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Original Article

The offset of the tibia plateau of osteoarthritis patients: a single-center study

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Abstract: Component position and good fixation are important factors determining the success of a primary or revision total knee arthroplasty (TKA). The aim of this study was to measure the anatomic features of the tibial plateau and to assess variations in the offset of the tibial shaft from the tibial plateau in osteoarthritis (OA) patients. Computed tomography (CT) scan results were obtained from 126 knees of 121 OA patients (72 female, 49 male) with an average age of 65 ± 7 years. The anatomic features of the tibial plateau were measured and analyzed using three-dimensional reconstruction information derived from a 64-slice spiral CT. The results showed significant variations in proximal tibial anatomy among the subjects. The mean offset was 7.61 ± 3.04 mm at the resection just distal to the subchondral bone. The mean anteroposterior and mediolateral dimensions of the tibial plateau were 53.05 ± 4.82 mm and 70.42 ± 8.33 mm, respectively, at the resection just distal to the subchondral bone. The tibial shaft axis was located anterolateral to the center of the tibial plateau in 62% of knees, while in 36% of these knees, it was located anterior medial to the center of the tibial plateau at the resection just distal to the subchondral bone. Our study shows that anatomic variations should be fully evaluated before performing TKA. A wide range of implant sizes is thus necessary for optimum replacement.

Keywords: Tibial shaft axis, tibial plateau, total knee arthroplasty, computed tomography

Introduction

Total knee arthroplasty (TKA) is among the most successful orthopedic procedures with proven efficacy in the treatment of advanced knee arthritis [1]. The prevalence of TKA has increased dramatically and is expected to increase by more than 600% by the year 2030 [2]. A recent Finnish Registry Study has reported that the 15-year survival of TKA is nearly 90% [3]. However, a substantial number of patients remain dissatisfied after TKA [4]. Many factors may influence the longevity of implants in TKA, for instance, component position, good fixation and osseous coverage have been shown to be important factors determining the success of a primary or revision TKA [5]. The long stem of the tibial component is designed to prevent subsidence and loosening in TKA and plays an important role in load-bearing and stress absorption for the proximal tibia [6-10]. It is usually an essential component in extensive proximal tibial bone loss and revision TKA.

The tibial shaft axis and tibial plateau center are critical reference points in TKA surgery. For good fixation as well as for tibial component coverage and implant stability, the tibial shaft axis and tibial plateau center must be determined accurately in TKA surgery. However, the tibial shaft axis does not always match the tibial plateau center. For example, in a study of 246 Korean patients, the tibial shaft axis was typically located lateral to the mechanical axis on anteroposterior radiographs [11]. Abraham et al. [12] performed TKA on twenty cadaver tibiae and found that the average distance between the centers of the tibial diaphysis and tibial metaphysis was 4.1 mm at the resection of the fibular head. The axis of the tibial shaft is located anteromedial to the center of the tibial plateau in Caucasians, for whom a medially-offset

