Three Dimensional Morphometric Differences of Resected Distal Femur and Proximal Tibia in Osteoarthritis and Normal Knees

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Research Article

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Three dimensional morphometric differences of resected distal femur and proximal tibia in osteoarthritis and normal knees

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Abstract

Background: There is a paucity of data concerning the morphological differences of resected distal femur and proximal tibias in osteoarthritis (OA) and normal knees. The objective of this study was to determine if morphometric differences exist in resected distal femur and proximal tibia surface between OA and normal knees in Chinese population.

Methods: Ninety-eight OA knee and ninety-six normal ones, taken from Chinese population, were measured by computed tomography for femoral mediolateral (fML), medial anteroposterior (fMAP), lateral anteroposterior (fLAP), medial condylar width (fMCW), lateral condylar width (fLCW) and tibial mediolateral (tML), middle anteroposterior (tAP), medial anteroposterior (tMAP), lateral anteroposterior (tLAP) dimensions to determine the morphologic differences between OA and normal knees.

Results: The average tMAP and fMCW dimensions were 50.2 ± 3.3 mm, 28.7±2.3 mm for OA, and 48.8 ± 3.8 mm, 27.1±2.2 mm for normal knees, respectively. There were significant differences between OA and normal knees with regard to tMAP and fMCW dimensions ($p<0.05$).

Conclusions: The study revealed the morphological differences of tMAP and fMCW between the OA and normal groups, which may provide guidelines for designing better knee implants that are more size-matching for OA knees.

Keywords: Computed tomography, Osteoarthritis, Normal knee, Total knee arthroplasty, Morphometry

Background

Appropriate prosthesis size marching the resected bony surfaces is considered a crucial factor for success in total knee arthroplasty (TKA) [1, 2]. If the prosthesis overhang or underhang the resected surface of the bone, it will increase the risk of component. Underhang may cause early subsidence and loosening of the prosthesis, whereas overhang may cause residual pain, poorer knee flexion, and decreased functional results [3, 4]. Thus, it becomes important to maximize coverage of the knee component on the resected bony surface to ensure a good clinical result and long-term survivorship of the prosthesis [5, 6]. To design proper knee component, many researchers have measured resected surface of normal knees from imaging [7, 8], others analyzed anthropometric features of diseased knees during TKA [9, 10]. It is unclear whether there are morphometric differences in resected bony surface between diseased and normal knees.

Generally, most knees that undergo TKA are deformed and shaped differently from healthy knees. It suggests that the design of the prosthesis should be based on the data from diseased knees [11]. However, most of the current available TKA prostheses are designed based on the anthropomorphic features of normal knees[12]. Such prostheses may not necessarily provide the best fit for TKA candidates. Osteoarthritis accounted for more than 90% of the patients who underwent primary TKA. To the best of our knowledge, none have compared morphometric differences in resected distal femur and proximal tibia surface between the OA and normal knees. The aim of this study, therefore, was to measure the morphometric features of resected distal femur and proximal tibia surface to determine whether there are morphometric differences between OA and normal knees.

Methods

This study was performed in accordance with the Declaration of Helsinkiwith and approved by institutional review board of Shannxi Provincial People's Hospital. The study recorded the morphology of 98 OA knees candidating for TKA and 96 normal knees without congenital anomalies or pathological deformities around the knee joint from June 2017 to April 2018. No knee had a varus or valgus deformity of >15°. The median hip-knee-ankle angle of the subjects was 7.4° for OA and 1.0° for normal. The median age of the subjects was 64.9 years for OA and 30.0 years for normal. The median height was 165.6 cm for the OA and 170.2 cm for normal knee.

Computer tomography (CT) imaging was performed using a helical CT scanner imaging machine (120kVp, 200mA, Somatom Sensation, Siemens Healthcare, Germany). The subjects were placed in the supine position on the scanner with knees in full extended position and their patellar facing towards the ceiling. The scanning procedure was performed to acquire 1.0 mm CT slices (image size, 512×512 pixels). All CT images were burn into discs. The images of the knees were segmented using a region-growing method to construct 3D bony models by Mimics17.0 (Belgium， Materialise). The measurements were performed using Geomagic studio14.0 software (USA, Raindrop).

