Original Research

Tibial Tuberosity Rotation in Patients With Patellar Instability Versus Age- and Sex-Matched Controls

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Background: Several methods have been described to measure external rotation of the tibial tuberosity; all use femoral landmarks.

Purpose: To develop reproducible tibial-based methods to measure external rotation of the tibial tuberosity in patients with patellar instability.

Study Design: Cross-sectional study; Level of evidence, 3.

Methods: Included were magnetic resonance images of 61 patients with patellar instability and 61 age- and sex-matched healthy controls. Three novel methods using tibial landmarks to measure the rotation of the tibial tuberosity (plateau axis-tuberosity axis [PA-TA] angle, tibial geometric center-tuberosity axis [GC-TA] angle, and plateau axis-midtuberosity point [PA-MT] angle) as well as a femoral-based rotational measurement (surgical transepicondylar axis-tuberosity axis [sTEA-TA] angle) and the tibial tuberosity-trochlear groove (TT-TG) distance were measured and compared in instability patients and controls using unpaired *t* tests, and the cutoff values for predicting instability were calculated using receiver operating characteristic curves. The correlations between the angle measurements and the TT-TG distance were analyzed.

Results: Instability patients had significantly higher external rotation of the tibial tuberosity compared with controls with regard to the PA-TA angle (18.2° ± 9.6° versus 13.1° ± 6.8°; $P = .001$), GC-TA angle (8.4° ± 4.5° versus 11.5° ± 3.9°; $P = .0001$) and sTEA-TA angle (122° ± 8.5° versus 113.6° ± 6.3°; $P = .0001$). The mean TT-TG distance was also significantly higher in the instability group (18.2 ± 5.4 versus 11.5 ± 2.7 mm; $P = .001$). The cutoff values were 17.5° (area under the receiver operating characteristic curve [AUC] = 0.66) for PA-TA angle, 8.5° (AUC = 0.705) for GC-TA angle, 118.8° (AUC = 0.79) for sTEA-TA angle, and 15.2 mm for TT-TG distance (AUC = 0.863). PA-TA angle was significantly correlated with all other measurements ($r = 0.35$-0.71; $P \leq .006$ for all), whereas sTEA-TA angle had the strongest correlation with TT-TG distance ($r = 0.78$; $P = .001$).

Conclusion: The tibial tuberosity was externally rotated in patellar instability patients compared with age- and sex-matched controls, and this intrinsic malalignment of the proximal tibia was demonstrated in the tibial-based measurements.

Keywords: knee magnetic resonance imaging; patellar instability; tibial tuberosity rotation

Several risk factors, including joint hyperlaxity, lateralization of the tibial tuberosity, trochlear dysplasia, and increased femoral anteversion, have been described for recurrent patellar instability.[21,24] The tibial tuberosity-trochlear groove (TT-TG) distance is widely used to define lateralization of the tibial tuberosity and is an important factor in the decision to perform a medialization osteotomy.[7,14] A TT-TG distance >15 mm is considered to be pathological; however, this varies significantly with age, knee flexion, and rotation.[1,8,10] The TT-TG distance is an absolute value and does not take into account patient size and age[2,4,16]; in contrast, angular measurements can be used universally without having to adapt for confounding variables.

External rotation of the tibial tuberosity has also been reported as a risk factor for patellofemoral pain, osteoarthritis, or instability.[5,6,15,22,23,28] Based on our observation that patients with a normal TT-TG distance might have an externally rotated tibial tuberosity in our cohort of patellar instability cases, we hypothesized that an externally rotated tibial tuberosity might not necessarily result in an increased TT-TG distance. Several methods have been described to measure external rotation of the tibial tuberosity; all use femoral landmarks, with 3 methods

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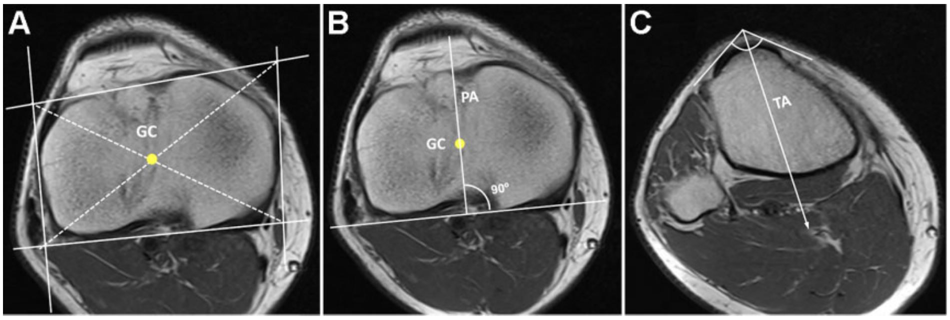

