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Primary Knee

Central Implantation of the Femoral Component Relative to the Tibial Insert Improves Clinical Outcomes in Fixed-Bearing Unicompartmental Knee Arthroplasty

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ABSTRACT

Background: The direct relationship between clinical outcomes and femoral component positioning relative to a tibial insert remains unknown. We determined whether the femoral component position relative to the tibial insert could affect clinical outcomes after fixed-bearing unicompartmental knee arthroplasty (UKA).
Methods: The femoral component position relative to the tibial insert of 66 patients with anteromedial osteoarthritis and osteonecrosis of the knee who underwent fixed-bearing UKA was assessed at 2 weeks postoperatively. We classified patients according to the contact point of the femoral component with the tibial component: group M (medial), 18 knees; group C (central), 30 knees; and group L (lateral), 18 knees. Patient-derived clinical scores using the 2011 Knee Society Score were also assessed preoperatively and at 2 years postoperatively and compared among the 3 groups using the analysis of variance.
Results: The average 2-year postoperative "symptom" and "patient satisfaction" scores based on the 2011 Knee Society Score were significantly higher in group C than in group M or group L.
Conclusion: Central implantation of the femoral component relative to the tibial insert plays an important role in decreasing pain and could result in better patient satisfaction after fixed-bearing UKA at 2 years postoperatively. Surgeons should set the femoral component at the center relative to the tibial insert for better patient satisfaction and higher active knee flexion after fixed-bearing UKA.

Numerous studies have demonstrated decreased postoperative morbidity and faster recovery with unicompartmental knee arthroplasty (UKA) than with total knee arthroplasties (TKAs) [1–3]. However, concerns regarding increased revision rates in UKA based on registry data remain. Moreover, the National Joint Registry of England and Wales demonstrated that both the overall revision rate and the revision rate for "unexplained" pain were higher in UKA than in TKA [4]. In the UKA cohort, revision for unexplained pain accounted for 23% of the total revisions, whereas in the TKA group, revision for unexplained pain accounted for only 9% of the total revisions [4]. These findings suggest that patient-reported outcome assessment appears necessary to unveil the cause of "unexplained pain" and help determine the factors under the surgeon's control that could influence the patient's pain and/or discomfort in UKA.

Component malposition could be a cause of poor clinical outcome in UKA. Particularly, valgus alignment [5–7], external rotation [8,9], and larger posterior slope [6,7,10] of the tibial component may result in negative biomechanical effect and potentially affect clinical outcome after UKA. A recent biomechanical study [11] revealed that the femoral component position (FCP) could be a sensitive factor that influences the contact stresses

Ethics approval: Our hospital's ethics committee approved the protocol of this study, and the patients provided written informed consent to participate.

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on the polyethylene insert and articular cartilage after fixed-bearing UKA; the study suggested that the femoral component should be placed at the center relative to the tibial insert.

The effect of FCP on clinical outcomes after fixed-bearing UKA remains unknown. Therefore, in this study, we determined whether FCP relative to the tibial insert would affect patient-reported clinical outcomes after fixed-bearing UKA.

Patients and Methods

Patients and Study Design

Our hospital's ethics committee approved the protocol of this retrospective study, and the patients provided written informed consent to participate. We conducted a retrospective analysis of 66 consecutive patients (56 women and 10 men) diagnosed with isolated anteromedial osteoarthritis or osteonecrosis with full-thickness lateral compartment articular cartilage and an intact anterior cruciate ligament and medial collateral ligament. Inclusion criteria are age ≥60 years, weight ≤82 kg, flexion contracture ≤15°, overall limb alignment varus ≤15°, and maximum flexion angle ≥90°. Patellofemoral (PF) joint degeneration was classified using the established grading system described by Kellgren and Lawrence (KL) [12]. We excluded PF degeneration more than KL-grade 3 and/or anterior knee pain as these could be confounding factors in terms of pain. The patients underwent primary fixed-bearing UKA with the Zimmer Unicompartmental High Flex Knee System (Zimmer Inc, Warsaw, IN) between January 2015 and December 2016. The age of the patients at the time of surgery was 73.0 ± 7.5 years (range, 60-88 years), and the body mass index (BMI) was 24.4 kg/m^2 (range, 17.6-31.5 kg/m^2). Preoperatively, the coronal plane overall limb alignment on one leg standing anteroposterior (AP) radiographs was 7.2° (range, −0.5° to 15.0°) in varus, with a range of motion of −5.3° (range, −15° to 5°) in extension and 122.4° (range, 90°-150°) in flexion.

