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Determination of knee joint line in relation to bony landmarks: a CT study in Turkish population

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Abstract

Objectives: Evaluation of the knee joint line is important in terms of clinical outcomes in lower extremity alignment surgeries. Since there are a limited number of studies examining the relationship between the normal knee joint line and the bony landmarks around the knee in Turkish society, we evaluated the relationship between the knee joint line and the bone landmarks in the Turkish population.

Methods: Knee CT images of 100 patients (50 females, 50 males) aged between 18–50 years were retrospectively evaluated. The distance between the joint line and the medial epicondyle, lateral epicondyle, apex of head of fibula, patella lower pole, tuberositas tibia and interepicondylar distance of the femur was evaluated.

Results: With the exception of lateral epicondyle/femoral transepicondylar width, tibial tubercle distance/femoral transepicondylar width, tibial width /femoral transepicondylar width, and tibial width/tibial tubercle distance; all ratios differed between the genders with statistical significance ($p<0.005$).

Conclusion: CT evaluation of the knee joint allows making precise measurements in the coronal, axial and sagittal planes. We believe that the values we determined will help surgeons to determine the joint line during total knee replacement and revision knee replacement surgery in Turkish patients.

Keywords: bony landmarks; femoral interepicondylar width; knee, knee joint line

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Introduction

The importance of the orientation of the joint line of the knee joint has been demonstrated in many clinical studies.[1,2] Defining the joint line is crucial in terms of clinical outcomes in lower extremity alignment surgeries. The importance of restoration of the knee joint line in total knee replacement and revision knee replacement surgeries has also been emphasized in many studies. It has been reported that a change of more than 4 mm in the joint line will affect the clinical outcome.[3–6] Particularly determining the intraoperative joint line is an important challenge for surgeons while operating patients with bone loss and osteolysis. In general, the joint line is evaluated radiologically during preoperative planning. In this evaluation process, certain anatomical bony landmarks are marked and the level of the joint line is calculated, and efforts are made to place the femoral and tibial components in accordance with the normal joint line during the operation. It has been reported that bony landmarks are reliable and widely used in determining the joint line during revision knee replacement surgery.[7–9]

The distances between the bony landmarks and the joint line have been found to be significantly affected by variables such as gender, ethnicity, and the height of the patient.[10] Some researchers have suggested that the ratio of the distance from bony landmarks to the joint line and the femoral transepicondylar width, also called the epicondylar ratio, is more reliable than the distances of the bony landmarks to the articular line.[8,9,11] However, studies conducted among specific ethnic populations have yielded differences in the recommended values.[12]

Since there is a limited number of studies examining the relationship between the normal knee joint line and the bony landmarks around the knee in the Turkish population, we aimed to evaluate the relationship between

the knee joint line and bony landmarks in the Turkish population using computerized tomography (CT) images of normal knees.

Materials and Methods

Knee CT images of 100 patients (50 females, 50 males) aged between 18–50 years were evaluated retrospectively. The images of the patients with fractures around the knee, degenerative changes in the articular cartilage, osteochondral defects, and patients with a history of previous knee surgery were not included.

All exams were performed with a 16-slice multidetector-row scanner (Toshiba Alexion, Toshiba Medical Systems Corporation, Otawara, Japan). The acquired 2-mm-thick axial images and reformatted coronal and sagittal images were observed independently with electronic calipers at a picture archiving and communication system (PACS) station by an orthopedic surgeon. First, the joint line of the knee (JL) was determined as the line passing through the most distal points of the medial and lateral femoral condyles in the coronal plane and/or as the line passing through the most distal point of the femur perpendicular to the anatomical axis of the tibial shaft in the sagittal plane. Subsequently, the following parameters were measured.

In the Coronal Plane

- **Medial epicondylar distance (MED):** The distance between the JL and the most medial point of the femur where the medial collateral ligament attached (**Figure 1**).
- **Lateral epicondylar distance (LED):** The distance between the JL and the most lateral point of the femur where the lateral collateral ligament attached (**Figure 1**).
- **Proximal tibiofibular joint distance (PTFJD):** The distance between the JL and the center of the horizontal portion of the proximal tibiofibular joint (**Figure 2**).
- **Apex of head of fibula distance (AFD):** The distance between the JL and the superior point of the apex of head of fibula (**Figure 3**).