Figure 1. (A) The geometric center (GC) of the tibia was marked by the center of the rhomboid tangential to the tibial plateau in the axial slice where the tibial plateau was widest. (B) A line vertical to the posterior condylar axis of the tibial plateau, passing through the geometric center of the tibia, was created; this was named plateau axis (PA). (C) Two lines tangent to the medial and lateral cortices of the tibial tuberosity were drawn in the axial slice where the tibial tuberosity was most prominent and the patellar tendon insertion was visible. The bisector of the angle between these 2 lines was named the tuberosity axis (TA).

referencing the posterior condylar axis (PCA)[6,15,22] and 2 referencing the transepicondylar axis (TEA).[23,28]

The aim of this study was to develop reproducible tibial-based methods to measure external rotation of the tuberosity in patients with patellar instability and to compare these with age- and sex-matched controls. We also sought to define a cutoff value between controls and patellar instability, aiding the surgeon in deciding for a tibial tuberosity osteotomy. Our hypotheses were that due to an intrinsic malalignment of the proximal tibia, the tibial tuberosity would be significantly externally rotated in patients with patellar instability compared with controls and our measurement methods would be repeatable and would reliably differentiate between pathological and normal values.

METHODS

The study protocol received institutional review board approval, and informed consent was obtained from all patients in the study and control groups for use of their anonymized radiological data. All patients with a documented history of patellar instability treated conservatively or surgically in a single institutional database within the last 5 years were screened for eligibility. A total of 63 patients with pretreatment magnetic resonance imaging (MRI) performed in the same radiology center using identical techniques were included. These were age and sex matched with 63 patients with no history of patellofemoral pain or instability who underwent knee MRI for other reasons, and constituted the control group. Two patients in the study group were excluded due to inadequate imaging passing through the region of interest, leaving 61 patients with patellar instability and 63 controls. Although we aimed for full knee extension, slight flexion was inevitable since the knees were fixed in a knee coil during MRI scanning.

The sample size was estimated based on data from a previous study in which the mean difference in TT-TG between patellar instability and control groups was 7.04 with standard deviations of 5.16 and 4.68, respectively.[25] For the unpaired t test, 9 subjects in each group were required to achieve a power of 0.80 at a .05 significance level.

MRI Measurements

Three novel methods for measuring the rotation of the tibial tuberosity based on tibial landmarks were used. In addition, we used 1 previously described method referencing the surgical TEA (sTEA) of the distal femur.[23,28] The TT-TG distance was also measured and correlated with all 4 methods. All MRI measurements were made using Infinitt PACS Software (Infinitt Healthcare Seoul).

For the tibial-based measurements, the axial slice below the joint surface where the tibial plateau was widest was chosen as the first reference slice (Figure 1). The PCA of the tibia (tangent to the posterior cortex of the medial and lateral plateaus) was drawn. A modification of the technique described by Drexler et al was used to define the geometric

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Ethical approval for this study was obtained from Halic University (No. 193/24.12.2020).