Operative Procedures

All UKAs were performed by one surgeon (T.M.), who has more than 10 years of experience in performing knee arthroplasty, conducting 175 per year, of which 20% are UKA. Surgeries were performed according to the previously described technique [13,14]. After inflating the tourniquet to 280 mm Hg, a medial parapatellar approach was performed with an incision from the superomedial border of the patella to 1.5 cm distal to the articular surface of the medial tibia plateau. After exposure of the anterior cruciate ligament and inspection of the PF and lateral compartments, minimal soft tissue release of the medial structures and osteophyte removal were performed. A proximal tibial osteotomy was subsequently performed using an extramedullary alignment guide after ensuring that the bone cut was made at 4 mm below the joint line and with slightly varus against perpendicular to the mechanical axis in the coronal plane and from 6° to 8° of posterior inclination along the sagittal plane of the tibia, with reference to an individual anatomical tibial slope. The thickness of the proximal tibia bony cut was also measured and the actual tibial osteotomy was calculated by adding the thickness of the bone saw blades (1.27 mm), as described previously [15,16]. Thereafter, the distal femoral osteotomy was performed using the tension spacer position method with reference to the surface of the proximal tibial cut with the knee in extension [17]. The femoral rotation was adjusted to the proximal tibial cut surface using the spacer block at knee flexion [17], and the remaining posterior osteotomies of the femur were performed. In this study, the insert thickness was selected depending on the flexion and/or extension gap using the 2-mm end of the tension gauge to ensure that flexion and extension gaps were not too tight and also according to the manufacturer's protocol.

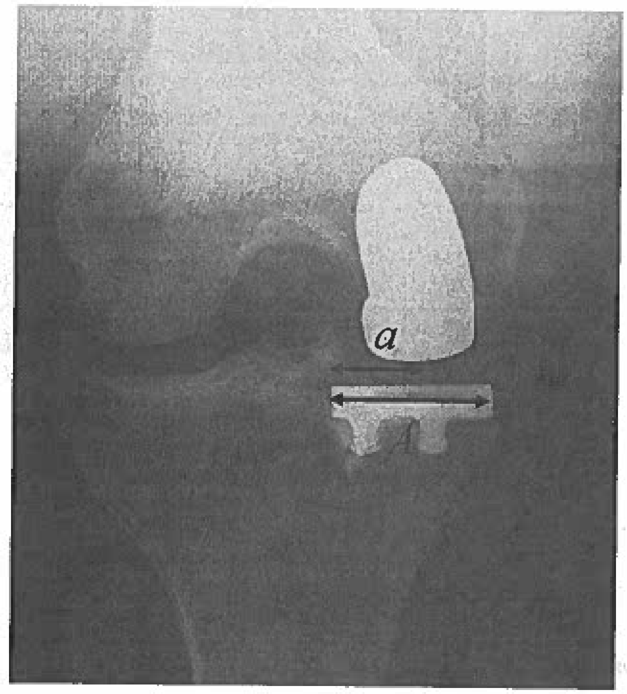

Fig. 1. Measurement of the mediolateral position of the femoral component relative to the tibial insert was assessed as *a/A* ratio using the stress epicondylar view.

Postoperative Assessment of the FCP Relative to the Tibial Insert

Based on a previous report [18], we calculated the mediolateral (ML) position of the femoral component relative to the tibial insert as *a/A* ratio using the epicondylar view [19,20] at 2 weeks postoperatively, where *A* is the ML width of the tibial component and *a* is the distance from the lowest point of the femoral component to the lateral wall of the tibial component. Lower values of FCP relative to the tibial insert indicate a more lateral implantation of the femoral component relative to the tibial insert (Fig. 1). The cases were stratified into 3 groups according to the setting position of the femoral component: group M, medial (18 cases); group C, center (30 cases); and group L, lateral (18 cases). Cases in which the values were within the range from 0.4 to 0.6 were classified into group C. Cases in which the values were more than 0.6 were classified into group M. Cases in which the values were less than 0.4 were classified into group L. Mean values were 0.68 (range, 0.607-0.817) in group M, 0.51 (range, 0.402-0.596) in group C, and 0.36 (range, 0.275-0.397) in group L, respectively. Figure 2 shows the typical x-ray in each group.

