A study on morphometric features of the distal femoral resected surface in the osteoarthritis knees of Chinese patients and the differences in Males and Females.

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Research Article

Keywords: distal femur, resected surface, aspect ratio, total knee arthroplasty

Posted Date: August 18th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1959976/v1

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Abstract

Purpose
To measure the morphometric features of the distal femoral resected surface in the osteoarthritis knees of Chinese patients and to analyze the morphometric variation of the distal femoral resected surface.

Method
The computer tomography (CT) images of a total of 406 knees from 203 osteoarthritis patients who underwent total knee arthroplasty (TKA) from January 2018 to December 2021 were analyzed. These imaging data were imported into the software of Mimics 21.0 and the three-dimensional (3D) model of the femur was reconstructed. When the distal femoral bone resection was simulated in this software, the measurement of medial-lateral (ML) dimension and anterior-posterior (AP) dimension of the resected surface was performed in the software. We analyzed the differences of AP dimension, ML dimension, and aspect ratio (ML/AP) between females and males.

Result
The mean ML dimension, the mean AP dimension, and the mean AR value measured in Chinese knees were 66.36 ± 4.61 mm, 58.39 ± 3.81 mm, and 1.14 ± 0.07 respectively. An obvious inter-individual morphometric variation of the distal femoral resected surface was observed between males and females. The data of the dimensions for Males are significantly larger than that for females, including the calculated values of AR. The results showed that the distal femoral resected surface of female seemed to be “narrower” than that of male.

Conclusion
The morphology of the distal femoral resected surface in Chinese patients with osteoarthritis shows great interpersonal variability, with men showing significantly higher values than women. Our results could provide a reference for the design of the prosthesis best fit for Chinese.

Introduction
Total knee arthroplasty (TKA) is currently the most successful and cost-effective surgical option for patients with end-stage knee osteoarthritis. It can correct deformity and relieve pain by restoring limb alignment and obtaining good soft tissue balance [1, 2]. Although at present TKA has achieved favorable clinical outcomes, about 20% of patients are still not satisfied with their results [3]. This procedure requires high precision on the procedure of bone resection, especially the femur, to acquire a perfect shape match between the component and the resected surface. Proper size and placement of the femoral component can provide the best coverage, and avoid patellar mal-tracking as well as soft tissue impingement [4, 5]. Currently, the mainstream brands of TKA prostheses are designed according to the Caucasian knees, which has been proved not properly fit in Asian patients. Many studies have shown that Asian knees are generally smaller than Caucasian knees and require smaller prostheses [6–8]. Thus, it's important to know the morphology polymorphism of the distal femur among ethnics [9].

Two major dimensions in the distal femur were chosen as the main reference for the selection of prosthesis size, the anterior-posterior (AP) length and medial-lateral (ML) width[5]. In addition, the femoral aspect ratio (AR), which is calculated by dividing the ML width by the AP length has been widely used as the proper parameter to describe the shape of the distal femur [10]. However, most literature related to this issue only focuses on measurements of the intact knees. The anthropometric measurement of the distal femoral resected surface could be more valuable because they are the final size prepared for the femoral component before implantation [11]. As the purpose of the morphometric research was to improve the design of the prosthesis, Dong XH et al[12] measured the morphometry of the resected distal femur surface between osteoarthritis (OA) and normal knees, finding that OA knees have an oval-shaped distal femur with a wider ML length than the normal knees. We insist that research should be based on data from osteoarthritis (OA) knees rather than normal knees.

Our primary objective of this study was to carry out an anthropometric analysis on the distal femoral resected surface based on the computer tomographic data obtained from osteoarthritis knees of Chinese people. The second objective was to discuss the extreme morphometric variation among females and males and the possible results they can lead.
Patients And Methods

