Anthropometric Measurements of the Proximal Tibia in Iranian knees: Correlation to Sizing of Current Tibial Implants

Abstract

Background and objectives: Clinical studies have reported that Asian knee anatomical aspects are smaller than the Caucasian population. The purpose of this study was to investigate morphometry of proximal tibia in standard resected surface of total knee arthroplasty.

Materials and methods: In this descriptive research in 2015, anthropometric data of proximal tibia were measured in 132 knees (80 males and 52 females) using magnetic resonance imaging (MRI). Data included anteroposterior (AP) length, mediolateral (ML) width, medial AP (MAP), lateral AP (LAP) 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 subjects was 38.26 ± 11.45 year (20-60 years). The mean AP length and the mean ML width in the resected surface of bone as well as the mean aspect ratio (ML/AP) of tibial bone in all subjects were respectively 46.53±4.05 mm, 73.36±6.86 mm and 1.58±0.11. The medial and lateral AP distance up to bone center were respectively 13.40±6.17 mm and 17.09±6.83 mm, indicating asymmetric proximal tibia in the study population.

Conclusion: Measurements of anatomic shapes and dimensions of proximal tibial revealed that women have smaller dimensions than their male counterparts. Prostheses with smaller AP size tended to be undersized and larger AP size had tendency towards overhang in the

mediolateral dimension. Data and the results of this study can be used as a guide to design tibial implant components suitable for total knee arthroplasty in Iranian population.

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

1- Introduction

Total knee arthroplasty is a surgical procedure that requires high accuracy and the balance should be established among resected soft tissue and bone surface with replaced prosthesis so that there should be enough space for knee flexion and extension and the knee joint must be stable in a wide range of motions (1-6).

Numbers 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 and most 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 fold 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 prosthesis (10-12).

Various studies show that proper bone implant coating is effective in the successful placement of tibial components in TKA surgery (4, 5, 13 and 14). To this end, there are needs to anthropometric data on proximal tibia (5, 15 and 16).

Therefore, 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 how to treat the various problems and outcomes (17).

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

2- Materials and methods

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

All patients required to MRI due to knee pain, uncertainty of history and physical examination according to scientific indications, having healthy knee in examination and in the age range between 20 and 60 years were enrolled in the study. The patients with history of advanced arthritis, previous fractures of proximal tibial and plateau, osteophytes and non-natural lower limb alignment were excluded from the study.

Informed consent was obtained from all participants in this study. Research committee of Shahid Beheshti University of Medical Sciences, Iran, approved the presented proposal.

All measurements were recorded in millimeters using the Philips imaging software (Philips DICOM Viewer, R3.0 SP3, 2013).

2-1- Measurement of proximal tibia

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

Fig 1- Frontal view of knee joint that 10-mm thickness is shown in proximal tibial surface

According to the definition of Kwak et al. and Dai et al. a set of morphological metrics was calculated (18,19), as follows:

ML width: ML dimension was taken as the longest mediolateral width of the resected proximal tibia surface, drawn parallel and collinear to the surgical epicondylar axis of the femur.

AP Length: The anteroposterior (AP) dimension was taken as the length of line drawn perpendicular and passing through the midpoint of the mediolateral (ML) line.

MAP and LAP: Medial anteroposterior (MAP) dimension and lateral anteroposterior (LAP) dimension were defined as the longest lines drawn parallel to the AP line and perpendicular ML lines, which connect the most anterior and the most posterior parts in the medial and lateral compartments, respectively, in the resected tibial surface.

CM and CL: The MAP and LAP distance to central point are called respectively medial to centre distance (CM) and lateral to centre distance (CL).

Plateau area: overall, as well as for each compartment.

Bounding Box area: overall, as well as 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) has been calculated respectively as MAP/ML and LAP/ML in the medial and lateral compartments.

Fig 2- Measurement method on the MRI; (A) medial anteroposterior (MAP) length, (B) anteroposterior (AP) length, (C) lateral anteroposterior (LAP) length, (D) mediolateral width, (E) medial to centre distance (CM), (F) lateral to centre distance (CL), (G) plateau area, (H) bounding box area

2-2- Statistical analysis

Data were analyzed statistically using SPSS version 22 software. Descriptive statistics were applied to measure the variables and age. In a comparison between the genders, t-test and Mann-Whitney tests were used for normal and non-normal variables, respectively. Linear regression was recruited to study the correlation between simulated bone cut and dimensions of prostheses used in TKA surgery. The P value<0.05 was considered as a significant difference.

3- Results

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

3-1- Proximal tibia

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

The mean AP length and the mean ML width as well as the mean aspect ratio of tibial bone in all subjects were respectively 46.53±4.05 mm, 73.36±6.86 mm and 1.58±0.11.

The mean MAP and the mean LAP were respectively 50.12±4.88 mm and 48.70±5.35 mm.

There was no significant difference for 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 with females ($P<0.05$).

Table 1- Average values of the proximal tibia morphology measurements.

