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TT-TG vs. modified lateral patellar edge for determination of tibial tubercle transfer distance in Fulkerson osteotomy procedures

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Abstract

Background: Tibial tubercle-trochlear groove (TT-TG) distance is currently used at our institution to determine tibial tubercle medialization required in Fulkerson osteotomies. If the correlation between a modified lateral patellar edge (LPE) and the transfer distance was found to be stronger than its correlation with TT-TG, it would suggest that the best measurement to use is actually modified LPE.

Methods: The electronic medical records of 32 patients who underwent Fulkerson osteotomy procedures with femoral nerve stimulation were reviewed and measured. For each patient, modified LPE was measured on quadriceps active hyperextension MRI, and TT-TG was measured on passive extension MRI. Correlation between both TT-TG and LPE and tibial tubercle transfer distance was then determined and analysed.

Results: The correlation between TT-TG and actual intra-operative tibial tubercle transfer distance in Fulkerson osteotomy procedures with intra-operative femoral nerve stimulation was found to be weak at 0.436 ($p < 0.05$). The correlation between modified LPE and actual intra-operative tibial tubercle transfer distance was found to be strong at 0.697 ($p < 0.001$).

Conclusions: The correlation between modified LPE and actual intra-operative tibial tubercle transfer distance was stronger than the correlation between TT-TG and tibial tubercle transfer distance. This suggests that the modified LPE may actually be a better preoperative determinant than the currently-utilized TT-TG of the transfer distance required during Fulkerson osteotomy procedures.

Level of evidence: Level II, diagnostic study.

Keywords

Patellar realignment; Fulkerson osteotomy; TT-TG

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Conflict of interest

All of the authors listed for this manuscript fulfil the criteria for authorship laid out by the ICJME. This manuscript has never been published and is not under consideration for publication by any other journal.

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1. Introduction

Lateral patellar instability is a disabling condition characterized by apprehension or subluxation episodes most often occurring between 30 degrees knee flexion and complete extension [1–3]. The interplay of soft and bony anatomy, as well as dynamic skeletal muscle action contributes to the complex kinematics of the patellofemoral joint and requires a careful and thorough preoperative evaluation for patients failing non-operative therapy [4–5]. Distal realignment is among a multitude of operative treatments that can be used to address patellofemoral instability [1,6,7].

Transfer of the tibial tubercle performed by the Fulkerson osteotomy procedure is frequently used at our institution to correct for lateral patellar instability. Femoral nerve stimulation is used by the senior author to ensure intra-operatively that the patella tracks correctly within the trochlear groove. If corrected patellofemoral congruency is found to be imperfect during this femoral nerve stimulation, the tibial tubercle is transferred farther and patellofemoral tracking is again assessed. This method allows direct visualization of patellar tracking within the trochlear groove through an arc of motion before a final intra-operative decision is made regarding final placement of the tibial tubercle. The amount of lateral patellar overhang from the trochlear groove, or lateral patellar edge (LPE), can be clinically assessed during active knee extension by palpation of the patella during its movement over the lateral femoral condyle in active knee extension. From this palpation, a clinical estimation of the amount of overhang present is made. The procedure is considered to have reached surgical endpoint when patellofemoral congruency is confirmed and lack of lateral patellar overlap is directly visualized and palpated intra-operatively during quadriceps active extension by stimulation of the femoral nerve.

In addition to clinical estimates, quantitative measures exist that further define the overlap of the lateral-most point of the patella past the lateral femoral condyle (the lateral border of the trochlear groove) that occurs in patients with positive J signs during active knee extension. Performance of these measurements on axial Magnetic Resonance Imaging (MRI) scans allows clinicians to further estimate and quantify the degree of patellar overlap, and make preoperative estimations of the amount of tibial tubercle transfer that will be required to achieve maximum patellofemoral congruency intra-operatively. MRI scans that are used in the performance of these measurements include scans taken in 1) passive knee extension, 2) quadriceps active knee hyperextension, and 3) quadriceps active knee extension at 30 degrees of flexion.

