

Measurement of Posterior Tibial Slope in Turkish Population Groups with Magnetic Resonance Imaging

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Abstract

Background

The posterior tibial slope (PTS) has great importance on the balance and the stability of the knee and has to be taken into account during the reconstruction and replacement procedure. However, the anthropometric measurements are not universal and show population-based variations. The purpose of this study is to find features of PTS in the Turkish population in regards to the medial and lateral compartment.

Methods

Magnetic resonance images (MRIs) were retrieved from the Picture Archiving and Communication System (PACS). Subjects from 25 to 45 years old were included from the MRIs taken between July 2015 to July 2017. Any MRI with radiological signs of osteoarthritis, chondral and meniscus (grade 3 & 4) lesions was excluded as well as a deformity in the lower extremity, patients with a history of fracture and/or history of knee surgery. The measurements were made using T1-weighted coronal and sagittal MRI planes with a slice thickness of 4 mm. The PTS of the medial, lateral plateau were recorded with gender and age of the subjects. Non-parametric Spearman's Correlation tests and Student T tests were used to calculate the relationship between medial-lateral PTS and ages and also to evaluate PTS differences between genders.

Results

Two-hundred thirty-two subjects (122 female, 110 male) were included in the study. The mean medial and lateral PTS were $7.7^{\circ} \pm 1.3^{\circ}$ and $7.5^{\circ} \pm 1.3^{\circ}$ respectively, and there was a significant correlation ($p < 0.001$). However, no significant difference was found in the mean medial PTS ($p = 0.45$) and lateral PTS ($p = 0.73$) between genders and matched age groups.

Conclusions

Our results showed that there is no gender-based variation in the Turkish population. Although we do not make a systematic comparison, the measurements of PTS in the Turkish population were different from other populations.

Background

The posterior tibial slope (PTS) is defined as the anatomic inclination of the proximal tibial plateau in the sagittal plane.^[1] Several studies showed that the PTS has been associated with the stability of the knee.

[2-4] Therefore, the slope of the plateau has great importance in patients who undergo surgical procedures, such as total knee arthroplasty (TKA) or corrective osteotomies. An inappropriate angle of the PTS cut in TKA or changing it during the reconstructive procedures may cause iatrogenic instability^[5-7]. Therefore, native PTS has to be taken into account during the surgical planning.

The posterior tibial slope does not have a universal value and shows racial variations which are shown in several national-based studies.^[8,9] However, the measurements in these studies were relying on the measurements on direct lateral knee radiographs. The direct radiography does not adequately reflect the precise inclination of PTS in medial and lateral plateau separately due to the superimposing of the medial and lateral plateau.

The purpose of this study is to find the average values of PTS in the Turkish population on medial and lateral plateau separately with using Magnetic Resonance Images (MRIs) of the knee.

Methods

The measurements were done on knee MRI scans those retrieved retrospectively between July 2015 to July 2017 from Picture Archiving and Communication System (PACS). The MRIs were taken with a slice thickness of 4 mm, with a 1.5 T MRI device (Siemens Avanto, Germany). The mean age of the subjects included was 35 (range 25 to 45). The patients with a fracture or any history of knee surgery, osteoarthritis, chondral and meniscus (grade 3 & 4) lesions, significant deformity in lower extremity were excluded. The patients were divided into two age groups, 25–35 and 36–45. Ethical approval has been taken from the Institutional Review Board.

Measurements

PTS of the medial and lateral tibial plateau measurements made retrospectively. According to the method [5], measurements were done in 3 steps:

1. Finding the anatomical axis of the tibia
2. Finding the mid-plateau line in the axial plane
3. The measurement of PTS

1. Finding the anatomical axis of the tibia

Two parallel lines of the medulla on the same sagittal plane that was 5 cm apart from each other at the diaphyseal level are identified. The longitudinal line is found by connecting the midpoints of two lines. All these lines are on the same sagittal plane, plane A. (Fig. 1)

2. Finding the medial and lateral mid-plateau lines in the axial plane

An axial plane, plane B, is identified perpendicular to plane A, through level of the highest point of articular surface in coronal plane. (Fig. 2) Then the longest medial and lateral articular axes are identified, on the plane A, line n for lateral and line n' for medial plateau. The lines those are projections of line n & n' on the articular surface are identified as line m & m'.