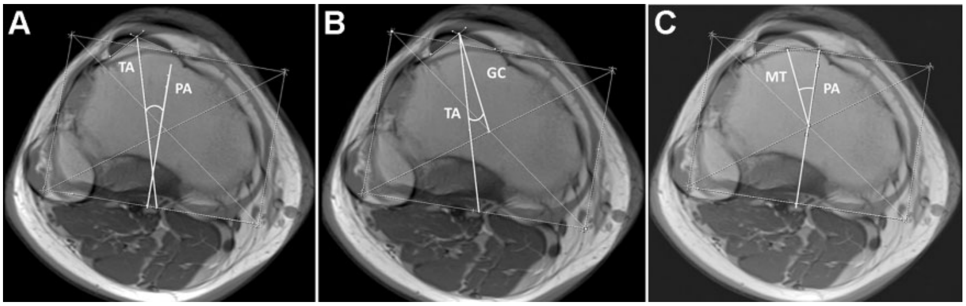

Figure 2. Tibial-based measurements. (A) PA-TA angle. The 2 axial slices described in Figure 1 were fused using PACS software, and the angle between the plateau axis (PA) and tuberosity axis (TA) was measured. (B) GC-TA angle. A line was drawn from the geometric center of the tibial plateau (GC) to the apex of the tibial tuberosity (TA). This apex was defined as the crossing of the medial and lateral tangents to the cortices of the tibial tuberosity. The angle between the line connecting the GC to the TA and the bisector of the medial and lateral tangents of the tibial tuberosity was measured. (C) PA-MT angle. A line was drawn connecting most lateral and medial ends of the patellar tendon insertion to the tibial tuberosity. The midpoint of this line was defined as the midtuberosity point (MT). The angle between the PA and the line connecting the MT to the GC was measured.

center of the tibial plateau (GC) using the rhomboid method.[12] Briefly, a rhomboid was created using the PCA of the tibia and the tangents to the most medial, lateral, anterior cortices of the tibial plateau. The geometric center of this rhomboid was defined as the GC (Figure 1A). A line vertical to the PCA of the tibial plateau, passing through the geometric center of the tibia was created; this was named the plateau axis (PA) (Figure 1B). A second axial slice distal to the first, in which the patellar tendon inserted fully on the tibial tuberosity and the tuberosity was most prominent was selected. Two lines tangent to the medial and lateral cortices of the tibial tuberosity were drawn. The bisector of the angle between these 2 lines was named the tuberosity axis (TA) (Figure 1C). The 2 axial slices were then fused using 3-dimensional (3D) registration and fusion software on a dedicated PACS workstation.

The following angles were measured in these images: PA-TA angle, GC-TA angle and PA-midtuberosity point (PA-MT) (Figure 2).

For the femoral-based measurement, the axial slices passing from the femoral epicondyles and the tibial tuberosity were fused using the above-mentioned 3D registration and fusion software, and the angle between the sTEA and the TA (sTEA-TA angle) was measured (Figure 3A). Finally, the axial slices passing through the deepest part of the trochlear groove and the insertion of the patellar tendon on the tibial tuberosity were fused, and the TT-TA distance was measured (Figure 3B).

All measurements were performed twice by 2 independent examiners (a musculoskeletal radiologist [E.P.S.] and an orthopaedic surgeon [M.P.]) 4 weeks apart so as to assess intra- and interrater reliability.

Statistical Analysis

SPSS version 15.0 (IBM Corp.) and MedCalc version 19.6.4 (MedCalc Software) were used in the statistical analysis. The Kolmogorov-Smirnov test was used to define normal distribution of values. Since all measurements had a normal distribution; unpaired *t* tests were used to compare the instability and control groups. Intra- and interobserver reliability of the MRI measurements was evaluated using the intraclass correlation coefficient (ICC), in which ICC values <0.5 are indicative of poor reliability, values between 0.5 and 0.74 indicate moderate reliability, values between 0.75 and 0.9 indicate good reliability, and values >0.90 indicate excellent reliability.[19] A comparison was made between the instability and control groups for all measured angles and the TT-TG distance. For measurements that showed significant differences between groups, the cutoff values for predicting instability were defined using receiver operating characteristic curves. The relationship between TT-TG distance and the 4 angle

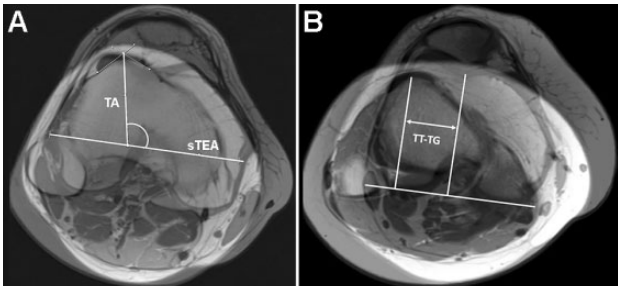

Figure 3. (A) Measurement of the sTEA-TA angle. The axial slices passing from the femoral epicondyles and the tibial tuberosity were fused. The angle between the surgical transepicondylar axis of the femur (sTEA) and the bisector of the tibial tuberosity (TA) was measured. (B) Measurement of the TT-TG distance. The axial slices passing through the deepest part of the trochlear groove and the insertion of the patellar tendon on the tibial tuberosity were fused. A line perpendicular to the posterior condylar axis of the femur passing through the deepest point of the trochlear groove (TG) was drawn. A second line perpendicular to the posterior condylar axis of the femur passing through the midpoint of the tibial tuberosity (TT) was drawn. The distance between TT and TG was measured in millimeters using PACS software (accuracy: 0.1 mm).