Patients

A search was performed in our institutional database for patients diagnosed with knee osteoarthritis during January 2018 to December 2022, whose AP and lateral view X-rays, full-length lower extremity radiography and computed tomography (CT) scan of the knees showed varying degrees of degeneration on unilateral or bilateral knees (Kellgren–Lawrence (K–L) grades III–IV). A total of 203 patients (48 males and 155 females) with 406 knees were identified. The patients with knee varus or valgus deformity of > 15°, severe extra-articular deformities, inflammatory arthritis, post-traumatic arthritis, or previous surgery history were excluded. All the identified patients had undergone unilateral or bilateral TKA. Patients who had bilateral TKA surgery were only included in the study once, regardless of whether it was a one- or two-stage procedure. The average ages of the subjects were 66.57 ± 8.34 years (range, 40–86 years), 67.38 ± 7.60 years for males, and 66.32 ± 8.56 years for females. The average BMI was 25.71 ± 3.50 kg/m² (range, 16.87–39.85 kg/m²), 25.63 ± 3.04 for males, and 25.74 ± 3.63 for females. There were statistically significant differences between males and females in mean height and weight, but not in average age or BMI (Table 1). The study protocol was authorized by our institutional ethical committee, and all patients consented to the use of their clinical and radiological data for the study.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Combined (n = 203)</th>
<th>Females (n = 155)</th>
<th>Males (n = 48)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>66.57 ± 8.34</td>
<td>66.32 ± 8.56</td>
<td>67.38 ± 7.60</td>
<td>0.446</td>
</tr>
<tr>
<td>Height (m)</td>
<td>154.45 ± 6.80</td>
<td>152.94 ± 6.14</td>
<td>159.33 ± 6.56</td>
<td>0.000</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>61.28 ± 8.87</td>
<td>60.14 ± 8.73</td>
<td>64.96 ± 7.90</td>
<td>0.001</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>25.71 ± 3.50</td>
<td>25.74 ± 3.64</td>
<td>25.63 ± 3.04</td>
<td>0.848</td>
</tr>
</tbody>
</table>

Values in mean ± standard deviation. BMI, body mass index.

Simulated Distal Femoral Bone Resection

The patients received the 64-slice spiral CT scan (Lightspeed-64, General Electric Company, USA) on both legs, with a scan thickness of 0.625 mm. Position: both legs were in the neutral position, and the patella was upward. Then, the CT scan data was imported into the software of Mimics 21.0 (Materialise company, Belgium) in DICOM format. The low threshold of 226 was used to distinguish the bone and the soft tissue. The images of the femurs were segmented using a region-growing method to reconstruct the three-dimensional (3D) model. The measurements were also performed on this software. The osteophytes, if any, surrounding the distal femoral resected surface were excluded from the measurements. The distal femoral osteotomy was performed perpendicular to the mechanical axis of the femur with a cutting thickness of 9 mm above the lowest point of the medial condyle.

Measurements

The medial-lateral (ML) dimension was taken as the longest mediolateral width of the distal femoral resected surface, as drawn parallel or collinear to the surgical transepicondylar axis (STEA) of the femur, formed by connecting the lateral epicondylar prominence and the medial sulcus of the medial epicondyte [13]. The anterior-posterior (AP) dimension was taken as the longest length of the lateral femoral condyle, which was drawn perpendicular to the ML dimension as described by Yang B et al. [14]. The femoral lateral anteroposterior (LAP) and medial anteroposterior (MAP) dimensions were defined as the longest line drawn perpendicular to the ML dimension between the most posterior condylar and the anterior trochlear point from the lateral and medial condyle of the femur. All measurements were recorded in millimeters (Fig. 1). Additionally, the aspect ratio (AR) of the resected distal femoral surface (ML/AP) was calculated.

Statistical analysis

SPSS software 20.0 (IBM, New York, USA) was used for statistical analysis. Quantitative data were expressed as mean and standard deviation (SD). As the sample size was less than 2000, we took the Shapiro-Wilk tests to assess the normality of data distribution. P<0.05 was considered normality. Independent samples t-tests were used to determine the significance of morphometric differences between
females and males. Linear regression analysis was performed in Origin 2021 (Origin Lab, Northampton, USA) to determine correlations for the ML and AP dimensions. Values for $P < 0.05$ were regarded as statistically significant. Additionally, the AR values of the distal femoral resected surface were distributed according to quartile. We defined the resected distal femoral surfaces with the smallest quarter AR values as “narrow”, surfaces with the intermediate half AR values as “moderate”, and surfaces with the largest quarter AR values as “dumpy”.

