



Obliquity of tibial component after unicompartmental knee arthroplasty

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ABSTRACT

Background: The native knee joint line is varus relative to the tibia and remains parallel to the floor during gait even with varus lower-limb alignment. We investigated the desired degree of frontal obliquity for positioning the tibial component during unicompartmental knee arthroplasty (UKA).

Methods: We retrospectively analyzed full-leg, standing, hip to ankle digital radiographs from 107 osteoarthritic knees. We measured the hip–knee–ankle (HKA) angle, the tibial joint-line orientation angle (JLOA), which indicates the angle of the joint line (tibial component) relative to the floor, and the medial proximal tibial angle (MPTA), which is the angle of the joint line (tibial component) relative to the tibial mechanical axis, before and after UKA in the coronal plane.

Results: The preoperative HKA angle (mean 7.3°, standard deviation (SD) 3.0) was significantly higher than the postoperative HKA angle (mean 3.4°, SD 3.0, $P < 0.0001$). The preoperative MPTA (mean 4.8°, SD 2.1) did not significantly differ from the postoperative MPTA (mean 4.5°, SD 3.0, $P = 0.47$). The mean postoperative JLOA was parallel to the floor (JLOA; 0.2°, SD 3.6).

Conclusion: When the tibial component is positioned along the natural joint slope restoring pre-disease alignment of the overall lower limb in the coronal plane, the tibial component was positioned parallel to the floor. When UKA is indicated for the medial osteoarthritis patient, the surgeon should install the tibial component four to five degrees varus to the tibial mechanical axis to maintain joint-line parallelism.

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1. Introduction

Although patients had a higher satisfaction rate after unicompartmental knee arthroplasty (UKA) than after total knee arthroplasty (TKA) [1,2], the survival rate was worse for UKA patients compared with TKA patients [3,4]. UKA may fail for many reasons. Important prognostic factors for UKA cited by numerous doctors are the device type used [5], age [5–7], unexplained pain [8], surgeon's skill [9], physical activity [10], body weight [10,11], limb alignment [7,12,16,17] and positioning of the unicompartmental implant [13–15]. Especially for coronal overall limb alignment, many authors have recommended undercorrecting the deformity during UKA [7,12,16]. Kennedy and White found that patients with slightly undercorrected postop-

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erative alignment had the longest survivorship [17]. Other studies have associated overcorrection of the tibiofemoral deformity with disease progression in the opposite compartment [18,19].

Joint-line orientation plays an important role in coronal alignment. The normal joint line of the proximal tibia relative to the mechanical axis is about three degrees varus. During gait, the lower limb comes into slight adduction bringing the tibial joint line parallel to the floor [20,21]. Bellemans et al. described how the periarticular knee anatomy contributes to overall lower-limb alignment in the asymptomatic patient with “constitutional varus” [22]. They showed that the joint line of the proximal tibia is more varus in knees with constitutional varus than in normal knees. Victor et al. demonstrated that the joint line remains parallel to the floor even in knees that have constitutional varus but no joint degeneration [23].

Howell et al. proposed the kinematically aligned TKA, which leaves the tibial component implant along the native joint line in the coronal plane and the postoperative joint-line orientation horizontal to the floor [24]. The varus alignment of the tibial component relative to the tibial mechanical axis did not adversely affect implant survival at a mean of 6.3 years after kinematically aligned TKA [25]. If the pre-disease alignment of the overall lower limb and joint line of the knee are restored during UKA, positioning the tibial component parallel to the floor may be ideal from a biomechanical view of joint loading and shear stress. This study attempted to answer the following questions: (1) If the tibial component implant is placed along the natural slope of the tibial surface in the coronal plane, would the orientation of the tibial component be parallel to the floor after UKA? and (2) If the pre-disease overall alignment of the lower limb is restored during UKA, how obliquely should the tibial component be positioned?

2. Materials & methods

2.1. Patient population

We enrolled 95 patients with 107 osteoarthritic knees that received UKAs between January 2012 and December 2014 at our institute. We retrospectively analyzed each patient's pre- and postoperative data. All patients gave their informed consent in accordance with our University's Institutional Review Board. The inclusion criterion was osteoarthritis (OA) with remaining cartilage of the varus knee prior to reaching stage III of the Kellgren–Lawrence classification. The exclusion criteria included absence of cartilage, valgus deformity of the knee, previous knee surgery or rheumatoid arthritis. The subjects were 67 women and 28 men with a median age of 72 years (range, 50–88 years). Average length of follow-up was 38 months (range, 24–59 months), and during that time period there were no component revisions and no reoperations. The hip–knee–ankle (HKA) angle averaged 7.3° (range, one degree valgus to 18.0° varus). Clinical outcomes of the participants were assessed at six months postoperatively using the Knee Society Score.