3. The measurement of PTS

The angles between lines m' and n' the medial and lateral lines m and n are measured separately on medial and lateral. (Fig. 2)

The measurements were done by two authors (MK, IC) who were blind to the subjects. The annotation tools of PACS were used for the measurement of medial and lateral PTS separately.

Statistical Analysis

The statistical analyses were done by using SPSS Statistics (IBM, USA, version 22.0). Spearman's correlation test was performed to determine whether there was a relationship between medial, lateral PTS and ages. The Student-T test was performed for differences between genders and also 10 years of age groups within each gender. Statistical significance for p value was < 0.05 for all performed tests.

Results

Totally, 520 knees MRIs were reviewed and 232 (122 female, 110 male) of them were found eligible for the study (Fig. 3). The medial and lateral PTS values are given in Table 1 separately.

The medial and lateral PTS were found correlated ($r = 0,64$; $p < 0.001$). The correlation were also seen within the genders (female $r = 0,62$; $p < 0.001$, male $r = 0,66$; $p < 0.001$), however there were no statistical difference between genders for medial PTS ($p = 0,9$) and lateral PTS ($p = 0,7$). Also, the two age groups and did not show statistically significant differences in female and male subjects for medial ($p = 0.45$) and lateral ($p = 0.73$) PTS measurements separately (Table 2).

Discussion

The anthropometric variations of the knee in different races are well-known and documented in the literature. Most studies were done on a national basis using different dimensions of the knee (Table 3). In this study, we measured the medial and lateral PTS and analyzed the measurements based on genders and age groups in the Turkish population.

According to our results, the mean medial and lateral PTS measurements show variations between genders without statistical significance. In similar studies which were done in other populations, demonstrated significant gender-based differences in PTS.

Hudek R. et al.^[5] reported that minimum values of medial PTS were $-1,2^\circ$ (range $-1,2^\circ$ to 11° , mean: $4,6^\circ \pm 2,4^\circ$) that value was 5° smaller than our findings and minimum values of lateral PTS was $-4,3^\circ$ (range

-4,3° to 12,8°, mean: 5,0°±3,6°) that value was 9° smaller than our findings in Swedish adults. Similarly, we found important difference in study which mean medial PTS in male subjects was 3,7 (range -3° to 10°, mean: 3,7°±3,1°) that angle was 4° smaller than our results and mean lateral PTS in male subjects was 5,4° (range 0° to 9°, mean: 5,4°±2,8°) this angle was 2° smaller than our results that were done in England.^[10] But on the other hand, our results show a similarity with the results of studies that were done in South Korea and Italy. Han H. et al.^[11] showed that mean medial PTS in South Korean subjects was 6,1°±1,7° and mean lateral PTS was 6,8°±1,8° all those close to values we found. A study that was done in Italy^[12] showed that mean medial PTS in male subjects was 7,6°±3,3° and mean lateral PTS was 7,5° ±3,5° almost same results that we found in male subjects. Also, Haddad B. et al.^[13] found that the medial and lateral PTS was significantly different in Asian subjects compared with other ethnic groups.

In the study using MRI, Hashemi J. et al.^[10] found that the medial and lateral PTS was statistically greater in female subjects than male subjects. Additionally, Haddad B. et al.^[13] reported that PTS was greater in female subjects than male subjects but they did not report a significant difference between medial PTS and lateral PTS. In our study, we did not find any significant differences between lateral PTS and medial PTS as well as within the genders similarly studies.^[11,12]PTS of medial and lateral tibial plateau with rising age can be expected to increase due to degeneration on the tibial plateau. But we couldn't find any correlation between the age and other variables (medial PTS, lateral PTS) similarly following studies.^[10-12]

