RESEARCH ARTICLE

Correlation of Anthropometric Measurements of Proximal Tibia in Iranian Knees with Size of Current Tibial Implants

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Abstract

Background: The results of clinical studies have reported that Asian knee anatomical aspects are smaller than those of the Caucasian population. The purpose of this study was to investigate the morphometry of the proximal tibia in the standard resected surface of total knee arthroplasty (TKA).

Methods: In this descriptive study, the anthropometric data of the proximal tibia were measured in 132 knees (80 males and 52 females) using magnetic resonance imaging in 2015. The collected data included anteroposterior (AP) length, mediolateral (ML) width, medial AP, lateral AP, and aspect ratio (ML/AP). The medial and lateral AP distance to bone center was calculated for symmetry analysis. The morphometric data were also compared with the same dimensions of four current tibial implants.

Results: The mean age of the subjects was 38.26±11.45 year (age range: 20-60 years). The mean AP length and mean ML width in the resected surface of the bone, as well as the mean aspect ratio (ML/AP) of tibial bone in all the subjects, were 46.53±4.05 mm, 73.36±6.86 mm, and 1.58±0.11, respectively. The mean values of medial and lateral AP distance up to bone center were 13.40±6.17 and 17.09±6.83 mm, respectively, indicating asymmetric proximal tibia in the study population.

Conclusion: The measurements of anatomic shapes and dimensions of the proximal tibia revealed that women have smaller dimensions than their male counterparts. Prostheses with smaller AP size tended to be undersized and larger AP size had a tendency towards overhang in the mediolateral dimension. The data and obtained results of this study can be used as guidance on designing tibial implant components suitable for TKA in the Iranian population.

Level of evidence: IV

Keywords: Implant, Knee, Morphometry, MRI, Proximal tibia

Introduction

Total knee arthroplasty (TKA) is a surgical procedure that requires high accuracy and the balance should be established among the resected soft tissue and bone surface with a replaced prosthesis so that there should be enough space for knee flexion and extension. In addition, the knee joint must be stable in a wide range of motions (1-6). The number of TKA surgeries with the aging population and the prevalence of obesity have increased in the past two decades.

The TKA surgery is currently one of the most common

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and costly medical procedures in the United States (7, 8). In addition, the need for knee arthroplasty with the increase in life expectancy is projected to elevate more than six times by 2030 (9). The TKA success rate greatly depends on the choice of prosthesis, exact size, and correct site of its components, and the observance of these principles are crucial to the success and long-term retention of the prosthesis (10-12).

The results of various studies showed that proper bone implant coating is effective in the successful placement of tibial components in TKA surgery (4, 5, 13, 14). To this end, it is required to collect anthropometric data regarding the proximal tibia (5, 15, 16). Therefore, the knowledge of anatomic and geometric values of body bones is one of the most important issues in orthopedic surgery, which has a great impact on the way various problems and outcomes are treated (17).

This study was performed to measure the dimensions of the proximal tibia, assess the differences between males' and females' dimensions, study the symmetry of tibial bone, compare measured dimensions with existing prosthetic systems, and evaluate the fit of the prosthesis with knee morphological dimensions among the Iranian population.

Materials and Methods

This prospective descriptive study was carried out on 132 knees (80 males and 52 females) in Imam Reza (AS) Hospital of Mashhad, Iran, using magnetic resonance imaging (MRI) in 2015.

All the patients who required MRI due to knee pain, uncertain history, and physical examination according to scientific indications with normal MRI report within the age range of 20-60 years were enrolled in the present study. The subjects with a history of advanced arthritis, previous fractures of proximal tibial and plateau, as well as osteophytes, and unnatural lower limb alignment were excluded from the study.

Informed consent was obtained from all the participants in the present study. The presented proposal was approved by the research committee of Shahid Beheshti University of Medical Sciences, Iran. All the measurements were recorded in millimeters using the Philips imaging software (Philips DICOM Viewer, R3.0 SP3, 2013).