Performance of these measurements preoperatively further defines the J sign, quantifies the degree of lateral patellar overlap in active knee extension, and allows surgeons to estimate the amount of tibial tubercle medialization that will be necessary to achieve maximum patellofemoral congruency. Tibial tubercle-trochlear groove distance (TT-TG) is the measurement currently utilized at our institution for estimation of the amount of tibial tubercle medialization required in these operations [8], however it is controversial how well this measurement serves as a patellofemoral index. Previous reports of normal TT-TG have varied between 10 and 15 mm, with a TT-TG over 20 mm considered abnormal [9–12]. TT-TG measurements can vary between imaging modalities, including Computerized

Tomography (CT) and MRI, and can show significant variability in intra- and inter-rater reliability [13–16]. Additionally, previous work by McDermott et al. [8] demonstrated that transfer distance representation by TT-TG varied based on whether the patella was in or out of the trochlear groove at 30 degrees of flexion. It has therefore been cautioned against the use of strict criteria to indicate patients for realignment surgery using the TT-TG [5].

Therefore, it is the hypothesis of this study that the modified LPE described by McDermott et al. [8] could also be used in the preoperative estimation of tibial tubercle medialization required to best achieve maximum postoperative patellofemoral congruency, and may actually correlate more strongly with actual final tibial tubercle transfer distance than TT-TG. The purpose of this case series is to determine whether the TT-TG or modified LPE correlates more strongly with actual intra-operative tibial tubercle transfer distance required to achieve maximum patellofemoral congruency post-operatively.

2. Materials and methods

The sample size was determined by the number of patients having Fulkerson osteotomy procedures performed by the senior author between the years 2006 and 2012, and had available imaging on which to perform the necessary measurements. As such, this was a sample of convenience. Patients were indicated for Fulkerson osteotomy after presenting clinically with lateral patellar instability in the setting of abnormal TT-TG and modified LPE, unresponsive to a trial of non-operative therapy. MRI scans of 43 Fulkerson Osteotomy patients were initially retrospectively reviewed. Eleven patients in total were ultimately excluded from the final study population. Eight patients were excluded because their axial quadriceps active hyperextension MRI was of very poor quality and measurements could not be performed. One patient was excluded because their chart did not contain all of the necessary imaging for the calculations required. Two patients were excluded due to poor radiographic representation of the tibial tubercle on MRI. After these exclusions were made, 32 patients were included in the final study population. All patients included in the final study population had a history of recurrent lateral subluxations and obvious patellofemoral maltracking on clinical exam. These findings were replicated mathematically on axial MRI scans.

All patients underwent Fulkerson osteotomy procedures using intra-operative femoral nerve stimulation of the quadriceps between the years 2006 and 2012 at a single institution. Tibial tubercle transfer was considered to be complete intra-operatively when the patella was visualized entering the trochlear groove congruently with the trochlea during knee extension.

Both tibial tubercle-trochlear groove (TT-TG) and modified LPE were observed in each patient. The measurements performed in this study were relatively simple, and the senior author taught the technique used to perform them to both investigators at the same time. By teaching the technique used to perform the measurements to both investigators simultaneously, the senior author ensured that the investigators were capable of performing the measurements both accurately and reliably before study data collection began.

As per previous descriptions in the literature, TT-TG was measured on passive knee extension MRI scans [18]. To perform this measurement, a reference line was first drawn tangentially to the posterior fem-oral condyles at the deepest point of the posterior intercondylar notch. A line perpendicular to the reference was then drawn at the deepest point of the trochlear groove. The distance from this line to the most prominent point on the tibial tubercle was then measured (the TT-TG, Figure 1) [19]. Modified LPE was measured on quadriceps active hyper-extension MRI scans. To perform this measurement, a line was drawn tangentially to the medial and lateral posterior femoral condyles. A line perpendicular was then drawn through the apex of the lateral fem-oral condyle extending through the patella. The centre of the patella was then found along this line. The distance from the center of the patella to the lateral-most anatomic aspect of the patella was then measured (the modified LPE, Figure 2) [8,20]. For the traditional LPE measurement, a line is drawn tangential to the medial and lateral border of the trochlear groove. A perpendicular line is then drawn through this reference line that intersects the lateral femoral condyle. The distance from this line to the lateral-most point of the patella (the traditional LPE, Figure 3) is then measured [4].

