (Q-angle) in extension; the amount of medialization being entirely empiric. Extensor mechanism malalignment with medial tibial tubercle transfer became a central concept of PF instability surgery.[5,6] Surgical procedures aimed at stabilizing the patella were often successful in eliminating instability, but frequently the patient was left with symptomatic pain.[7-9] The literature at this time, largely reflecting the clinician's surgical approach, rarely distinguished surgery for pain from surgery for patellar dislocations. "Instability" was variably described, with the

characteristics of the patient population imprecisely defined.

The origins of the use of the tibial tubercle-trochlear groove (TT-TG) distance can be traced to the Q-angle[10] and the desire for a more objective measurement.[11] With the arrival of the CT scan, a method to measure TT-TG on slice imaging was devised, with defined thresholds in patellar instability populations.[12]

The clinical threshold of a TT-TG > 20 mm has been used as a surgical criterion to lower this distance to prevent lateral patellar dislocation (LPD) recurrence. Continued concerns include:

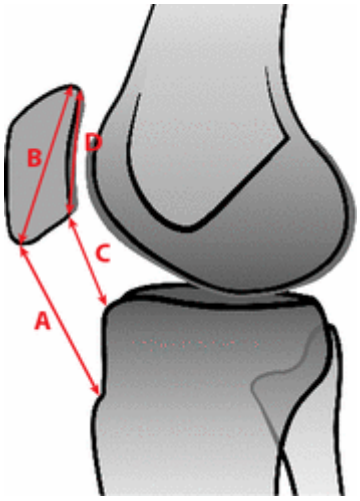
- It is a distance, not a ratio; therefore, its utility across different body types is not well understood.
- A common assumption is that increased TT-TG is due to increased lateralization of the distal extensor mechanism, and therefore 'corrected' by medialization of the tibial tubercle. With high grade trochlear dysplasia, the proximal sulcus medializes creating a higher TT-TG distance.
- There is increasing concern about the role of tibial rotation and the lack of good measurement schemes to understand its role in changing this measurement.[13]
- Elevated TTTG is rarely present in isolation in a patient with primary LPD, and is more often present when multiple anatomic patellar instability risk factors.[14,15]

The TT-PCL measurement attempts to control some of the concerns with this measurement by removing the tibia from the measurement,[16] but this does not eliminate the potential variability of tibial rotation. Current surgical algorithms place less emphasis on the need for medialization of the tibial tubercle in treatment of LPD.[17]

Distal TTO

Blumensaat (1938) was one of the first to recognize the patella's cephalad position, as viewed on lateral radiographs, and its relationship to patellar dislocation.[18] The association of patella alta with patellar instability was subsequently discussed by numerous authors.[12,19-21] The need for precise measurement of the patellar height was recognized and many methods were described.[22] The four most established methods of measurement include: the Insall-Salvati (I/S) index (1971),[23] the Blackburne-Peel (B/P) ratio (1977),[24] the Caton-Deschamps (C/D) ratio (1982, 1989),[25,26] and the modified I/S index (1992)[27] (Figure 1). A surgical procedure to correct patella alta was also described by Caton and Deschamps using their radiographic analysis to measure the correction needed, with correction accomplished by distalization of the tibial tubercle.[26,28]

Figure 1. Schematic diagram of two popular patella height ratios.



Insall-Salvati ratio: Measure on sagittal cut with greatest patellar length. Line (B) from most superior subchondral bone to 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 = A ÷ B

Caton-Deschamps index: Measure on sagittal cut with greatest patellar length. Line (D) measurement of cartilage articular surface; line (C) to the anterior corner of the superior tibial joint surface.