TABLE 1
Intra- and Interobserver Reliability of Measurements[a]

Interobserver	ICC	Intraobserver	ICC
PA-TA angle		PA-TA angle	
Observer 1	0.960	First measurement	0.916
Observer 2	0.963	Second measurement	0.910
GC-TA angle		GC-TA angle	
Observer 1	0.919	First measurement	0.817
Observer 2	0.891	Second measurement	0.869
PA-MT angle		PA-MT angle	
Observer 1	0.988	First measurement	0.972
Observer 2	0.965	Second measurement	0.975
sTEA-TA angle		sTEA-TA angle	
Observer 1	0.921	First measurement	0.9
Observer 2	0.985	Second measurement	0.977
TT-TG distance		TT-TG distance	
Observer 1	0.971	First measurement	0.84
Observer 2	0.893	Second measurement	0.975

[a]GC-TA, tibial geometric center-tuberosity axis; ICC, intraclass correlation coefficient; PA-MT, plateau axis-midtuberosity point; PA-TA, plateau axis-tuberosity axis; sTEA-TA, surgical transepicondylar axis-tuberosity axis; TT-TG, tibial tuberosity-trochlear groove.

TABLE 2
Comparison of Mean Values for Rotational Measurements and TT-TG Distance[a]

Measurement	Patellar Instability (n = 61)	Control (n = 63)	*P*
PA-TA angle, deg	18.2 ± 9.6	13.1 ± 6.8	**.001**
GC-TA angle, deg	8.4 ± 4.5	11.5 ± 3.9	**.0001**
PA-MT angle, deg	30.8 ± 6.7	28.8 ± 5.7	.073
sTEA-TA angle, deg	122 ± 8.5	113.6 ± 6.3	**.0001**
TT-TG distance, mm	18.2 ± 5.4	11.5 ± 2.7	**.001**

[a]Boldface *P* values indicate statistically significant difference between groups ($P < .05$). GC-TA, tibial geometric center-tuberosity axis; PA-MT, plateau axis-midtuberosity point; PA-TA, plateau axis-tuberosity axis; sTEA-TA, surgical transepicondylar axis-tuberosity axis; TT-TG, tibial tuberosity-trochlear groove.

measurements described was analyzed using the Pearson correlation coefficient. Statistical significance level for Alpha was set at 0.05.

RESULTS

The mean age was 23 ± 8 years in both the patellar instability group (n = 61) and control group (n = 63; $P = .98$), and the sex distribution was also similar between groups: 27 men and 34 women in the instability group versus 28 men and 35 women in the control group ($P > .99$). The intraobserver reliability values of the measurements were good to excellent for most values, ranging from 0.732 to 0.985 (Table 1). Although most ICC values for interobserver reliability were good to excellent (range, 0.734-0.988), the highest reliability was for PA-MT and sTEA-TA measurements and the lowest reliability was for TT-TG and GC-TA values (Table 1). Since both intra- and interobserver reliability were good, the mean values of 2 measurements of 2 observers were used in the further comparison of instability and control groups.

Our data revealed that the tibial tuberosity was externally rotated in the instability group compared with controls (Table 2). In brief, the PA-TA angle (18.2° ± 9.6° versus 13.1° ± 6.8°; $P = .001$), GC-TA (8.4° ± 4.5° versus 11.5° ± 3.9°; $P = .0001$) and sTEA-TA (122° ± 8.5° versus 113.6° ± 6.3°; $P = .0001$) depicted a significantly higher external rotation of the tibial tuberosity compared with controls. Although there was a tendency for greater external rotation of the tibial tuberosity in the instability group when measured with the PA-MT method, this did not reach statistical significance ($P = .073$). The mean TT-TG distance was also significantly higher in the instability group compared with controls (18.2 versus 11.5 mm; $P = .001$).

The results of the receiver operating characteristic curve analysis for measurements that were significantly different between groups are shown in Figure 4. The cutoff values between the instability and control groups were as follows: 17.5° (AUC = 0.66) for PA-TA, 8.5° (AUC = 0.705) for GC-TA, 118.8° (AUC = 0.79) for sTEA-TA, and 15.2 mm for TT-TG (AUC = 0.863).