2.2. Surgical technique

All patients were implanted with a medial Zimmer Unicompartamental High Flex Knee System (Zimmer Inc., Warsaw, IN, USA). Two senior surgeons (M.A. and S.A.) performed all surgeries through the quadriceps sparing approach. The surgeon made a tibial cut reproducing the native joint-line inclination in the coronal plane and the natural posterior slope of the tibia in the sagittal plane using an extramedullary system. After resecting the proximal tibia, the surgeon made the femoral distal cut parallel to the tibial cut with the aid of a spacer block inserted into the joint space. The surgeon used posterior referencing instrumentation to determine the sizing of the distal femur and the femoral posterior cuts and to restore the flexion gap accurately. Bone cement fixed all components in place.

2.3. The alignment measurements

Patients underwent full-leg, standing, hip to ankle digital radiographs one month before surgery and six months after surgery. These weight-bearing, full-leg radiographs were obtained with patients standing barefoot with feet together and patellae forward using a digital radiographic system (RAD speed Pro V4; Shimadzu, Kyoto, Japan) [23,26]. Measurements were performed with the measurement tool of a picture-archiving and communication system (PACS: SYNAPSE PACS, Fuji film, Tokyo, Japan). We measured three parameters to evaluate pre- and postoperative alignment: the HKA angle, the tibial joint-line orientation angle (JLOA) and the medial proximal tibial angle (MPTA) (Figure 1) [23,26]. The HKA angle is the angle between the mechanical axes of the femur and the tibia. The JLOA is the angle formed between a line parallel to the floor and the preoperative joint line or the tibial component in the coronal plane. The MPTA is the angle of the line perpendicular to the tibial mechanical axis with respect to the preoperative joint line or the tibial component in the coronal plane. Positive values of these three angles indicate varus inclination. Because the software provided values to one decimal place, the measured and calculated data are reported to one decimal place in this study.

2.4. Observer errors

Two observers (I.T. and S.I.) performed measurements on each subject twice, one week apart. We recorded the average of these four values. To assess the intra-observer variations of measurement values, one observer (S.M.) repeated the measurements 10 times in three randomly selected patients. We assessed the measurement reliabilities using an intra-class correlation coefficient