Caton-Deschamps = C ÷ D

Though the patellar height is well recognized as a risk factor for patellar instability, most measurement schemes relate the patella to the tibia. The importance of measuring the patella's sagittal position in relation to the trochlear groove is a critical factor when combined with trochlear dysplasia, which often results in a shallow but also shortened sulcus proximally. The overlap of the patellar cartilage with the trochlear cartilage (termed "functional engagement") combined with the trochlear depth is critical to understanding how quickly the patella is stabilized by the bony walls of the trochlea. Bernageau, a French radiologist, described an "engagement index" in 1969, defining the relative position of the patella to the groove on lateral radiographs.[29] The method was not widely accepted, possibly because it required quadriceps contraction, a source of variability. The patellar position in the sagittal plane, or *Patella-Trochlear Index,* was further analyzed by sagittal MR imaging, with upper and lower thresholds for patella-to-sulcus cartilage contact more precisely defined[30] (Figure 2).

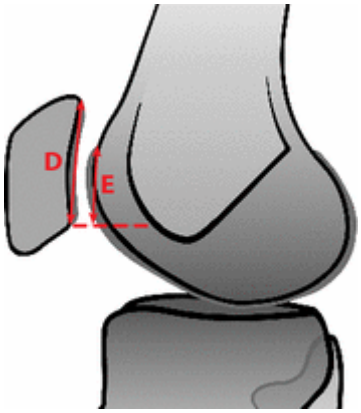


Figure 2. Patella Trochlear Index: Another method of measuring patella height is to use sagittal MRI to measure the true articular cartilage patellotrochlear relationship. In addition to giving a patella height measurement, this can be used to observe the "functional engagement" for the patella with the groove, which is dependent on the length of the trochlea in addition to the height of the patella.

Patellotrochlear index: Measure on sagittal cut with greatest patellar length. Line (D) measurement of cartilage articular surface. Strike a reference line at 90° to inferior end of line (D). Line (E) parallel to line (D), most superior femoral articular cartilage to reference line.

Patellotrochlear index = E ÷ D

Patellar height measurements on MRI have the advantage of:

- One can measure the engagement of the patellar cartilage with the trochlear groove cartilage
- MRI shows chondral surface, which is often different to the osseous surface
- One can see precisely the soft tissue attachment of the patellar tendon

Patellar height measurements on MRI have the disadvantage of:

- The degree of quadriceps contraction is difficult to quantify and will increase the patella's cephalad position when the knee is in extension
- MRI and CT measurements of patellar height are not equal[22,23] and the confidence intervals of "normal" patellar height should not be used interchangeably
- When there is significant lateral patellar tilt (chronic condition or with a large effusion) the best MRI cut showing the trochlear cartilage and the patellar cartilage is not in the same plane

A further method of evaluating patellar position through a two-slice technique in both sagittal and axial planes was defined by subsequent authors.[31]

There is little evidence to support the accuracy and validity of any one method, and none has proved to be suitable for universal application. Clinical interpretation of patellar height, along with patellotrochlear engagement, remains an 'evolving' clinical entity after nearly a century of recognition of patella alta as a risk factor for patellar dislocation.

When to perform a TTO

Central to the clinical approach to LPD is knowledge of the anatomic risk factors defined by imaging, as previously discussed (patella alta, trochlear dysplasia, increased TT-TG, excessive

lateral patellar tilt). H. Dejour and G. Walch, along with the "Lyonnaise" team, analysed over 1800 radiographic cases of recurrent patellar instability patients and controls utilizing true lateral knee radiographs to define patella alta and trochlear dysplasia, and a standardised computer tomography (CT) protocol to define TT-TG and lateral patellar tilt.[12,32] This effort defined a treatment algorithm utilizing threshold measurements for the four principal factors: trochlear dysplasia, patella alta > 1.2 as defined by the C/D index, excessive quadriceps vector as defined by TT-TG > 20 mm, and excessive lateral patellar tilt >20°. An algorithm for treating patellar instability, "le menu à la carte," corrected each anatomic (imaging) abnormality. Each procedure (trochleoplasty, tibial tubercle medialization, tibial tubercle distalization, vastus medialis plasty) was combined with a lateral release. Numerous publications are in the literature evaluating patient results using this algorithm.[5,6,12,28,33,34]