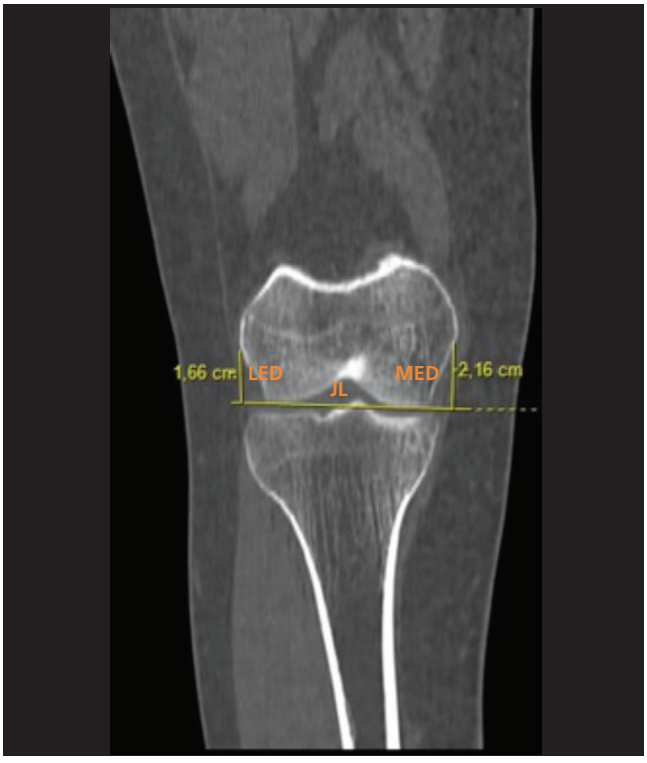

Figure 1. Coronal CT image. Medial epicondylar distance (**MED**) is the distance between joint line (**JL**) and the most medial point of the femur where the medial collateral ligament originated and the lateral epicondylar distance (**LED**) is the distance between JL and the most lateral point of the femur where the lateral collateral ligament originated.

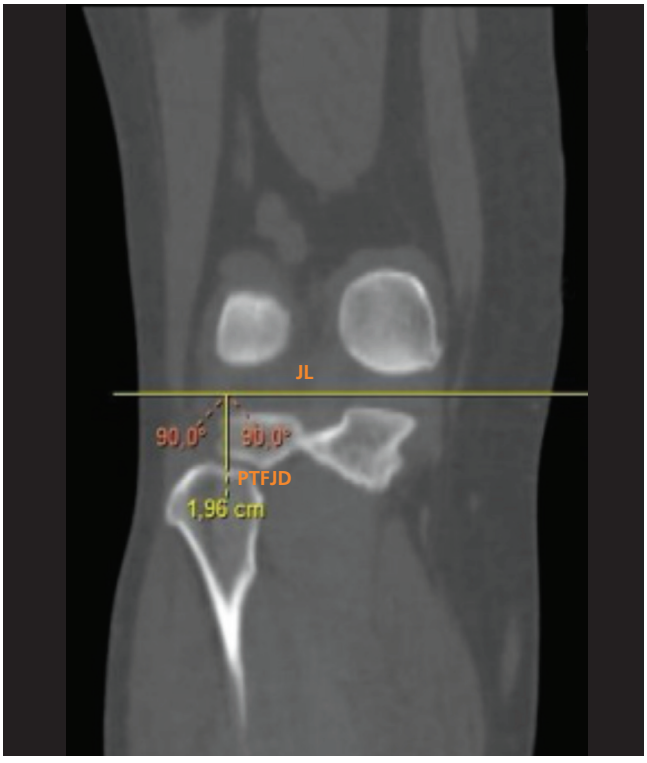

Figure 2. Coronal CT image. Proximal tibio-fibular joint distance (**PTFJD**) is the distance between JL and the center of the horizontal portion of the proximal tibiofibular joint.

In the Sagittal Plane

- **Tibial width (TW):** The diameter of the tibia at the level of the tibial tubercle (TT) or the most proximal point where the patellar tendon is attached to the tibial tubercle (**Figure 4**).
- **Tibial tubercle distance (TTD):** The distance between the JL and the level of the TT or the most proximal point where the patellar tendon is attached to the tibial tubercle (**Figure 5**).
- **Patellar distance (PD):** The distance between the JL and the most inferior point of the inferior pole of the patella (**Figure 5**).