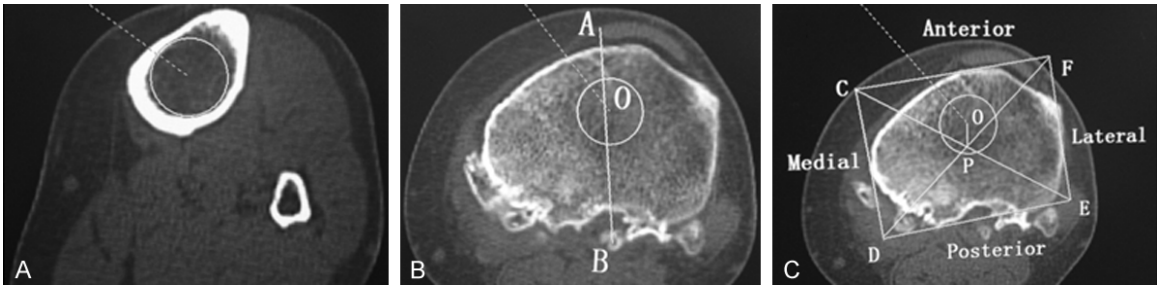

Figure 1. CT measurement of the offset of the tibial shaft from the tibial plateau. The line connecting the center of the incircle was defined as the tibial shaft axis (A) Incircle of tibial canal drawn at a surface 7 cm distal to the knee. Point O was the center of the incircle. The anteroposterior axis of the rotational alignment of the tibial plateau (B), AB was the line connecting the midpoint of posterior cruciate ligament and the medial edge of patellar tendon. Measurement of tibial shaft axis offset from the tibial plateau center (C), CD is the line at the most medial point of the tibial plateau, EF is the line at the most lateral point of tibial plateau, and both CD and EF parallel to the anteroposterior axis. P was the center of the rectangle CDEF, which was defined as the tibial plateau. The distance of line PO is the offset of the tibial shaft axis from the tibial plateau center.

stem seems more suitable [13-15]. Nagamine et al. [16] studied 133 Japanese patients and noted that the tibial shaft axis was usually located lateral to the mechanical axis. Yoo et al. [11] suggested that the medially offset stem might not be a good option for some Korean patients undergoing TKA. Among healthy Chinese subjects, the tibial shaft axis is located anterolateral to the center of the tibial plateau with the offset of the tibial shaft from the tibial plateau being 7.23 mm on average at the resection just distal to the subchondral bone of the tibial plateau [17]. However, the subjects of this Chinese study were relatively young and had no bone abnormalities. Thus, the results may not be a reliable reference for TKA.

The long-stem tibial component designed using data from measurements of Caucasian bone structure does not always match the tibial features of Asian populations. For example, Yoo et al. [11] noticed that Asian subjects using these components, with a medially-offset tibial stem, frequently experienced contact between the tip of the stem and the medial cortex of the tibia when TKA was performed. In our experience performing TKA, we were sometimes forced to insert a smaller or larger tibial component to solve this mismatch problem. However, this will at times cause either poor coverage or overhang. When TKA was performed using components with a long stem, we frequently experienced the aforementioned contact. We have attempted to determine whether the medially-offset stem in a tibial component would fit the anatomy of the tibia in Chinese osteoarthritis patients. Our hypothesis was that the axis of the tibial shaft would be located more laterally than the mechanical axis of the tibia, which would suggest that a laterally-offset stem would be more suitable for such patients. The purposes of this study were 1) to assess the variations in the offset of the tibial shaft from the tibial plateau in the affected knees of Chinese patients with osteoarthritis and 2) to determine the most suitable magnitude of tibial shaft offset for primary or revision TKA in the Chinese population.

Patients and methods

This study was approved by the institutional review board of the Lanzhou University Second Hospital. All participants provide their written consent to participate in this study.

This is a prospective single-center study. Preoperative computed tomography (CT) scans of patients scheduled to undergo TKA from January 2012 to October 2014 were analyzed. All patients had medial-type primary OA of the knee with varus deformity. Patients with inflammatory arthritis, post-traumatic arthritis, valgus deformity, and flexion contracture were excluded from the study. In addition, patients who had undergone previous femoral or tibial osteotomy or who had previous fractures or congenital anomalies were excluded too. A total of 126 knees of 121 patients (72 female, 49 male) were included in the study with an average age of 65 ± 7 years (range 43 to 77 years).

We obtained 64-slice spiral CT scans from the OA patients as part of pre-operative planning for robotic TKA using a Light-Speed VCT scan-

Table 1. Offset data of the tibial shaft from the tibial plateau

Resection	Mean offset (mm)	Mediolateral dimension	Anteroposterior dimension
Subchondral bone	7.61 ± 3.04	70.42 ± 8.33	53.05 ± 4.82
2 mm*	7.80 ± 3.24	71.73 ± 6.98	53.34 ± 4.10
4 mm	7.88 ± 3.30	72.06 ± 6.26	53.69 ± 3.78
6 mm (fibular head) level)	7.49 ± 3.13	70.69 ± 6.63	53.23 ± 3.82
8 mm	7.02 ± 2.89	71.95 ± 6.73	52.44 ± 4.70
10 mm	5.97 ± 2.55	70.06 ± 5.96	50.70 ± 5.06
12 mm	4.72 ± 2.45	68.51 ± 6.18	48.59 ± 5.38
14 mm	3.83 ± 2.31	66.70 ± 6.52	46.01 ± 5.79
16 mm	3.19 ± 2.49	64.66 ± 6.93	44.25 ± 5.79
18 mm	2.88 ± 2.39	62.34 ± 7.95	42.77 ± 5.76

*2 mm distal to subchondral bone. Resection thickness was 2 mm.

ner (GE Healthcare, Milwaukee, WI). The subjects were placed supine in the scanner with the lower limb in full extension, parallel to the bed in the sagittal and coronal planes.