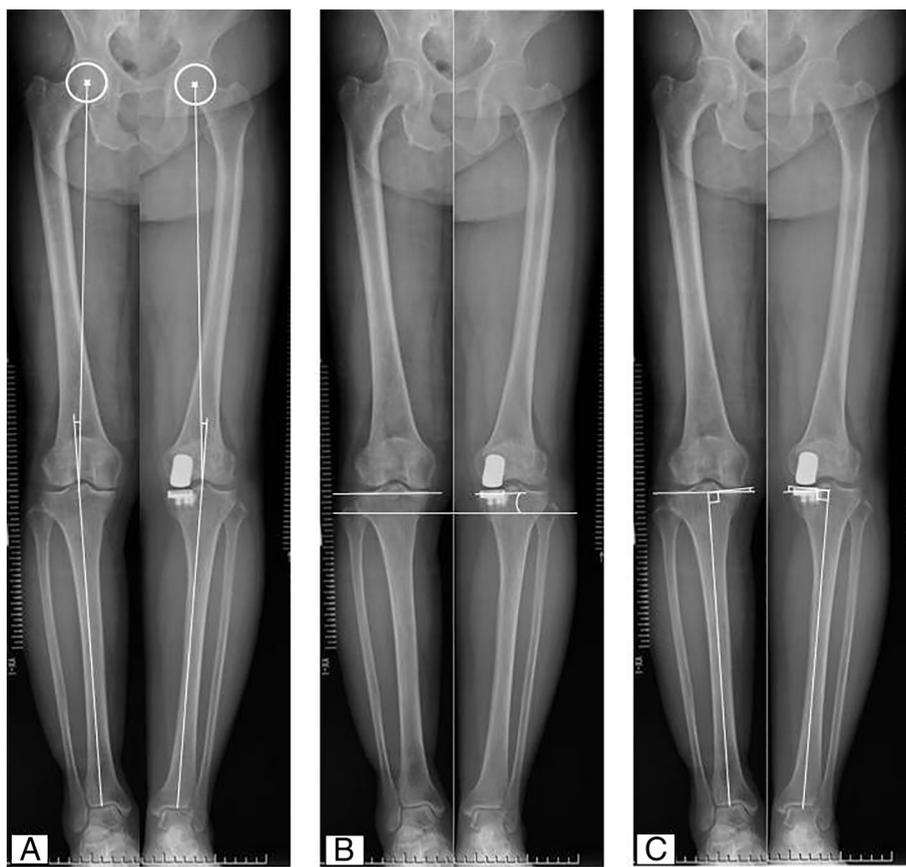


Figure 1. Radiographic measurements of the hip-knee-ankle angle (a; HKA), the tibial joint line orientation angle (b; JLOA) and the medial proximal tibial angle (c; MPTA) before and after UKA. Positive values of the HKA angle, the JLOA and the MPTA indicate varus inclination.

(ICC); the ICC (one, one) indicated that intra-observer reliability was greater than 0.85 in all measurements. Furthermore, both observers (I.T. and S.I.) performed the same measurements once in 10 subjects to assess inter-observer measurement variations; the ICC (two, one) was greater than 0.88 for all measurements. From these findings, we concluded the measured values were valid and reliable.

2.5. Statistical analysis

We used SPSS statistics 15 (SPSS Japan, Inc., Tokyo, Japan) to perform the statistical analysis. We made pair-wise comparisons using Student's *t*-test. An *F*-test was used to test whether the variances of the two populations were equal and Welch's *t*-test when two samples had unequal variances. We evaluated correlations using Pearson's correlation coefficient test. *P*-values of less than 0.05 were considered statistically significant.

3. Results

Table 1 shows the preoperative mean values of the HKA angle, the JLOA and the MPTA grouped by OA grade. HKA angle and MPTA increased with advanced OA grade, while, the JLOA decreased. Figure 2 shows scatter plots of the JLOA and the MPTA

Table 1
Preoperative values of hip-knee-ankle angle (HKA), the tibial joint-line orientation angle (JLOA) and the medial proximal tibial angle (MPTA) grouped by osteoarthritis grade.

OA grade (no.)	HKA	JLOA	MPTA
I (8)	6.3 ± 2.9	-0.1 ± 3.6	4.4 ± 2.2
II (43)	6.5 ± 3.0	-0.3 ± 2.2	4.6 ± 2.0
III (23)	9.1 ± 3.0	-1.4 ± 2.1	5.1 ± 2.1
All (74)	7.6 ± 3.5	-0.7 ± 2.2	4.9 ± 2.1

The values are given are the means and the standard deviations. Varus measurements are positive.

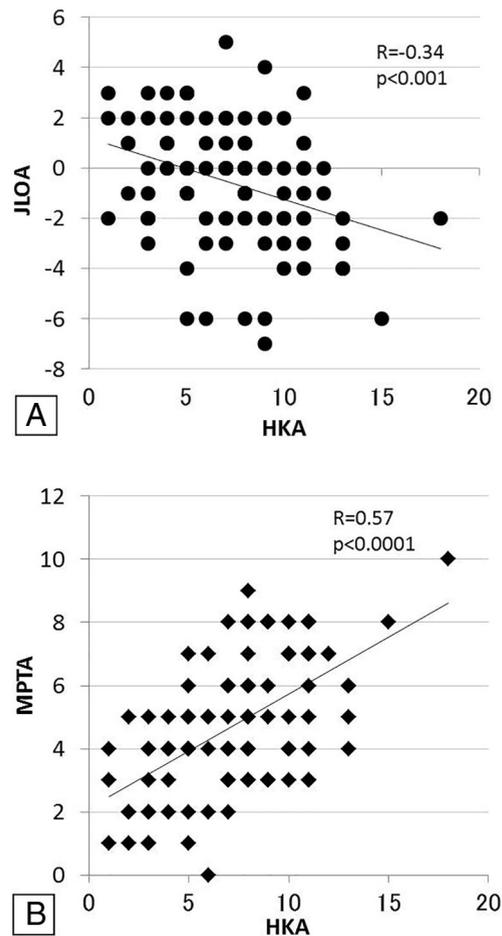


Figure 2. Relationships between proximal tibial anatomy and overall coronal lower leg alignment. Scatter plots for the tibial joint-line orientation angle (JLOA; a) or the medial proximal tibial angle (MPTA; b) against the hip–knee–ankle angle (HKA). R, coefficient correlation.

against the HKA angle. The JLOA and MPTA correlated significantly with the HKA angle ($R = -0.34$, $P < 0.001$ on the JLOA, Figure 2(a); $R = 0.57$, $P < 0.0001$ on the MPTA, Figure 2(b)).