Results of the correlation analysis of the measured parameters in patients with patellar instability are given in Table 3. PA-TA was significantly correlated with all other measurements ($r = 0.35\text{-}0.71$; $P \leq .006$ for all), whereas sTEA-TA had the strongest correlation with TT-TG ($r = 0.78$; $P = .001$). The entire data sets for the patellar instability and control groups are shown in Supplemental Tables S1 and S2, available online.

DISCUSSION

The most important findings of this study were that the tibial tuberosity was externally rotated in patients with patellar instability compared with age- and sex-matched controls, confirming our first hypothesis. This difference reached statistical significance for PA-TA, GC-TA, and sTEA-TA angle measurements (instability versus controls: PA-TA, 18.2° ± 9.6° versus 13.1° ± 6.8° [$P = .001$]; GC-TA, 8.4° ± 4.5° versus 11.5° ± 3.9° [$P = .0001$]; sTEA-TA: 122° ± 8.5° versus 113.6° ± 6.3° [$P = .0001$]).

The rotational malalignment of the lower extremity in patients with patellar instability has been studied extensively. Tensho et al[27] measured the angle between the PCAs of the femur and tibia concluded that knee rotation was a more important factor than tibial tuberosity lateralization in patients with patellar instability. This finding was corroborated by Diederichs et al,[9] who found a 1.6-fold higher knee rotation in patients with patellar instability compared with controls in 60 knees. These studies underlined the importance of rotational mismatch of the distal femur and proximal tibia; however, they did not specifically analyze the rotational profile of the tibial tuberosity.

All previous studies measuring the rotational profile of the tibial tuberosity have referenced femoral landmarks.[6,15,22,28] Chassaing et al[6] used the angle between the

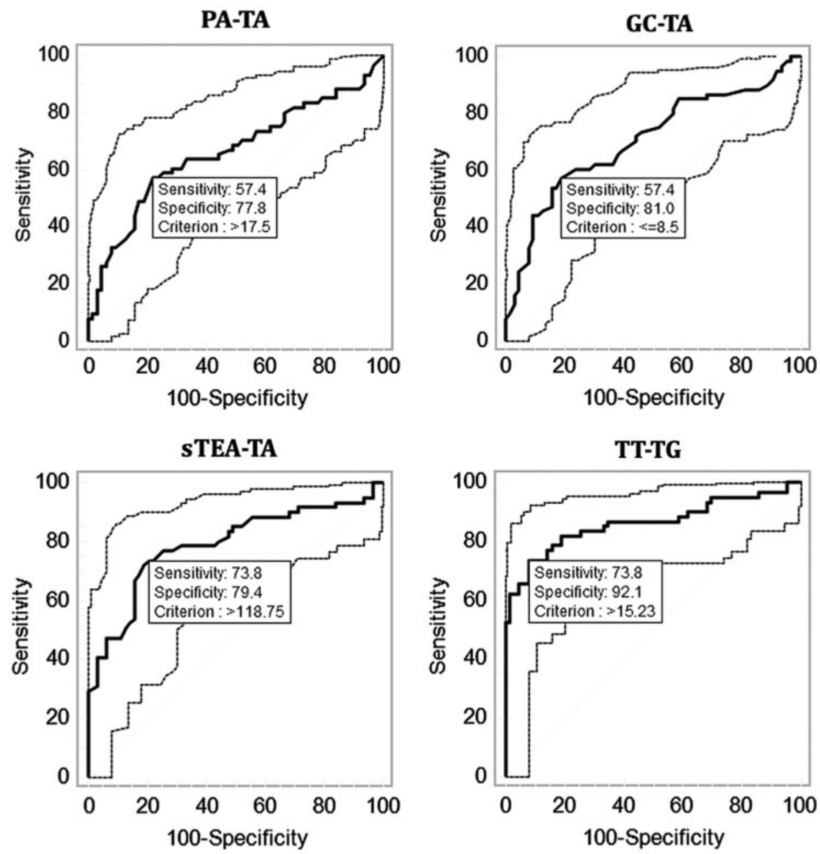

Figure 4. ROC curves showing cutoff values ("criterion") for PA-TA, GC-TA, sTEA-TA, and TT-TG. GC-TA, tibial geometric center-tuberosity axis angle; PA-TA, plateau axis-tuberosity axis angle; ROC, receiver operating characteristic; sTEA-TA, surgical trans-epicondylar axis-tuberosity axis angle; TT-TG, tibial tuberosity-trochlear groove distance.