To measure the offset of the tibial shaft from the tibial plateau, in circles of the tibial canal were drawn around the surface perpendicular to the coronal and sagittal sections of the tibiae at 7 cm and 11 cm distal to the knee. The line connecting the centers of the incircles was defined as the tibial shaft axis (**Figure 1A**). The anteroposterior axis of the rotational alignment of the tibial plateau was the line connecting the midpoint of the posterior cruciate ligament (PCL) and the medial edge of the patellar tendon [18] (**Figure 1B**). CD was defined as the line at the most medial point of the tibial plateau and parallel to the anteroposterior axis (**Figure 1C**). EF was defined as the line at the most lateral point of tibial plateau and parallel to the anteroposterior axis. CF and DE were the lines at the most anterior and posterolateral points of the tibial plateau, respectively, and perpendicular to the anteroposterior axis. P was defined as the center of the rectangle CDEF, which, in turn was defined as the tibial plateau. The length of the line PO was defined as the offset of the tibial shaft axis from the tibial plateau center (**Figure 1C**). All the subjects were measured at ten resections. The first resection was just distal to the subchondral bone of the medial tibial plateau, which equated to the clinical situation of the level of a bone cut in a proximal tibial segment with mild bone loss. The other resections were 2 mm in thickness and made at 2 mm intervals by helical CT scans.

Intraclass correlation analysis was performed to assess the extent of the reproducibility of the measurements. All the measurements were performed using a picture archiving and communication system and were carried out twice by one observer. The intra-rater and inter-rater reliability of the measurements was assessed using the intraclass correlation coefficient (ICC).

Statistical analyses of the measured data were performed using SPSS10.0 software; all numerical data were expressed as the mean ± SEM (the standard error of the mean). The averages from the two groups were compared by t tests. Enumeration data were compared by χ^2 tests and $P < 0.05$ was considered statistically significant.

Results

A total of 121 patients who underwent TKA were included in the study. All the patients had complete follow-up with complete data. The mean age was 65 ± 7 years (range from 43 to 77); the sex ratio (49 male to 72 female) was 0.68.

Offset data of the tibial shaft from the tibial plateau is shown in **Table 1**. **Figure 2A** shows the mean offset of the tibial shaft from the tibial plateau. The mean offset was 7.61 ± 3.04 mm (range 2.03 to 14.71 mm) at the resection just distal to the subchondral bone and 7.49 ± 3.13 mm (range 1.18 to 14.97 mm) at the resection of the fibular head (**Figure 2A**).

Figure 2B shows the mean mediolateral dimensions of the tibial plateau were 70.42 ± 8.33 mm at the resection just distal to the subchondral bone, 70.69 ± 6.63 mm at the fibular head, and 62.34 ± 7.95 mm at the resection located 18 mm distal to the subchondral bone. **Figure 2C** shows that the mean anteroposterior dimensions of the tibial plateau were 53.05 ± 4.82 mm at the resection just distal to the subchondral bone, 53.23 ± 3.82 mm at the fibular head, and 42.77 ± 5.76 mm at the resection located 18 mm distal to the subchondral bone.

