RESEARCH ARTICLE

Measurement of Posterior Tibial Slope Using Magnetic Resonance Imaging

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Abstract

Background: Posterior tibial slope (PTS) is an important factor in the knee joint biomechanics and one of the bone features, which affects knee joint stability. Posterior tibial slope has impact on flexion gap, knee joint stability and posterior femoral rollback that are related to wide range of knee motion. During high tibial osteotomy and total knee arthroplasty (TKA) surgery, proper retaining the mechanical and anatomical axis is important. The aim of this study was to evaluate the value of posterior tibial slope in medial and lateral compartments of tibial plateau and to assess the relationship among the slope with age, gender and other variables of tibial plateau surface.

Methods: This descriptive study was conducted on 132 healthy knees (80 males and 52 females) with a mean age of 38.26±11.45 (20-60 years) at Imam Reza hospital in Mashhad, Iran. All patients, selected and enrolled for MRI in this study, were admitted for knee pain with uncertain clinical history. According to initial physical knee examinations the study subjects were reported healthy.

Results: The mean posterior tibial slope was 7.78±2.48 degrees in the medial compartment and 6.85±2.24 degrees in lateral compartment. No significant correlation was found between age and gender with posterior tibial slope ($P \geq 0.05$), but there was significant relationship among PTS with mediolateral width, plateau area and medial plateau.

Conclusion: Comparison of different studies revealed that the PTS value in our study is different from other communities, which can be associated with genetic and racial factors. The results of our study are useful to PTS reconstruction in surgeries.

Keywords: Plateau, Posterior tibial slope, Tibia, Total knee arthroplasty

Introduction

Majority of daily living activities is based on lower limbs. The importance of leg as the most distal part of the body is very clear. It plays a major role in weight bearing, absorbing and adjusting pressures and exerted blows during walking, running, jumping and maintaining the position, whether standing or moving (1). Orthopedic surgeries are often performed with the aim of returning anatomy of the organ or bone to its normal status. Maintaining the lower limb angles and axes is very critical in surgeries on lower extremity reconstruction such as surrounding the knee. Knowing these angles are essential, especially for knee osteotomy and total knee arthroplasty (TKA), since one of the major factors of success for such surgery with increased longevity of knee joint replacement is to maintain normal axis of the lower limb (2, 3). Tibial slope is an important factor in weight bearing and implant design (4, 5). Posterior tibial slope (PTS) is actually the slope of tibial plateau normally from anterior to posterior relative to its longitudinal axis (6). It is a key parameter in the knee joint biomechanics, and leads to anterior-posterior stability of the knee (7, 8).

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Posterior tibial slope (PTS) affects knee joint stability, ACL ligament, flexion gap and posterior femoral rollback that are associated with wide range of knee motion (9).

To the best of our knowledge, previous studies have examined only the PTS value in Iranian population and relationship of this angle with age and gender. In this study, we focused on posterior tibial slope in Iranian adults to investigate its association with other variables of tibial plateau surface. Finally obtained results were compared with the outcomes of similar studies conducted in other countries.

Materials and Methods

Research methodology due to the nature of subject is a descriptive study that was conducted from January to September 2015 on 132 knees including 80 males (61%) and 52 females (39%) at Imam Reza (AS) Hospital in Mashhad, Iran. Ethics Committee of Shahid Beheshti University of Medical Sciences approved the proposal. Informed consent was obtained from all patients.

All patients admitted to the hospital clinic due to complaints of knee problems who were needed to knee MRI based on scientific indications. Then after obtaining history and physical examination by specialists, the patient who had no problems in terms of bone and soft tissue examinations were included in the study.

Exclusion criteria were history of advanced arthrosis and rheumatoid arthritis, previous fracture in the proximal tibial, congenital anatomy or deformity gross and lower extremity length discrepancy.

To measure the PTS angle, first line was drawn tangential to posterior tibial cortex, and the other perpendicular to the first line. A third line was drawn tangential to the surface of the tibial plateau. The angle between the third and the second lines was considered as posterior tibial slope, Figure 1 (10).

A fixed cut was elected to measure posterior tibial slope in the middle of medial and lateral compartments to avoid measurement errors and to perform all measurements in a certain cut.