TABLE 3
Correlation Analysis of Measured Parameters in the Patellar Instability Patients[a]

Measurement	GC-TA Angle	PA-MT Angle	sTEA-TA Angle	TT-TG Distance
PA-TA angle	$r = 0.71$ $P = .001$	$r = 0.43$ $P = .001$	$r = 0.39$ $P = .002$	$r = 0.35$ $P = .006$
GC-TA angle		$r = 0.14$ $P =$ NS	$r = 0.18$ $P =$ NS	$r = 0.18$ $P =$ NS
PA-MT angle			$r = 0.34$ $P = .008$	$r = 0.17$ $P =$ NS
sTEA-TA angle				$r = 0.78$ $P = .001$

[a]GC-TA, tibial geometric center-tuberosity axis; NS, nonsignificant; PA-MT, plateau axis-midtuberosity point; PA-TA, plateau axis-tuberosity axis; sTEA-TA, surgical transepicondylar axis-tuberosity axis; TT-TG, tibial tuberosity-trochlear groove.

PCA of the femur and a line connecting the medial and lateral borders of the patellar tendon insertion on the tibial tuberosity to measure the torsion of the tibial tuberosity. They reported that external torsion of the tibial tuberosity was strongly correlated with patellar instability. This measurement was also correlated with TT-TG distance in patients with patellar instability. Several other methods based on femoral landmarks have been described to measure this excessive external rotation of the tibial tuberosity. Nagamine et al[23] measured the angle between the most prominent part of the lateral femoral condyle and the midpoint of the tibial tuberosity in CT scans at 30° of flexion, and found this angle to be increased in patients with patellofemoral osteoarthritis. Hinckel et al[15] described 3 variations of the patellar tendon-trochlear groove angle, referencing the posterior femoral condylar axis or the TEA. These authors found increased external rotation of the tibial tuberosity in patients with patellar instability versus controls (30.8° and 15.7°, respectively). After calculating cutoff values, the authors concluded that angular measurements were more sensitive than distance measurements such as TT-TG or PT-TT. Tsujimoto et al[28] described a lateral deviation angle of the tibial tuberosity with the trochlea and found significant external rotation of the tibial tuberosity in patients with recurrent patellar dislocation compared with controls (36.3° versus 20.2°, respectively). Muneta et al[22] used the angle between the posterior femoral condylar axis and a line connecting the center of the patellar tendon insertion on the tibial tuberosity passing through the central point of the intercondylar notch. They called this the tibial tuberosity rotation angle and found this to be significantly different in patients with patellar subluxation compared with controls (64.5° versus 70°, respectively, with smaller angles denoting greater external rotation). Our findings confirmed that the tibial tuberosity is more externally rotated in patients with patellar instability compared with age- and sex-matched controls using different measurement methods based on tibial landmarks. This suggests that there may be an intrinsic anomaly of the proximal tibia in patients with patellar instability that causes an increase in the lateral quadriceps vector.

Imhoff et al[17] found no significant correlation between tibial torsion and trochlear dysplasia in 151 patients with patellar malalignment. The same group found no association with external tibial torsion and the lateralized position of the tibial tuberosity in 91 patients with patellar instability, and concluded that tibial torsion was an infratuberosity deformity.[29] These findings are in line with our results, since tibial torsion is measured between the axes of the proximal tibia and the malleoli and does not measure the intrinsic proximal tibial malalignment that we propose is present in the supratuberosity region. The measurements we propose are objective indicators of an externally rotated tibial tuberosity in relation to the proximal tibial condylar axis.

Jud et al[18] proposed a single supratuberosity derotational osteotomy of the proximal tibia to correct both the increased TT-TG distance and the excessive external rotation of the tibial tuberosity. In their computer-simulated osteotomies, they observed a 0.68-mm correction in TT-TG for every degree of derotation. A computer simulation study by Smith et al[26] found similar results, with each degree of tibial rotation causing approximately 0.5-mm change in TT-TG distance. These findings underscore the importance of the measurements that we propose to define the dysmorphic anatomy of the proximal tibial and may be helpful in planning the amount of derotation needed to correct patellar malalignment.

