Tibial Tuberosity–Trochlear Groove Distance Shows no Change in Patients with or Without Knee Osteoarthritis

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ABSTRACT

Objective: The primary aim of this study is to compare tibial tuberosity–trochlear groove (TTTG) distance in patients with or without knee osteoarthritis. Additionally, the variability of tibial tubercle according to trochlear groove was evaluated.

Materials and Methods: In this retrospective cohort study, TTTG distance was measured with two different methods on magnetic resonance (MR) images. TTTG distance was measured by the familiar method on 173 MR images, and by the novel method on 157 MR images of 175 patients totally. The patients were divided into two groups as group 1 (Kellgren Lawrence osteoarthritis grade <2) and group 2 (Kellgren Lawrence osteoarthritis grade ≥2). TTTG values measured by both methods were compared between groups. The coefficient of variation for all patients in TTTG values were calculated. A p-value <0.05 was considered as significant.

Results: The mean age, sex distributions, and side ratios were different between groups. There was no statistical difference in TTTG values between group 1 and 2. There was no statistically significant difference between the two measurement methods. The coefficient of variation for all patients in TTTG values were high (43.95% for familiar method and 44.64% for novel method). There was excellent interrater reliability for two measurement methods in both groups.

Conclusion: The TTTG distance is similar in patients with/without knee osteoarthritis. The position of the tibial tubercle according to the trochlear groove is variable, so the tibial tubercle may not be a good reference point for rotational position of the tibial component in total knee arthroplasty.

Keywords: Osteoarthritis, knee, femur, tibia

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Introduction

Tibial tuberosity–trochlear groove (TTTG) distance is a radiographic measurement that is often used to quantify malalignment on an axial plane. It is accepted as a reference in the assessment and treatment of patellofemoral problems [1-4]. Normal values for TTTG distance reported in the literature show a high degree of variability, and it is noted that these values are altered with knee flexion and weight bearing [1, 5-9]. TTTG distances exceeding 15 or 20 mm are generally considered pathological and may necessitate operative medialization of tibial tubercle in symptomatic patients [3, 4].

It is known that the shape of the trochlea and increased TTTG distance may affect patellofemoral dynamics and play a role in the etiology of patellofemoral osteoarthritis (OA) [10, 11]. However, the relationship between TTTG distance and tibiofemoral OA is unclear. We did not find any information in the English literature about the effect of TTTG distance on tibiofemoral OA or whether it should be taken into consideration the total knee arthroplasty surgical technique. On the other hand, the tibial tubercle is frequently used as a reference point to assess the rotational positioning of the tibial component in total knee arthroplasty. Despite its common use, its accuracy as a reference point is subject to debate. Its potential variability causing an altered TTTG distance is a concern for the consistency of the tibial and femoral component rotational alignment.

In the present study, we have aimed to answer the following questions: (1) Does TTTG distance differ between normal patients and patients with OA? (2) Does TTTG distance change if transepicondylar axis (TEA) is taken as the reference line instead of the posterior condylar line (PCL), in an attempt to eliminate possible measuring errors caused by posterior femoral chondral defects in arthritic knees? (3) Is TTTG distance, the position of the tibial tubercle in the mediolateral aspect with respect to the trochlear groove, variable?

Materials and Methods

Following approval from the Institutional Review Board, magnetic resonance (MR) images of 175 knees of 175 consecutive patients were evaluated retrospectively. Informed consent for acquiring the MR images of the knee was obtained from all patients. All measurements on MR images were performed by two of the authors (TA and UK), and the arthrosis grade was determined by the consensus of the same authors. The patients were divided in two groups. Group 1 comprised 102 patients with normal-appearing bilateral standing knee antero-posterior (AP) radiographs (Kellgren–Lawrence OA grade <2) who had their MR images acquired because of the suspicion of meniscal injury. Group 2 comprised 73 patients with osteoarthritic changes on bilateral standing AP radiographs (Kellgren–Lawrence OA grade ≥2) who had their MR images taken for degenerative OA. Group 1 comprised 50 males and 52 females [mean age=45 years (30–59), standard deviation (SD)=11.1], and Group 2 comprised 9 males and 64 females [mean age=65 years (45–80), SD=7.7]. Patients with AP and lateral knee graphs and knee MR and who were above 18 years of age were included in the study. No patient had any history of fracture around the knee, full ligamentous injury, or inflammatory arthropathy. TTTG distance was measured using the PCL reference technique in a total of 173 patients. In two patients from the osteoarthritic group, TTTG distance could not be measured because of the bad quality of MRI scans. Alternative TTTG (TTTG-A) distance was measured in a total of 157 patients (88 patients in Group 1 and 69 patients in Group 2) who had MR images in which medial and lateral femoral condyles were clearly observed.