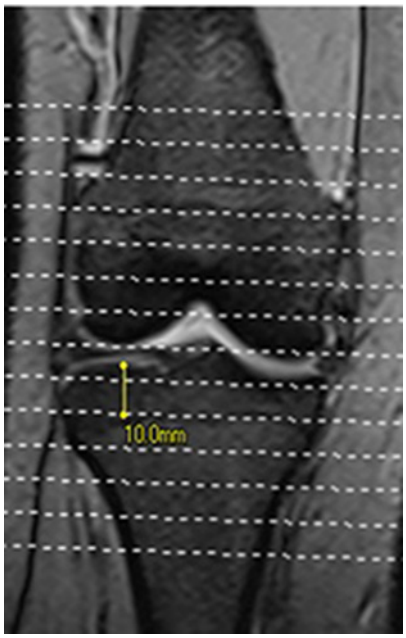

Figure 1. Frontal view of knee joint with 10-mm thickness in proximal tibial surface.

Measurement of proximal tibia

To simulate the proximal tibial cut with standard cutting for TKA, initially in the frontal plane, 10-mm thickness was considered below the tibial plateau surface [Figure 1]. Then, the desired parameters were measured in the axial plane.

According to a definition by Kwak et al. and Dai et al., a set of morphological metrics were calculated as follows [Figure 2] (18, 19):

- **Mediolateral (ML) width:** The ML dimension was taken as the longest ML width of the resected proximal tibial surface, drawn parallel and collinear to the surgical epicondylar axis of the femur.
- **Anteroposterior (AP) length:** The AP dimension was taken as the length of a line drawn perpendicular and passing through the midpoint of the ML line.

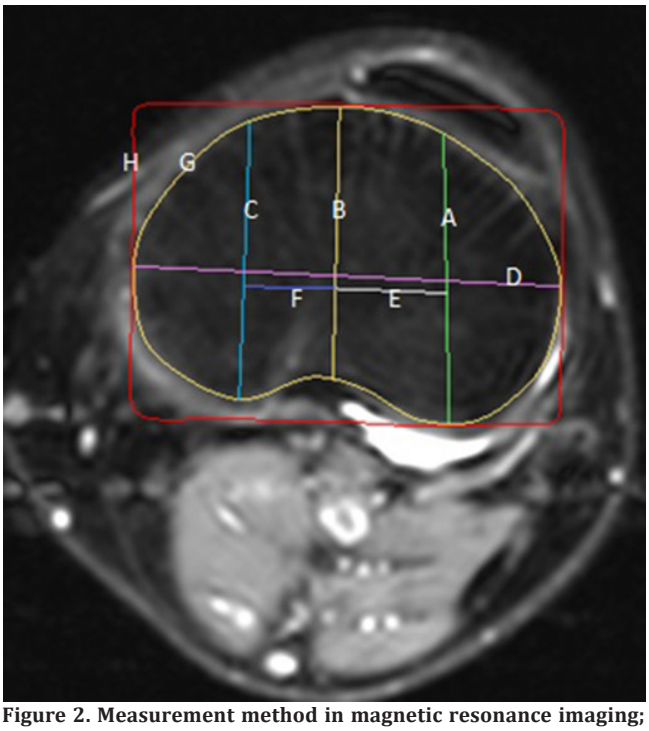

Figure 2. Measurement method in magnetic resonance imaging; (A) medial anteroposterior length, (B) anteroposterior length, (C) lateral anteroposterior length, (D) mediolateral width, (E) medial to center distance, (F) lateral to center distance, (G) plateau area, and (H) bounding box area.

- **Medial anteroposterior (MAP) and lateral anteroposterior (LAP):** The MAP dimension and LAP dimension were defined as the longest lines drawn parallel to the AP line and perpendicular ML lines that connect the most anterior and the most posterior parts in the medial and lateral compartments in the resected tibial surface, respectively.
- **Medial to center distance (CM) and lateral to center distance (CL):** The MAP and LAP distances to the central point are called CM and CL, respectively
- **Plateau area:** Overall and for each compartment
- **Bounding box area:** Overall and for each compartment
- **Aspect ratio:** The resected tibial plateau aspect ratio has been defined as ML/AP ratio, and for each compartment (compartment aspect ratio) it has been calculated as MAP/ML and LAP/ML in the medial and lateral compartments, respectively.