The distal femur was cut 9 mm above the lowest point of the medial condyle with 6° valgus to the anatomical axis (Fig. 1 a). A line connecting the medial sulcus of the medial epicondyle and the lateral epicondylar prominence was defined as the surgical transepicondylar axis (STEA). The femoral mediolateral (fML) dimension was defined as the longest ML length of the distal cut femur surface; this line paralleled the STEA. The femoral lateral anteroposterior (fLAP) and medial anteroposterior (fMAP) dimensions were defined as the longest line drawn perpendicular to the fML between the most posterior condylar and the anterior trochlear point from the lateral and medial condyle of the femur. The medial and lateral condyle width were measured 10 mm above the lowest point of the medial posterior condyles to simulate the optimal cutting thickness (Fig. 1 b).

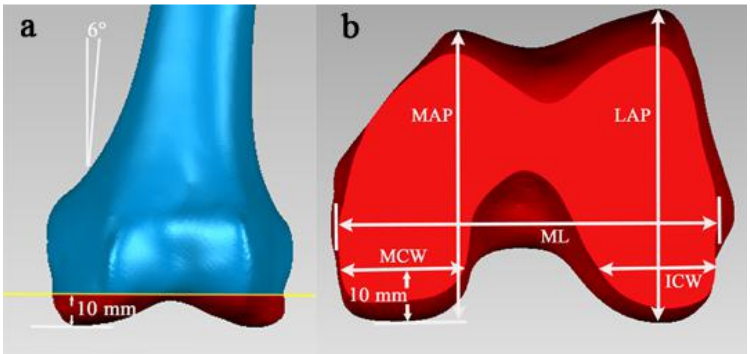

Fig. 1 Distal femur resection and measurement on CT images. a Resection method of distal femur. b Measurements of resected femoral surfaces.

The proximal tibial cut was performed perpendicular to the mechanical axis of the tibia, 8 mm below the lateral tibial plateau with 5° of posterior inclination (Fig.2 a). The tibial mediolateral (tML) dimension was taken as the longest mediolateral length of the resected tibial surface. This line is parallel to the surgical epicondylar axis of the femur and formed by connecting the medial sulcus of the medial epicondyle and the lateral epicondylar prominence. The tibial middle anteroposterior (tAP) dimension was taken as the length of line drawn perpendicular and passing through the midpoint of the tML line. The tibial lateral anteroposterior (tMAP) and medial anteroposterior (tLAP) dimension was taken as the length of the line drawn perpendicular to tML and passing through the posterior-most point of the lateral and medial tibial condyle (Fig.2 b).

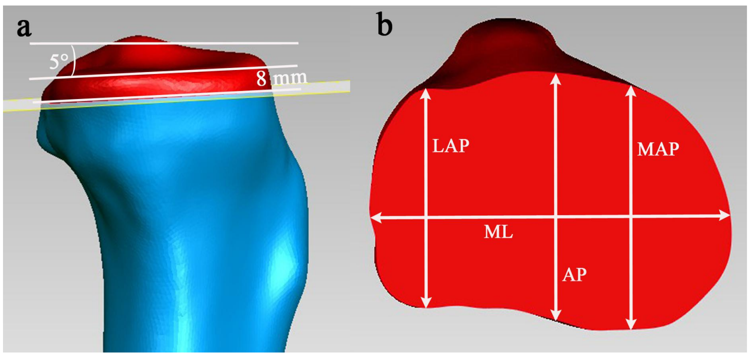

Fig. 2 Proximal tibia resection and measurement on CT images. a Resection method of proximal tibia.

b Measurements of resected tibial surfaces.

Statistical analysis

The SPSS software 18.0 (SPSS, Chicago, IL) was used for statistical analysis. Mean and standard deviation of measured dimensions were calculated. Independent sample t-test was used to determine the significance of morphological differences between OA and normal knees. The differences were regarded as significant when $P<0.05$.

Results

On the basis of the numbers available, the mean fML, fMAP, fLAP and fLCW dimensions were 74.3 ± 4.8 mm, 62.3 ± 3.9 mm, 64.5 ± 4.9 mm, 27.3 ± 2.4 mm for OA, and 73.1 ± 5.5 mm, 62.0 ± 4.0 mm, 64.2 ± 4.3 mm, 26.6 ± 3.3 mm for normal, respectively. There were no significant difference between OA and normals in relation to fML, fMAP, fLAP and fLCW dimensions ($p>0.05$). The average fMCW dimensions were 28.7 ± 2.3 mm for OA, and 27.1 ± 2.2 mm for normal, respectively. There were significant differences between the OA and normal with respect to fMCW dimensions ($p< 0.001$). (table 1).