Imaging protocol

Images were taken on a 1.5 T scanner (GE Medical Systems, Milwaukee, WI). Fast spin echo images (repetition time=2600, echo time=35.0) were obtained from above the patella to below the tibial tubercle. The standard clinical protocol was followed for MR image sections of the knees in relaxed position, and axial sections were constructed on a parallel plane to the tibial joint surface. The field of view was 20 cm, and the slice thickness was 4 mm with a 1 mm interslice gap.

TTTG measurement

All the measurements were performed by an experienced orthopedic surgeon and a musculoskeletal radiologist. All measurements were taken using electronic calipers on a picture archiving and communication system workstation (ExtremePACS 2010-001, Hacettepe University, Teknokent, Ankara, Turkey). Two different methods were used for the measurement of TTTG distance.

The first method was performed on normal and osteoarthritic knee MR scans using the technique described by Camp et al. [6] on T1-weighted transverse MR images (Figure 1a, c). The most distal MR image slice with full cartilage coverage of the trochlear groove was chosen to assess the trochlear groove. The MR image containing the midpoint of the distal insertion of the patellar tendon at the tibial tuberosity was used to estimate the position of the tibial tubercle. On the first image, a line was drawn tangential to the chondral border of the posterior condyles of the femur. The trochlear line was drawn perpendicular to PCL through the deepest portion of the trochlear groove. This line was then transferred to the most cephalad image in which the patellar tendon was fully in contact with the tibial tubercle. The center of the tibial tubercle was marked at the midpoint of the patellar tendon on this image. The final TTTG distance was calculated by taking the perpendicular distance from the center of the tibial tubercle to the transferred trochlear line.

For the second technique (Figure 1b, c), the knee T1-weighted transverse MR image scans in which medial and lateral femoral epicondyles could be determined were evaluated. The femoral side of the transverse MR images was selected as follows: Transverse MR image sections were examined, and by using consecutive scans, the appropriate scans which showed the most prominent point of the lateral epicondyle and the deepest point of the sulcus of the medial epicondyle were determined. TEA is defined as the line joining the most prominent point of the lateral epicondyle and the deepest point of the medial epicondyle. The trochlear line was drawn