**Results**

In the present study, we analyzed the anthropometric data of the distal femoral resected surface in 406 knees (310 females/96 males) using CT images. There were significant statistical differences between males and females in mean height and weight, but not in average age or BMI. The demographic characteristics of the patients are summarized in Table 1. All the measured dimensions in this study were found to be normally distributed and were analyzed by independent samples t-tests between males and females. The average values for ML, AP, MAP, LAP, and AR measured in this study were $66.36 \pm 4.61$ mm (range, 53.03–83.35 mm), $58.39 \pm 3.81$ mm (range, 46.19–68.99 mm), $49.81 \pm 3.35$ mm (range, 33.40–59.09 mm), $45.97 \pm 4.62$ mm (range, 31.00–57.24 mm), and $1.14 \pm 0.07$ (range, 1.00–1.34) respectively. The quartiles of ARs from smallest to largest are 1.09 (25%), 1.13 (50%), and 1.18 (75%) respectively. The statistical results showed that the dimensions for males are significantly larger than those for females, including the calculated values of AR ($P < 0.05$). To find if the femur condyles were asymmetric, we measured the MAP and LAP, and found that the MAP (49.81 ± 3.35 mm) had larger values than LAP (45.97 ± 4.62 mm) ($P < 0.05$). As shown in Table 2. In the linear regression analysis, results showed a positive correlation between the ML and AP dimensions in both males ($R^2 = 0.318$) and females ($R^2 = 0.182$), with the ML dimension increasing as the AP dimension increased. The linear fitting for the AP and ML dimensions of the females lies below the one of males, showing that females generally have a smaller ML dimension than males for a given AP dimension. (Fig. 2).

**Table 2**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Combined (n = 406)</th>
<th>Females (n = 310)</th>
<th>Males (n = 96)</th>
<th>$P$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ML (mm)</td>
<td>66.36 ± 4.61</td>
<td>64.78 ± 3.57</td>
<td>71.47 ± 3.84</td>
<td>0.000</td>
</tr>
<tr>
<td>AP (mm)</td>
<td>58.39 ± 3.81</td>
<td>57.31 ± 3.26</td>
<td>61.87 ± 3.38</td>
<td>0.000</td>
</tr>
<tr>
<td>ML/AP</td>
<td>1.14 ± 0.07</td>
<td>1.13 ± 0.07</td>
<td>1.16 ± 0.06</td>
<td>0.003</td>
</tr>
<tr>
<td>MAP (mm)</td>
<td>49.81 ± 3.35</td>
<td>49.57 ± 3.14</td>
<td>50.57 ± 3.89</td>
<td>0.011</td>
</tr>
<tr>
<td>LAP (mm)</td>
<td>45.97 ± 4.62</td>
<td>45.70 ± 4.71</td>
<td>46.83 ± 4.21</td>
<td>0.036</td>
</tr>
</tbody>
</table>

ML, mediolateral dimension; AP, anteroposterior dimension; MAP, medial anteroposterior dimension; LAP, lateral anteroposterior dimension.

**Discussion**

In TKA, precise shape matching between the prosthesis and the distal femoral resected surface is a determining factor for a long-term successful outcome. The femoral component fitting is important, especially in the anterior-posterior direction and the medial-lateral direction. Mismatch of the prosthesis in the two directions will have a different impact on clinical outcomes and even affect the survival rate of the prosthesis. Oversizing of the femoral component in the anterior-posterior direction alters the flexion gap, leading to patellofemoral tightness or overstuffing, which can cause unexplained pain or stiffness postoperatively [15]. However, undersizing of the femoral component may require over-resection of the distal femur, which leads to the elevation of the joint line and thus causes laxity in flexion [16]. Furthermore, Downsized femoral component may increase the risk of anterior cortical notching in the use of a posterior referencing system [17]. In the medial-lateral direction, both overhang and underhang (inadequate coverage of the distal end of the femur) of the femoral component were frequently encountered. Bonnin et al have reported that ML overhang is observed in 66% of femurs (84% in females). The overhang can cause soft-tissue irritation, residual pain, poor knee flexion, and poor functional outcome [5, 18]. Whereas components underhang may expose increased contact stress to more cancellous bones, which results in early subsidence and loosening of the prosthesis [19]. Current prosthesis designs and surgical techniques should be able to cope with morphologic variances by making surgical adjustments to fit a proper component on the resected surface, avoiding overhang and soft tissue impingement caused by bigger prostheses or instability due to smaller prostheses.