In the Axial Plane

- **Femoral transepicondylar width (FW):** The distance between the most prominent point of the medial femoral epicondyle and the most prominent point of the lateral femoral epicondyle (**Figure 6**).

Femoral ratios, taken as the ratios of the femoral width to JL-MED, JL-LED, PJL-TFJD, JL-AFD, JL-TTD, and JL-PD were evaluated. The tibial ratio, as the ratio of the tibial width to to the JL-TTD, was also calculated. All measurements were repeated twice by a single observer. The mean values of these measurements were used.

Categorical variables were presented as frequencies and percentages. The chi-square test was used for comparisons of categorical variables. The Shapiro-Wilk test was used to test the normality of distribution. All continuous variables were normally distributed; therefore, when comparing clinical characteristics, the Student t-test was used for continuous variables and values were presented as mean± standard deviation (SD). The data obtained in the study were analyzed using SPSS (Statistical Package for Social Sciences) for Windows (Version 26, IBM Corp., Armonk, NY, USA). For all analyses; $p<0.05$ was considered as significant.

Results

The mean age of the of the participants was 43.56±7.0 in males and 45.4±10.1 years in females (p=0.294). The distances between the anatomical landmarks and the joint line of the knee and the tibial and femoral diameters are pre-

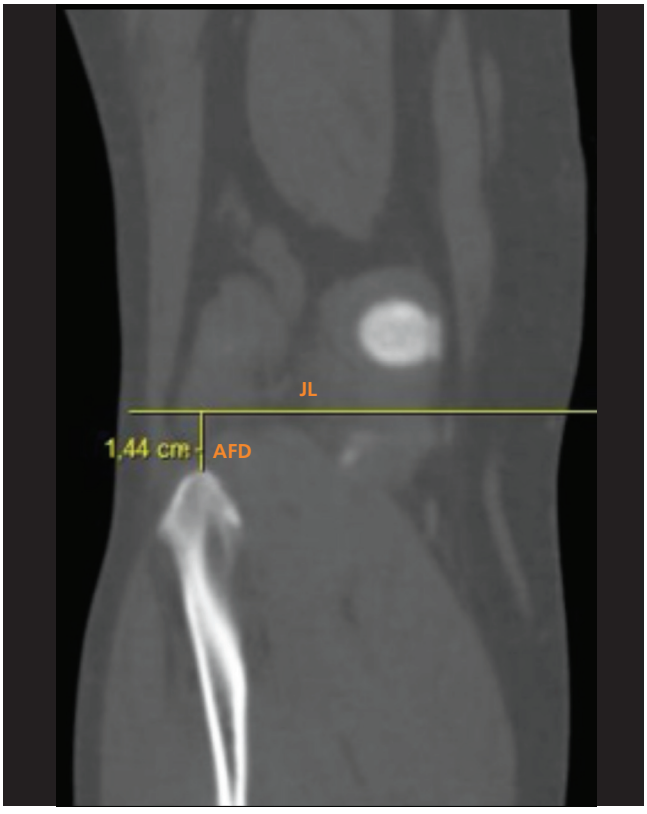

Figure 3. Coronal CT image. Apex of head of fibula distance (AFD) is the distance between joint line (JL) and the superior point of the apex of head of fibula.

Figure 4. Sagittal CT image. Tibial width (TW) is the diameter of the tibia at the level of the tibial tubercle (TT) or the most proximal point where the patella tendon is inserted into the tibial tubercle (TT).

Figure 5. Sagittal CT image. Tibial tubercle distance (**TTD**) is the distance between the joint line (**JL**) and the level of the tibial tubercle (**TT**) or the most proximal point where the patella tendon is inserted into the tibial tubercle (**TT**) and the patellar distance (**PD**) is the distance between the joint line (**JL**) and the most inferior point of inferior pole of patella.