Table 1 The distal femur dimensions in OA and normal knee (mm)

Parameter	OA	Normal	p
Femoral mediolateral (fML)	74.3±4.8	73.1±5.5	0.108
Femoral medial anteroposterior (fMAP)	62.3±3.9	62.0±4.0	0.699
Femoral lateral anteroposterior (fLAP)	64.5±4.9	64.2±4.3	0.564
Femoral medial condylar width (fMCW)	28.7±2.3	27.1±2.2	0.000
Femoral lateral condylar width (fLCW)	27.3±2.4	26.6±3.3	0.096

The average tML, tAP and tLAP dimensions were 75.1 ± 5.2 mm, 53.3 ± 3.9 mm and 48.4 ± 4.2 mm for OA, and 74.4 ± 5.5mm, 49.3 ± 4.0 mm and 47.7 ± 4.0 mm for normal, respectively. There was no significant difference between the OA and normal knee with respect to tML, tAP and tLAP ($p>0.05$). The average tMAP dimensions were 52.3 ± 3.3mm for OA, and 51.1 ± 3.7 mm for normal, respectively. There were significant differences between the OA and normal knee with respect to tMAP dimensions (p= 0.028). Table 2.

Table 2 The proximal tibia dimensions in OA and normal knee (mm)

Parameter	OA	Normal	p
Tibial mediolateral (tML)	75.1±5.2	74.4±5.5	0.368
Tibial medial anteroposterior (tMAP)	52.3±4.0	51.1±3.7	0.028
Tibial middle anteroposterior (tAP)	50.3±3.9	49.3±4.0	0.069
Tibial lateral anteroposterior (tLAP)	48.4±4.2	47.7±4.0	0.187

Discussion

Optimal coverage of the component to the resected bony surface is essential for long-term good outcomes after TKA. If the implant mismatches the resected bone surface, there will be undersizing or overhang, which could result in worse clinical outcomes [13]. Thus, it is critical to design size-matching component for TKA candidates according to knee mophology. Various morphological studies of the resected bony surfaces from normal [7, 14] or OA knees [9, 15] have been conducted to provide data for proper size-matching. Cheng et al [11] suggested that the design of knee component should be based on the data from diseased knee, rather than the normal knees. To date, no studies have looked into the morphology differences of resected femoral and tibial surface between the diseased and normal knee to determine which morphological data is more suitable for designing proper component.

In this study, we measured morphology of the resected distal femur and proximal tibia surfaces in OA and normal knees. The major findings were that the tMAP and fMCW dimensions in OA subjects were significantly larger than those of normal knee. In a study by Puthumanapully et al, the authors found that varus knees had larger femur dimension of medial condyle compared with normal knees[16]. The morphological differences of medial condyle between OA and normal knees may be explained by the pathological change of OA knees. Most OA knees of TKA candidates were varus deformtiy, and the medial condyle experienced destroying and remodeling as a response to larger loads during gait[17], which could eventually result in bony structural change in medial condyle of OA knees.

Many studies have reported on the measurements of resected proximal tibia surface in Asian knees. Cheng et al [7] reported mean tML, tAP , tMAP, and tLAP values were 73.0 mm, 48.8 mm，50.7 mm, and 45.3 mm in 172 Chinese normal tibias by CT imaging, which was similar to our data in normal tibias. Kwak et al [18] studied tibial 200 normal cadaver tibias and determined that tML, tAP , tMAP, and tLAP values were 71.9 mm, 48.8 mm， 45.9 mm, and 42.2 mm respectively on CT imaging. Uehara et al [19] studied 100 TKA tibias from the Japanese population on the CT scan and determined that the tML and tAP dimensions were 74.3 mm and 48.3 mm. The results in our Chinese subjects were a little larger than these Asians, which might be due to the difference between the heights of study groups. Charlton et al [20] reported a significant difference in the femoral bicondylar width between short and tall subjects, with the taller subjects having larger values. The average height (166.9 cm) in our study was a little higher than the Japanese subjects (151.9 cm) and Korean subjects (161.2 cm).