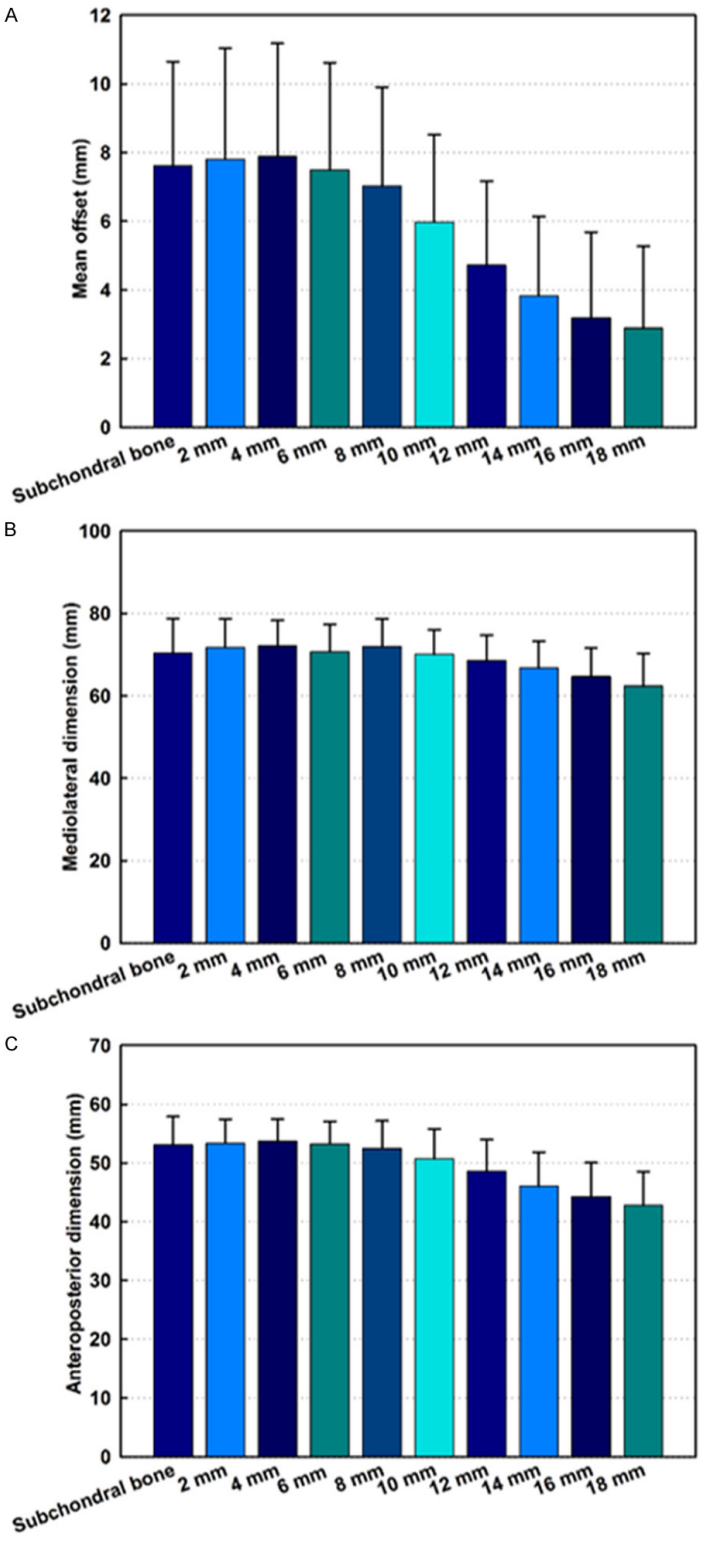

Figure 2. Offset data of the tibial shaft from the tibial plateau. A. Shows the mean offset of the tibial shaft from the tibial plateau. B. Shows the mean mediolateral dimensions of the tibial plateau. C. Shows the mean anteroposterior dimensions of the tibial plateau.

At the resection from the subchondral bone to the fibular head level, the tibial shaft axis in 62% of knees was located anterolateral to the center of the tibial plateau, the tibial shaft axis in 36% of knees was located anteromedial to the center of the tibial plateau, and 1% of knees were located posteromedial to the center of the tibial plateau. At the 2 mm, 4 mm, and 6 mm resections, the axis of the tibial shaft in 64-65% of the knees was located anterolateral to the center of the tibial plateau and in 33-35% of the knees it was located anteromedial to the center of the tibial plateau. At the 8 mm, 10 mm, and 12 mm resections, the tibial shaft axis in 55-58% of knees was located anterolateral, in 41-44% of the knees it was located anteromedial, and in 1% knees it was located posteromedial to the center of the tibial plateau. At the 14 mm, 16 mm, and 18 mm resections, the tibial shaft axis was located anterolateral in 44-58% of knees, was located anteromedial in 26-36% of knees, was located posterolateral in 2-7% of knees, and was located posteromedial to the center of the tibial plateau in 1-6% of knees (**Figure 3**).