The pre- and postoperative measurements for each parameter appear in Figure 3. The preoperative HKA angle was significantly smaller than the postoperative HKA angle ($P < 0.0001$). The mean postoperative JLOA was parallel to the floor (mean: 0.2° , standard deviation (SD): 3.6). The MPTA did not differ significantly between pre- and postoperative values ($P = 0.47$).

The Knee Society Score (the objective knee score and the functional score) did not correlate with the absolute value of the JLOA angle ($R = -0.07$, $P = 0.50$ on the objective knee score, $R = -0.02$, $P = 0.83$ on the functional score).

4. Discussion

When the tibial component of the implant is installed along the natural slope of the proximal tibia in the coronal plane, the tibial component is positioned parallel to the floor after UKA. The mean preoperative MPTA, which indicates the proximal tibial vara, was 4.8° varus to the tibial mechanical axis. Victor et al. showed that knees with constitutional varus have a more varus joint line of the proximal tibia than normal knees, and the mean MPTA was 5.2° [23]. Bellemans J et al. divided 250 Caucasian, asymptomatic volunteers into three groups using their HKA angles in full-leg, standing digital radiographs [22]. The mean MPTA was 4.9° in the varus group, whereas it was 2.4° in the neutral group. That varus group had a similar mean MPTA as the current study's preoperative MPTA, and the MPTA increased with increasing varus alignment in the arthritic knees (Figure 2(b)). Knees with constitutional varus and without joint degeneration have a joint line that remains parallel to the floor. When cartilage loss occurs with OA, joint-line parallelism is not sustained. Consequently, the joint line changes valgus to the floor [23]. Therefore, the mean preoperative JLOA was -0.6° , and the joint line slanted down to the lateral side with increasing varus alignment in the arthritic knees (Figure 2(a)). Because preoperative to postoperative MPTA did not change, the tibial component of the implant had been positioned along the natural joint slope of the proximal tibia in the coronal plane. Consequently, after surgery, the tibial component was parallel to the floor, restoring the pre-disease overall alignment of the lower limb.

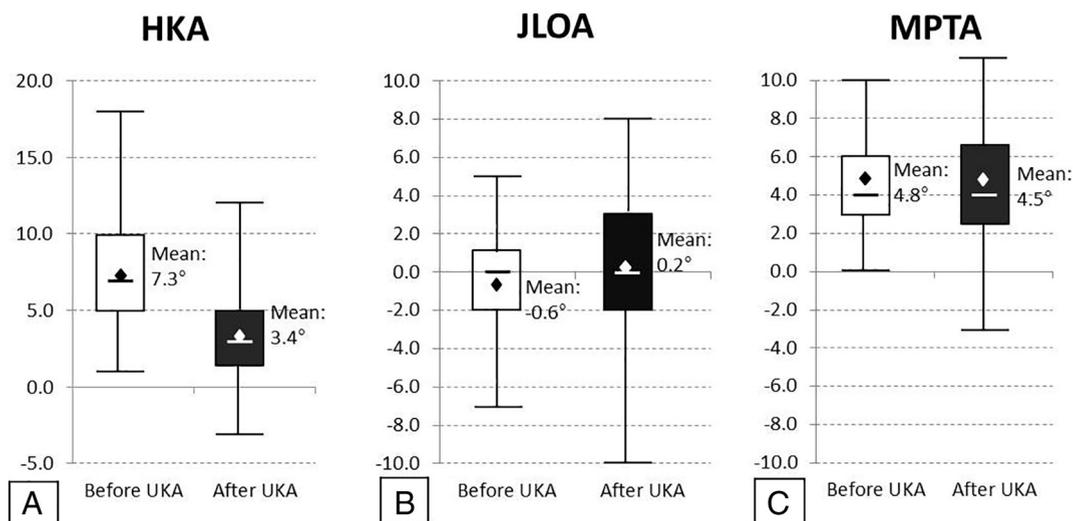


Figure 3. Pre- and postoperative measurements for each parameter. Box and whisker plots for (a) hip–knee–ankle angle (HKA), (b) joint-line orientation angle (JLOA) and (c) medial proximal tibial angle (MPTA) before and after unicompartmental knee arthroplasty (UKA). Bottom borders of the box represent the 25th and 75th percentiles; the bar (–) in the box is the median and the rhombus (♦) in the box is the mean. The ends of the whiskers represent the minimum and maximum of all data.

