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Original Article

A Comparison Between Chinese and Caucasian 3-Dimensional Bony Morphometry in Presimulated and Postsimulated Osteotomy for Total Knee Arthroplasty

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ABSTRACT

Background: The bone morphologies of intact knees were measured and compared between Chinese and Caucasian populations. However, to assess if distinct designs of implants are necessary for the Chinese population owing to different morphologies and sizes, the knee measurements after osteotomy performed in total knee arthroplasty were evaluated.

Methods: Thirty-seven Caucasian and 50 Chinese patients' knees were examined using computed tomography scans. Mimics were applied to reconstruct 3-dimensional bone models. Dimensions of the 3-dimensional knee models and simulated bone resections during total knee arthroplasty were measured using Geomagic Studio and Pro/ENGINEER. The morphologic measurements of the native and resected femur and tibia included the anteroposterior (AP) depth, mediolateral (ML) width, notch width, knee physical valgus angle, tibial slope angle, and the ML-to-AP ratio of the femur, tibia, and resected femur. Statistical analysis was performed using the independent samples *t* test and the Pearson correlation coefficient in SPSS for Windows. Values of $P < .05$ were considered significant.

Results: No measurements were significantly different between the Chinese and Caucasian knees. However, the Chinese female showed significant differences compared with the Chinese male on distal femoral measurements both presimulated and postsimulated osteotomy such as a smaller mean ML-to-AP ratio in presimulated (1.3 ± 0.1) and postsimulated (1.3 ± 0.1) osteotomy.

Conclusion: The necessity of designing a full set of total knee components specifically for the Chinese population is still undetermined. However, we suggest designing femoral components specific for the Chinese females because of different postosteotomy distal femoral ML-to-AP ratio between the Chinese males and the Chinese females.

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Most current available knee implants in the market are designed according to Caucasian knee anatomy. Some literature shows that there are differences between the Asian and the Caucasian knee geometries [1,2]. In the research of Indian people's knee anthropometry by Vaidya et al in 2000 [3], they found the current available femoral components fit most Indian knees. The only exception was extra-small femoral components did not fit a small number of Indian female knees especially for their anteroposterior (AP) diameter <50 mm and their mediolateral (ML) diameter <54 mm. A publication from Korea published in the *Journal of Bone and Joint Surgery* in 2012 shows that the current femoral components do not fit the distal femurs of the Asian population [4]. The downsized implant would have ML undercoverage and the larger size would overhang. The study by Yue et al [5] compared the distal femoral geometry between the Chinese and Caucasian people and then concluded that the Chinese knees were generally smaller than the Caucasian knees. The aforementioned research indicated that

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Chinese surgeons may meet problems such as overhang, mismatched sizing, and inadequate coverage in resected knees of the Chinese patients as they use current implants during total knee arthroplasty (TKA) surgery. Therefore, it is still a question whether it is necessary to design new implants specific for the Chinese population. Most literature related with this issue only focuses on measurements of the intact knee. The bony measurement values of the post-TKA osteotomy knee could be more valuable because they are the final size prepared for total knee implants before implantation [6]. In this study, we made both computer-simulated pre-TKA and post-TKA osteotomy on reconstructed 3-dimensional (3D) knee models and measured both unresected and resected knee bones to evaluate the geometric differences between the Chinese and Caucasian knees. The measurements and comparisons were also analyzed separately regarding genders. This research can also help us to know whether preosteotomy and postosteotomy measurements would have similar results as we compare bony geometry of Chinese and Caucasian knees.

Materials and Methods

Eighty-seven knee samples were used in the study to determine the knee anatomy. Thirty-seven of them were Caucasian knees including 27 males and 10 females. Fifty of them were knees from the Chinese people including 29 males and 21 females.

The samples were from both cadavers and living patients. Both the Caucasian and Chinese specimens were adults between the ages of 18 and 92 years. The left and the right lower extremities of the individual sample were randomly selected for a computed tomography (CT) scan. We followed the Kellgren and Lawrence grading system for classification of knee osteoarthritis [7], and as such, we excluded samples with severe knee osteoarthritis (ie, grades 3-4) and included samples with minor osteoarthritis (ie, grades 0-2). Samples with deformity and any congenital and traumatic anomaly in the lower extremity were excluded.

The mean body mass index (BMI) of each of the Caucasian male and female groups and the Chinese male and female groups was 25.9, 27.0, 23.8, and 23.2 kg/m^2, respectively. The BMIs of different sample groups in the study were similar to each other. The ages, genders, heights, and BMIs of the samples were recorded.