The static stabilizers in patella instability, in particular the MPFL, have been shown to have an important role in patellofemoral biomechanics[35-38] and injury;[39-41] the MPFL has emerged as the major stabilizer against lateral patellar translation in terminal extension This knowledge has allowed a paradigm shift in our surgical approach to lateral patellar dislocations; reconstruction of the MPFL is currently the cornerstone of surgical solutions for recurrent lateral patellar dislocation.[42-45] Combining the MPFL reconstruction with the established 'menu a la carte' continues to evolve. Despite early short term success with MPFL reconstruction,[42,44,46] complications are not infrequent.[47,48] The clinical scenario of when an isolated MPFL reconstruction is *'enough'* to stabilize the patella, without any bony work to compensate for a shallow trochlea, patella alta, or lateralized tibial tubercle, has not yet been categorized with clarity.[49] There is lack of consensus on the importance / necessity of surgical correction of ***all dysplastic factors*** and ***at what threshold***. The original "menu a la carte," correcting each risk

factor when excessive, has been challenged with the current inclusion of MPFL reconstruction in our surgical armamentarium. However, publications of outcomes of MPFL reconstruction separating patients according to a threshold measurement are rare.[17,50,51]

The clinical challenge that remains is detailing the anatomic thresholds for surgical correction of patellar height, combined with patellotrochlear engagement, that have the highest likelihood of resulting in optimal outcomes. This would allow better clinical algorithms of when (at what threshold) and how (what surgical procedure) to normalize this risk factor.

A similar clinical challenge is true for increased quad vector as reported by an elevated TT-TG. Elevated TT-TG, as an isolated risk factor, is rare in a population of primary lateral patellar dislocators. In a study of 159 patients, a '4-factor' analysis (Lyon factors) was reviewed for each patient (Figure 3). Twenty knees (13 %) had no excessive 'Lyon' factors. Excessive 4-factor measurements were present as follows: trochlear dysplasia (trochlear depth) 61%, patella alta (C/D) 54%, tilt 29%, and TT-TG 13%.

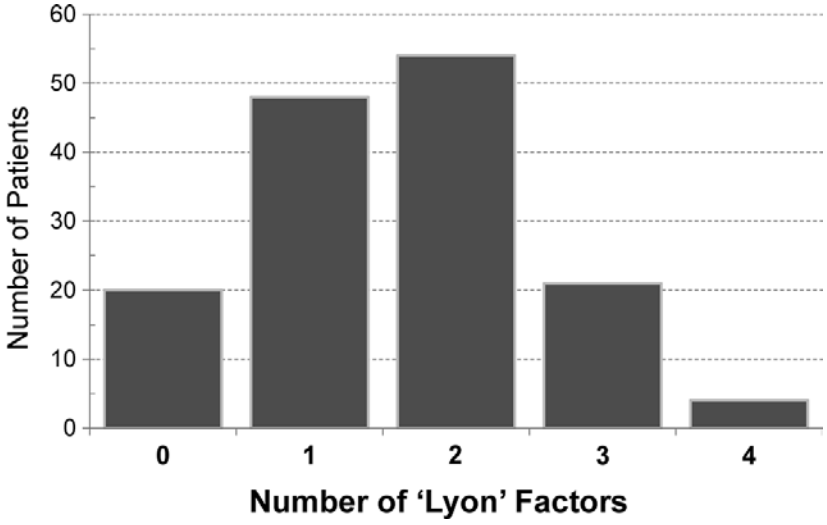


Figure 3. Number of measurements that were excessive (C/D > 1.2, trochlear depth < 3 mm, TT-TG > 20 mm, tilt > 20°) within each individual of our primary LPD patients.

Within a single individual, patella alta (C/D) had the highest representation when there was just one risk factor (23/48), followed by trochlear depth (19/48). TT-TG presented as an isolated risk factor in 4% of patients. In patients who had 2 excessive measurements, 71% of the time it was the combination of trochlear depth and C/D.[14] This and other studies suggest that the use of medialization without distalization, when following anatomic instability factors as an algorithm for patella stabilization, is a rare entity.

To answer this question of ideal surgical management for patellar stabilization, we need published studies to include evaluation and documentation of preoperative physical examination and imaging factors, and relate these factors to outcome measures.

