Anthropometric measurements of distal femur to design the femoral component of total knee arthroplasty for the Iranian population

Abstract

Background and objectives: Acquiring knowledge about anatomic and geometric quantities of bones is among the most vital parameters in orthopedic surgery, which has a significant effect on the treatment of various disorders and subsequent outcomes. The aim of this study was to obtain anthropometric information for distal femur in order to compare with similar dimensions of prosthesis used in total knee arthroplasty (TKA) surgery and to design suitable and optimal components.

Materials and methods: Morphological data of distal femur were measured in 132 knees (81 males and 51 females) using magnetic resonance imaging (MRI). The data included anterior-posterior (AP) length, medial-lateral (ML) width, medial AP (MAP), lateral AP (LAP), MAP to LAP distance in the anterior distal femur namely anterior medial lateral (AML) width, medial and lateral condyle width and intercondylar notch. The aspect ratio (ML/AP) was also calculated and the results were compared with similar dimensions of currently used knee implants.

Results: Our data showed that men are significantly larger in all dimensions than women. In the distal femur with similar AP lengths in both sexes, women had a smaller ML width than men ($p < 0.001$). Comparison between the distal femur and studied prostheses showed no high correlation and similarity between femoral component and femoral condyle prostheses in the resected surface of the bone.

Conclusion: The results of this study can provide the data needed to design prostheses suitable for the Iranian population.

Keywords: Anthropometric, Distal Femur, Prosthesis, Magnetic Resonance Imaging, Knee

1- Introduction

Knee joint is the largest weight bearing and transferring joint in the body, which subsequently is affected by various inflammatory and degenerative diseases, ultimately destroying articular cartilage and proper joint function. Symptoms of knee joint disorders in the patient are characterized by pain, joint instability, reduced range of motion and deformity (1).

There are different therapeutic approaches for solving this problem, including changing the lifestyle, weight loss, nonsteroidal anti-inflammatory drugs (NSAIDs), physiotherapy, use of a cane, muscle strengthening, use of brace, debridement and osteotomy all of which are palliative methods, only reduce the patient's pain and delay the course of the disease; the disease progression leads to the need for definitive and final treatment of the disease, which is the Total knee arthroplasty (TKA) surgery (1-6).

Although TKA has been associated with many successes, but it has some disadvantages; for example, prosthetic damage results in a revision surgery that imposes a much higher cost and more dangers. For this purpose, researchers have always sought to find ways to increase the longevity and durability of prosthesis, one of which is the design of prosthesis that are appropriate to the anthropometry of each population because the success rate of TKA largely depends on the choice of prosthesis, the exact size, and the correct location of its components, and adherence to these principles is very important in the success and long-term survival of TKA prosthesis (7-9).

In this study, we decided to measure the anthropometric dimensions of distal femur and compare with available prostheses, as well as examine the necessity of gender- specific prosthesis.

2- Materials and methods

This descriptive study was performed on 132 knees using MRI in Imam Reza Hospital in Mashhad, Iran, in 2015.

Informed consent was obtained from all participants in this study. The proposed study was approved by the ethics committee of Shahid Beheshti University of Medical Sciences.

Inclusion criteria were people aged 20 to 60 years and normal lower extremity alignment. The patients with advanced arthritis history and any rheumatoid conditions, previous fractures in distal femur, osteophytes and gross congenital anatomy or deformity were excluded from the study.

The individual femur contour following each resection was exported for further analysis. All MRI were analyzed by pmsD view (Philips DICOM Viewer, R3.0 SP3, 2013) program.

2-1-Measurement of distal femur

To simulate femoral bone with a TKA surgical incision, a line was drawn in the frontal plate at 10 mm above the articular level, followed by measuring anterior-posterior (AP) length, medial-lateral (ML) width, medial AP (MAP) length, lateral AP (LAP) and length anterior medial lateral (AML) width in the axial plan. The width of the medial and lateral condyles (WM, WL) and intercondylar notch (WI) were also measured (Figure 1). All measurements were recorded in millimeters. To measure AP length, a line was drawn from the anterior cortex, the posterior femoral AP is also obtained by a line drawn as described by Ho et al (10), according to this method:

The measured points were 10mm on the medial condyle and 8mm on the lateral condyle from the lowest points on the medial and lateral posterior condyles.

The MAP and the LAP are the longest lines drawn in femoral medial and lateral compartment respectively. The AML is the distance between the two MAP and LAP points in the anterior

distal femur. The sum of the medial and lateral condyle widths and the inter condylar notch represent the ML width (Figure 1).