Statistical analysis

The data were statistically analyzed using SPSS software (version 22). Descriptive statistics were applied to measure the variables and age. In a comparison between the genders, the t-test and Mann-Whitney U test were used for normal and nonnormal variables, respectively. Linear regression was recruited to study the correlation between simulated bone cut and dimensions of prostheses used in TKA surgery. *P-value* less than 0.05 was considered statistically significant.

Results

In total, 132 patients, including 80 males (61%) and 52 females (39%) within the age range of 20-60 years were enrolled in the present study.

Proximal tibia

All the study parameters were measured after the simulation of the proximal tibia with TKA surgical cut (Table 1).

The mean scores of AP length and ML width, as well as the aspect ratio of tibial bone, in all subjects were 46.53±4.05 mm, 73.36±6.86 mm, and 1.58±0.11, respectively. The mean values of MAP and LAP were 50.12±4.88 and 48.70±5.35 mm, respectively. There was no significant difference regarding the variables of MAP/LAP, MAP/ML, and LAP/ML between males and females (*P>0.05*). Other variables were significantly higher in males, compared to those in females (*P<0.05*).

Table 1. Average values of the proximal tibial morphological measurements

parameters	Male	Female	Total	*P-value*
	Mean±SD	Mean±SD	Mean±SD	
Age (year)	34.69±10.95	43.75 ±10.01	38.26±11.45	<0.001
Dimension (mm)				
AP	48.79±3.08	43.07±2.68	46.53±4.05	<0.001
ML	77.80±3.78	66.52±4.48	73.36±6.86	<0.001
MAP	53.14±3.21	45.48±2.98	50.12±4.88	<0.001
LAP	51.94±3.57	43.71±3.46	48.70±5.35	<0.001
CM	14.68±7.34	11.43±2.76	13.40±6.17	0.003
CL	18.43±8.03	15.04±3.61	17.09±6.83	0.005
Area (mm^2 × 1,000)				
Plateau	3.40±0.31	2.52±0.24	3.06±0.52	<0.001
Medial Plateau	1.66±0.20	1.24±0.17	1.49±0.28	<0.001
Lateral Plateau	1.75±0.24	1.29±0.17	1.57±0.31	<0.001
Bounding box	4.35±0.43	3.20±0.34	3.90±0.69	<0.001
Medial Bound box	2.11±0.25	1.59±0.22	1.91±0.35	<0.001
Lateral Bound box	2.23±0.38	1.61±0.22	1.98±0.45	<0.001
Aspect ratio				
MAP/LAP	1.03±0.07	1.05±0.09	1.03±0.08	0.184
ML/AP	1.60±0.10	1.55±0.11	1.58±0.11	0.008
MAP/ML	0.68±0.03	0.69±0.05	0.68±0.04	0.752
LAP/ML	0.67±0.03	0.66±0.05	0.66±0.04	0.308

SD :standard deviation.

