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A lateralized anterior flange improves femoral component bone coverage in current total knee prostheses

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ABSTRACT

Background: Poor femoral implant fit to resected bone surfaces recently has been the motivation for several new total knee arthroplasty implant designs. Implant overhang risks adverse soft-tissue interaction while uncovered cut bone surfaces (underhang) risks increased postoperative bleeding or development of heterotopic bone.
Methods: Femoral implant fit was studied systematically, and without the influence of surgical variation, by virtually implanting standard and narrow width femoral components (Bi-Surface 5) using preoperative computed tomography data for 150 varus osteoarthritic knees in Japanese patients. Overhang and underhang rates and bone widths were determined by gender.
Results: Narrow femoral components helped avoid or minimize overhang in most female and some male knees. Although anterior width in the narrow components closely matched female bone width, the femoral component was necessarily displaced laterally to avoid overhang in the anteromedial portion. Consequently, there was significant medial underhang in the distal and posterior zones.
Conclusions: Ideally, the anterior femoral flange should be shifted 2 to 2.5 mm laterally relative to the distal and posterior aspects to provide optimal femoral bone coverage in this prosthesis. The current study also confirmed that this modification can be generalized to the other two currently available “narrow type” prostheses. This geometric modification might allow surgeons to select a femoral component with slightly wider mediolateral dimensions in the distal and posterior aspects to minimize underhang, while eliminating anterior overhang.
Level of Evidence: III.

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1. Introduction

Femoral components with narrower mediolateral (ML) dimensions recently have been used clinically to avoid ML overhang for narrow-shaped femora [1–3] in total knee arthroplasty (TKA). This modification is mainly based on several studies about the morphological features of the distal femur showing that the ML diameter is narrower in female than male knees [4–9]. This observation has also been supported by clinical studies showing that more women than men had ML overhang of the femoral component when a standard prosthesis was used [2,10,11].

Surgeons can avoid excessive ML overhang by using narrow femoral components in some female knees [2,7,11–13], which may reduce soft-tissue interactions that cause pain and limit range of motion (ROM) [10, 14]. However, the indications for narrow components are uncertain, given that ML overhang rates in females with standard TKA components vary from 7.5% to 68% [2,10,11,15–17]. ML overhang is affected by implant design, surgical factors, and probably race and lifestyle factors. Variations in component size and surgical alignment affect overhang, so surgical techniques, i.e. conventionally instrumented versus computer navigated, can have an influence [18,19]. Distal femur morphology in Asians is reported to be different from Caucasians, so prostheses designed for Caucasians may not fit as well [20,21]. Therefore, it is important to evaluate the need for narrow femoral components, excluding the potential for surgical errors, based upon ML overhang rates and especially in Asian females.

Overhang is not the whole story, as uncovered cut bone surfaces (defined as underhang hereafter) carry risks for increased postoperative bleeding or development of heterotopic bone [15,16,22]. However, there have been few descriptions of underhang rates when using narrow femoral components in female knees, and these all were measured during surgery with conventional techniques [15, 16]. Thus, the purposes of this study are to simulate TKA in Japanese varus osteoarthritic knees, to determine the detailed overhang and underhang rates and bone widths in each portion of the distal femur by gender, and to determine if it is necessary to use narrow femoral components or to further modify femoral component shape to optimize prosthetic coverage of bone.

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2. Materials and methods

Eighty-seven female patients (100 knees) and 43 male patients (50 knees) who underwent TKA with primary varus osteoarthritis and provided informed consent formed the study group (Table 1). Patients were all Japanese. Preoperative computed tomography (CT) scans of the whole lower-extremity (including hip and ankle joints) were obtained from all patients. The local Institutional Review Board (201440122) approved this study.

We simulated primary TKAs in these 150 knees using preoperative surgical planning software (3D Template, Kyocera Medical, Osaka, Japan). The surgical plan was based upon three-dimensional (3D) knee models from the CT scans [23–28], and standard and narrow width femoral components were virtually implanted (Bi-Surface 5, Kyocera Medical, Osaka, Japan). Femoral component coronal alignment was set perpendicular to the mechanical axis of the femur [18], sagittal alignment was set parallel to the anatomical axis of the distal femur [27, 28], and rotational alignment was parallel to the surgical epicondylar axis (SEA) connecting the tip of the lateral epicondyle and the medial epicondylar sulcus [25,29,30]. The posterior condylar angle (PCA), defined as the angle between the SEA and the posterior condylar line, was measured [31]. We chose the femoral component size that best matched the anteroposterior (AP) dimension of the native femoral lateral condyle (Fig. 1) [32].

We performed eight measurements on four zones of the medial and lateral femoral component; Antero-Proximal (Ant-Prox) zone, Antero-Distal (Ant-Dist) zone, Postero-Distal (Post-Dist) zone and Postero-Proximal (Post-Prox) zone (Fig. 2). Osteophyte formations, especially on the medial side, were excluded from width measurements. “Positive” overhang/underhang measures were defined as overhang or underhang greater than two millimeters in each zone. The ML implant position was set to avoid or minimize overhang greater than two millimeters in each portion to the extent possible. If there was no overhang in any zone, the ML position was set in the center of the distal femur. First, we selected one of the standard or narrow femoral component which best fit the femur bone without excessive overhang. Second, the narrow component was aligned and the amount of overhang or underhang was measured in the medial and lateral portions of the four zones (Fig. 3). Knees with at least one positive overhang measure were defined as overhang positive knees. Finally, the standard width component was aligned and the overhang or underhang was measured in the same manner. Overhang width is described with positive values and underhang is described with negative numerical values.