Additionally, the aspect ratio (the ML dimension divided by the AP dimension × 100) was calculated as well. The measured dimensions were compared with four available femoral components, including NexGen, Scorpio, GenesisII and Aesculap, and a gender-specific femoral component (NexGen-csf prosthesis); ML and AP values and ML / AP aspect ratio were also calculated for the prostheses.

Fig 1- Schematic representation(A)(10) and Axial MRI image(B) of the distal femur resected surface, showing the measurement methods used in the MR analysis.
MAP and LAP are respectively medial anterior-posterior length and lateral anterior-posterior length; AML is medial lateral width in anterior distal femur. WL, WM and WI are the width of lateral condyle, medial condyle and intercondylar notch respectively.

2-2- Statistical analysis

The SPSS version 22 software was used for statistical analysis. Descriptive statistics were used to measure the variables. For comparison between men and women, the t-test was used for parametric variables, and the Mann -Whitney test was used for nonparametric variables. Finally, linear regression was used to compare the results and determine the cut correlation of simulated bones with the dimensions of the prostheses. P value <0.05 indicated a significant difference.

3- Results

A total of 132 patients, including 81 men (62%) and 51 women (38%) aged 20-60 years, were enrolled in the study.

The mean AP length was 42.22±4.89 mm, the mean ML width was 67.53±6.66 mm, the mean WM, WI and WL were 26.72±3.41 mm, 20.90±3.31 mm and 24.49 ± 2.49 mm, the mean MAP was 53.88±6.64 mm, the mean LAP was 55.85±5.44 mm, the mean AML was 37.75±4.74 mm and the mean ML / AL aspect ratio was 1.61 ± 0.16.

Regarding the distal femoral morphology, our data showed that, except for LAP / ML in all dimensions, men were significantly larger in size than women ($p < 0.05$), MAP / ML and MAP / LAP variables were not significantly different ($P > 0.05$) between men and women (Table 1).

Table 1- Anthropometric Measurements of distal femur resected surface

3-1- Comparison of distal femur dimensions with available prostheses

Comparison between distal femur and prostheses (NexGen, Scorpio, GenesisII and Aesculap) showed a low correlation between all femoral component prostheses and femoral condyle in the resected surface of the bone(Figure 2).

In this study, we compared the mean AP and ML dimensions with gender-specific prosthesis (NexGen). For further investigation, the distal femur morphology was examined separately among the sexes (Figure 2) and it was found that the mean AP and ML dimensions in the female knee were more fit with gender-specific prostheses. Simply put, in the Iranian

population, like other ethnic groups, women have a smaller ML size for a similar amount of AP that justifies the use of gender-specific prostheses. As has been shown in various studies, there are differences between men and women in modern total knee arthroplasty (11-14).

In terms of prosthetic fitting among the sexes, all prostheses indicated size mismatch in larger and smaller sizes. In women, the implants tended to undersize in smaller AP dimensions and overhang in larger AP dimensions. In men, almost all prostheses in the ML dimensions tended to undersize with an increase in AP dimensions (Figure 2).

In the comparison graphs of the aspect ratio (Figure 3), a different trend can be seen between men and women. An increase in AP size, the ML / AP aspect ratio indicated a gradual decrease in men and a mild upward in women.

The femur aspect ratio on data simulated in men show a greater ratio for smaller knees and a lower ratio for larger knees.

Fig 2- The relationship between the ML and AP dimensions of the examined population with the femoral components available in men and women

Fig 3- The relationship between the AP/ aspect ratio of the examined population with the femoral components available in men and women

4- Discussion

Modern total knee arthroplasty began with the development of condylar knee prosthesis in 1970 and is considered one of the most successful orthopedic surgeries, according to the knee association. The main indication of knee joint replacement is the removal of severe knee pain with or without deformity (15, 16).

As noted in the literature, in addition to the patient's condition and surgical procedure, improving the design of the prosthesis promotes the normal functioning of patients after TKA surgery (17).

It is well-known that the Asian population has smaller dimensions of the knee than its western counterparts and imported implants, which are mainly based on Western anthropometrics, are unsuitable for patients in Asian countries (18-20).

Therefore, anthropometric and morphological studies of different ethnic groups are required to improve the quality, shelf-life and longevity of prostheses.

Our study on the same distal femur AP size in both genders showed that women had a smaller medial-lateral size than males ($P < 0.001$), similar to those of the study in Korea (21). There was also a significant difference in the resected surface between the sexes and the measured parameters; in all of these parameters, the amount in men was higher than that of women.