All radiographs were taken by our institution's dedicated musculoskeletal radiology team that possesses more than 5 years of experience as instructed by the standardized protocol of our institution. For evaluation of radiographs at extension, the lower limb was slightly rotated internally so that the patient's patella was placed forward and ankle was in the neutral position to unify the rotation. Radiographs at flexion were assessed by the epicondylar view [19,20], which enabled us to visualize the posterior condylar axis and the tibia articular line. The x-ray beam was centered on the knee from a distance of 2 m and tilted around 10° to the head so that it was parallel to the joint surface and tibial component. If the beam was not parallel to the tibia component, radiologists adjusted

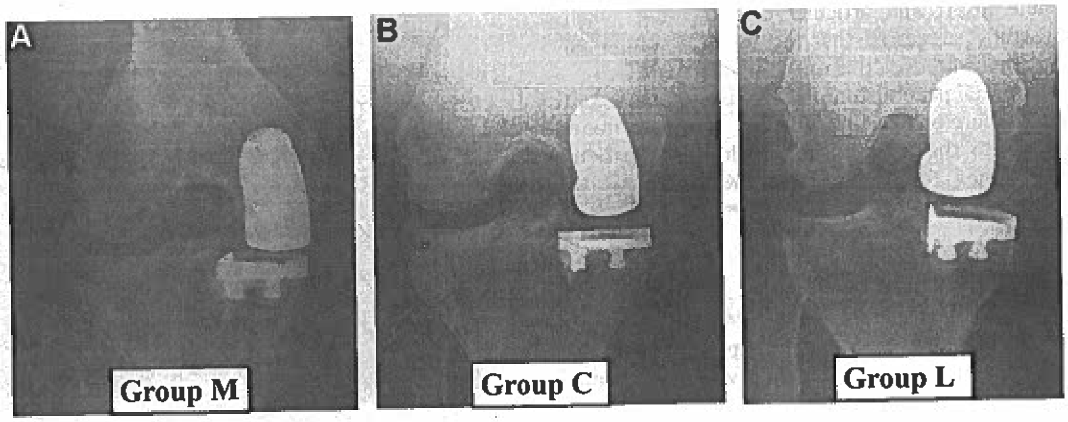

Fig. 2. Representative radiographs at flexion in groups M (A), C (B), and L (C).

it to be parallel and retook the image. Voltage and current were set at 200 mA and 85 kV, respectively.

Postoperative Assessment of the Anatomical Tibial Component Position

To assess the anatomical ML position of the tibial component relative to the proximal tibia (mediolateral tibial component position [ml-TCP]) in the coronal plane, AP radiographs at flexion were obtained at 2 weeks postoperatively. The ml-TCP was computed as b/B ratio, where b is the distance from the medial edge of the proximal tibia to the lateral wall of the tibial component and B is the total distance from the medial edge of the proximal tibia to the tibial axis, according to a previously reported method [21]. Smaller values indicate a more medial implantation of the tibial component (Fig. 3A).

The coronal and sagittal positions of the tibial component were also assessed on radiographs according to a previously published protocol [22]. The position of the tibial component relative to the tibial axis, the varus and/or valgus alignment, and posterior slope were evaluated. In these measurements, the values of the tibial component varus alignment and posterior slope were considered to be positive.

Postoperative Assessment of the Anatomical Femoral Component Position

In accordance with a previously reported method [21], the ML position of the femoral component relative to the distal femur (mediolateral femoral component position [ml-FCP]), which was assessed using radiographs at flexion obtained at 2 week postoperatively, was calculated as c/C ratio, where C is the distance from the center of the intercondylar notch to the line drawn from the medial femoral epicondyle perpendicularly to the transepicondylar axis and c is the distance from the center of the femoral component to the same line in the axial plane. Smaller values indicated a more medial implantation of the femoral component (Fig. 3B).

The varus and/or valgus alignment and degree of flexion and/or extension of the femoral component relative to the femoral axis were measured on radiographs taken at 2 weeks postoperatively. In these measurements, the values corresponding to varus alignment and flexion of the femoral component were considered to be positive.

Postoperative Posterior Condylar Offset Ratio

The lateral knee radiographs were used to calculate the posterior condylar offset ratio 2 weeks postoperatively using the previously described method [23].

Postoperative Overall Coronal Limb Alignment

The overall coronal plane limb alignment was assessed using one leg standing weight-bearing AP radiographs at 2 weeks postoperatively.

Assessment of Tibiofemoral Subluxation

Tibiofemoral subluxation (TFS) was measured preoperatively and at 2 weeks postoperatively, according to a previously developed method [24]. In brief, tibial mechanical axis was drawn, which was followed by drawing a line from the apex of the intercondylar notch and parallel to the tibial mechanical axis. The distance between the two parallel lines was measured as the TFS (Fig. 3C). Good reliability has been reported for such measurement, with high interobserver correlation coefficients [24].