3-2- Correlation of current tibial components and the resected proximal tibia

The comparisons were conducted between the proximal tibial sizes obtained in this study among 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 and low correlation with the Genesis II prosthesis.

In terms of prosthesis fit between the genders, all prostheses showed mismatch in smaller and larger AP values. In fact, implants with smaller AP size tended to be undersized and larger AP size had tendency towards overhang in the mediolateral dimension (Figure 3).

In the diagrams comparing the aspect ratio (Figure 4), a glimpse into the slopes of correlation indicated different trend between males and females.

In men's knee, a progressive decrease can be seen in the aspect ratio (ML/AP) by increasing the size of AP. However, the aspect ratio in designing of most prosthesis is considered to be fixed or is on the rise (18).

In women's knee, the aspect ratio (ML/AP) is almost constant with increasing the size of AP, which is consistent with the prostheses design with fixed ratio.

Fig 3- Correlations of resected tibial mediolateral (ML) width and anteroposterior (AP) length in 132 knees of males and females compared with the dimensions in four current tibial prostheses

Fig 4- The aspect ratio (ML/AP in %) and the anteroposterior dimension (AP) in 132 knees of males and females compared with the dimensions of four current tibial prostheses

4- Discussion

Due to the increasing TKA, we should seek approaches to raise longevity and retention of the prosthesis. One of these methods is the design of prostheses fitted with the anthropometry of any population.

Regarding the majority of the pieces are designed to fit with the anatomical features of Western countries and the difference in the anatomical and morphological characteristics of the lower limbs in Western and Asian communities according to various studies, so these variations should be taken into account in the design of the pieces (17, 20 and 21).

In the present study, the AP and ML sizes were larger in males than in females, and this is supported by other studies (18, 22-26).

In this study, when females and males were compared with the same AP length, we found that females have smaller ML width.

Kwak et al. after adjusting the size of AP in the proximal tibial surface observed that females have smaller ML width than in males (18).

Cheng et al. 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 the males compare to females (25).

In contrast, Lim et al. 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 differences in height among participants as well as imaging technique type.

In order to match the geometry of the components of the tibial prosthesis with the bone surface, the symmetry of proximal tibial cut was discussed in this study (27-30).

The mean MAP and the mean LAP were respectively 50.12±4.88 mm and 48.70±5.35 mm as well as the mean CL and the mean CM were respectively 17.09±6.83 mm and 13.40±6.17 mm, indicating asymmetric proximal tibia in the study population.

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

Incavo et al. reported that the tibial coating improved in symmetric component design (5). However, no study has compared the longevity and retention of the tibial component between symmetric and asymmetric components designed (26).

In this study, the aspect ratio in males is greater in smaller knees. This explanation confirms the findings of other Asian studies that have obtained such a decrease in the aspect ratio; but

unlike some studies, no significant changes in the aspect ratios is seen in females by increasing the AP size (24, 26) (Figure 4).

The point to note is that in all the prostheses, the aspect ratio is almost constant or on the rise, although the NexGen system is trying to be more diverse by providing two medial-lateral sizes for an fixed anterior-posterior, but this type of prosthesis design is in contrast with the our male population (18,26) (Figure 4).

In a study carried out by Hitt et al. and Moghtadaei et al. similar to our 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 by increasing the AP length in women is almost constant, implying a forecast for the oval-shaped implants (18). However, in the study by Uehara et al. the aspect ratio was increased in females; and in studies by Moghtadaei et al. and Kwak et al. the aspect ratio was reduced in women by increasing the AP length (18,22,26).

Distribution of measured value indicates that there are different ML sizes for a given value of AP (18, 27-29, 32). To overcome the possible mismatch and better coating, it is suggested few or at least two sizes of ML available for an AP size (26).

5- Conclusion

Measurement of proximal tibial anatomic shapes and dimensions in the studied population showed that women have smaller dimensions compared to their male counterparts. By taking a fixed AP size in both genders, we found that women have smaller mediolateral size than in men, so prosthesis made for women should have smaller mediolateral width for a fixed anteroposterior length.

In addition, for better fit of prosthesis with tibial plateau surface, the medial AP length is better to be larger than the lateral AP length.

Determine the morphological differences in tibial bone in resected surface can improve 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 a guide to select the most appropriate prosthesis prior to surgery.

6- Suggestions

1- Our sample had normal knees and relatively young; consequently, our results may not be suitable for people with degenerative arthritis candidate for TKA surgery. Therefore, it is suggested to be added some elderly people in Iranian studies.

2- We did not measure two height and weight variables as independent factors in dimensions of the proximal tibia; future studies should cover these issues.

3- Given the vastness of Iran and the existence of various tribes and races as well as the importance of morphological and anthropometric indices of tibial bone, this study is suggested to be done more widely and in other places with larger population.

Disclosure

Authors report no conflict of interest.

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Figure legends

Fig 1- Frontal view of knee joint that 10-mm thickness is shown in proximal tibial surface.

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