Despite the tibiofemoral joint has an asymmetrical, complex, three-dimensional structure; generally, PTS is evaluated from lateral knee radiographs after uni-total knee arthroplasties or tibial osteotomies in daily clinic routine.^[12] As we mentioned before, medial and lateral PTS can not be truly distinguished from plain radiographs due to its nature; superimposing.^[5,10,14,15] The accurate measurement method of PTS must be contained exact localization of the center of articular surfaces. On MRI measurement, the medial and lateral plateau of the tibia can be assessed separately. Differences between the assessing medial, lateral tibial plateau and lateral radiographs were reported in cadaveric, CT and MRI imaging studies.^[16-18] We found differences between our results and other results that were done in Turkey with a lateral radiographic method.^[9] Mean and standard deviation of PTS of the radiographic study was 13,4°±3,2°; this angle was 6° greater than our result. Besides the all positive features of MRI measurement, Hudek R. et al.^[5] stated that cost and total time consumption of a routine knee MRI is approximately five times greater than for a lateral radiograph based on the accounting data of their clinic. But they also stated that MRI scans can be applicable to daily clinic routine due to it allows to assessment of medial and lateral plateaus separately with reliable method.

One of the importance of PTS in daily life is it has a close relationship with anterior tibial translations of the knee. This relationship is shown in a cadaveric study [20] especially, with the application of compressive load to the knee.^[19] Knee produces anteriorly directed shear force then shifting to anteriorly with the application of compressive load and the amount of shifting is greater in anterior cruciate

ligament resected knees than in intact knees. Additionally, Dejour H. and Bonnin M. stated in their studies that tibia had a 6 mm anterior translation for a 10° increase in PTS.^[20]

Gender-specific prostheses, primarily designed according to characteristic features of the female knee joint. Their main differences based on three anatomic differences which are narrower mediolateral diameter, the anterior flange of the prosthesis was modified to include a recessed patellar sulcus and reduced anterior condylar height (to avoid “overstuffing” during knee flexion) and a lateralized patellar sulcus (to accommodate the increased Q-angle associated with a wider pelvis).^[21] According to a meta-analysis, no statistically significant differences were observed between the gender-specific prostheses and unisex prostheses designs regarding pain, range of motion (ROM), knee scores, satisfaction, preference, complications, and radiographic results.^[22] Also in our study, we did not find any statistically significant differences between genders in the Turkish population. Our results showed that gender-specific prosthesis is not useful in the Turkish population-based on PTS measurements.

Moreover, in total knee arthroplasty operations, PTS is critical for the proper size of prostheses and determining its last sagittal alignment and also for patients to benefit from this operation. A decrease in the slope of medial and lateral tibial plateau results in insufficient flexion of the knee, early overloading of polyethylenes in the tibial plateau. Then, it causes early anteroposterior laxity, increased polyethylene wear. Dorr et al. found that 90°-110° knee flexions can be reachable when PTS would be in a range of 5°-10°. If the posterior inclination of tibia turns through anteriorly, knee flexion would be quite insufficient in which the posterior cruciate ligament was preserved knees.^[23] Blunn GW. et al. reported that knee anatomy should be reshaped as original as possible, deviations from this will cause excessive movements on the polyethylene and early wearing of polyethylene.^[24]

According to the study, tibial slope also should be considered when high tibial osteotomy operation is planned, leveling of cutting point in the surgery and it can affect the functional level of a patient, the success of surgical treatment, the contribution of physical therapy.^[25] Dejour H. and Bonnin M. showed that evaluation of sagittal plane such as the frontal plane is necessary before high tibial osteotomy is performed in patients which have gonarthrosis and varus or valgus deformities together, late outcomes of high tibial osteotomy are very poor in the increased PTS patient group.^[20]

This study has several limitations. One of them is all measurements were done just once time by one observer and one co-observer. Thus, we could not have a chance to assess differences in the interobserver and intraobserver variations and calculate the reliability of the measurements. Medial and lateral tibial slope measurements could be repeated, the first time starting the study and the second time 2 weeks after and with the more than one observer. On the other hand, we couldn't obtain the weight and height of subjects to assess whether there is a relationship between PTS and other anthropometric measurements. Differences between our findings and other studies could be based on these other variations in anthropometric features. Routine knee MRIs are included the distal femur and proximal tibia so we tried to identify tibial longitudinal axis from this limited area. Measurement of PTS from the tibial mechanical axis could provide more accurate results but determining of tibial mechanical axis requires

MRI of the whole tibia. We don't think that this limitation will not affect a general minimum and maximum values in large scale subjects or subject-to-subject variations.

