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Morphology of the Proximal Tibia at Different Levels of Bone Resection in Japanese Knees

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ABSTRACT

The purpose was to measure the morphology of the proximal tibia at different levels for consideration of tibial tray design and placement. The morphology was analysed in 51 knees at 10, 15, 20, and 25 mm below the centre of the lateral tibial plateau. Surface rotation was measured by fitting an ellipse on the resection surface. The anteroposterior (AP), mediolateral (ML), medial AP (MAP) and lateral AP (LAP) dimensions were also measured. The resection surface showed internal rotation of 22.9° from the 10 mm level to the 25 mm level. More distally, the ML/AP and MAP/LAP ratios showed significant changes. Surgeons should pay attention to morphological changes for patients with gross tibial bone defects in primary and revision total knee arthroplasty.

In revision total knee arthroplasty (TKA), bone loss secondary to loosened implants is a common feature, with further bone loss occurring during component removal [1]. Therefore, it is often necessary to position the tibial component at a lower level in comparison with primary TKA using metal augments and/or bone graft to make up the difference [1–3]. Shifting the tibial component distally from the original bone surface of primary TKA usually causes a decrease in the anteroposterior (AP) and mediolateral (ML) lengths, which makes appropriate fixation of the tibial component more difficult because of the decrease of the bone surface.

Proper positioning of the components during TKA is critical for a good clinical outcome. Correct rotational alignment is related to better function, clinical scores, and range of motion after TKA [4]. Excessive malposition of the tibial component, especially internal rotation, can lead to complications such as painful knee, stiff knee, patellofemoral instability, or excessive polyethylene wear in the tibial component [5–8]. In revision TKA, it is sometimes difficult to identify tibial bony landmarks such as the tibial tubercle, posterior cruciate ligament (PCL) insertion, posterior condylar line of the tibia, and widest dimension of the tibial surface [9]. Moreover, the morphology of the tibial cut surface may be different at a more distal resection level.

The morphology of the proximal tibia at the standard resection level has been previously analysed for designing the tibial component used in TKA [10–13]. Several studies have shown that the AP length of the medial condyle was greater than that of the lateral condyle and that an averaged asymmetrical anatomical silhouette may provide an improved overall fit with optimised cortical support and minimised overlap in comparison with the standard symmetrical tibial component [14,15]. However, it is still unknown if these asymmetrical tibial components are optimal for revision TKA with a more distal bone resection level.

Therefore, the purpose of the current study was to measure the morphology of the proximal tibia at different levels of bone resection to determine the optimal tibial component for revision TKA. We hypothesised that the tibial morphology at a more distal bone resection level compared to that in primary TKA would be different, and a redesigned tibial component would therefore be required for revision TKA accompanied by severe bone loss.

Materials and Methods

Patients who underwent primary TKA for the diagnosis of osteoarthritis from December 2013 to October 2014 were selected for this study. Computed tomography was taken for all TKA surgical candidates to perform preoperative planning. Those with bone defects of the lateral tibial plateau due to lateral osteoarthritis and those who had previously undergone high tibial osteotomy were considered ineligible for this study. A total of 47 patients (51 knees; 9 male and 42 female knees) with a mean age of 73.8 (range, 46–87; standard deviation [SD] = 9.1) years were included in the study. All patients included in the current study were ethnic Japanese. The mean height and weight of the patients were 153 (range, 140–174; SD = 8) cm and 61 (range, 43–90; SD = 11) kg, respectively, and the mean body mass index (BMI) was

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26.2 (range, 17.1–35.7; SD = 3.2). Appropriate IRB approval and informed consent from all the patients were obtained.

The patients were positioned in a scanner in a supine position with both knees extended. Computed tomography images were acquired in 1-mm thick slices from the hip joint to the ankle joint, and three-dimensional images of the tibia were reconstructed perpendicular to the mechanical axis of the tibia. The AP axis of the tibia was defined as the line connecting the middle of the PCL and the medial border of the patellar tendon at the tibial attachment [16]. The resection level was 10, 15, 20, and 25 mm below the centre of the lateral tibial plateau without posterior slope. The first resection level was the same as the level in a standard primary TKA, and the more distal resection levels were at levels frequently required in a revision TKA or in a primary TKA with gross bony defects.