The heights and BMIs of the Caucasian samples were consistent with the data from the report of Anthropometric Reference Data for Children and Adults: United States, 2011-2014 [8]. The Caucasian specimens were collected from a hospital in the United States and restricted to the Caucasian people aged 18 to 95 years who resided around the United States. The ages of the Caucasian male samples ranged from 18 to 92 years with the average age of 51 years. The ages of the Caucasian female samples ranged from 39 to 80 years with the average age of 54 years. The heights of the Caucasian male samples ranged from 169.6 to 186.3 cm with the average height of 174.5 cm, which is in close proximity to the average height of 177.1 cm for the Caucasian males mentioned in the report [8]. The heights of the Caucasian male samples in the research were distributed evenly from the 10th (168.0 cm) to the 90th (186.3 cm) percentile of the heights of the Caucasian males mentioned in the report [8]. The heights of the Caucasian female samples ranged from 155.6 to 169.7 cm with the average height of 162.3 cm, which is in close proximity to the average height of 162.9 cm for the Caucasian females mentioned in the report [8]. The heights of the Caucasian female samples in the research were distributed evenly from the 10th (154.0 cm) to the 85th (169.7 cm) percentile of the heights of the Caucasian females mentioned in the report [8]. The BMIs of Caucasian male samples ranged from 22.3 to 34.1 kg/m^2 with the average BMI of 25.9 kg/m^2. The BMIs of the Caucasian male samples in the research were distributed evenly from the 10th (22.2 kg/m^2) to the 85th (34.0 kg/m^2) percentile of the BMI of the Caucasian males mentioned in the report [8]. The BMIs of the Caucasian female samples ranged from 22.3 to 36.5 kg/m^2 with the average BMI of 27.0 kg/m^2. The BMIs of Caucasian female samples in the research were distributed evenly from the 10th (21.0 kg/m^2) to the 85th (36.5 kg/m^2) percentile of the BMIs of the Caucasian females mentioned in the report [8].

The heights and BMIs of the Chinese specimens were consistent with the report of Survey of Nutrition and Chronic Illness of Chinese inhabitants in 2015 [9]. The Chinese specimens were collected from a hospital in China and restricted to native Chinese people aged from 18 to 95 years who resided around China. The ages of the Chinese male specimens ranged from 22 to 78 years with a mean age of 45 years. The ages of the Chinese female specimens ranged from 24 to 79 years with a mean of 51 years. The heights of the Chinese male specimens ranged from 160.1 to 179.4 cm with a mean of 169.8 cm, which was in close proximity to the mean height of 167.1 cm for the Chinese males mentioned in the report [9]. The heights of the Chinese female specimens ranged from 150.4 to 168.0 cm with a mean of 158.9 cm, which was in close proximity to the mean height of 155.8 cm for the Chinese females mentioned in the report [9]. The BMIs of the Chinese male specimens ranged from 22.9 to 25 kg/m^2 with a mean of 23.8 kg/m^2, which was in close proximity to the mean BMI of 23.7 kg/m^2 for the Chinese males mentioned in the report [9]. The BMIs of the Chinese female specimens ranged from 22.5 to 24.2 kg/m^2 with a mean of 23.2 kg/m^2, which was in close proximity to the average BMI of 23.6 kg/m^2 for the Chinese females mentioned in the report [9].

The axial scans of the knees were obtained from helical CT scan. The scanning procedure was performed to acquire 1-mm CT slices. The scan included the pelvic bone that was adjacent to the hip joint all the way to the ankle. We segmented intact femur, tibia, fibula, and partial of talus.

The trunks were supine with their knees at full extension. The 3D modeling software (Mimics; materialise, Leuven, Belgium) was used to segment and edit the images of the femur, tibia, and patella. The low threshold of 226 was used to distinguish the bone and the soft tissue. The marginal osteophytes and image artifacts were removed from the 3D models. We also removed extra-articular internal fixation plates from 3D models of 2 Chinese samples with Mimics software to facilitate the measurements. Finally, we exported 3D bone models and measured the anatomy parameters of the bone by the software packages (Geomagic Studio; 3D Systems, Rock Hill, SC; and Pro/ENGINEER; PTC Inc, Needham, MA). Tables 1 and 2 are the 2 synopses of abbreviations and definitions of knee measurement variables.

Femur Measurements

First, we determined the mechanical axis, the coronal, and the sagittal plane of the femur. The center of the femoral head was obtained with the Geomagic Studio to generate a best-fit sphere from a cloud of points on the surface of the head. The transepicondylar axis (TEA) was defined as a line between the most medial and the most lateral prominences of the femoral epicondyles. The mechanical axis of the femur was the line from the center of the femoral head to the midpoint of the TEA. The mechanical axis and the TEA defined the coronal plane. The sagittal plane was defined as the plane perpendicular to this plane passing through the mechanical axis of the femur. The axial plane was defined as the plane perpendicular to the coronal plane while passing through the TEA.

The femoral anatomic axis was defined as a line with equal distance to the anterior and posterior rims of the femoral shaft cortex in the sagittal plane and equal distance to the medial and

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