Conclusion

In conclusion, we presented the mean medial and lateral PTS and analyzed possible differences between genders and age groups in the Turkish population with MRI measurement. The measurements in the Turkish population were found different than similar studies that were done in different populations. We do not compare our findings with the available implant designs and surgical techniques that are performed in Turkey. Knowing the normal values of the PTS is important when to decide treatment for cruciate ligaments repair surgery, correction of knee deformities, rearrangement of depletion or collapse fractures and also both total and unicondylar knee arthroplasty. It is also a parameter affecting the success of high tibial osteotomy and total knee arthroplasty operations. In terms of anthropometric subject-to-subject differences, more accurate implants and surgical techniques should be used that adequately reflect medial and lateral PTS of the normal knee. For achieving this, countries should measure their average values and develop strategies that keep original medial and lateral PTS of the subjects.

List Of Abbreviations

posterior tibial slope (PTS)

Magnetic resonance images (MRIs)

Picture Archiving and Communication System (PACS)

total knee arthroplasty (TKA)

range of motion (ROM)

Declarations

Ethical approval has been taken from the Institutional Review Board.(Bezmialem Vakif University Ethic Committe(Decision Number:10/98)

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request

The authors declare that they have no competing interests

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Tables

Table 1

The medial and lateral PTS for male and female subjects are given

	Age	Medial PTS	Lateral PTS
Male (n = 110)	34,6 (range 25–45,SD: 5,8)	7,66°±1,2° (6°-11°)	7,30°±1,2° (5°-10°)
Female (n = 122)	35,6 (range 25–45, SD: 5,7)	7,77°±1,4° (4°-11°)	7,63°±1,3° (5°-11°)
All	35,0 (range 25–45, SD: 5,8)	7,72°±1,3° (4°-11°)	7,47°±1,3° (5°-11°)

Table 2

The PTS measurements are given in males and females for medial and lateral plateau for two age groups.

	25–35 years		36–45 years	
	Medial PTS	Lateral PTS	Medial PTS	Lateral PTS
All*	7,71°±1,3° (5°-11°) n = 113	7,44°±1,3° (5°-10°) n = 113	7,74°±1,3° (4°-11°) n = 119	7,51°±1,3° (5°-11°) n = 119
Male	7,69°±1,1° (6°-10°) n = 59	7,27°±1,2° (5°-10°) n = 59	7,63°±1,4° (6°-11°) n = 51	7,35°±1,2° (5°-10°) n = 51
Female	7,72°±1,6° (5°-11°) n = 54	7,63°±1,3° (5°-10°) n = 54	7,82°±1,2° (4°-10°) n = 68	7,82°±1,2° (4°-10°) n = 68
*mean ± SD(min-max)				

Table 3

Comparison of mean values of medial and lateral PTS between different researches N/A: Not Applicable

	Male		Female		Mean PTS	n	Method
	Med PTS	Lat PTS	Med PTS	Lat PTS			
Current study (Turkey)	7,7°±1,2°	7,3°±1,2°	7,8°±1,4°	7,6°±1,3°	-	232	MRI
Hudek R. et al. ^[5] (2009, Switzerland)	4,6°±2,4°	5,0°±3,6°	-	-	-	100	MRI
Han H. et al. ^[11] (2016, South Korea)	6,1°±1,7°	6,9°±1,7°	6,1°±1,8°	6,8°±1,9°	-	535	MRI
Hashemi J. et al. ^[10] (2010, U.S.A.)	3,7°±3,1°	5,4°±2,8°	5,9°±3,0°	7,0°±3,1°	-	55	MRI
Cinotti G. et al. ^[12] (2012, Italy)	7,6°±3,3°	7,5°±3,5°	8,6°±2,6°	8,0°±3,6°	-	80	MRI
Faschingbauer M. et al. ^[26] (2014, Germany)	N/A	N/A	N/A	N/A	6,9°±3,3°	100	X-Ray
Ozsahin M. et al. ^[9] (2013, Turkey)	N/A	N/A	N/A	N/A	13,0°±3,1°	100	X-Ray