To pursue inter- and intra-rater reliability, each measurement was performed twice each by two investigators. The average of the four values obtained was used in the final analysis [21].

The correlations for 1) average TT-TG measurement vs. actual intra-operative tibial tubercle transfer distance and 2) average modified LPE measurement vs. actual intra-operative tibial tubercle transfer distance were determined using Pearson correlation coefficients. Statistical significance was set at $p < 0.05$.

Since this study was performed retrospectively, using data available in the electronic medical records of the patients operated on by the senior author. As such, no external source of funding was necessary to achieve completion of the study.

3. Results

A Fulkerson osteotomy was performed on 32 patients (32 knees), 17 on the left knee and 15 on the right. There were 15 males and 17 females. The age of the patients ranged from 13 to 51 years old with an average of 23.40 ± 8.57 . The average height was 169.15 ± 11.99 cm. Average weight was 83.74 ± 19.43 kg. Average Body Mass Index (BMI) was 28.53 ± 6.15 kg/m². These findings are summarized in Table 1.

Inter- and intra-rater reliability values were found to be very strong across all measurements. For TT-TG, intra-class correlation values for intra-rater reliability of investigator 1 were 0.897 (95% CI 0.802 to 0.948, $p < 0.05$) for single measures and 0.946 (95% CI 0.890 to 0.973, $p < 0.05$) for average measures. Intra-class correlation values for intra-rater reliability of investigator 2 were 0.794 (95% CI 0.623 to 0.893, $p < 0.05$) for single measures and 0.885 (95% CI 0.767 to 0.943, $p < 0.05$) for average measures. Intra-class correlation values for TT-TG inter-rater reliability were 0.940 (95% CI 0.882 to 0.970, $p < 0.05$) for single measures and 0.969 (95% CI 0.938 to 0.985, $p < 0.05$) for average measures (Tables 2–4).

For modified LPE, intra-class correlation values for intra-rater reliability of investigator 1 were 0.962 (95% CI 0.924 to 0.981, $p < 0.05$) for single measures and 0.981 (95% CI 0.961 to 0.991, $p < 0.05$) for average measures. Intra-class correlation values for intra-rater reliability of investigator 2 were 0.974 (95% CI 0.948 to 0.987, $p < 0.05$) for single measures and 0.987 (95% CI 0.973 to 0.994, $p < 0.05$) for average measures. Intra-class correlation values for modified LPE inter-rater reliability were 0.926 (95% CI 0.855 to 0.963, $p < 0.05$) for single measures and 0.962 (95% CI 0.922 to 0.981, $p < 0.05$) for average measures (Tables 5–7).

The Pearson correlation coefficient for average passive extension TT-TG measurement vs. actual tibial tubercle transfer distance was found to be weak, at 0.436 ($p < 0.05$). The Pearson correlation coefficient for average quadriceps active hyperextension modified LPE measurement vs. actual tibial tubercle transfer distance was found to be strong, at 0.697 ($p < 0.0001$).

4. Discussion

The results of this study showed a stronger correlation of actual intra-operative tibial tubercle transfer distance with modified LPE than TT-TG during Fulkerson osteotomy procedures. Measurements of modified LPE were shown to be consistent between examiners, with greater intra-rater reliability and similar inter-rater reliability values than the respective measurements of TT-TG. This suggests that modified LPE may be a better patellofemoral index during the preoperative assessment of patients undergoing Fulkerson osteotomy using the femoral nerve stimulation technique. Previous reports suggested that the traditional LPE was not predictive of actual intra-operative tibial tubercle transfer distance [8], however no prior literature has compared the two measures used in this current study.

At our institution up to the point of this study, the TT-TG was the most commonly utilized measure in the prediction of tibial tubercle medialization necessary to achieve maximum patellofemoral congruency in Fulkerson osteotomy procedures involving intra-operative femoral nerve stimulation. Achievement of this congruency allows the patella to travel smoothly in the trochlear groove across all degrees of knee flexion and extension, and corrects patellofemoral maltracking, preventing further extensor pathology of the knee and the need for further surgeries.

