

Morphometrical measurement of resected surface of medial and lateral proximal tibia for Chinese population

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Abstract

Purpose The objective of this study was to analyze the morphology of the medial tibial plateau and lateral tibial plateau in Chinese knees and compared these measurements and features with those of commercial unicondylar tibial baseplates.

Methods Three-dimensional knee models were reconstructed from computed tomography slices of 81 subjects. Among the series, 27 knees were from male subjects and 54 knees from female subjects. The dimensions and shape of the medial and lateral tibial plateaus were measured and compared with six commercially available unicondylar tibial baseplates.

Results The results showed significant differences between the shapes of the medial and lateral tibial plateaus. For the lateral tibial plateau, the shape was symmetric about the mediolateral axis. The medial plateaus presented their widest mediolateral width in an obviously more posterior position than the lateral compartment. Additionally, the plateau aspect ratio decreased with increasing

mediolateral dimensions, in contrast to the constant aspect ratio shown by conventional unicondylar knee prostheses.

Conclusion Compartment-specific designs may optimize coverage between the prosthesis and resected tibial surface. The morphometrical measurements presented may allow manufacturers to design tibial baseplates that accommodate the structural variability between different ethnic groups.

Level of evidence Prospective comparative study, Level II.

Keywords Morphometrical measurement · Unicondylar knee arthroplasty · Tibial plateau · Resected surface

Introduction

In recent years, unicondylar knee arthroplasty (UKA) has been the treatment of choice for isolated medial or lateral tibiofemoral osteoarthritis (OA) [11, 14]. The functional advantages of UKA over total knee arthroplasty (TKA) include greater range of motion (2 years, 127° vs. 118°, $P < 0.01$) [9], improved proprioception, more normalized joint kinematics, and excellent long-term survival rates [10, 13]. Whereas medial UKA is already used extensively, lateral UKA's are increasing in popularity, with an incidence of 5–10% being reported. [15, 16]. Although previous studies suggested that the same baseplates and surgical principles might be unsuitable for use in both compartments [3, 12], there is insufficient information regarding the geometrical differences seen between the medial and lateral tibial plateau and how well current UKA tibial components conform to the plateau geometry.

Most surgeons agree that for a unicondylar replacement, the knee should be slightly under-corrected [12]. In this situation, the replaced tibial plateau will share some of the

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imposed loads with the contralateral component and sustain a higher external loading after UKA [5]. An undersized tibial baseplate could lead to component subsidence from loss of cortical bone support. Conversely, an oversized baseplate might overhang the resected surface, resulting in impingement of soft tissue. Currently available UKA prostheses in the Asian-Pacific market are produced to conform to Caucasian physiology. It is known that knee sizes in Asian people are smaller than in Western ethnicities [4, 24]. Thus, it is important to looking at the medial and lateral tibial plateau morphology to achieve a better anatomic match and clinical outcome for various ethnic groups.

The present study hypothesized that morphometrical parameters and the plateau aspect ratio of the lateral tibial plateau differed from those of the medial tibial plateau. Identical plateau designs may not provide adequate bone coverage of the resected tibial surface if a compartment-specific design is not considered. The study analyzed the morphology of the medial tibial plateau and lateral tibial plateau in Chinese knees and compared these measurements and features with plateau dimensions of different commercial unicondylar tibial baseplates.

Materials and methods

This study was approved by the ethics committee of the author's institution. The study recorded the morphology of eighty-one normal knees (27 men, 54 women) without congenital anomalies or pathological deformities around the knee joint. The median age was 57 years (28–75). The median height was 155 cm (142–178), and the median weight was 60 kg (40–90).

Morphologic data were measured from three-dimensional proximal tibial models that were reconstructed from computed tomography (CT) images (HiSpeed CT/I system, GE Medical, USA). The patients were placed supine in the scanner with their knees taped to the scanner platform in the fully extended position. The bones were scanned with thicknesses ranging from 1.5 to 2.5 mm from the distal femur to proximal tibia, including the region 150 mm above and below the joint line. Image-processing software was used to punctuate and draw the cortical outline for reconstructing the bone model (Fig. 1). The resections and measurements were analyzed using the software, Pro/Engineer Wildfire 4.0 (Parametric Technologies Corp., Needham, MA, USA).