Figures

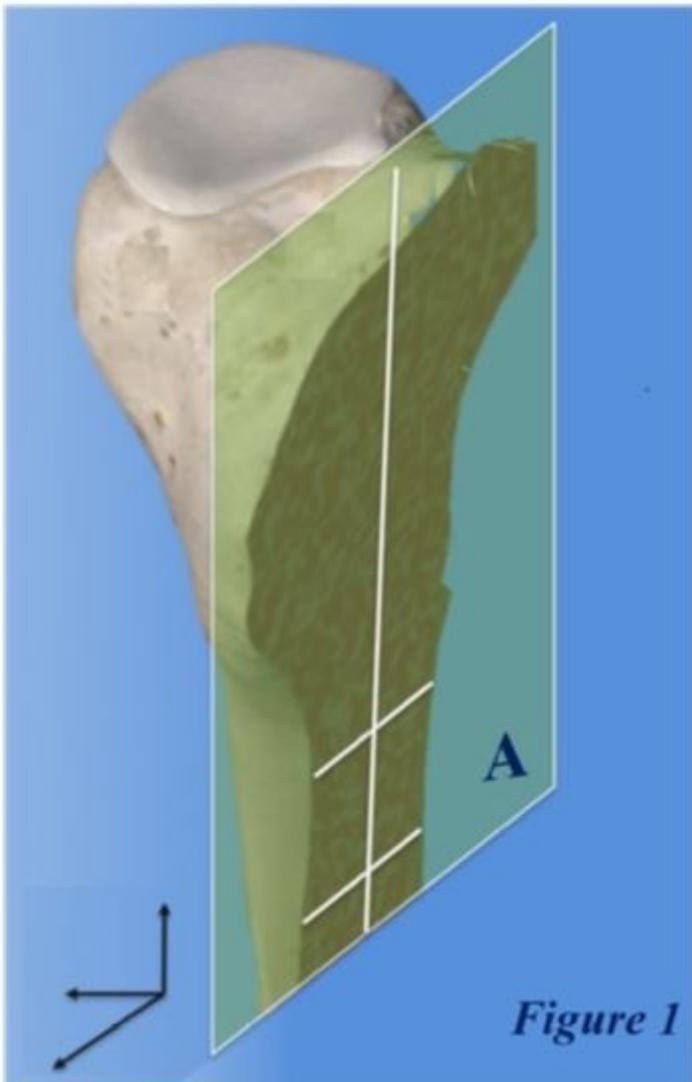


Figure 1

Perpendicular to plane A, passing through the tibiofemoral joint.