Several researchers have studied the dimensions of the distal femur in Asian populations. Cheng et al [7] reported the mean fML, fLAP values on CT to be 71.0 mm and 64.1 mm respectively in Chinese normal femurs. Lim et al. [14] showed that femoral fML, fMAP and fLAP dimensions were 78.6 mm, 59.6 mm and 58.7 mm in a Korean population using MRI. Urabe et al. [21] studied knees using CT imaging in a Japanese population and reported values of fML, fMCW and fLCW dimensions was 70.6 mm, 30.1 mm and 24.8 mm in OA subjects. The results of ours showed minor differences between these Asian populations. These differences may be due to the difference imaging technique and the difference between the height of study group. In additional, the depth of the resection affects the sizing of the resected bony surface. The depth of the distal femroal resection in our study at a thickness of 9 mm below the medial condyle was lower than the 10 mm [14, 21] depth used in other studies.

To date, many studies have confirmed knee anatomic differences of the Caucasian and Asian population [22, 23]. However, nearly all existing TKA components were designed based on the anatomy of Caucasian populations and not suitable for Asian patients [7, 24]. In clinical, Iorio et al followed (9 vs. 6.6 years) American and Japanese patients after primary TKA, and showed the American patients required significantly larger size implants than the Japanese patients. The authors also found that Japanese patients had significantly less postoperative range of motion (93.7 vs. 106.6°) and a higher revision rate (4.1% vs. 2.6%) than American patients [25]. Anatomy studies and clinical outcomes all demonstrated that ethnic differences should be considered for designing proper TKA component for Asian population.

We acknowledge that this study included a limited number of subjects and may not reflect the real features of knees in OA and normal knees. If a larger sample size was studied, other significant differences may be noticed. We are also aware of that only one bone resection level was measured. However, resection depth varies according to the stage of disease during TKA. In the future, we will report data for a larger sample size and measure the depth at different resection levels.

Conclusion

In summary, our study demonstrated that the tMAP and fMCW dimensions of resected knee surfaces were indeed significantly larger in OA than normal knees. As a result, we believe that the shape variations of the knee in OA and normal should be a concern when designing components for TKA candidates.

Abbreviations

OA: osteoarthritis; tML: Tibial mediolateral; tAP: Tibial mediolateral middle anteroposterior; tMAP: Tibial medial anteroposterior; tLAP: Tibial lateral anteroposterior; fML: Femoral mediolateral; fMAP: Femoral medial anteroposterior; fLAP: Femoral lateral anteroposterior; fMCW: Femoral medial condylar width; fLCW: Femoral lateral condylar width; TKA:Total knee arthroplasty; CT:Computer tomography; STEA: Surgical transepicondylar axis

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Not applicable.

Authors' contributions

XHD designed the study, analyzed the data, wrote the manuscript. BY designed the study, analyzed the data and revised the manuscript. XHH and MC performed measurements and analysis the data. YHC and ML designed the study and reviewed the manuscript. All authors read and approved the final content of the manuscript.

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Availability of data and materials

The datasets used and/or analyzed during the present study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate

This study was approved by the institutional review board of Shannxi Provincial People's Hospital(No.2017-052), and written informed consent for participation was obtained from all subjects.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Figures