Current barriers to clarity in our clinical approach to LPD is the lack of specificity in the imaging measurement that are central to our current clinical algorithms. A recent systematic search with meta-analysis of MR imaging measurements reveals wide variation imaging measurements used for clinical decision-making within both the controls and PF instability groups.[52] This study showed that appropriate abnormality thresholds exist for anatomic patellar instability MR imaging factors within groups of patients classified as PF instability, indicating sensitivity. The wide variation in the majority of measurements, especially in the control group, suggested poor specificity in most MR imaging measurements. Caton-Deschamps patella height index and trochlear depth measurement showed non-overlapping confidence intervals between the control and PF instability groups. Trochlear depth had the best discrimination in evaluation between the control and the PF instability groups.

References

1. Goldthwait JE. Permanent dislocation of the patella. The report of a case of twenty years' duration, successfully treated by transplantation of the patella tendons with the tubercle of the tibia. *Ann Surg.* 1899;29(1):62-68.
2. Hauser EDW. Total tendon transplant for slipping patella: A new operation for recurrent dislocation of the patella. *Surg Gynecol Obstet.* 1938;66:199-214.
3. Roux C. Luxation habituelle de la rotule. Traitement opératoire / [Recurrent dislocation of the patella. Operative treatment]. *Rev Chir*. 1888;8:682-689.
4. Trillat A, Dejour H, Couette A. Diagnostic et traitement des subluxation récidivantes de la rotule / [Diagnosis and treatment of recurrent dislocations of the patella]. *Rev Chir Orthop Reparatrice Appar Mot.* 1964;50:813-824.
5. Cox JS. An evaluation of the Elmslie-Trillat procedure for management of patellar dislocations and subluxations: A preliminary report. *Am J Sports Med*. 1976;4(2):72-77.
6. Brown DE, Alexander AH, Lichtman DM. The Elmslie-Trillat procedure: Evaluation in patellar dislocation and subluxation. *Am J Sports Med.* 1984;12(2):104-109.
7. Campbell WC, Edmonson JH, Crenshaw JR. Dislocations. In: Edmonson AS, Crenshaw AH, eds. *Campbell's Operative Orthopaedics, 6th Edition*. 6th ed. St. Louis, MO: Elsevier (C.V. Mosby); 1980:464.
8. Hawkins RJ, Bell RH, Anisette G. Acute patellar dislocations. The natural history. *Am J Sports Med.* 1986;14(2):117-120.
9. Macnab I. Recurrent dislocation of the patella. *J Bone Joint Surg [Am]*. 1952;34(4):957-967.
10. Brattström H. Shape of the intercondylar groove normally and in recurrent dislocation of patella. A clinical and x-ray-anatomical investigation. *Acta Orthop Scand.* 1964;Suppl 68:1-148.

11. Dejour D, Byn P, Ntagiopoulos PG. The Lyon's sulcus-deepening trochleoplasty in previous unsuccessful patellofemoral surgery. *Int Orthop*. 2013;37(3):433-439.
12. Dejour H, Walch G, Nove-Josserand L, Guier C. Factors of patellar instability: An anatomic radiographic study. *Knee Surg Sports Traumatol Arthrosc*. 1994;2(1):19-26.
13. Tensho K, Akaoka Y, Shimodaira H, et al. What components comprise the measurement of the tibial tuberosity-trochlear groove distance in a patellar dislocation population? *J Bone Joint Surg Am*. 2015;97(17):1441-1448.
14. Arendt EA, England K, Agel J, Tompkins MA. An analysis of knee anatomic imaging factors associated with primary lateral patellar dislocations. *Knee Surg Sports Traumatol Arthrosc*. 2016;[Epub ahead of print 04 May 2016] doi: 10.1007/s00167-016-4117-y:1-9.
15. Askenberger M, Janarv P-M, Finnbogason T, Arendt EA. Morphology and anatomic patellar instability risk factors in first-time traumatic lateral patellar dislocations. *Am J Sports Med*. 2017;45(1):50-58.
16. Seitlinger G, Scheurecker G, Hogler R, Labey L, Innocenti B, Hofmann S. Tibial tubercle-posterior cruciate ligament distance: A new measurement to define the position of the tibial tubercle in patients with patellar dislocation. *Am J Sports Med*. 2012;40(5):1119-1125.
17. Matsushita T, Kuroda R, Oka S, Matsumoto T, Takayama K, Kurosaka M. Clinical outcomes of medial patellofemoral ligament reconstruction in patients with an increased tibial tuberosity-trochlear groove distance. *Knee Surg Sports Traumatol Arthrosc*. 2014;22(10):2438-2444.
18. Blumensaat C. Die lageabweichungen und verrenkungen der kniescheibe / [The positional deviation and dislocation of the kneecap]. In: Payr E, Kirschner M, eds. *Ergebnisse der Chirurgie und Orthopädie. Einunddreissigster Band*. Berlin: Springer-Verlag; 1938:149-223.