Clinical Outcome

The maximum knee flexion angle was evaluated in 5° increments at hip flexion using a 2-arm goniometer preoperatively and at 2 years postoperatively by physiotherapists with more than 5 years of experience, where the femoral axis is the line connecting the greater trochanter and the femoral epicondyle in the tibial axis is the line connecting the femoral head and lateral malleolus. In addition, we used the 2011 Knee Society Score (KSS), which was developed as a patient-derived outcome measure to better characterize satisfaction, expectations, and physical activities after TKA [25]. We evaluated 2 patient-reported subscales of the 2011 KSS preoperatively and at 2 years postoperatively: symptom and patient satisfaction. The measurements were conducted by the same clinician. We also evaluated the improvement in the 2011 KSS and maximum knee flexion angle at 2 years after the operation.

Assessment of Osteoarthritis Severity in the Lateral Tibiofemoral and PF Compartments

Osteoarthritis severity in the lateral tibiofemoral and PF compartments was graded in a blinded fashion using AP and skyline

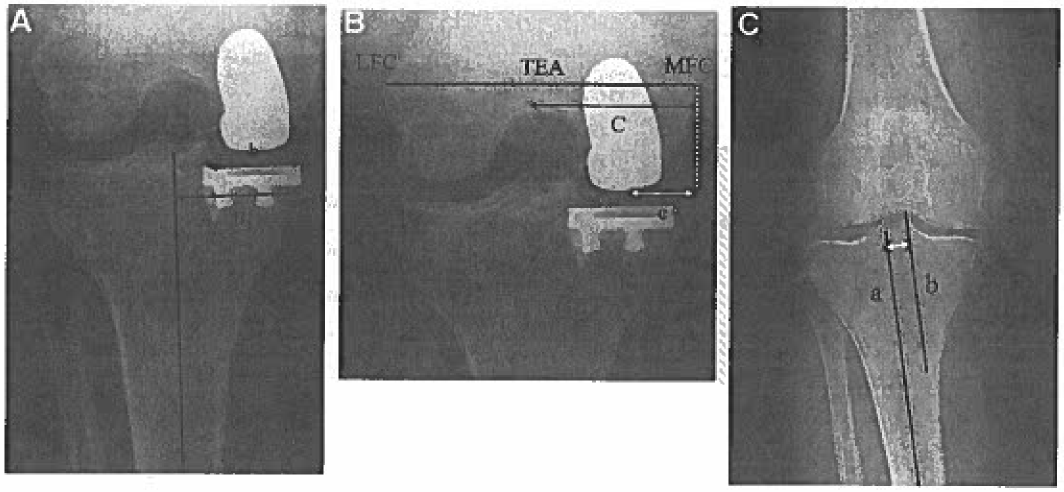

Fig. 3. (A) Measurement of the tibial component position relative to the proximal tibia (mediolateral tibial component position [ml-TCP]) on the anteroposterior radiograph at 2 weeks postoperatively. (B) Measurement of the femoral component position relative to the distal femur (mediolateral femoral component position [ml-FCP]) on the stress epicondylar view at 2 weeks postoperatively. (C) Measurement of the tibiofemoral subluxation. The tibial mechanical axis is first drawn (a), and a line parallel to the tibial mechanical axis is drawn from the apex of the intercondylar notch (b). Tibiofemoral subluxation is the distance between the two parallel lines. LFC, lateral femoral epicondyle; MFC, medial femoral epicondyle; TEA, transepicondylar axis.

radiographs obtained 2 years postoperatively based on established grading systems described by Kellgren [12].

Implant Size In Terms of the Tibial and Femoral Components

The implant size was also recorded in each patient, and the percentage of each selected implant size was compared among the 3 groups.

Statistical Analysis

To evaluate the intraobserver and interobserver reproducibility of the radiographical measurements, all measurements were performed twice by the same surgeon (T.K.) at intervals of >2 weeks and once by another surgeon (K.T.). The intraclass correlation coefficients for the intraobserver reproducibility were 0.90, 0.84, 0.91, and 0.82 and the interclass correlation coefficients for the interobserver reproducibility were 0.89, 0.80, 0.87, and 0.89 for FCP relative to the tibial insert, ml-TCP, ml-FCP, and TFS, respectively. In addition, to validate the accuracy of the radiographical measurements of the FCP relative to the tibial insert, we performed the Spearman rank test to assess the correlation between the measurement values using computed tomography (CT) and AP radiographs taken in the supine position for 18 patients with postoperative CT data. With CT, FCP relative to the tibial insert was measured in the axial plane of the tibial insert level, by projecting onto the most distal point of the femoral component. The correlation between the measurement values using CT and those with the AP radiograph was 0.83.