Discussion

The most important finding of our prospective study was that there were significant variations in proximal tibial anatomy among the subjects from our department. Our results indicate that the tibial shaft axis of a large proportion of knees was located anterolateral to the center of the tibial plateau at the resection just distal to the subchondral bone.

The anatomic features of Asian populations differ from those of Caucasian populations [16, 19-21]. Most current TKA protocols have been developed using the anatomical data of normal knees of Caucasians [22-25] and thus may not be suitable for Chinese knees having different anatomical features [12, 14, 15]. Hicks et al. [13] found that the tibial shaft axis was positioned relatively medi-

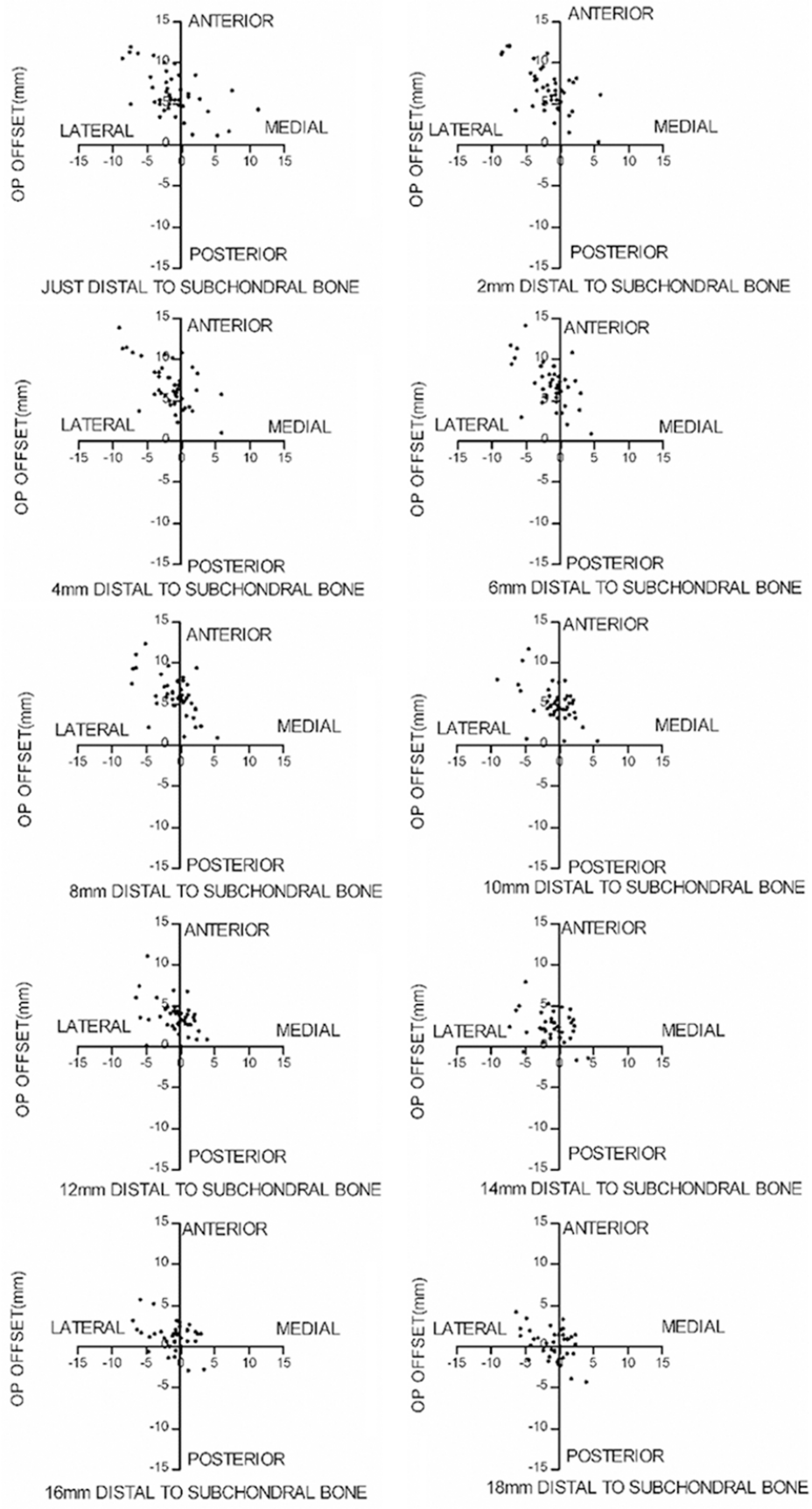

Figure 3. The offset of the tibial shaft from center of the tibial plateau at the different resections.

ally in the tibial plateau. Other researchers found that the tibial shaft axis was located lateral to the mechanical axis in Chinese, Japanese, and Korean patients [11, 12, 19]. Tang et al. [17] studied healthyyoungChinese people and found that the tibial shaft axis in 98% of the knees was located anterolateral and in 2% of knees anteromedial to the center of the tibial plateau. The results of this study, which are largely different from the results of Tang et al., show that the tibial shaft axis is located anterolateral to the center of the tibial plateau in 62% of knees, while in 36% of these knees, it was located anteriormedial to the center of the tibial plateau at the resection just distal to the subchondral bone of OA patients.

There were w-i de variations in the site of the tibial shaft axis at the resection

of the proximal part of the tibia [8]. Abraham et al. performed TKA in twenty cadaver tibiae and found that the average distance between the center of the tibial diaphysis and the center of the tibial metaphysis was 4.1 mm at the resection at the fibular head [12]. In our results, it was at an average of 7.49 ± 3.13 mm (range from 1.18 to 14.97 mm) at the resection at the fibular head. This indicates that the tibial plateau of Chinese patients has a different anatomic profile than in Caucasians. There are significant differences between the proximal tibial anatomy of Caucasian and Chinese individuals; however, tibial implants have been designed based on measurements taken from the anatomy of Western subjects. Thus, a wider range of offsets is necessary for the optimum placement of implants.