At each resection level, the osteophytes surrounding the tibial cut surface were excluded from the following measurements. All the measurements were performed using Image J (U.S. National Institutes of Health, Bethesda, Maryland, USA). To measure surface rotation relative to the tibial AP axis, the outline of the tibial cortex was first detected. A best-fit ellipse with the same area, orientation, and centroids as the selected area was then placed on the bone surface surrounding the outline. The surface rotation angle was defined as the angle between the AP axis of the tibia and the minor axis of the best-fit ellipse (Fig. 1). The ML dimension was measured as the longest ML length of the proximal cut surface. The middle AP dimension was measured as the length of the line drawn perpendicular and passing through the midpoint of the ML line. The medial AP (MAP) dimension was measured as the length of the line drawn parallel to the middle AP line and passing through the posterior-most point of the medial tibial condyle. The lateral AP (LAP) dimension was measured as the length of the line drawn parallel to the middle AP line and passing through the posterior-most point of the lateral tibial condyle. To measure the tibial posterior condylar (PC) angle, a line was drawn connecting the posterior-most point of the medial and lateral tibial condyles. The PC angle was defined as the angle between this line and a line perpendicular to the AP axis (Fig. 2A). The surface rotation angle and PC angle were denoted as positive if the minor axis and PC were internally rotated relative the AP axis. The ML, AP, MAP, and LAP of the original bone surface were measured according to the tibial AP axis, and those of the rotated surface were measured according to the minor axis of the best-fit ellipse (Fig. 2B). An experienced orthopaedic surgeon performed all measurements in the current study.

Sample size estimation at an alpha level of 0.05 and a statistical power of 80% to detect 3° of rotational differences with an SD of 6°, as in previous studies, revealed that 51 knees were required for the analysis. Intraclass correlation coefficients were calculated to quantify inter-observer and intra-observer agreement of the measurements. All measurements were repeated for 10 randomly selected knees by an orthopaedic resident as a second observer to test the inter-observer reliability. Intraclass correlation coefficients of the surface rotation angle, PC angle, ML, AP, MAP, and LAP length were 0.986, 0.916, 0.961, 0.973, 0.951, and 0.950 between two examiners, respectively. To test the intra-observer reliability, the same orthopaedic surgeon repeated

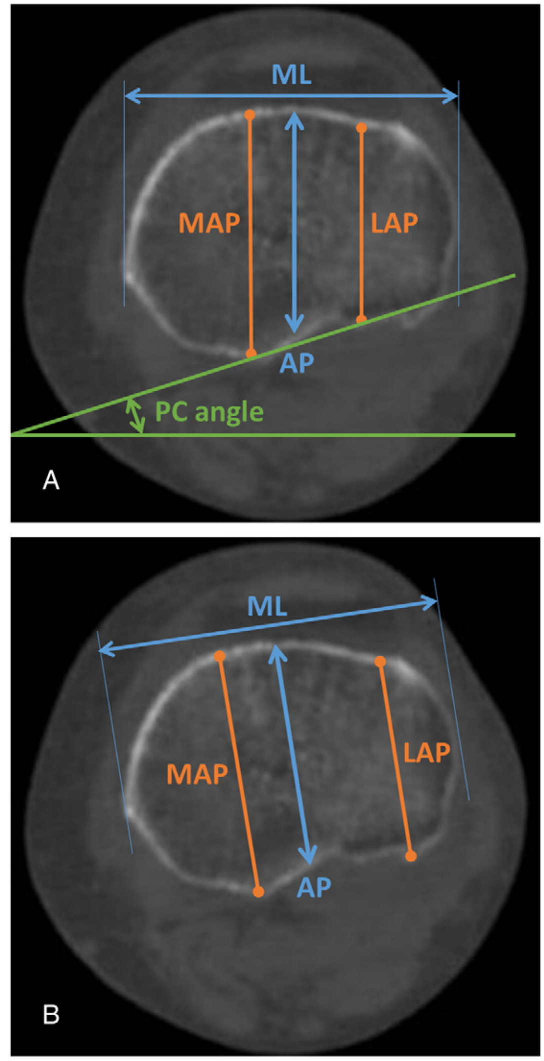

Fig. 2. Measurement of ML, AP, MAP, and LAP dimensions, and PC angle. (A) Measurement according to the tibial AP axis. (B) Measurement according to the minor axis of the best-fit ellipse.

Fig. 1. Measurement of surface rotation angle. Left; resection surface. Middle; after detection of the cortical bone. Right; after fitting the ellipse. The green line indicates the minor axis of the best-fit ellipse.