First, the line AB, defined in the mediolateral direction, was drawn over the upper tibial surface, and it was parallel and collinear to the surgical epicondylar axis of the femur in the coronal plane [21]. Another line CD was drawn perpendicular to the line AB in the anteroposterior direction and passed through its mid-point. Line M_AP, defined as the cut

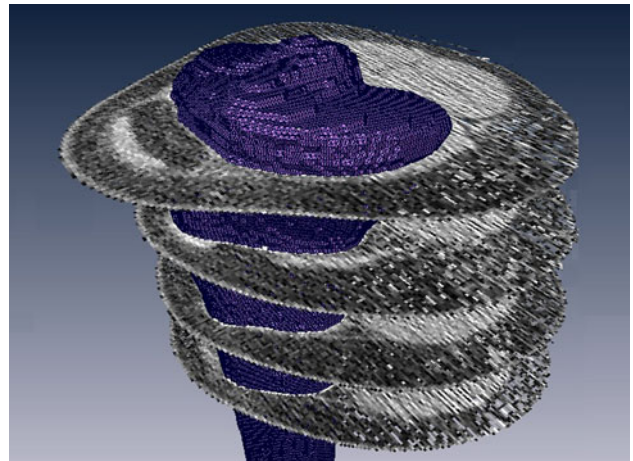


Fig. 1 Solid bony model of the tibia developed from computed tomography data

on the medial plateau in the sagittal plane, was drawn parallel to the line CD and tangential to the medial border of the cruciate ligament insertion. The assumed surgical techniques are expected to avoid damage to cruciate ligament attachments (Fig. 2a), as is currently the case for all UKA procedures. The same procedure was performed to draw another line L_AP for a lateral UKA. The line L_AP was drawn parallel to the line CD and tangential to the lateral border of the cruciate ligament insertion. A tibial surface cut to a depth of 5 mm was made along the tibial mechanical axis. Afterward, the desired cutting plane with 5° posterior and inferior slopes off the horizontal axis was simulated as the optimal cutting thickness (Fig. 2b).

The contours of the medial and lateral tibial plateaus were then measured for all models. The measurement accuracy was validated according to the authors' previous study [6] with an accuracy of 0.1 mm. Six morphometrical parameters were measured on the resected surface (Fig. 3): the largest anteroposterior dimension (AP), the widest medio-lateral dimension (ML), the perpendicular bisectors, MA and MP (anterior and posterior to the ML line along the AP line), the distance AD (from the point at the anterior of the AP line to the ML line), and the location ratio of anteroposterior direction ($AD/AP \times 100$). In order to reduce the bias of morphometrical measurements, each measurement was done by two coauthors and ratified by the coauthors with a tolerance level of 0.1 mm of this study.

In addition, this study compared the AP, ML, and the plateau aspect ratio (AP/ML) of the resected medial and lateral tibial plateaus with six different commercially available unicondylar tibial baseplates: Accuris (Smith and Nephew, Memphis, TN, USA), Advance (Wright Medical Technology, Arlington, TN, USA), High Flex (Zimmer, Warsaw, IN, USA), Oxford (Biomet, Warsaw, IN, USA), Preservation (DePuy, Johnson and Johnson, Warsaw, IN, USA), and Unix (Stryker, Mahwah, NJ, USA) (Table 1).