This study had a number of limitations. First, we did not report postoperative outcomes in this initial comparison study. Our intention of this current study however was to simply compare two preoperative objective MRI measurements. It is anticipated that future research will look into patient outcomes after realignment procedures using preoperative modified LPE as a guide to intra-operative decision making. Additionally, only 32 patients were included in the data analysis after elimination of 11 patients due to inadequate preoperative MRI imaging. Further research on this topic should therefore involve a prospective evaluation of a larger patient population before using these findings to direct clinical or intra-operative judgement.

5. Conclusions

TT-TG is an imperfect measurement for preoperative assessment of patients undergoing surgery for patellar instability as discussed in Section 1. The findings of this study suggest that a strong correlation exists between actual intra-operative transfer distance during realignment surgery and the modified LPE measurement. This correlation was stronger than the currently-utilized TT-TG. As such, it is the belief of this study that the modified LPE serves to predict the tibial tubercle transfer distance required in Fulkerson osteotomy procedures involving intra-operative femoral nerve stimulation and can be used to guide intra-operative decisions during realignment procedures if further research is in agreement with our current findings.

References

- [1]. Dejour D, Le Coultre B. Osteotomies in patello-femoral instabilities. *Sports Med Arthrosc* 2007;15(1):39–46. [PubMed: 17301701]
- [2]. Powers CM, Ward SR, Fredericson M, et al. Patellofemoral kinematics during weight-bearing and non-weight-bearing knee extension in persons with lateral subluxation of the patella: a preliminary study. *J Orthop Sports Phys Ther* 2003;33(11):677–85. [PubMed: 14669963]
- [3]. Stanford W, Phelan J, Kathol MH, et al. Patellofemoral joint motion: evaluation by ultrafast computed tomography. *Skeletal Radiol* 1988;17(7):487–92. [PubMed: 3201275]
- [4]. Duchman K, Mellecker C, El-Hattab AY, et al. Quantitative MRI of tibial tubercle transfer during active quadriceps contraction. *Clin Orthop Relat Res* 2011;469: 294–9. [PubMed: 20941650]
- [5]. Duchman K, Bollier M. Distal realignment: indications, technique, and results. *Clin Sports Med* 2014;33(3):517–30. [PubMed: 24993413]
- [6]. Redziniak DE, Diduch DR, Mihalko WM, et al. Patellar instability. *J Bone Joint Surg Am* 2009;91(9):2264–75. [PubMed: 19724006]
- [7]. Southwick WO, Becker GE, Albright JA. Dovetail patellar tendon transfer for recurrent dislocating patella. *JAMA* 5 20 1968;204(8):665–9. [PubMed: 5694507]
- [8]. McDermott SE, Anthony CA, McCunniff P, et al. A clinical and radiographic approach for establishing proper tibial tubercle transfer when using quad active femoral nerve stimulation. *Iowa Orthop J* 2013;33:84–9. [PubMed: 24027466]
- [9]. Ding DY, Kanevsky R, Strauss EJ, Jazrawi LM. Anteromedialisation tibial tubercle osteotomy for recurrent patellar instability in young active patients: a retrospective case series. *Injury* 2016;47(3):737–41. [PubMed: 26803695]
- [10]. Pandit S, Frampton C, Stoddart J, Lynskey T. Magnetic resonance imaging assessment of tibial tuberosity-trochlear groove distance: normal values for males and females. *Int Orthop* 2011;35(12):1799–803. [PubMed: 21394593]
- [11]. Alemparte J, Ekdahl M, Burnier L, Hernandez R, Cardemil A, Cielo R, et al. Patellofemoral evaluation with radiographs and computed tomography scans in 60 knees of asymptomatic subjects. *Arthroscopy* 2007;23(2):170–7. [PubMed: 17276225]
- [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. [PubMed: 7584171]
- [13]. Smith TO, Davies L, Donell ST. The reliability and validity of assessing medio-lateral patellar position: a systematic review. *Man Ther* 2009;14(4):355–62. [PubMed: 18824392]
- [14]. Camp CL, Stuart MJ, Krych AJ, 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. [PubMed: 23857884]
- [15]. Schoettle PB, Zanetti M, Seifert B, et al. The tibial tuberosity-trochlear groove distance; a comparative study between CT and MRI scanning. *Knee* 2006;13(1):26–31. [PubMed: 16023858]