Mahfouz et al. in the Caucasus showed that the anterior condylar height and eminence in women are less than that of men (22).

Dargel et al. reported significant differences between male and female samples, as the knee dimensions of men in many parameters were significantly higher than women (23).

Comparison of distal femur dimensions in Table (2) shows racial differences that may be important for the design of implants.

Table 2- Comparison of findings from distal femur in different countries

We measured the ML width for further fitting with TKA surgical incision in the condylar surface; the studies have been conducted in China, Korea, Caucasus, Malaysia and India anatomic intercondylar axis (19, 21, 24, 25), other studies in Table 2, like ours, computed the ML width in the condylar surface, which makes the reported results smaller.

However, we are unable to compare our population and dimensions with other studies in this area because of differences in imaging and measuring techniques (20, 26, 27).

In examining the measured dimensions of knee bones, it was found that there are different sizes of the ML width for a constant AP value. In contrast, most implant systems consider only one ML width for an AP length (Figure 2). Therefore, implants with multiple ML widths should be designed for an AP length to get better anatomical fit. The need for gender-specific prosthesis in knee joint replacement surgery is a part involved in the recent orthopedic community. Clinical trials done so far, regardless of the patient's gender, have proven that TKA surgery successfully eliminates pain in patients with knee osteoarthritis and improves knee function (28-34).

However, orthopedic surgeons accept the differences in knee anatomy between men and women, and numerous studies support the existence of such gender changes (11-13, 35), but the clinical relevance of these differences is still unclear (28, 36).

Conley et al. argued that since the mean female distal femur is more trapezoidal shape, when using standardized-size prostheses with respect to gender differences in the size of medial condyle and lateral distal femur, female patients may receive too many large patello-femoral components (12). In the main dimension in the femoral component implant, the AP length and the ML width are used to select an appropriate size for each patient. The AP length is

198 widely utilized as the main parameter for the implant size, because it is strongly associated
199 with the moving and walking and symmetric balanced flexion and extension gaps (37).
200 It is also very important to understand the relationship between the AP length and the ML
201 width of the knee joint for implant design.
202 Chin et al. suggested that when the size of a prosthesis is determined based on the AP length,
203 if the ML width of the prosthesis is larger than the ML width of resected distal femur surface,
204 it will lead to ML overhang, which may lead to the soft tissue inflammation and imbalance
205 (14). Other studies also show that in the distal femur with the same AP length in both
206 genders, women have a smaller ML width. Therefore, if the implant components are made
207 according to the femoral AP length, the ML width may be overhang (11-13, 35).
208 Wei-pin et al. compared AP and ML dimensions of the subjects with the Uknee, NexGen, and
209 Duracon systems and found that in a similar AP length, the ML width in these prostheses was
210 greater than the ML width in the resected surface of the bone. Therefore, this implant in
211 Chinese patients tended to the ML width overhang in the distal femur resected surface. In this
212 study, the aspect ratio for femur bone in the resected surface of the bone showed a higher
213 ratio for smaller knees and a lower ratio for larger knees, but the examined prostheses showed
214 slight changes in the aspect ratio compared to the AP length (10).
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Study limitations

1- We did not calculate the two variables of height and weight of patients as independent factors in the distal femur dimensions.

2. Our samples were related to young and healthy knees, which may be unsuitable for people with degenerative arthritis who are candidates for TKA surgery.

3. Statistical homogenization was performed for age, but the results might be affected due to the age difference between male and female samples.

4- Due to the vastness of Iran and the existence of various tribes and races, as well as the importance of morphological and anthropometric indices of tibial and femoral bones, it is recommended that the similar research should be carried out more widely and in other parts with larger statistical sample size.

5- Conclusion

A wide range of two measured ML and AP dimensions has been distributed excessively in this study. Therefore, an implant component with the same AP length should have a multiple ML widths for anatomical fit.

In addition, due to the anthropometric differences of various ethnicities, it is necessary to design and construct the prostheses with normal anatomical fit for each ethnic group. In this study, we tried to investigate the anthropometric dimensions of femur to improve the design of existing prostheses. This data may be useful for designing fully fitted implants with a resected surface of the bone.

Disclosure

Authors report no conflict of interest.

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Figure legends

Fig 1- Schematic representation(A)(10) and Axial MRI image(B) of the distal femur resected surface, showing the measurement methods used in the MR analysis.
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