Lee et al [25] investigated CT scan measurements of knee morphologic data and found that CT scan measurements are comparable to intraoperative measurements. In this study, we choose CT data for the anthropometric measurement because its advantage in obtaining the anatomic landmarks and measurement on the 3D model of the femur can reduce the interobserver error generated from different view
compared with the intraoperative measurement or the cadaver measurement. Moreover, the data of CT is more convenient to be obtained. Regarding all the dimensions of the distal femur measured in this study, including ML, AP, MAP, LAP, those of females were significantly smaller than those of males. The ARs of females were smaller than that of males ($P = 0.003$). In addition, the linear fitting for the AP and ML dimensions of the females lies below those of males, showing that females generally have a smaller ML dimension than males for a given AP dimension, i.e. that the femurs of females are “narrower” comparing to males. (Fig. 2). In our study, the MAP and LAP on the femoral surface were also measured, and it was found that the MAP was larger than the LAP, similar to other studies [17, 20]. The anthropometric differences between females and males shown in our study were consistent with the results reported in other previous studies as the list in Table 3. Conley et al [21] identify three notable anatomic differences in females: a less prominent anterior condyle, an increased Q angle, and a reduced aspect ratio. Since the above differences exist and females account for almost two-thirds of TKA [22], the need for gender-specific knee prosthesis was proposed. But the necessity has been an issue of debate. Some studies have suggested that gender-specific prostheses do have an advantage on better radiographic fit than the standard unisex prosthesis [23, 24]. However, many studies and even systematic reviews do not give evidences to support that gender-specific prosthesis brings more favorable clinical outcomes [25–28].
Table 3
Summary of the morphometry of the distal femoral resected surface reported by different authors

<table>
<thead>
<tr>
<th>Authors</th>
<th>Population</th>
<th>Journal</th>
<th>Published time</th>
<th>Measured method</th>
<th>ML (mm)</th>
<th>AP (mm)</th>
<th>ML/AP(AR)</th>
<th>MAP (mm)</th>
<th>LAP (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Our study</td>
<td>Chinese</td>
<td></td>
<td>2022</td>
<td>CT</td>
<td>66.36 ± 4.61(C)</td>
<td>58.39 ± 3.81(C)</td>
<td>1.14 ± 0.07(C)</td>
<td>49.81 ± 3.35(C)</td>
<td>45.97 ± 4.62(C)</td>
</tr>
<tr>
<td>Ho WP et al.[15]</td>
<td>Chinese</td>
<td>The KNEE</td>
<td>2006</td>
<td>intraoperative</td>
<td>70.2 ± 5.4</td>
<td>63.7 ± 5.1</td>
<td>1.09 ± 0.06</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cheng FB et al.[7]</td>
<td>Chinese</td>
<td>The KNEE</td>
<td>2009</td>
<td>CT</td>
<td>71.0 ± 3.0(C)</td>
<td>64.1 ± 2.7(C)</td>
<td>111.1 ± 2.7%(C)</td>
<td>51.3 ± 3.3(C)</td>
<td>50.7 ± 4.0(C)</td>
</tr>
<tr>
<td>Yang B et al.[14]</td>
<td>Chinese</td>
<td>PLOS ONE</td>
<td>2014</td>
<td>CT</td>
<td>79.0 ± 5.0(M)</td>
<td>66.8 ± 4.0(M)</td>
<td>1.18 ± 0.06(M)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ha CW et al.[8]</td>
<td>Korean</td>
<td>The Journal of Bone and Joint Surgery</td>
<td>2012</td>
<td>intraoperative</td>
<td>74.8(M)</td>
<td>66.3(M)</td>
<td>1.12(M)</td>
<td>67.4(M)</td>
<td>66.3(M)</td>
</tr>
<tr>
<td>Lim HC et al.[16]</td>
<td>Korean</td>
<td>The KNEE</td>
<td>2013</td>
<td>MRI</td>
<td>78.6 ± 5.1(C)</td>
<td>58.7 ± 3.81(C)</td>
<td>1.25(C)</td>
<td>59.6 ± 4.75(C)</td>
<td>58.7 ± 3.81(C)</td>
</tr>
<tr>
<td>Bellemans J et al.[17]</td>
<td>European</td>
<td>Clinical orthopaedics and related research</td>
<td>2010</td>
<td>CT</td>
<td></td>
<td></td>
<td></td>
<td>1.31 ± 0.06(M)</td>
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<tr>
<td>Loures FB et al.[18]</td>
<td>Brazilian</td>
<td>PLOS ONE</td>
<td>2019</td>
<td>intraoperative</td>
<td>79.9 ± 5.7(M)</td>
<td>68.4 ± 5.6(M)</td>
<td>1.16 ± 0.1(M)</td>
<td>68.6 ± 5.7(M)</td>
<td>68.4 ± 5.6(M)</td>
</tr>
<tr>
<td>Serhat Mutlu et al.[19]</td>
<td>Turkish</td>
<td>Journal of Back and Musculoskeletal Rehabilitation</td>
<td>2021</td>
<td>CT</td>
<td>72.1 ± 2.8(C)</td>
<td>66.1 ± 2.1(C)</td>
<td>1.09(C)</td>
<td>53.7 ± 2.8(C)</td>
<td>53.0 ± 3.7(C)</td>
</tr>
<tr>
<td>Hafez MA et al.[20]</td>
<td>Arabian</td>
<td>The Journal of Arthroplasty</td>
<td>2016</td>
<td>CT</td>
<td>72.04 ± 6.6(C)</td>
<td>68.1 ± 7.75(C)</td>
<td>1.06 ± 0.14(C)</td>
<td>51.82 ± 6.06(C)</td>
<td>49.45 ± 6.24(C)</td>
</tr>
</tbody>
</table>