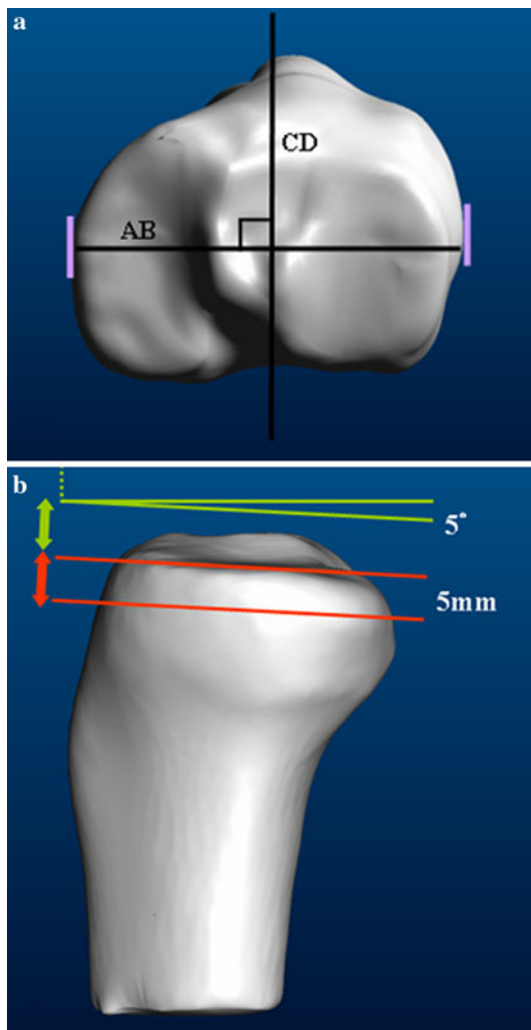


Fig. 2 Schematic representation of measurement methods used for the resection of the medial tibial plateau using a 3D solid model. **a** The line *AB*, taken as the widest mediolateral length over the upper tibial surface, drawn parallel and collinear to the surgical epicondylar axis of the femur. **b** The upper tibial cut was made 5 mm below the medial and lateral tibial plateau with a 5° posterior slope

Statistical analysis

For the statistical analysis, the Student's *t* test and Pearson's correlation were performed using SPSS (Version 12.0, SPSS, Chicago, IL, USA). The morphology of the medial and lateral tibial plateaus was compared using the paired *t* test with a level of significance set at $P < 0.05$.

Results

The mean overall values of AP and the ML were 47.1 ± 3.9 mm and 25.3 ± 2.3 mm, respectively. The medial tibial plateau displayed larger dimensions than the lateral tibial plateau ($P < 0.05$), and there were significant

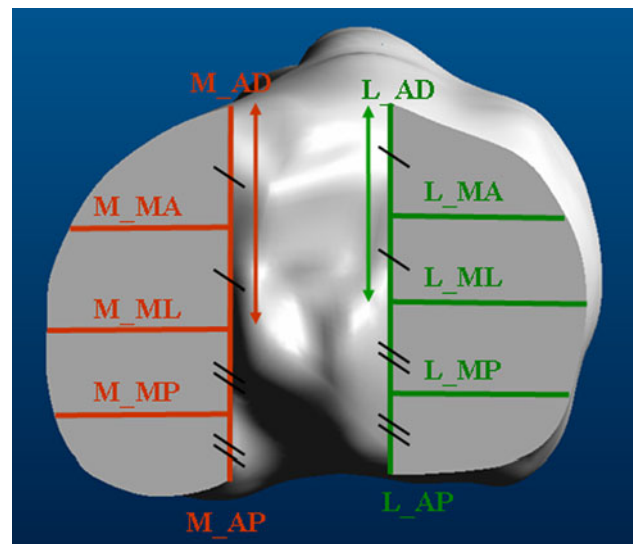


Fig. 3 Schematic representation of the anthropometric parameters measured on the resected surface of the medial and lateral tibial plateau, including the anteroposterior dimensions (*AP*), the widest mediolateral dimension (*ML*), the distance *AD* (from the point at the anterior of the *AP* line to the *ML* line), the perpendicular bisectors, and *MA* and *MP* (anterior and posterior to the *ML* line along the *AP* line)

differences in shape. The morphologic measurements are summarized in Table 2.