The positions of the tibial shaft axis and offsets were different between healthy individuals and OA patients. Tang et al. found the axis of the tibial shaft in 98% of knees to be located anterolaterally at 5 mm thick resections, and in 94% of the knees at 10 mm resections, in healthy Chinese individuals [17]. Our results showed that the axis of the tibial shaft was located anterolateral to the center of the tibial plateau in 65% of the knees and was located anteromedial in 33% of the knees at the 6 mm thickness resection. In addition, the axis of the tibial shaft was located anterolateral to the center of the tibial plateau in 58% of the knees, was anteromedial in 44% of the knees, and was located posteriormedial in 1% of the knees at 10 mm thick resections. These findings suggest that there are a large proportion of OA patients whose tibial shaft axis was located anterolateral to the center of the tibial plateau. Thus, the morphology of an OA knee is different from that of a normal knee, especially the position of the tibial shaft axis in relation to the center of tibial plateau. Furthermore, our results show that the average off set was 7.61 mm at the resection just distal to the subchondral bone of the medial plateau. This distance is much longer than 6.14 mm, which is the average offset among healthy Chinese people at an average age of 38.4 years [17]. Thus, data from OA patients could be more suitable for component design.

Nonetheless, this study has certain limitations. First is the small sample size, which may not be representative of the overall population. Another limitation is that individuals with valgus deformity were excluded, which should make one cautious about applying the results of this study to patients with valgus deformity.

This prospective study demonstrates that the anatomy of the proximal tibia varies significantly among OA patients. The tibial shaft axis of most knees in this population is located anterolateral to the center of the tibial metaphysis. These anatomic variations and features should be properly evaluated in individual patients before they undergo TKA.

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Disclosure of conflict of interest

None.

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