All values are presented as mean ± standard deviation (SD). A dedicated statistical software package (StatView 5.0; Abacus Concepts Inc, Berkeley, CA) was used to analyze the collected data. We compared the preoperative patient characteristics, prothesis positional parameters, postoperative posterior condylar offset, coronal limb alignment, TFS, maximum knee flexion angle, and 2011 KSS (symptom and patient satisfaction) among the 3 groups using the analysis of variance. Furthermore, a single linear regression analysis was used to examine the correlations of the mediolateral positional parameters (ml-TCP and ml-FCP) and TFS, with FCP relative to the tibial insert. The distribution of the osteoarthritis Kellgren's grade in both the lateral tibiofemoral and PF compartments and the percentage of each selected implant size were compared among the 3 groups using the Fisher exact test. *P* values <.05 were considered to be statistically significant.

Post-hoc power analysis was performed using G*Power 3 [26]. For a sample size of 66 in 3 groups (18 versus 30 versus 18) and a type I error (α) of 0.05 (one-way analysis of variance), the study is expected to provide a power (1-β) of 0.90 and 0.96 for detecting calculated effect sizes by means and SDs with respect to the end point of "symptom" and "patient satisfaction" scores of the 2011

Table 1
Preoperative Demographic Data.

Characteristic	Group M	Group C	Group L	*P* Value
Number of cases	18	30	18	
Sex, male/female	2/16	5/25	3/15	NS
Diagnosis, OA/ON	13/5	22/8	12/6	NS
Age (y)	71.1 (62-88)	73.4 (55-88)	72.0 (57-84)	NS
Body mass index (kg/m^2)	23.5 (17.6-29.8)	24.8 (19.2-31.5)	24.9 ± 3.2 (18.5-30.7)	NS
Coronal alignment in varus (°)	7.2 (−2.5-15.5)	7.0 (−1.0-16.5)	6.7 (−0.5-14.0)	NS
Maximum knee flexion (°)	122.9 (95-140)	121.8 (90-145)	122.6 (100-150)	NS

Group M, patients whose femoral component position relative to the tibial insert was more than 0.6; group C, cases in which the values were within the range from 0.4 to 0.6; group L, cases in which the values at both flexion and extension or either were less than 0.4.
NS, not significant; OA, osteoarthritis; ON, osteonecrosis.