The preoperative MPTA, that is the target angle for setting the tibial component, was mean 4.8° varus to the tibial mechanical axis. The UKA retains the four main ligaments of the knee (medial and lateral co-lateral ligaments and anterior and posterior cruciate ligaments) unlike the TKA. To maintain the function of these ligaments following UKA, the alignment of the knee should be restored to the pre-arthritis condition. Therefore, the postoperative HKA angle, that is the coronal overall limb alignment, was a mean of 3.4° varus, which was a slight undercorrection following UKA. If we want to realign the knee to its neutral alignment (HKA = 0), the joint line of the proximal tibia relative to the tibial mechanical axis should be set to about three degrees as the MPTA is in neutral knees. However, Vandekerckhove et al. reported that the contribution of constitutional varus in the medial OA population is greater than in the general population [27]. When UKA is indicated for medial OA patients, we should install the tibial component four to five degrees varus to the tibial mechanical axis to maintain joint-line parallelism.

UKA has been associated with consistently worse implant survival rates than TKA in worldwide arthroplasty registers [3,4]. The overall limb alignment and position of the tibial component after UKA affect the prosthesis survival, but may not be associated with the clinical outcome directly. Chatellard et al. sought to identify tibial component position criteria associated with clinical outcomes, and investigated the following parameters of the component position: joint space height, obliquity and slope of the tibial implant, whether the tibial component was perpendicular to the femoral component, and lower limb malalignment. The only factor associated with worse functional score values was joint space elevation by more than two millimeters [14]. The obliquity of the tibial component did not influence the clinical outcomes in the current study. In the prosthesis survival, Kennedy and White found that patients with slightly undercorrected postoperative alignment had the longest survivorship in the coronal overall limb alignment [17]. Chatellard et al. demonstrated that postoperative varus of the limb (HKA < 175°) and varus position of the tibial component (three degrees more of varus relative to the natural slope) were associated with mechanical failure of the tibial component of the implant [14]. They recommended that the tibial component's position be restored to physiological obliquity within three degrees in either direction, in keeping with previously published opinions [15,28].

On the other hand, revision for unexplained pain was more common after UKA than after TKA (23% vs nine percent) [8], and this is an important complication for UKA. After UKA the most common site for pain is anteromedial over the proximal tibia, and Simpson et al. explained that abnormally high bone strain on the anteromedial proximal tibia causes the pain. Using the finite-element model, they demonstrated that there is a large increase in strain on the anteromedial aspect of the proximal tibia following implantation with a UKA device [29]. Inoue et al. investigated the influence of the tibial component's position on bone strain in the proximal tibia using the finite-element model [30]. A valgus inclination of the tibial component increased the stress concentration on the medial tibial metaphyseal cortex to a remarkable degree. Therefore, installing the tibial component along the neutral varus slope of the proximal tibia should improve prosthesis survival.

The present study had several limitations. First, the study population included only Japanese patients. A study indicates that there are more varus knees among the Japanese population than among Caucasian people [31]. However, the mean MPTA of our patients, which indicates the proximal tibial vara, was similar to previous published data of Caucasian patients. Therefore, our data might still apply to relatively mild medial OA patients from other ethnic and racial groups in which UKA is indicated. Second, we reported the joint-line parallelism to the floor, but the dynamic joint loading during gait remains unknown. We made our assessment with a single plane and static measurements from the biomechanical viewpoint of joint loading. Furthermore, we need further studies on joint-line parallelism during the dynamic gait situation. Third, due to the short observation period, it is not clear whether the obliquity of the tibial component affects the prosthesis survival. We need further long-term

observation for the prosthesis survival. In conclusion, a surgeon performing UKA for medial OA should restore the tibial component's position to physiological obliquity to maintain joint-line parallelism.

Conflict of interest

The authors declare that they have no conflicts of interest.

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