ML, mediolateral dimension; AP, anteroposterior dimension; MAP, medial anteroposterior dimension; LAP, lateral anteroposterior dimension; AR, femoral aspect ratio; M, Male; F, Female; C, Combined.
To date, many recent anthropometric studies have demonstrated knee anthropometric differences in Caucasians and other ethnicities [6, 9, 10, 29–31]. Among them, the difference between the Asian race and Caucasian race has been studied the most. And it is shown most clearly that all the measured distal femoral dimensions of the Asians and as well as the ARs of Asians [7, 8, 14, 32, 33] were generally smaller than those of the Caucasians. The smaller ARs of Asian knees means the distal femur seemed to be “narrower” than that of the Caucasian knees. The morphometric data of the distal femoral resected surface in our study was compared with that of previous investigations obtained from other ethnicities in Table 3. Our present study revealed that the average ARs of the distal femoral resected surface was 1.14 ± 0.07, which was consistent with the data measured in other studies of Chinese knees [7, 14, 32], and similar to those of knees of other Asian ethnicities, like Korean, but smaller than those of Caucasian knees [10]. Bellemans J et al.[34] reported that the average ARs of the distal femoral resected surface of European was 1.31 ± 0.06 for males, and 1.29 ± 0.06 for females. Hafez MA et al. reported that the size of Arab knees was generally smaller than Caucasian's and larger than Asian's [19]. However, the comparison of the differences of the diameters and AR values between different ethnicities could not be authentically realized due to differences in methods of measurement and imaging technology.

In 2019, the total number of TKAs performed in China was 374,833, of which 54.8% adopted imported prostheses [35]. The currently imported prostheses used in China are designed based on the anthropometric data of Caucasian knees and do not accommodate the Chinese knees. Cheng FB et al. [7] compared the morphometric data of Chinese knee with those of five prostheses currently used in China: Scorpio and Duracon (Stryker Howmedica Osteonics, Allendale, NJ); PFC sigma (DePuy-Johnson and Johnson, Warsaw, IN); Nexgen (Zimmer, Warsaw, IN) and DC-Dynamic (Plus-Fosun ortho Co., Beijing, China), four of which were imported prostheses. The results suggest that the imported prostheses which are suitable for Caucasian patients may be larger in ML dimension, and this situation was more evident in females.

The above situation not only exists in China, relevant studies in South Korea, Japan, Thailand, and other countries also have reached similar conclusions. The current design of prosthesis according to Caucasian knees does not cater to femoral anthropometric differences among races, which will bring the risks of overhang in the femoral component [6, 8, 10, 30, 31]. And thus, the idea of the racial-specific prosthesis was proposed. However, more studies are needed to determine whether the long-term clinical outcome of racial-specific prostheses will be as controversial as gender-specific ones.