- [16]. Saudan M, Fritschy D. AT-TG (anterior tuberosity-trochlear groove): interobserver variability in CT measurements in subjects with patellar instability. *Rev Chir Orthop Reparatrice Appar Mot* 2000;86(3):250–5. [PubMed: 10844355]
- [17]. Dejour H, Walch G, Nove-Josserand L, and Guier C Factors of patellar instability: an anatomic radiographic study. *Knee Surg Sports Traumatol Arthrosc*. 1994; 2: 19–26 [PubMed: 7584171]
- [18]. 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. [PubMed: 7584171]
- [19]. Duchman K, Mellecker C, Thedens DR, et al. Quantifying the effects of extensor mechanism medialization procedures using MRI: a cadaver-based study. *Iowa Orthop J* 2011;31:90–8. [PubMed: 22096427]
- [20]. Laurin CA, Dussault R, Levesque HP. The tangential X-ray investigation of the patellofemoral joint: X-ray technique, diagnostic criteria and their interpretation. *Clin Orthop Relat Res* 1979;144:16–26.
- [21]. Shoukri MM, Pause CA. *Statistical methods for health sciences*. 2nd ed. CRC Press; 1998.

Figure 1.

TT-TG Distance, reproduced with permission (Duchman K, Mellecker C, Thedens DR, Albright JP. Quantifying the effects of extensor mechanism medialization procedures using MRI: a cadaver-based study. *Iowa Orthop J.* 2011;31:90–8.)

Figure 2. Modified LPE Measurement, reproduced with permission (McDermott SE, Anthony CA, McCunniff P, Duchman K, Albright JP. A clinical and radiographic approach for establishing proper tibial tubercle transfer when using quad active femoral nerve stimulation. Iowa Orthop J. 2013;33:84–9.)

Figure 3.
Traditional LPE Measurement, reproduced with permission (Duchman K, Mellecker C, El-Hattab AY, Albright JP. Quantitative MRI of tibial tubercle transfer during active quadriceps contraction. *Clinical Orthopaedic Related Research*. 2011; 469:294–299.

Table 1

Patient demographic data.

Parameter	Mean
Age (years)	23.40 $\pm$ 8.57
Height (cm)	169.15 $\pm$ 11.99
Weight (kg)	83.74 $\pm$ 19.43
BMI (kg/m ²)	28.53 $\pm$ 6.15

Table 2

TT-TG intra-rater reliability, investigator 1.

Intra-class correlation (intra-rater, TT-TG)	Value	95% CI	p value
Single measures	0.897	0.802–0.948	<.05
Average measures	0.946	0.890–0.973	<.05

Table 3

TT-TG intra-rater reliability, investigator 2.

Intra-dass correlation (inter-rater, TT-TG)	Value	95% CI	p value
Single measures	0.794	0.623–0.893	<.05
Average measures	0.885	0.767–0.943	<.05

Table 4

TT-TG inter-rater reliability.

Intra-class correlation (intra-rater, Mod LPE)	Value	95% CI	p value
Single measures	0.940	0.882–0.970	<.05
Average measures	0.969	0.938–0.985	<.05

Table 5

Modified LPE intra-rater reliability, investigator 1.

Intra-class correlation (inter-rater, Mod LPE)	Value	95% CI	P value
Single measures	0.962	0.924–0.981	<.05
Average measures	0.981	0.961–0.991	<.05

Table 6

Modified LPE intra-rater reliability, investigator 2.

Intra-class correlation (intra-rater, Mod LPE)	Value	95% CI	P value
Single measures	0.974	0.948–0.987	<.05
Average measures	0.987	0.973–0.994	<.05

Table 7

Modified LPE inter-rater reliability.

Intra-class correlation (inter-rater, Mod LPE)	Value	95% CI	P value
Single measures	0.926	0.855–0.963	<.05
Average measures	0.962	0.922–0.981	<.05