In this study, proximal tibial dimensions were measured which included anteroposterior length (AP), mediolateral width (ML), medial anteroposterior length (MAP), lateral anteroposterior length (LAP), tibial plateau area, medial and lateral tibial plateau areas, complete bounding box area (the smallest quadrilateral surrounding tibial plateau), medial bonding box and lateral bonding box areas, Figure 2. Finally, the relationship between morphological data obtained from these variables and the degrees of tibial plateau slope was evaluated.

Results

In this study, 132 knees were studied. The mean age of patients was 38.26±11.45 with a range of 20-60 years. The mean posterior tibial slope was 7.78±2.48 degrees in the medial compartment and 6.85±2.24 degrees in lateral compartment. In addition, the mean angle (degree) in medial and lateral compartments was respectively 8.08±2.35 and 6.48±1.98 in females and 7.58±2.53 and 7.09±2.37 in males.

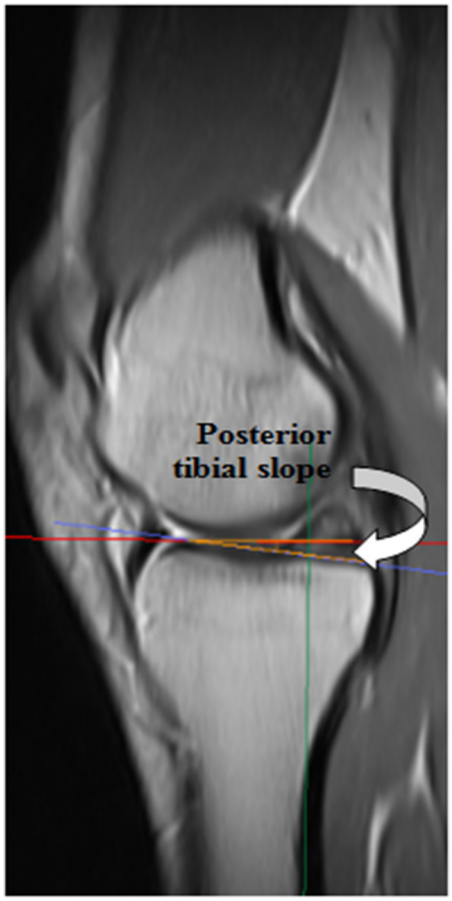

Figure 1. An example of measuring anterior - posterior slope of tibial plateau.

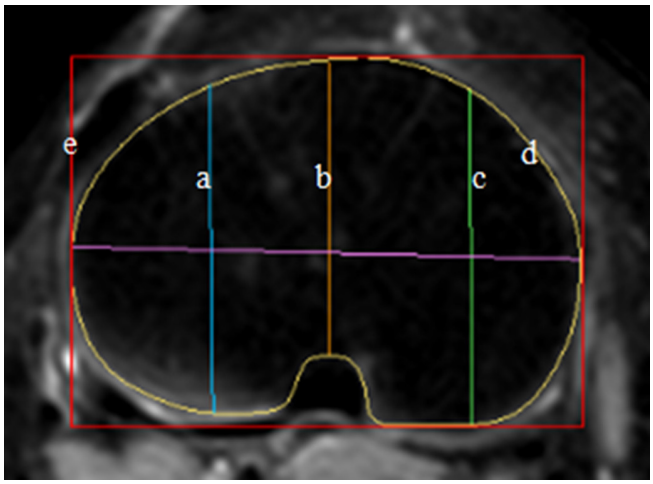

Figure 2. Axial MRI image of the proximal tibia showing (a) the lateral anteroposterior length (LAP), (b) the anteroposterior length (AP), (c) the medial anteroposterior length (MAP), (d) the plateau area, and (e) the bounding box area.

Maximum and minimum PTS angle measured in these patients were respectively 13.9 and 2.4 degrees in the medial compartment, with 15.0 and 2.6 degrees in the lateral compartment.

Categories of individuals in terms of percentage of various degrees of tibial plateau slope in the medial and lateral compartments are shown in Figures 3 and 4.

Also, the number of males and females in terms of slope with less or more than 10 degrees in the medial and lateral compartments has been determined [Table 1].

Discussion

The importance of determining the angle and direction is clear economically and scientifically. It is mainly because of the increasing number of knee reconstruction surgeries, particularly knee joint replacement, and the important role of maintaining normal lower limb angles in the longevity of the joints (11-13).

Concerns for impact of PTS on knee joint loading resulted in the development of surgical techniques to precisely PTS control during surgery (14). Usually, it is tried to maintain posterior tibial slope as much as possible in knee anatomical conditions during TKA surgery to enhance knee flexion (15). In the current study, the mean posterior tibial slope was 7.78±2.48 degrees in the medial compartment and 6.85±2.24 degrees in lateral compartment. Comparison of different studies revealed that the PTS value in our study is different from other communities.