In addition to the differences among gender and race, a wide inter-individual variation was observed in the present study ranging from 1.00 to 1.34, which deserves more attention and is worthy of our exploration on how to select the proper component size for coping with such a large variety of distal femoral resected surface. In this study we distributed ARs according to the quartiles and defined the morphometric features of the distal femoral resected surfaces into three morphotypes: “narrow” (AR values from 1.00 to 1.09, smallest, accounting for 25%), “moderate” (AR values from 1.09 to 1.18, immediate, accounting for 50%), and “dumpty” (AR values from 1.18 to 1.34, largest, accounting for 25%) (Fig. 3). As the number of current component sizes available to surgeons was limited, there were two situations we may encounter during the operation: When the components with a small AR value, the resected femoral surface is “narrow”; when the components with a larger AR value, the femoral resected surface is “dumpty”. After the distal femoral resection, we choose the femoral component size by referring to AP dimension or ML dimension on the resected surface. In the “narrow” surface, referring to the AP dimension can lead to an overhang in the ML direction; referring to the ML dimension can cause excess osteotomy of the posterior condyle or notch in the anterior cortex. While in the “dumpty” surface, referring to the AP dimension can lead to underhang in ML direction; referring to ML dimension can cause overstuffing. However, we only defined the morphotypes of the distal femoral resected surface according to the calculated quartiles of ARs in this study, but didn’t investigate component position on the postoperative radiography and the clinical outcomes of TKA knees with different morphometric features. In the further study, we will focus on the proposal of a classification system of the distal femoral resected surface to instruct us how to choose the proper femoral component size.

Our study has some limitations. Firstly, all participants enrolled in the present study received the treatment limited to a single orthopedic center in southwest China, which may not sufficiently represent the whole Chinese population. However, research regionalization is the common problem in the current study of femoral morphology. Secondly, all the measurements and analysis in this study were carried out by the same person, which may lead to information bias. Thirdly, we did not combine the postoperative radiography and the clinical

<table>
<thead>
<tr>
<th>Authors</th>
<th>Population</th>
<th>Journal</th>
<th>Published time</th>
<th>Measured method</th>
<th>ML (mm)</th>
<th>AP (mm)</th>
<th>ML/AP(AR)</th>
<th>MAP (mm)</th>
<th>LAP (mm)</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>70.5 ± 5.48(F)</td>
<td>67.26 ± 7.39(F)</td>
<td>1.06 ± 0.15(F)</td>
<td>51.02 ± 6.12(F)</td>
<td>48.14 ± 5.68(F)</td>
</tr>
</tbody>
</table>

ML, mediolateral dimension; AP, anteroposterior dimension; MAP, medial anteroposterior dimension; LAP, lateral anteroposterior dimension; AR, femoral aspect ratio; M, Male; F, Female; C, Combined.
outcomes with the variable AR values. This part of the research requires careful design and more data on clinical outcomes, we will continue this part of the research in the future.

Conclusion

In conclusion, the present study found that the morphometric features of the distal femoral resected surface in OA knees of Chinese patients shows great gender differences, with females showing significantly smaller dimensions than males and the distal femoral resected surface of the females seemed to be "narrower" than that of males. Also, the inter-individual variety of the distal femoral resected surface should be taken into account when choosing the proper femoral component size during operation. These data may also be useful for designing racial-specific TKA prostheses in China. Understanding the morphometric features of the knee has become essential for both TKA prosthesis manufacturers and orthopedic surgeons. As the words said that "If you can't measure it, you can't manage it".

Declarations

Ethical Approval

This retrospective study was approved by the medical ethics committee of the second affiliated hospital of Army Medical University (2018-YD-084-01). All patients involved in this study had given their consent to participate and to be published.

Competing interests

The authors declare there is no conflicts of interest regarding the publication of this paper.

Authors' contributions

Dr. Wang conceived and designed the study. Dr. Ke wrote the main manuscript. Dr. Rad, Dr. Ma, Dr. Qin collected the data. Dr. Ke and Dr. Zhang performed the statistical analysis on data. All authors read and approved the manuscript.

Funding

This work was supported by the Science and Technology Innovation and Application Development Project of Chongqing (Grant No. 2020C069).

Availability of data and materials

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

References


Figures
Photos of distal femoral resection and measurements were taken in the three-dimensional (3D) model of the femur. The distal femoral osteotomy was performed perpendicular to the mechanical axis of the femur with a cutting thickness of 9 mm above the lowest point of the medial condyle. ML was measured as the width of the resected surface, as drawn parallel or collinear to the STEA. MAP and LAP were taken as the widest dimension of the medial and lateral condyles and perpendicular to the ML. AP was taken as the longest length of the lateral femoral condyle, which was drawn perpendicular to ML.

The linear regression analysis showed a positive correlation between the ML and AP dimensions in both males ($R^2=0.318$) and females ($R^2=0.182$), with the ML dimension increasing as the AP dimension increases. The linear fitting for the AP and ML dimensions of females lies below the one of males.

Three different morphotypes of the distal femoral resected surfaces: “narrow”, “moderate”, and “dumpy”.

Figure 2

Figure 3