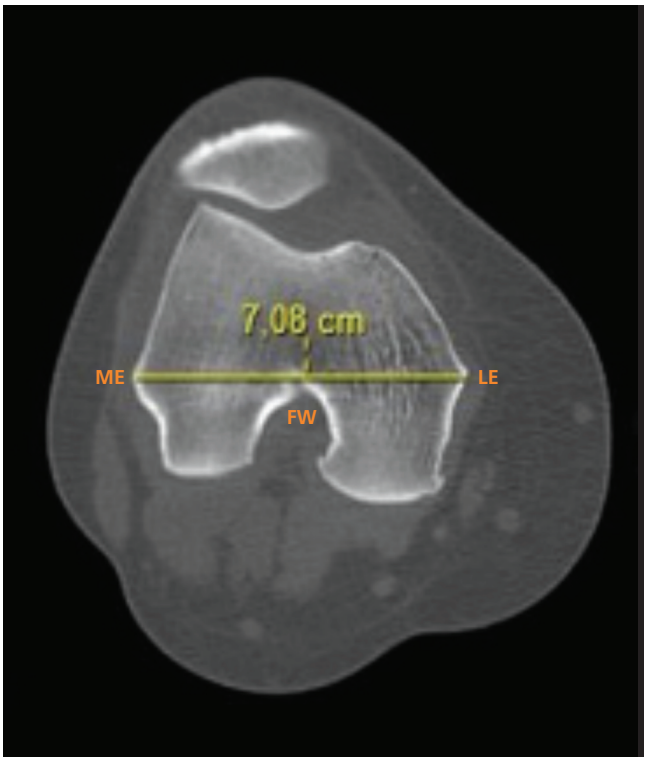

Figure 6. Axial CT image. Femoral transepicondylar width (**FW**) is the distance between the most prominent point of medial femoral epicondyle (**ME**) and the most prominent point of the lateral femoral epicondyle (**LE**).

sented in **Table 1**. All distances and diameters differed between the genders with statistical significance ($p<0.005$). The mean and SD values of the femoral and tibial ratios for all landmarks are presented in **Table 2**. With the exception of LED/FW, TTD/FW, TW/FW, and TW/TTD, all ratios differed between the genders with statistical significance.

Discussion

The medial epicondyle, lateral epicondyle, tibial tubercle, apex of head of fibula, and lower pole of the patella are commonly used bone reference points in clinical settings. Surgeons can evaluate these points in preoperative radiological examinations or intraoperatively with palpation. In the current CT study, we investigated the distances between bony landmarks such as the medial epicondyle, lateral epicondyle, apex of head of fibula, proximal tibiofibular joint, tibial tubercle, and lower pole of the patella and the knee joint line as well as the ratios of these distances to femoral width and tibial width in the Turkish population. Knowing the normal range of values for the knee joint line in a society is of great importance in planning knee arthroplasty and especially revision surgery because slippage of the joint line may disrupt the biomechanics of the knee, resulting in complications such as decreased strength of the extensor mechanism, increased patellofemoral joint pressure, anterior knee pain, and decreased range of motion.[13–15] Although it is necessary to restore the normal joint line for both primary and revision total knee arthroplasty, there is still no consensus on how to determine the normal joint line.[10] During primary total knee arthroplasty, surgeons can estimate the normal joint line position based on the thickness of the femoral osteotomy. However, in the case of revision total knee arthroplasty, reliable references are needed to find the normal articular line because of bone loss in the distal femur and proximal tibia due to previous surgery. The use of anatomical landmarks to determine the position of the joint line is well accepted in clinical practice.[8] However, the mean distances from the bony reference points to the knee joint line are strongly correlated with body build, gender and race.[7] To overcome this disadvantage, Servien et al.[8] proposed evaluation of the ratios of these measured distances

Table 1
Summary of the measurements and gender difference.

Distance (mm)	Overall (Mean±SD)	Males (Mean±SD)	Females (Mean±SD)	p-value*
MED	27.8±1.1	28.1±0.6	27.5±1.4	0.007
LED	23.6±1.8	24.3±1.7	22.8±1.6	**<0.001**
PTJFD	26.0±2.5	27.8±0.9	24.1±2.2	**<0.001**
AFD	19.1±5.0	22.8±2.6	15.4±3.9	**<0.001**
PD	13.3±1.7	14.4±0.7	12.2±1.7	**<0.001**
TTD	23.0±1.7	23.7±0.3	22.3±2.1	**<0.001**
FW	77.3±2.3	78.9±0.9	75.8±2.3	**<0.001**
TW	43.5±4.0	44.9±3.5	42.1±3.9	<0.001

*Distances and diameters differed between the genders with statistical significance (p<0.005). **AFD:** apex of head of fibula distance; **FW:** femoral transepicondylar width; **LED:** lateral epicondylar distance; **MED:** medial epicondylar distance; **PT:** patellar distance; **PTJFD:** proximal tibiofibular joint distance; **TTD:** tibial tubercle distance; **TW:** tibial width.

to the femoral transepicondylar width and claimed that these ratios would be less affected by variables such as gender, race, or body mass index (BMI). The use of ratios has proven to be more reliable. It has been shown that ratios are less affected by the variations caused by age, BMI, and gender, and they can be used easily with information obtained from both radiological examinations and intraoperative measurements.[11,16–18] In our study, we considered the epicondylar ratio as well as the distances of the bone reference points to the joint line.