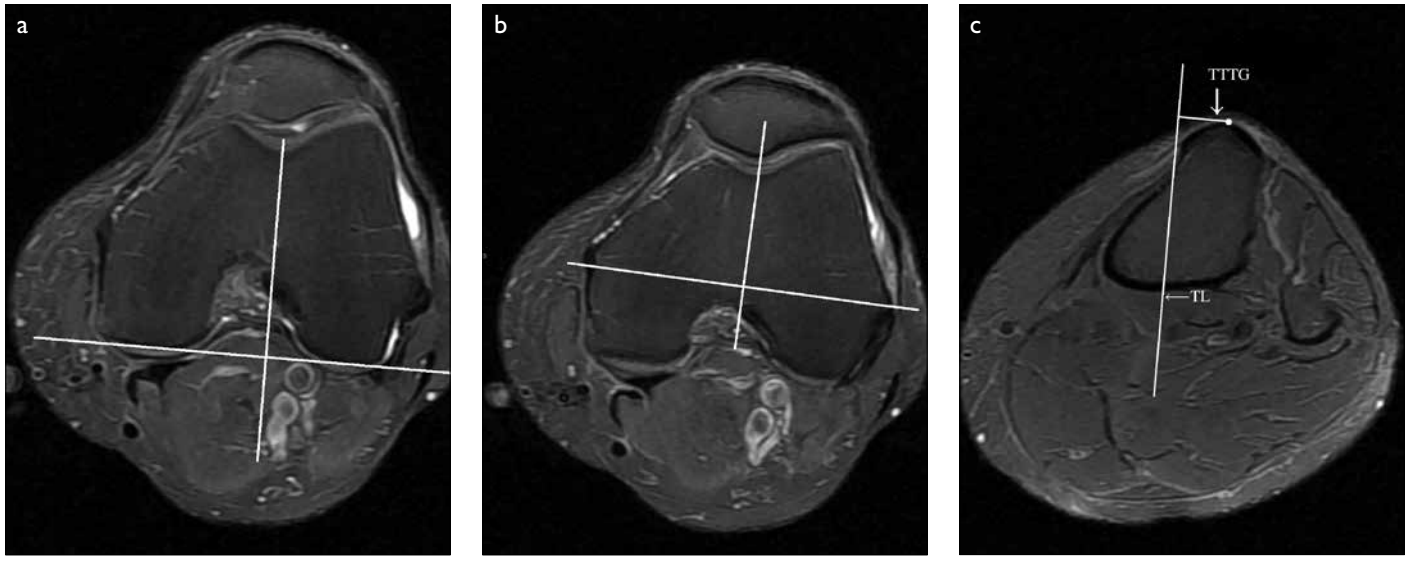

Figure 1. a-c. Determination of the trochlear line according to PCL. The most distal MR image slice with full cartilage coverage of the trochlear groove was chosen to assess the trochlear groove, and PCL was drawn tangential to the chondral border of the posterior condyles of the femur. The trochlear line was drawn perpendicular to PCL (a). Determination of the trochlear line according to TEA. The appropriate scans showing the most prominent point of the lateral epicondyle and the deepest point of the sulcus were determined. The trochlear line was drawn perpendicular to TEA (b). In both techniques, the trochlear line was then transferred to the most cephalad image in which the patellar tendon was fully in contact with the tibial tubercle. The center of the tibial tubercle was marked at the midpoint of the patellar tendon on this image. The final TTTG distance was taken as the perpendicular distance from the center of the tibial tubercle to the transferred trochlear line (c)

PCL: posterior condylar line; MR: magnetic resonance; TEA: transepicondylar axis; TTTG: tibial tuberosity–trochlear groove

perpendicular to TEA, and TTTG-A distance was measured as described in the previous technique.

Statistical analysis

The sample size was calculated on values of TTTG as primary outcomes. Based on our unpublished pilot data, the sample size for two groups was calculated based on the data with an expected difference between group means is 1.7 and SD is 3.50, α=0.05, and β=0.2. A sample size of 73 patients per group was necessary. Shapiro–Wilk test was used as a normality test. Continuous variables were compared using Student's t-test and Mann–Whitney U test when the data were not normally distributed. Categorical variables were compared using Pearson's chi-squared test and Fisher's exact test. Paired data were analyzed using paired t-test. Intraclass correlation coefficients were calculated to determine the interobserver reliability of the measurements. A p-value of <0.05 was considered significant. All statistical analyses were performed using the Statistical Package for Social Sciences version 22.0 (IBM Corp.; Armonk, NY, USA).

Results

The demographic data (mean age, sex ratio, and side) were different between groups 1 and 2 (Table 1). There was no statistical difference in the TTTG and TTTG-A values between groups 1 and 2 (Table 2, 3). TTTG and TTTG-A values were similar between sexes and sides in both groups. Furthermore, there was no statistically significant difference between the two measurement methods (Table 4). The interobserver reliabilities for both measurement methods are shown in Table 5. On the other hand, the coefficient of variation (CV) in TTTG and TTTG-A values for both groups was high (43.95% for TTTG and 44.64% for TTTG-A).

Discussion

In the present study, no difference in TTTG values between healthy and osteoarthritic knees was found. On the other hand, using TEA line instead of PCL for measuring TTTG distance did not make a difference in TTTG values. Furthermore, the location of the tibial tubercle in the mediolateral direction with respect to the trochlear groove was variable.

Tibial tuberosity-trochlear groove distance was originally described on radiographs and was later adapted to computerized tomography (CT) and MR. All three methods are accepted as reliable methods [1, 4, 7]. Alemparte et al. [5] studied the knees of healthy volunteers with 15° of flexion by CT and found that normal values for TTTG distance were 13.6±8.8 mm in asymptomatic patients. Pandit et al. [7] reported that the normal TTTG distance in patients without any patellofemoral or ligamentous instability with the knee in full extension was 10±1 mm and MR imaging was a reliable imaging modality for measurement. In a study by Camp et al. [6], MR images of patients with patellar instability were evaluated by radiologists and orthopedists and the mean TTTG distances were found to be 14.7±4.87 mm and 15.4±5.41 mm, respectively. All TTTG values that we measured in both groups were less than 20 mm and were similar for both normal patients and patients with OA.

In the standard technique for the measurement of TTTG distance, the reference line for the trochlear groove is drawn perpendicular to PCL [6, 12]. PCL can be drawn from the bone or cartilage. For the measurement of functional TTTG distance, the PCL line that is drawn from the cartilage (chondral PCL) can provide more reliable results [12]. We created the reference line perpendicular to chondral PCL for the conventional method and TEA for the alternative method, hypothesizing that using chondral PCL in osteoarthritic knees would confound measurements. However, the results were similar

Table 1. Age, sex, and side comparison between groups

	Group 1	Group 2	p
Age	45 (30–59)±11.1	65 (45–80)+7.7	<0.001
Sex Male	52 (51%)	9 (12.3%)	
Female	50 (49%)	64 (87.7%)	<0.001
Side Right	45 (44.1%)	48 (67.6%)	
Left	57 (55.9%)	23 (32.4%)	0.002

†Spearman's correlation test.