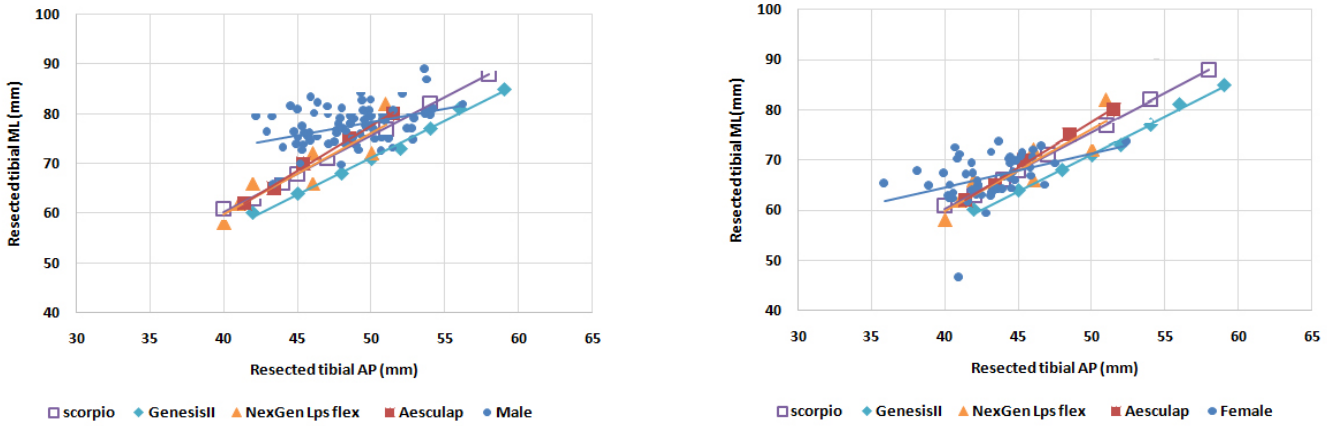

Figure 3. Correlations of resected tibial mediolateral width and anteroposterior length in 132 knees of study population in comparison with dimensions in four current tibial prostheses.

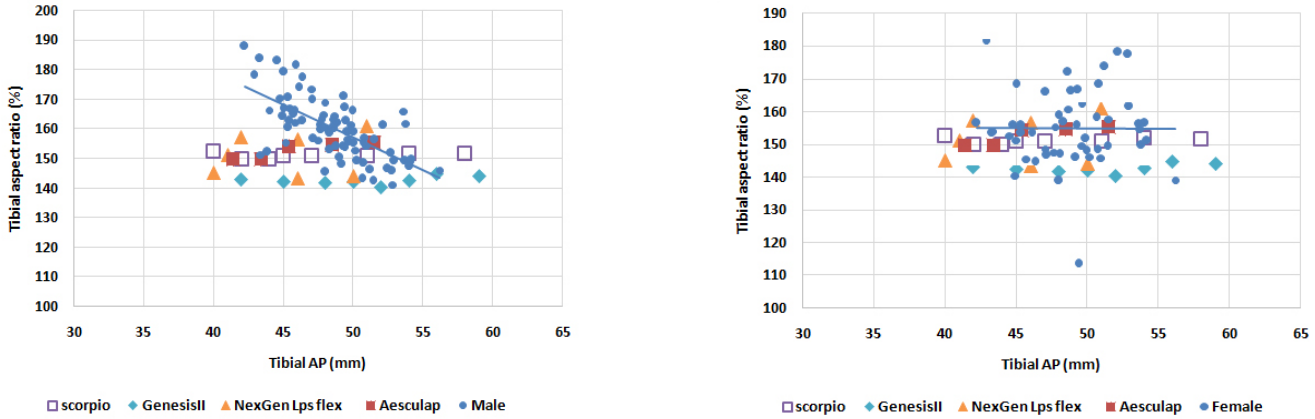

Figure 4. Aspect ratio (ML/AP) and anteroposterior dimension in 132 knees of study population in comparison with dimensions of four current tibial prostheses.

Correlation of current tibial components and resected proximal tibia

The comparisons were conducted between the obtained size of the proximal tibia in this study among the Iranian population and prostheses, including NexGen, Scorpio, Genesis II, and Aesculap. The diagrams showed the relative correlation between the proximal tibia and tibial components of the NexGen, Scorpio, and Aesculap prostheses, as well as low correlation with the Genesis II prosthesis.

In terms of prosthetic fit between the genders, all prostheses showed mismatch in smaller and larger AP values. In fact, the implants with smaller AP size tended to be undersized and larger AP size had a tendency towards overhang in the mediolateral dimension [Figure 3]. In the diagrams that compared the aspect ratio, a glimpse into the slopes of correlation indicated a different trend between males and females [Figure 4].

In men's knees, a progressive decrease was observed in the aspect ratio (ML/AP) by increasing the size of AP. However, the aspect ratio in designing most of the prostheses is considered to be fixed or on the rise (18). In women's knee, the aspect ratio (ML/AP) was almost constant with increasing the size of AP that is consistent with the designing of prostheses with a fixed ratio.

Discussion

Due to the increasing TKA, researchers should seek approaches to raise longevity and retention of the prosthesis. One of these methods is designing prostheses fitted in the anthropometry of any population. The majority of the pieces are designed to fit into the anatomical features of Western people. Moreover, the results of various studies are indicative of the differences in the anatomical and morphological characteristics of the lower limbs betwwen Western and Asian communities.