The results of our study revealed the mean FW as 77.3 mm. This value was previously reported by Romero et al.[19] as 79.9 mm, by Servien et al.[8] as 81.7 mm, by Lee et al.[20] as 75 mm, by Seedhom et al.[21] as 77.2 mm, and by Iacono et al.[22] as 89.7 mm. Differences between our results and previous studies can be explained by differences in the patients' ethnicities, participant selection, measurement methodology or observer differences. The mean distance between the head of the fibula and the joint line was reported as 20.5 mm by Gurbuz et al.,[12] while Mason et al.[23] found it as 20 mm. We found this mean value to be 19.1 mm, similar to the reported ranges in the literature. In our study, the mean MED was 27.8 mm and the mean LED was 23.6 mm. These values were determined as 28.95 mm and 23.97 mm, respectively by Ozkurt et al.[11] in a cadaver study. Iacono et al.[22] reported a correlation between the medial epicondyle-joint line distance and femur interepicondylar width, calculating a ratio value of 0.343. This value was 0.327 in a study conducted by Fan et al.[9] among the Chinese population, while it was 0.34 in the study of Servien et al.[8] and 0.35 in the study of Ozkurt et al.[11] Similarly, we determined this value as 0.35. This

Table 2
Mean ratios and gender difference.

Ratio	Overall (Mean±SD)	Males (Mean±SD)	Females (Mean±SD)	p-value
MED/FW	0.35±0.01	0.35±0.0	0.36±0.01	0.007
LED/FW	0.30±0.02	0.31±0.02	0.30±0.02	0.116
PD/FW	0.17±0.01	0.18±0.0	0.16±0.02	**<0.001***
TTD/FW	0.29±0.02	0.30±0.0	0.29±0.02	0.122
AFD/FW	0.24±0.06	0.28±0.03	0.2±0.05	**<0.001***
PTFJD/FW	0.33±0.02	0.35±0.01	0.31±0.02	**<0.001***
TW/FW	0.56±0.04	0.57±0.04	0.55±0.04	0.120
TW/TTD	1.9±0.2	1.8±0.1	1.9±0.3	0.759

*Ratios differed between the genders with statistical significance (p<0.005). **AFD:** apex of head of fibula distance; **FW:** femoral transepicondylar width; **LED:** lateral epicondylar distance; **MED:** medial epicondylar distance; **PT:** patellar distance; **PTJFD:** proximal tibiofibular joint distance; **TTD:** tibial tubercle distance; **TW:** tibial width.

ratio does not reflect significant differences between the genders and its standard deviation is low; therefore, we think that it can guide surgeons with high reliability.

Computed tomography, magnetic resonance imaging, and direct radiographs are used to determine the location of the joint line.[24–26] We used CT in our study because CT is known to be superior in evaluating bony structures and we anticipated that it would be possible to locate the bone reference points from coronal, sagittal, and axial sections with higher reliability. While CT has disadvantages such as higher radiation load compared to conventional radiographs and magnetic resonance imaging and being more costly than conventional radiographs, these disadvantages were not reflected in our study because our study entailed a retrospective review of CT images taken in the emergency room and outpatient clinic for different reasons.

One of the limitations of the present study may be that the measurements were made by one observer. We thought that measurements made by a single observer would ensure standardization among slices. Repeated measurements performed at two different times were used to overcome the possible limitation. Since our study was a CT-based study, it allowed us to make precise measurements in the coronal, axial, and sagittal planes.

Conclusion

There are few publications in the literature examining the relationship between the knee joint line and the bony landmarks around the knee in the Turkish population. We anticipate that the values we determined will help surgeons who often perform total knee replacement and revision knee replacement surgeries for Turkish patients to determine the joint line.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

CÖ: conceiving and designing the analysis, collecting the data; AS: analyzing the data, writing the manuscript.

Ethics Approval

The study was approved by the non-interventional clinical research ethics committee of Izmir Katip Çelebi University (No: 0086/0107) and carried out in compliance with the Declaration of Helsinki's guiding principles.

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