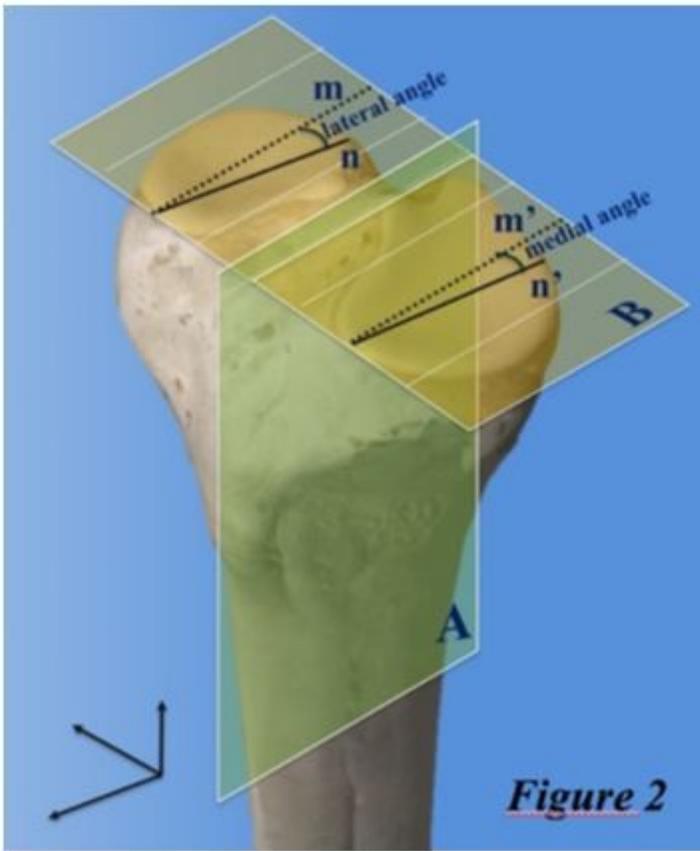


Figure 2

Final step for identifying medial and lateral posterior tibial slope. An axial plane, plane B, is identified perpendicular to plane A, through level of the highest point of articular surface in coronal plane. The longest medial and lateral articular axes are identified, on the plane A, line n for lateral and line n' for medial plateau. The lines those are projections of line n & n' on the articular surface are identified as line m & m'.

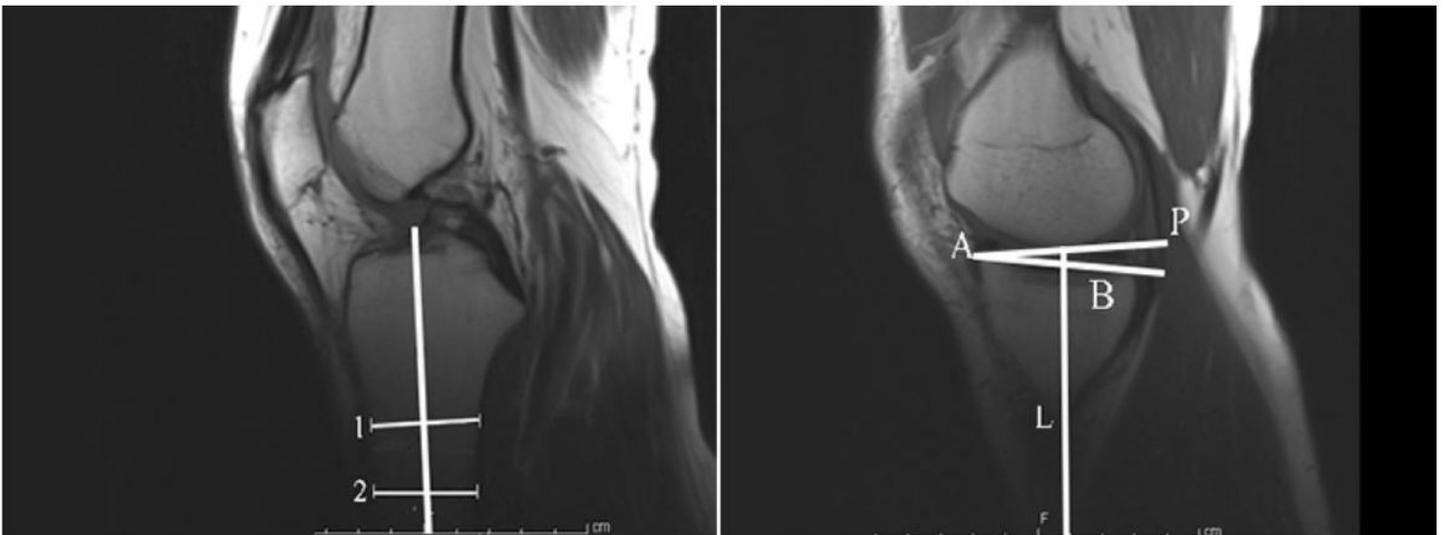


Figure 3

Perpendicular to plane A, passing through the tibiofemoral joint. An axial plane, plane B, is identified perpendicular to plane A, through level of the highest point of articular surface in coronal plane.