In order to compare the shape of medial and lateral tibial plateau, the anthropometric data of *MA*, *MP*, *AD*, and location ratio ($AD/AP \times 100$) were measured in this study. The results of *MA* and *MP* showed the medial side to be smaller than the lateral, but statistically, there were no significant differences. However, the results of *AD* and location ratio revealed the medial tibial plateau to be larger and with asymmetric geometry (Table 2). Additionally, the values of plateau aspect ratio (AP/ML) showed a significant difference between the two plateaus ($P < 0.05$). These results further demonstrated that the structure of the lateral tibial plateau differs from that of the medial side and is symmetric about the mediolateral axis.

Comparing the distribution of size and shape of the six commercially available unicompartmental tibial baseplates with the collected resected surface data, most brands would display *ML* overhang for all ranges of *AP* and relatively constant values of plateau aspect ratio with increasing *ML* irrespective of whether the medial tibial plateau or lateral tibial plateau was under consideration. The regression lines of *ML* against *AP* of the resected surface for the medial tibial plateau and lateral tibial plateau were plotted and compared with the six commercially available components (Fig. 4). Additionally, the morphologic data showed a progressive descent in plateau aspect ratio (AP/ML) with increasing *ML* width (Fig. 5). Most of the commercial baseplates studied showed relatively constant values of

Table 1 Six different commercially available UKA tibial components [anteroposterior length, mediolateral width, and plateau aspect ratio (AP/ML)]

Accuris (Smith and Nephew)			Advance (Wright medical)			High flex (Zimmer)			Oxford (Biomet)			Preservation (DePuy)			Unix (Stryker)		
AP	ML	AP/ML	AP	ML	AP/ML	AP	ML	AP/ML	AP	ML	AP/ML	AP	ML	AP/ML	AP	ML	AP/ML
40	23.5	1.7	40	24	1.7	41	23	1.8	38	26	1.5	41	20	2.1	39.5	24	1.6
44	25	1.8	44	26	1.7	44	25	1.8	41	26	1.6	45	23	2.0	43.5	26	1.7
48	27.5	1.7	49	29	1.7	47	27	1.7	44	28	1.6	49	26	1.9	47.5	28	1.7
52	30	1.7	54	33	1.6	50	29	1.7	47	30	1.6	53	29	1.8	51.5	30	1.7
53	31	1.7	50	32	1.6	57	32	1.8	55.5	32	1.7						
56	33	1.7	53	34	1.6												

Table 2 Anthropometric measurements of the resected medial and lateral tibial plateau from 27 male and 54 female subjects

	Medial TP	Lateral TP	Combined
Anteroposterior length, AP (mm)	48.1 ± 3.8	46.2 ± 3.9	47.1 ± 3.9
Mediolateral width, ML (mm)	25.0 ± 2.3	25.5 ± 2.3	25.3 ± 2.3
Plateau aspect ratio, AP/ML	1.9 ± 0.1	1.8 ± 0.1	1.9 ± 0.1
Distance of AD (mm)	27.9 ± 3.1	23.4 ± 2.6	25.6 ± 3.7
Location ratio of ML (%)	57.9 ± 4.0	50.6 ± 4.4	54.3 ± 5.6
Perpendicular bisectors of MA (mm)	21.1 ± 2.1	22.5 ± 1.8	21.8 ± 2.1
Perpendicular bisectors of MP (mm)	22.5 ± 2.3	23.0 ± 1.9	22.7 ± 2.1

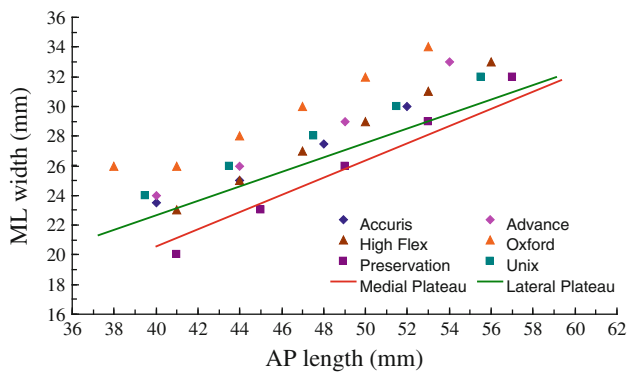


Fig. 4 Comparison of anteroposterior length (AP) versus the mediolateral width (ML) for the resected bony surface and the six tibial components