Moore et al. reported the slope value of 14±3.7° (range: 7-22°) in 50 Americans (16). Matsuda et al. obtained this value about 10.7 ° (range: 5-15.5°) in 30 Japanese patients, and Chiu et al. found the mean slope of 14.7±3.7° (range: 5- 22°) in 25 Chinese cases (17, 18).

In a study by Hosseinzadeh et al. conducted in Iran, the slope value was 9.4±1.8° (range: 2-18°) in 108 knees.

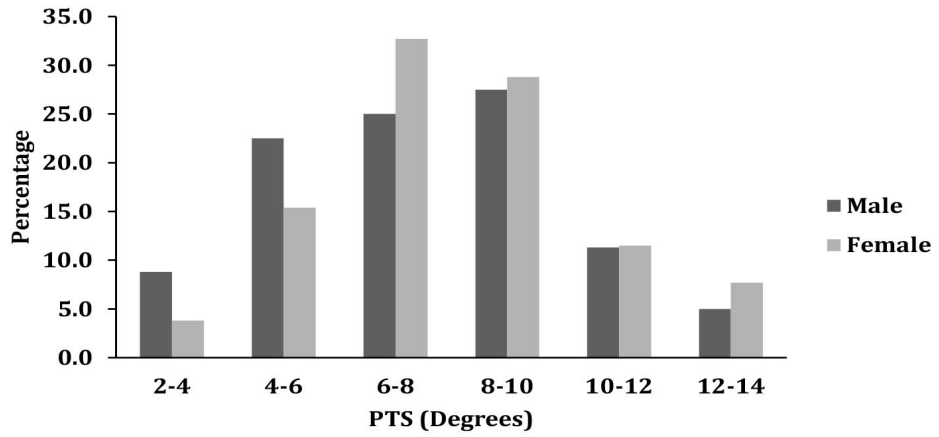

Figure 3. Percentage of different tibial plateau slope for both sexes in medial compartment.

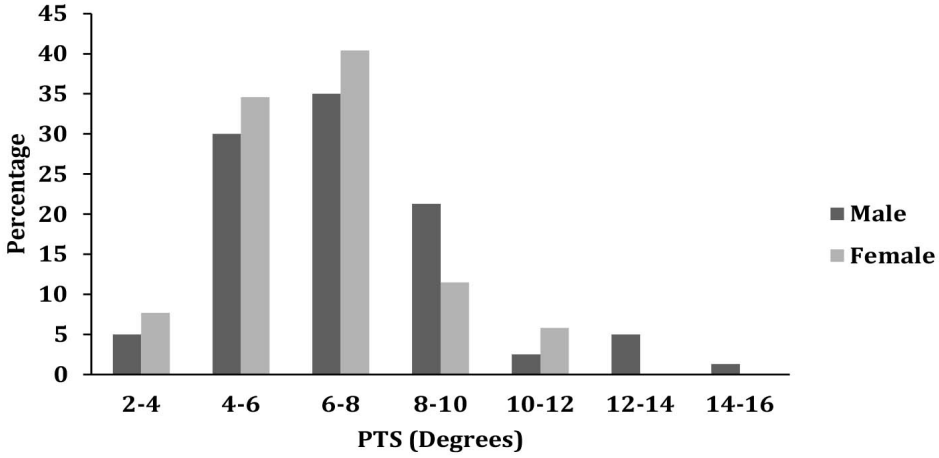

Figure 4. Percentage of different tibial plateau slope for both sexes in lateral compartment.

Table 1. Number of male and female study subjects in terms of tibial plateau slope with less or more than 10 degrees in medial and lateral compartments

	Gender	Slope < 10º	Slope ≥ 10º
Medial compartment	Male	67	13
	Female	42	10
Lateral compartment	Male	72	8
	Female	49	3

In another study by Qureyshi et al., the slope value was reported 9.3±1.4° (range: 1-19°) in 431 knees (19, 20).

The reason for differences in the values of posterior tibial slope between our study and other studies carried out in Iran could be due to differences in individual heights and imaging technique.

The results indicate that the values of posterior tibial slope in Iranian society are larger different compared to other societies, especially Western societies, and smaller than other ethnic groups.