All 3 tibial-based measurement methods described in this study showed good to excellent intra- and interobserver reliability, confirming repeatability. Of these, the PA-TA angle had the highest reliability and was significantly correlated with all other measurements, including sTEA-TA angle and TT-TG distance. The mean PA-TA was 18.2° in the instability group versus 13.1° in the control; furthermore, the cutoff point to discriminate between instability and control for PA-TA was 17.5°. We therefore propose using PA-TA measurements to define the rotational profile of the proximal tibia in addition to other femoral-based measurements to better understand the underlying factors for patellar instability. Patients with a PA-TA over 18° may be candidates for derotational osteotomies of the proximal tibia. PA-TA values might also be helpful to decide on the type of tibial tuberosity osteotomy in patients with patellar instability having TT-TG values in the "gray zone" of 15 to 20 mm.

Femoral reference measurements also have an important role to define the mismatch between the trochlea and tibial tuberosity. Any one of the previously described measurements referencing the posterior femoral condylar axis or TEA can be utilized. The sTEA-TA measurement described in this study had a strong correlation with TT-TG ($r = 0.78$; $P = .001$) and a cutoff point of 118.8° with an AUC of 79%, indicating a strong discriminatory effect.

Derotational osteotomies have been described to correct the excessive external rotation of the tibial tuberosity in patients with patellar instability or patellofemoral pain syndrome. Fouilleron et al[13] reported good clinical outcomes and no recurrences in 36 patients after a derotational osteotomy performed between the tibial tuberosity and the joint line. More recently, Chassaing et al[6] described an internal rotation osteotomy without medialization in cadavers to improve patellar tracking in patients with patellar instability. Manilov et al[20] have described supra- and infratuberosity osteotomies to correct the rotation of the tibial tuberosity in 60 knees with patellar instability, reporting excellent Kujala scores at 66 months of follow-up. These studies highlight the clinical relevance of an accurate measurement of external rotation of the tibial tuberosity proposed in our study.

TT-TG distance measurements are widely used to quantify the increased lateral quadriceps vector in patellar instability. Dejour et al,[7] in their landmark article, used CT scans to measure the TT-TG distance and found this to be 19.8 mm in patients with patellar instability compared with 12.7 mm in normal knees. These values are smaller in the pediatric population with 1 study reporting 8.5 mm in the normal children and 12.1 mm in patients with patellar instability.[8] A TT-TG distance over 15 mm is generally considered to be pathological. We found that the cutoff point between the patellar instability and control groups for TT-TG was 15.2 mm, with an AUC value of 0.863, making this the most discriminatory parameter between normal and pathological in our study population. However, TT-TG measurements have several drawbacks. The TT-TG distance varies with knee flexion and rotation, with higher measurements in extension. Differences of 5 to 15 mm have been reported in the same knee between full extension and 30° of flexion.[1,10] Since MRI requires a knee coil, this leads to slight knee flexion and the values may be different from CT based measurements performed in full extension.[3]

TT-TG distance is an absolute measurement and does not take individual joint size into consideration. The variability of TT-TG values with patient size is controversial, with some studies describing the need for a TT-TG index to standardize this variability,[2,4,16] whereas 1 study showed no correlation with body height and knee size.[11] The angular measurements that we proposed are not affected by patient size or age and can be used an objective tool to decide for a tibial tuberosity osteotomy, independent from TT-TG distance measurements.

Limitations

Although a robust number of age- and sex-matched patients were analyzed with MRI using the same techniques by an orthopaedic surgeon and a musculoskeletal radiologist to ensure reproducibility, several limitations of this study must be considered. The study was carried out in adolescents and younger adults and the outcomes may not be applicable to smaller children. Not all the described methods reached statistical significance to depict the increased external rotation of the tibial tuberosity. Since no previous tibia referenced method existed, we had to develop and test novel methods and decide on the method that most accurately reflected the rotation of the tibial tuberosity. We did not take femoral anteversion into account; however, the main purpose of this study was to define the intrinsic malalignment of the proximal tibia and not analyze the rotational alignment of the limb, which has been extensively reported previously. Finally, the study carries the risk of all inherent biases of a retrospective study.

CONCLUSION

The tibial tuberosity is externally rotated in patients with patellar instability compared with age- and sex-matched controls and this intrinsic malalignment of the proximal tibia can be demonstrated with both femur and tibia referenced techniques. Tibia referenced measurements, specifically the PA-TA angle, may aid in the decision to perform a tibial tuberosity osteotomy in patients with moderate lateralization measured by TT-TG distance and may be helpful in planning supratuberosity derotation osteotomies of the proximal tibia.

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