plateau aspect ratio with increasing ML. The regression plot of AP/ML to ML for the commercial baseplates was lower than that of the morphologic data. One exception, the Preservation design, had an aspect ratio closer to that of the medial tibial plateau, showing a decreasing aspect ratio with increases in ML (Table 3).

Discussion

The most important finding of the present study was that the anatomic shape of the medial tibial plateau shows

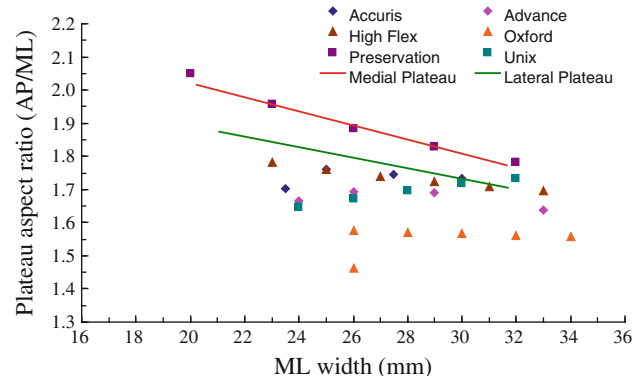


Fig. 5 Tibial plateau aspect ratio versus the mediolateral width (ML) for the resected bony surface and the six tibial components

obvious differences from that of the lateral plateau. A compartment-specific baseplate design may help optimize coverage between the resected tibial surface and tibial baseplate. Tibial baseplates are designed to distribute loading over the tibial plateau, reducing stress concentrations in the underlying trabecular bone. It is suggested that surgeons should position the tibial baseplate to firmly contact the rim of the proximal tibia (stress transfer by cortical bone) [2, 22]. Previous studies have suggested the use of different UKA baseplates for the medial and lateral tibiofemoral compartments according to the differing anatomic shape and biomechanics [1, 16]. Significant

Table 3 Summary of the morphology of the unilateral tibia in various studies

Authors	Population	Medial tibial plateau			Lateral tibial plateau		
		AP (mm)	ML (mm)	PAR	AP (mm)	ML (mm)	PAR
Servien et al. [17]	French	50.8 ± 3.3	28.8 ± 2.5	1.8 ± 0.1	47.2 ± 3.3	29.3 ± 2.4	1.6 ± 0.1
Surendran et al. [19]	Korean	47.1 ± 4.1	24.8 ± 2.5	1.9 ± 0.1			
Cheng et al. [7]	Chinese	49.8 ± 3.7	28.2 ± 2.2	1.8 ± 0.1			
Our study	Chinese	48.1 ± 3.8	25.0 ± 2.3	1.9 ± 0.1	46.2 ± 3.9	25.5 ± 2.3	1.8 ± 0.1

AP Anteroposterior length, ML Mediolateral width, PAR plateau aspect ratio, AP/ML

dimensional and morphological differences were seen between the medial tibial plateau and lateral tibial plateau in this present study. Furthermore, the measured dimensions and plateau aspect ratio (AP/ML) of the commercial UKA prostheses were proven unsuitable for use in Asians. Therefore, based on our accumulated morphologic data, these findings demonstrate that a novel UKA system must be designed that is suitable for use in Chinese patients.

Quantification of the AP and ML revealed that the measurements of the lateral tibial plateau were significantly different from those of the medial tibial plateau in the Chinese population, comparable to finding in other studies [8, 17]. Simultaneously, our results showed that the AP and ML dimensions were obviously smaller than those reported in studies on Caucasian patients [17]. Comparing previous studies of the medial tibial plateau in Asian-Pacific knees, our results were slightly larger than the results of the Surendran et al. [19] but smaller than the results of Cheng et al. [7]. A possible cause for these inconsistencies was due to the high ratio of female patients involved in this present study, approximately 75%:25% female-to-male ratio. The proximal tibia is morphologically different for Chinese men and women [24, 25]. Therefore, further research may be needed to undertake a gender analysis for the medial tibial plateau and lateral tibial plateau.