Regarding this, these variations should be considered in designing the pieces (17, 20, 21).

In the present study, the sizes of AP and ML were larger in males than in females that is supported by other studies (18, 22-26). In this study, the comparison of females and males with the same AP length revealed that the females had smaller ML width. In a study carried out by Kwak et al., after adjusting the size of AP in the proximal tibial surface it was observed that females had smaller ML width than males (18).

In another study conducted by Cheng et al., it was also reported that among females and males in the Chinese population with the same AP length, the ML width and aspect ratio are larger in males, compare to those in females (25). In contrast, according to a study performed by Lim et al., it was reported that among females and males with the same AP length, females had larger ML width (23). The contradiction among the studies may be due to the differences in height among participants, as well as the type of imaging technique.

In order to match the geometry of the components of the tibial prosthesis with the bone surface, the symmetry of the proximal tibial cut was discussed in this study (27-30). The mean values of MAP and LAP were 50.12±4.88 and 48.70±5.35 mm, respectively. Furthermore, the mean scores of CL and CM were reported as 17.09±6.83 and 13.40±6.17 mm, respectively, indicating asymmetric proximal tibia in the study population.

Although several authors have reported that asymmetric tibial components will fit better in the bone surface, some studies have pointed out that the tibial coating was improved in symmetric component design (27, 28). They believe that the asymmetrical models are not readily available and asymmetric implant design intensifies the need for operating room (18, 26).

Incavo et al. reported that the tibial coating was improved in the symmetric component design (5). However, no study has compared the longevity and retention of the tibial component between symmetric and asymmetric designed components (26). In the present study, the aspect ratio in males was greater in smaller knees. This explanation confirms the findings of other Asian studies that obtained such a decrease in the aspect ratio. However, unlike some studies, no significant changes in the aspect ratios were observed in females by increasing the AP size [Figure 4] (24, 26).

It should be noted that in all the prostheses the aspect ratio is almost constant or on the rise. Although the NexGen system tries to be more diverse by providing two medial-lateral sizes for a fixed anterior-posterior this type of prosthesis design is in contrast with the male population of the present study [Figure 4] (18, 26). In two studies carried out by Hitt et al. and Moghtadaei et al. similar to the present study, a progressive decrease was observed in the aspect ratio of men by increasing the AP length (26, 31).

In this study, the aspect ratio was almost constant in women by increasing the AP length implying a forecast for the oval-shaped implants (18). However, in a study carried out by Uehara et al. the aspect ratio increased in females. Moreover, in studies by Moghtadaei et al. and Kwak et al., the aspect ratio reduced in women by increasing the AP length (18, 22, 26). The distribution of measured value indicates that there are different ML sizes for a given value of AP (18, 27-29, 32). Several or at least two sizes of ML for an AP size are suggested to be available to overcome the possible mismatch and better coating (26).

The measurement of proximal tibial anatomic shapes and dimensions in the study population showed that women had smaller dimensions, compared to their male counterparts. By taking a fixed AP size in both genders, it was observed that women had smaller mediolateral size than men; therefore, prosthesis for women should have smaller ML width for a fixed AP length.

In addition, for better fitting of the prosthesis in tibial plateau surface, the medial AP length is better to be larger than the lateral AP length. The determination of morphological differences in tibial bone in the resected surface can improve the perception of anatomical variation in these bones and potentially provide a basis for understanding the differences in clinical outcomes. The findings of this study can be used as guidance to select the most appropriate prosthesis prior to surgery.

Suggestions

1. The subjects had normal knees and were relatively young; consequently, the obtained results may not be suitable for individuals with degenerative arthritis candidate for TKA surgery. Therefore, it is suggested to perform future studies on both elderly and young individuals in Iranian studies.
2. In this study, height and weight variables were not measured as independent factors in the dimensions of the proximal tibia; therefore, future studies should be conducted to investigate these issues.
3. Given the vastness of Iran, existence of various tribes and races, as well as the importance of morphological and anthropometric indices of tibial bone, it is suggested to carry out the same study in other places with a larger population.

Conflicts of interest: The authors declare that there is no conflict of interest.

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