In this study, the relationship among the values of posterior tibial slope with age and gender were examined, which no significant correlation was found between these two factors and PTS (*P≥0.05*). The results are in agreement with other studies conducted in Iran (19, 20).

Comparison of PTS with dimensions of other tibial variables revealed significant relationship between posterior tibial slope and variables of plateau, ML and medial plateau. Thus, in the medial compartment, the posterior tibial slope decreases a degree per each mm increase in ML, and the posterior tibial slope decreases 2.9 degrees per square millimeter (mm^2) elevation in medial plateau. This rise is 5.3 degrees per each square millimeter increase in plateau in the medial compartment, and 3.9 degrees in the lateral compartment.

Some assumptions stated that anatomic factors, including PTS value, are considered as contributing factors in osteoarthritis (21-23). Dehghan and Bahmani examined the posterior tibial slope in two groups with knee osteoarthritis and healthy knee; they reported that PTS values in patients with osteoarthritis were significantly higher than in healthy subjects (24).

In an in vitro study, Garg and Walke observed significant improvement in motion in PTS with 10 degrees (25). In contrast, other studies have shown that increased posterior slope cannot improve the motion and can cause anterior displacement and thus increase the load on anterior cruciate ligament. This increased load in turn would be a predisposing factor for ACL rupture (26).

Moreover, excessive PTS may lead to abnormal anterior tibial translation and instability in posterior and anterior cam-post, which can lead to an increase in molecular weight of polyethylene coating and biomechanical changes that eventually can reduce the TKA survival (27, 28).

PTS angle changes also affect the relationship between patellar bone and patellar tendon. Kaper et al. showed that changes in PTS might cause patella baja (29). Therefore, PTS in the upper tibial cutting in TKA surgery is considered as an important factor in postoperative knee joint biomechanics and clinical outcome (15).

The results revealed the difference of posterior tibial slope in Iranian population compared to other communities. Thus, more detailed studies to investigate the cause of the mentioned difference and computation of real slope values of the Iranian population is required.

These changes might be due to differences in race and genetic factors. Moreover, difference of Iranian's lifestyle compared to other nations including sitting on the ground, way of worship and specific shape of toilets could be considered as effective factors (19).

Due to the significance of PTS, retaining normal knee slope is important during arthroplasty and high tibial osteotomy (14, 30, 31). Results and data obtained from this study can be used in PTS reconstruction in knee surgery.

Given the ethnic distribution in Iran and the importance of anatomical and morphological indicators, this study is proposed to be carried out more widely in other regions. We did not calculate two variables of height and weight in the patients as independent factors. Therefore, future studies should consider these parameters.

Authors report no conflict of interest.