The ratio of anteroposterior dimensions to mediolateral dimensions (AP/ML), defined as the PRA, is important in predicting the shape of knee prostheses. The results showed that the medial tibial plateau has a larger aspect ratio than the lateral tibial plateau. Furthermore, in order to accurately reveal the different morphology of the medial and lateral tibial plateaus, the AD and the location ratio for the widest mediolateral dimension on the resected surfaces were measured in this study. Both parameters were smaller for the lateral plateau. Moreover, the widest ML width was located close to the plateau center, and the shape was near symmetric about the mediolateral axis for the lateral tibial plateau. Conversely, the medial tibial plateau presented the widest ML width in a slightly more posterior position. Additionally, some reports have suggested that asymmetric tibial baseplates are more anatomic in nature and therefore cover the tibial plateau surface more completely than

symmetric components in TKA [18, 20, 23]. These results may imply that compartment-specific designs could optimize the anatomic match between the prosthesis and the resected surface.

A good tibial baseplate design should conform to the size and shape of the resected surface. Comparing the morphologic data of AP and ML with the different commercially available unicondylar tibial baseplates, all of the commercial baseplates displayed an overhang for all measured AP lengths irrespective of whether the medial tibial plateau or lateral tibial plateau was under consideration, with one exception being the Preservation UKA (Fig. 4). These results were consistent with previous studies of Asian-Pacific knees [7, 19]. In practice, surgeons must avoid tibial component overhang to help prevent irritation of soft tissues and pain [5]. Additionally, in order to avoid damage to the cruciate ligament attachment sites, a smaller prosthetic size with suitable ML may be selected by the surgeon. However, insufficient tibial coverage may induce collapse or subsidence of the tibial baseplate [5]. These complications are similar to situations where the baseplate was placed in weaker cancellous bone. Insufficient coverage would induce posterior loosening or restricted movement with high flexion from the larger roll-back translation during a flexion-extension movement. Additionally, the morphologic data showed that decreasing values of the plateau aspect ratio correlated with increasing ML irrespective of whether the medial tibial plateau or lateral tibial plateau was being examined. In contrast, the majority of the baseplates showed a relatively constant value of plateau aspect ratio (AP/ML) with increasing ML, and all of the values surpassed the regression line of the morphologic data. Therefore, the baseplates should be modified with reduced ML dimensions and an inconstant value of plateau aspect ratio (AP/ML) to obtain a better anatomic fit for Chinese or Asian-Pacific populations.

A limitation of this study is that it contained a majority of female patients, so the study could not analyze differences between genders. Whether prostheses should be designed to conform to the differing morphology between male and female patients needs further study. Furthermore, in this study, the resected surface was based on the

commonly performed proximal tibial cut for the medial and lateral tibial plateau. The rotational positioning of tibial baseplates is not considered. Obviating these limitations, this study not only demonstrates that a system suitable for use in Caucasians may not be suitable for other ethnic groups, but also can provide some information for design an appropriate series of unicondylar tibial baseplates.

The present study suggests that it may be useful to develop a compartmental-specific design that is more anatomically conforming to the resected surface of the medial and lateral tibial plateau of the Asian-Pacific population.

Conclusion

Examination of the resected surfaces of the Chinese knees in this study proved that the anatomic shape of the medial tibial plateau shows obvious differences from that of the lateral plateau. Additionally, the majority of unicondylar tibial baseplate in use in Asian countries was specifically designed for the Caucasian population. The present study supports the concept that compartment-specific designs or sufficient component sizes can optimize the anatomic match between the prostheses and the resected surface.

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Conflict of interest No conflicts of interest on this manuscript.

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