2.1. Statistical analysis

All measurement procedures were repeated three times at least two weeks apart for all patients by a single surgeon examiner (SK). The average of the three measurements was used for each parameter. Valgus, flexion and PCA femoral component alignment were compared between males and females with a Student t-test. Detailed overhang and underhang rates in each portion of the distal femur were compared between standard and narrow width components, and between males and females with a chi-square test. Detailed overhang and underhang widths in each portion of the distal femur were compared between standard and narrow width components, and between males and females with an unpaired t-test. Statistical analyses were performed with EZR (Saitama Medical Center, Jichi Medical University), which is a graphical user interface for R (The R Foundation for Statistical Computing, version 2.13.0) [33] that includes statistical functions frequently used in biostatistics. Significance was set at a p-value of <0.05.

To evaluate intraobserver and interobserver reproducibility, the measurements of overhang/underhang widths in each portion were performed three times by one examiner (SK) and once by another examiner (SO) on 10 knees randomly selected from the study group. The intraclass correlation coefficient and the interclass correlation coefficient were 0.91 and 0.83, and femoral component sizes

Table 1
Patient details of females and males.

	Female (n = 100)	Male (n = 50)
Age (yr)	75.7 ± 7.4	74.6 ± 7.5
Side (Rt/Lt)	Rt 52 knees/Lt 48 knees	Rt 30 knees/Lt 20 knees
Height (cm)	148.7 ± 4.2	162.0 ± 6.5
Body weight (kg)	58.1 ± 9.2	68.3 ± 9.5
Body mass index (BMI)	26.3 ± 4.1	26.0 ± 3.1
Hip–knee–ankle angle (HKA)	9.9 ± 4.8° varus	8.6 ± 3.8° varus

All values are given as the mean and standard deviation.

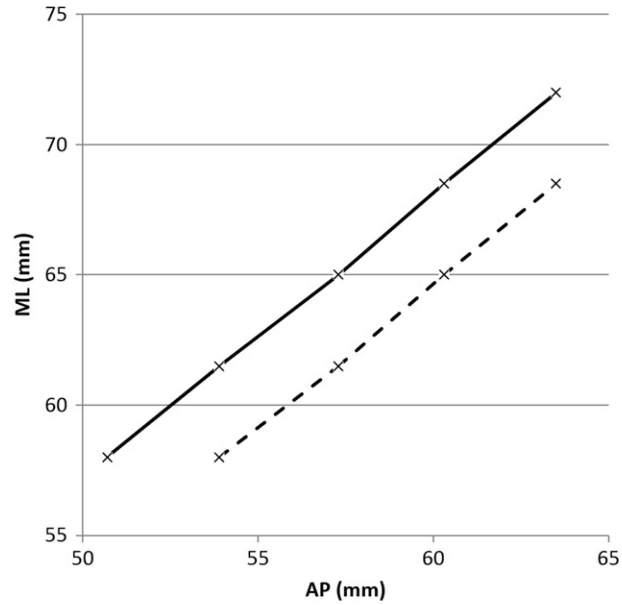

Fig. 1. AP/ML ratio of Bi-Surface 5 femoral component (standard: solid line, narrow: broken line) with 5 sizes (XSML — no narrow option, SML, STD, LAG, XLAG).

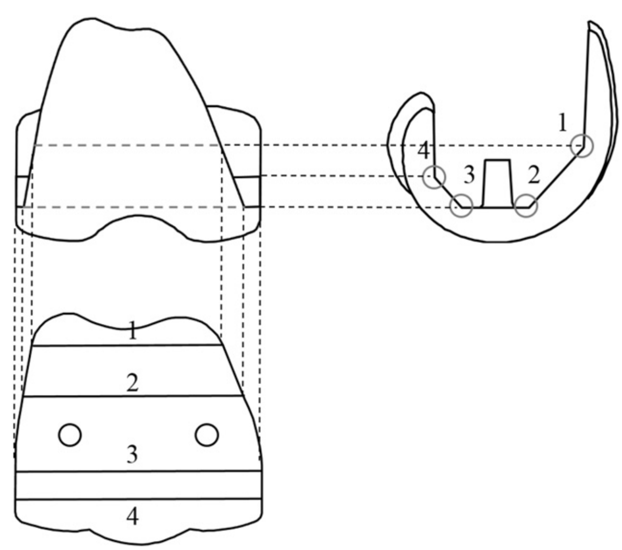

Fig. 2. Four zones of the femoral component were analyzed for bone coverage: 1. Antero-Proximal (Ant-Prox) zone, 2. Antero-Distal (Ant-Dist) zone, 3. Postero-Distal (Post-Dist) zone and 4. Postero-Proximal (Post-Prox) zone.

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