Table 2. TTTG values in groups 1 and 2

	Group 1 (n=102)	Group 2 (n=71)	p
TTTG	8.69±3.82	7.90±3.43	0.163

TTTG: tibial tuberosity–trochlear groove distance

Table 3. TTTG-A values in groups 1 and 2

	Group 1 (n=88)	Group 2 (n=69)	p
TTTG-A	8.70±3.69	7.62±3.58	0.064

TTTG: tibial tuberosity–trochlear groove distance

Table 4. Comparison of TTTG and TTTG-A values calculated by both measurement methods in patients

	Group 1 (n=88)	Group 2 (n=69)	p
Group 1 (n=88)	8.70±3.55	8.70±3.69	0.986
Group 2 (n=69)	8.03±3.38	7.73±3.57	0.153

TTTG: tibial tuberosity–trochlear groove distance; TTTG-A: alternative tibial tuberosity–trochlear groove distance

Table 5. Interobserver reliability for two measurement methods in both groups

Group 1	Intraclass correlation coefficients	95% confidence intervals
TTTG	0.9507	0.9279–0.9664
TTTG-A	0.9961	0.9941–0.9974
Group 2		
TTTG	0.8953	0.8375–0.9333
TTTG-A	0.9883	0.9813–0.9927
Total		
TTTG	0.9308	0.9078–0.9483
TTTG-A	0.9928	0.9902–0.9948

TTTG: tibial tuberosity–trochlear groove distance; TTTG-A: alternative tibial tuberosity–trochlear groove distance

with the standard and alternative methods. We suggest that both reference lines can be used for TTTG distance measurement.

Howell et al. [13] studied MR images of 115 knees treated with total knee arthroplasty and reported that the location of the tibial tubercle in the mediolateral direction was variable with respect to the medial tibia. They concluded that the medial border and medial one third of the tibial tubercle are not reliable landmarks when the goal is to kinematically align the rotation of the tibial component on the tibia. The aim of total knee arthroplasty is not only to achieve adequate tibial rotation but also to ensure the rotational compliance of both components. Therefore, we evaluated the location of the tibial tubercle in the mediolateral direction according to the trochlear groove. We found the mean TTTG distance and SDs to be 8.3±3.6 and 8.2±3.6 for groups 1 and 2, respectively. The CV values were alpproximately 44% for both groups, and this finding may indicate that the position of the tibial tubercle is variable depending on the trochlear groove. Owing to this variability, choosing the medial one third of the tibial tubercle as a landmark to determine the rotation of the tibial component in the total knee arthroplasty surgical technique may not provide rotational compliance of both components. Whether pre-operative measurement of TTTG distance contributes to total knee arthroplasty surgery may be the subject of a different study.

The present study had several limitations. Different demographic data (mean age, sex ratio, and side) of the groups may have affected the results. However, especially in terms of age, ages of patients with or without knee OA are expected to be different. Furthermore, the present study mainly focused on the relationship between TTTG distance and knee OA. However, besides TTTG distance, the rotational alignment from the hip to the ankle (femoral anteversion, tibial torsion, rotational alignment of the distal femur, and proximal tibia) may affect the load to the knee joint. We did not evaluate the degree of OA of the patellofemoral joint and the femorotibial angle in our patients. On the other hand, a recent study [11] showed that the femorotibial angles in patients with severe patellofemoral OA were significantly larger than those in patients with mild patellofemoral OA, and TTTG distance in patients with severe patellofemoral OA was significantly larger than those in patients with mild patellofemoral OA. However, the aforementioned study did not address the relationship between TTTG distance and tibiofemoral OA.

In conclusion, the TTTG distance in patients with knee OA is similar to the TTTG distance in those with normal knees. The position of the tibial tubercle according to the trochlear groove is variable. Therefore the tibial tubercle alone may not be a good reference point for rotational position of the tibial component in total knee arthroplasty. For TTTG distance measurement, TEA can be used instead of PCL if needed.

Ethics Committee Approval: Ethics committee approval was received for this study from the local Clinical Research Ethics Committee.

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - N.S., T.A., G.O.; Design - N.S., G.O.; Supervision - N.S.; Materials - N.S.; Data Collection and/or Processing - G.O.; Analysis and/or Interpretation - G.O., N.S.; Literature Search - T.A., N.S.; Writing Manuscript - N.S.; Critical Review - T.A.

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