19. Brattström H. Patella alta in non-dislocating knee joints. *Acta Orthop Scand.* 1970;41(5):578-588.
20. Geenen E, Molenaers G, Martens M. Patella alta in patellofemoral instability. *Acta Orthop Belg.* 1989;55(3):387-393.
21. Lancourt JE, Cristini JA. Patella alta and patella infera. Their etiological role in patellar dislocation, chondromalacia, and apophysitis of the tibial tubercle. *J Bone Joint Surg Am.* 1975;57(8):1112-1115.
22. Phillips CL, Silver DA, Schranz PJ, Mandalia V. The measurement of patellar height: A review of the methods of imaging. *J Bone Joint Surg Br.* 2010;92(8):1045-1053.
23. Insall J, Salvati E. Patella position in the normal knee joint. *Radiology.* 1971;101(1):101-104.
24. Blackburne JS, Peel TE. A new method of measuring patellar height. *J Bone Joint Surg Br.* 1977;59(2):241-242.
25. Caton J, Deschamps G, Chambat P, Lerat JL, Dejour H. [Patella infera. Apropos of 128 cases]. *Rev Chir Orthop Reparatrice Appar Mot.* 1982;68(5):317-325.
26. Caton J. [Method of measuring the height of the patella]. *Acta Orthop Belg.* 1989;55(3):385-386.
27. Grelsamer RP, Meadows S. The modified Insall-Salvati ratio for assessment of patellar height. *Clin Orthop Relat Res.* 1992;282:170-176.
28. Caton JH, Dejour D. Tibial tubercle osteotomy in patello-femoral instability and in patellar height abnormality. *Int Orthop.* 2010;34(2):305-309.
29. Bernageau J, Goutallier D, Debeyre J, Ferrané J. Nouvelle technique d'exploration de l'articulation fémoro-patellaire : incidences axiales quadriceps décontractés et quadriceps contractés. / [New exploration technique of the patellofemoral joint. Relaxed axial

quadriceps and contracted quadriceps]. *Rev Chir Orthop Reparatrice Appar Mot.* 1975;61(Suppl 2):286-290.

30. Biedert RM, Albrecht S. The patellotrochlear index: A new index for assessing patellar height. *Knee Surg Sports Traumatol Arthrosc.* 2006;14(8):707-712.
31. Dejour D, Ferrua P, Ntagiopoulos PG, et al. The introduction of a new MRI index to evaluate sagittal patellofemoral engagement. *Orthop Traumatol Surg Res.* 2013;99(8 Suppl):S391-398.
32. Walch G, Dejour H. Radiology in femoro-patellar pathology (in French). *Acta Orthop Belg.* 1989;55:371-380.
33. Donell ST, Joseph G, Hing CB, Marshall TJ. Modified Dejour trochleoplasty for severe dysplasia: Operative technique and early clinical results. *Knee.* 2006;13(4):266-273.
34. Verdonk R, Jansegers E, Stuyts B. Trochleoplasty in dysplastic knee trochlea. *Knee Surg Sports Traumatol Arthrosc.* 2005;13(7):529-533.
35. Amis AA, Firer P, Mountney J, Senavongse W, Thomas NP. Anatomy and biomechanics of the medial patellofemoral ligament. *Knee.* 2003;10(3):215-220.
36. Conlan T, Garth WP, Jr., Lemons JE. Evaluation of the medial soft-tissue restraints of the extensor mechanism of the knee. *J Bone Joint Surg Am.* 1993;75(5):682-693.
37. Desio SM, Burks RT, Bachus KN. Soft tissue restraints to lateral patellar translation in the human knee. *Am J Sports Med.* 1998;26(1):59-65.
38. Hautamaa PV, Fithian DC, Kaufman KR, Daniel DM, Pohlmeyer AM. Medial soft tissue restraints in lateral patellar instability and repair. *Clin Orthop Relat Res.* 1998;349(349):174-182.
39. Nomura E. Classification of lesions of the medial patello-femoral ligament in patellar dislocation. *Int Orthop.* 1999;23(5):260-263.