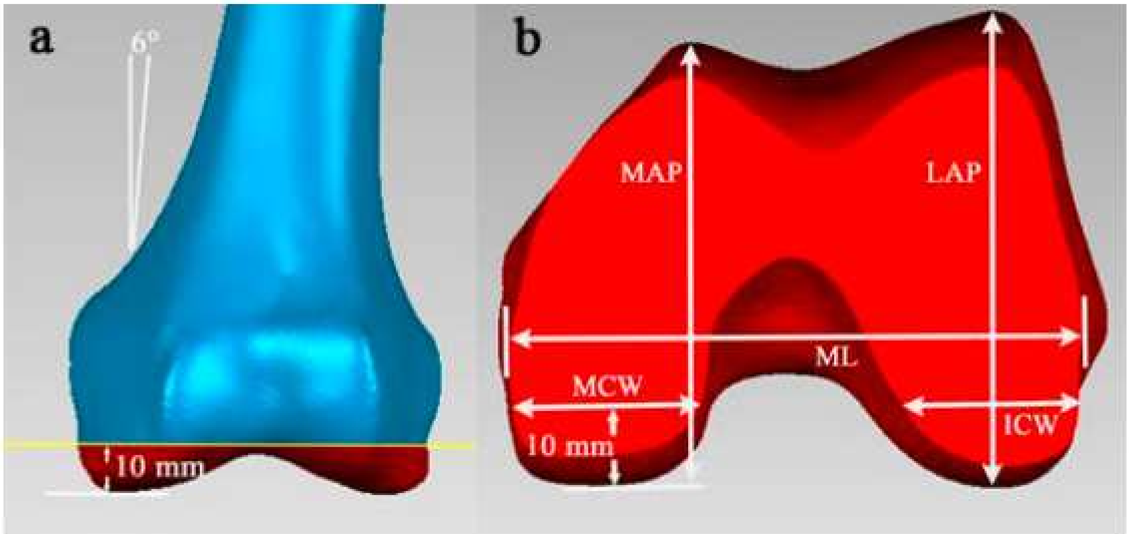

Figure 1

Distal femur resection and measurement on CT images. a Resection method of distal femur. b Measurements of resected femoral surfaces

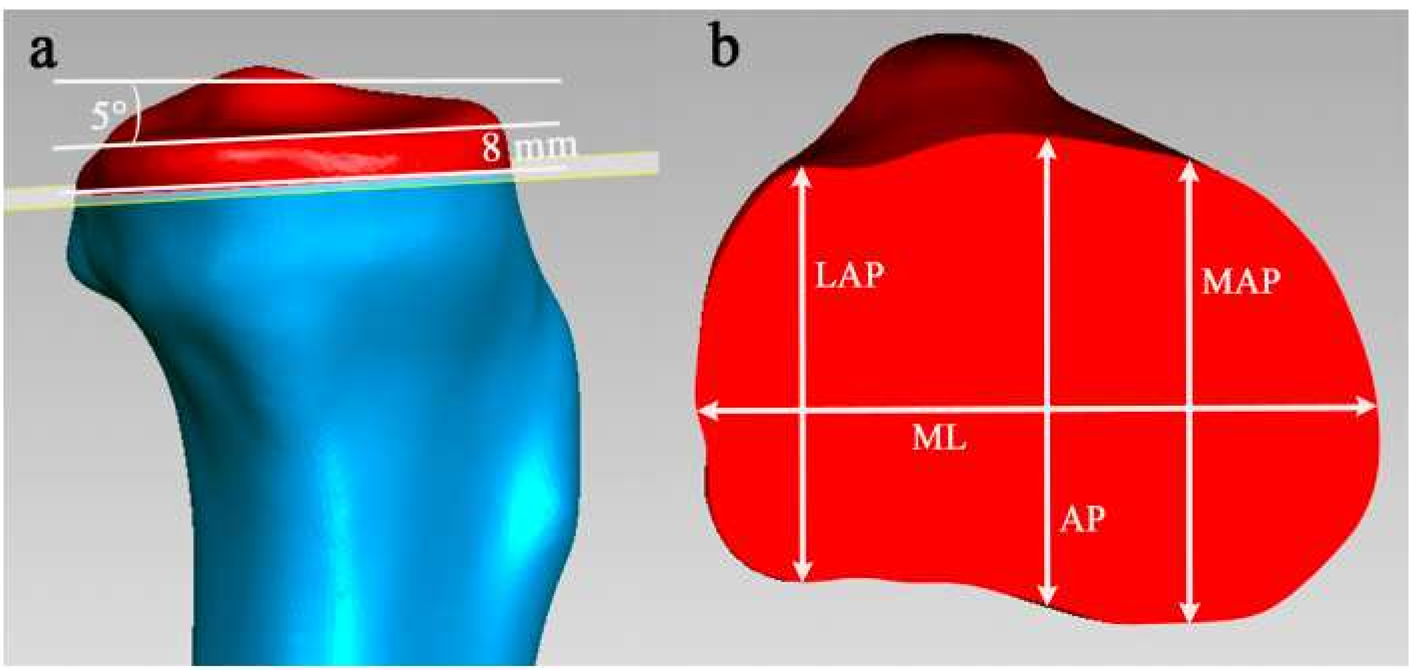

Figure 2

Proximal tibia resection and measurement on CT images. a Resection method of proximal tibia. b Measurements of resected tibial surface