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References

1. Heidari Nik H. The study of body abnormalities in student's boy in Komijan city. Available at: URL: http://Komijanpazhoheshblogfacom/post-4aspx/; 2007.
2. Moreland JR, Bassett LW, Hanker GJ. Radiographic analysis of the axial alignment of the lower extremity. J Bone Joint Surg Am. 1987; 69(5):745-9.
3. Hsu RW, Himeno S, Coventry MB, Chao EY. Normal axial alignment of the lower extremity and load-bearing distribution at the knee. Clin Orthop Relat Res. 1990; 255(1):21527-.
4. Dejour H, Bonnin M. Tibial translation after anterior cruciate ligament rupture. Two radiological tests compared. J Bone Joint Surg Br. 1994; 76(5):745-9.
5. Shoemaker SC, Markolf KL, Finerman G. In vitro stability of the implanted total condylar prosthesis. Effects of joint load and of sectioning the posterior cruciate ligament. J Bone Joint Surg Am. 1982; 64(8):1201-13.
6. Genin P, Weill G, Julliard R. The tibial slope. Proposal for a measurement method. J Radiol. 1993; 74(1):27-33.
7. Brandon ML, Haynes PT, Bonamo JR, Flynn MI, Barrett GR, Sherman MF. The association between posterior-inferior tibial slope and anterior cruciate ligament insufficiency. Arthroscopy. 2006; 22(8):894-9.
8. Giffin JR, Vogrin TM, Zantop T, Woo SL, Harner CD. Effects of increasing tibial slope on the biomechanics of the knee. Am J Sports Med. 2004; 32(2):376-82.
9. Bae DK, Yoon KH, Song SJ, Noh JH, Kim MH. The change of the posterior tibial slope after cruciate retaining total knee arthroplasty. J Korean Orthop Assoc. 2008; 43(2):207-12.
10. Martineau PA, Fening SD, Miniaci A. Anterior opening wedge high tibial osteotomy: the effect of increasing posterior tibial slope on ligament strain. Can J Surg. 2010; 53(4):261-7.
11. Campbell W, Canale ST, Beaty JH. Campbell's operative orthopaedics. 11th ed. Philadelphia: Mosby, Elsevier; 2008.
12. Insall JN. Surgical techniques and instrumentation in total knee arthroplasty. Surg Knee. 1993; 43(2):739-804.
13. Stöckl B, Nogler M, Rosiek R, Fischer M, Krismer M, Kessler O. Navigation improves accuracy of rotational alignment in total knee arthroplasty. Clin Orthop Relat Res. 2004; 426(1):1806-.
14. Noyes FR, Goebel SX, West J. Opening wedge tibial osteotomy the 3-triangle method to correct axial alignment and tibial slope. Am J Sports Med. 2005; 33(3):378-87.
15. Seo JG, Moon YW, Kim JH. Influence of posterior tibial slope on stability after total knee arthroplasty. J Korean Knee Soc. 2007; 19(2):218-24.
16. Moore TM, Harvey JP Jr. Roentgenographic measurement of tibial-plateau depression due to fracture. J Bone Joint Surg Am. 1974; 56(1):155-60.
17. Matsuda S, Miura H, Nagamine R, Urabe K, Ikenoue T, Okazaki K, et al. Posterior tibial slope in the normal and varus knee. Am J Knee Surg. 1998; 12(3):165-8.
18. Chiu KY, Zhang SD, Zhang GH. Posterior slope of tibial plateau in Chinese. J Arthroplasty. 2000; 15(2):224-7.
19. Hosseinzadeh HR, Zandi R, Kazemi SM, Qoreishi SM, Shahi S, Safdari F, et al. Measurement of posterior tibial slope (a cross-sectional study in Tehran). Iran J Orthop Surg. 2011; 9(2):61-4.
20. Mohamad Qoreishi M, Syavash Hemmati M, Ali Sina Shahi M, Mehrnoush Hassas Yeganeh M, Kazemi SM. Measurement of posterior tibial slope (a cross-sectional study in Tehran). JBS J. 2015; 2(1):10-5.
21. Mahmodi SM, Zahraii M. An introduction and study of the knee joint structural parameters and their impact on degenerative joint disease. Med J Iran Hospital Dubai. 1998; 1:40-1.
22. Shahla A, Charesaz S. Hamze zade A. Influence of anatomical parameters in knee osteoarthritis. Urmia Med J. 2007; 18(1):402-6.
23. Fukubayashi T, Kurosawa H. The contact area and pressure distributionpattern of the knee: a study of normal and osteoarthrotic knee joints. Acta Orthop Scand. 1980; 51(6):871-9.
24. Dehghan M, Bahmani MT. Anatomical parameters associated with osteoarthritis of the knee joint. Armaghane Danesh. 2014; 19(5):462-9.
25. Garg A, Walker PS. Prediction of total knee motion using a three-dimensional computer-graphics model. J Biomech. 1990; 23(1):45-58.
26. Hernigou P, Deschamps G. Posterior slope of the tibial implant and the outcome of unicompartmental knee arthroplasty. J Bone Joint Surg Am. 2004; 86(3):506-11.
27. Hofmann AA, Bachus KN, Wyatt RW. Effect of the tibial cut on subsidence following total knee arthroplasty. Clin Orthop Relat Res. 1991; 269(1):63-9.
28. Callaghan JJ, O'Rourke MR, Goetz DD, Schmalzried TP, Campbell PA, Johnston RC. Tibial post impingement in posterior-stabilized total knee arthroplasty. Clin Orthop Relat Res. 2002; 404(1):83-8.
29. Kaper BP, Bourne RB, Rorabeck CH, MacDonald SJ. Patellar infera after high tibial osteotomy. J Arthroplasty. 2001; 16(2):168-73.
30. Hohmann E, Bryant A, Imhoff AB. The effect of closed wedge high tibial osteotomy on tibial slope: a radiographic study. Knee Surg Sports Traumatol Arthrosc. 2006; 14(5):454-9.
31. Çullu E, Aydoğdu S, Alparslan B, Sur H. Tibial slope changes following dome-type high tibial osteotomy. Knee Surg Sports Traumatol Arthrosc. 2005; 13(1):38-43.