40. Nomura E, Horiuchi Y, Inoue M. Correlation of MR imaging findings and open exploration of medial patellofemoral ligament injuries in acute patellar dislocations. *Knee.* 2002;9(2):139-143.
41. Sallay PI, Poggi J, Speer KP, Garrett WE. Acute dislocation of the patella. A correlative pathoanatomic study. *Am J Sports Med.* 1996;24(1):52-60.
42. Deie M, Ochi M, Sumen Y, Adachi N, Kobayashi K, Yasumoto M. A long-term follow-up study after medial patellofemoral ligament reconstruction using the transferred semitendinosus tendon for patellar dislocation. *Knee Surg Sports Traumatol Arthrosc.* 2005;13(7):522-528.
43. Ellera Gomes JL. Medial patellofemoral ligament reconstruction for recurrent dislocation of the patella: A preliminary report. *Arthroscopy.* 1992;8(3):335-340.
44. Mikashima Y, Kimura M, Kobayashi Y, Miyawaki M, Tomatsu T. Clinical results of isolated reconstruction of the medial patellofemoral ligament for recurrent dislocation and subluxation of the patella. *Acta Orthop Belg.* 2006;72(1):65-71.
45. Steiner TM, Torga-Spak R, Teitge RA. Medial patellofemoral ligament reconstruction in patients with lateral patellar instability and trochlear dysplasia. *Am J Sports Med.* 2006;34(8):1254-1261.
46. Arendt EA, Lind M, van der Merwe WM. Indications for MPFL reconstruction after patellar dislocation. *ISAKOS Newsletter.* 2009;13(2):29-31.
47. Tompkins M, Arendt EA. Complications in patellofemoral surgery. *Sports Med Arthrosc.* 2012;20(3):187-193.
48. Shah JN, Howard JS, Flanigan DC, Brophy RH, Carey JL, Lattermann C. A systematic review of complications and failures associated with medial patellofemoral ligament reconstruction for recurrent patellar dislocation. *Am J Sports Med.* 2012;40(8):1916-1923.

49. Tompkins MA, Arendt EA. Patellar instability factors in isolated medial patellofemoral ligament reconstructions – What does the literature tell us? A systematic review. *Am J Sports Med*. 2015;43(9):2318-2327.
50. Nelitz M, Dreyhaupt J, Reichel H, Woelfle J, Lippacher S. Anatomic reconstruction of the medial patellofemoral ligament in children and adolescents with open growth plates: Surgical technique and clinical outcome. *Am J Sports Med*. 2013;41(1):58-63.
51. Wagner D, Pfalzer F, Hingelbaum S, Huth J, Mauch F, Bauer G. The influence of risk factors on clinical outcomes following anatomical medial patellofemoral ligament (MPFL) reconstruction using the gracilis tendon. *Knee Surg Sports Traumatol Arthrosc*. 2013;21(2):318-324.
52. Ridley TJ, Bremer Hinckel B, Kruckeberg BM, Agel J, Arendt EA. Anatomical patella instability risk factors on MRI show sensitivity without specificity in patients with patellofemoral instability: A systematic review. *J ISAKOS*. 2016;1(3):141-152.