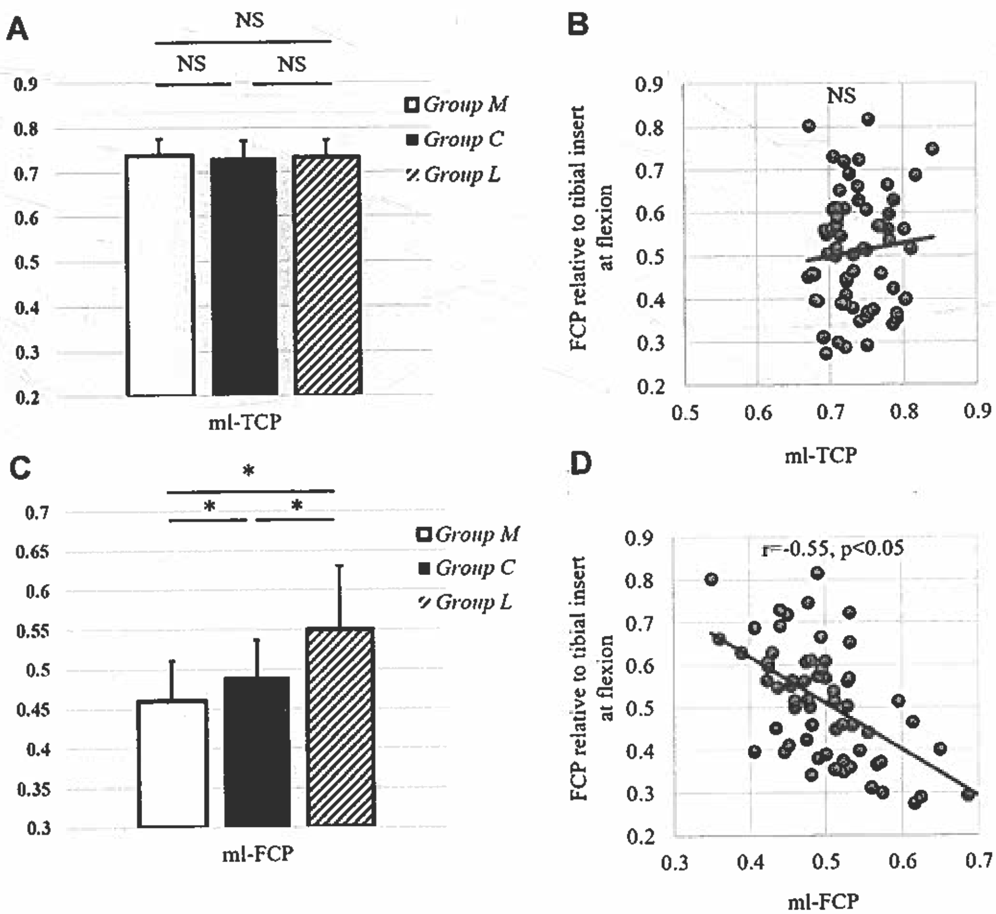

Fig. 4. Mediolateral positional parameters (ml-FCP and ml-TCP). (A) Comparison of tibial component position relative to the proximal tibia among the 3 groups. (B) Correlation between femoral component position (FCP) relative to the tibial insert and tibial component position relative to the proximal tibia (ml-TCP). (C) Comparison of femoral component position relative to the distal femur (ml-FCP) among the 3 groups. (D) Correlation between FCP relative to the tibial insert and femoral component position relative to the distal femur (ml-CP). NS, not significant.

KSS at 2 years after the operation, respectively. For a total sample size of 66 and type I error (α) of 0.05 (linear regression), the study is expected to provide a power (1-β) of 0.81 and 0.97 for detecting an effect size q (H1) of 0.3 and 0.4, respectively.

Results

Comparison of Preoperative Patient Characteristics Among the 3 Groups

The clinical data of the patients in the 3 groups are shown in Table 1. No statistically significant differences in age, sex, BMI, diagnosis, and preoperative coronal alignment and maximum flexion angle among the 3 groups were found.

Thickness of the Tibial Bone Cut

The mean actual thickness of the proximal tibial osteotomy was 4.10 ± 1.1 mm. There were no significant differences in the values among the 3 groups (4.12 ± 1.0 mm in group M, 4.11 ± 1.2 mm in group C, and 4.05 ± 1.2 mm in group L).

Assessment of Mediolateral Positional Parameters (ml-TCP and ml-FCP)

Mean ml-TCP and ml-FCP were 0.74 (range, 0.67-0.84) and 0.50 (range, 0.35-0.74), respectively.

The ml-TCP showed no significant differences among the 3 groups, and no significant correlation with FCP relative to the tibial insert was found (Fig. 4A and B). By contrast, the mean ml-FCP was lower in group M (0.46 mm [range, 0.35-0.53 mm]) than in group C (0.50 mm [range, 0.42-0.65 mm]) ($P < .01$), and group C (0.50 mm [range, 0.42-0.65 mm]) had a lower ml-FCP than group L (0.55 mm [0.41-0.74 mm]) ($P < .01$) (Fig. 4C). In addition, a significant negative correlation with FCP relative to the tibial insert ($r = -0.55$, $P < .05$; Fig. 4D) was observed.

Comparison of Positional Parameters Among the 3 Groups

There were no significant differences among the 3 groups regarding other positional parameters including tibial component

Table 2
Comparison of Prosthesis Component Positional Parameters According to the Femoral Component Position Relative to the Tibial Insert.

Parameter	Group M	Group C	Group L	*P* Value
Tibial component varus/valgus (°)	2.3 ± 2.6	2.3 ± 3.4	2.0 ± 3.5	NS
Tibial component posterior slope (°)	7.0 ± 2.6	6.7 ± 2.2	7.4 ± 2.8	NS
Femoral component varus/valgus (°)	3.6 ± 2.8	3.2 ± 2.0	3.1 ± 2.4	NS
Femoral component flexion/extension (°)	7.7 ± 4.4	6.8 ± 3.8	7.4 ± 3.7	NS

Group M, patients whose femoral component position relative to the tibial insert was more than 0.6; group C, cases in which the values were within the range from 0.4 to 0.6; group L, cases in which the values at both flexion and extension or either were less than 0.4.
NS, not significant.

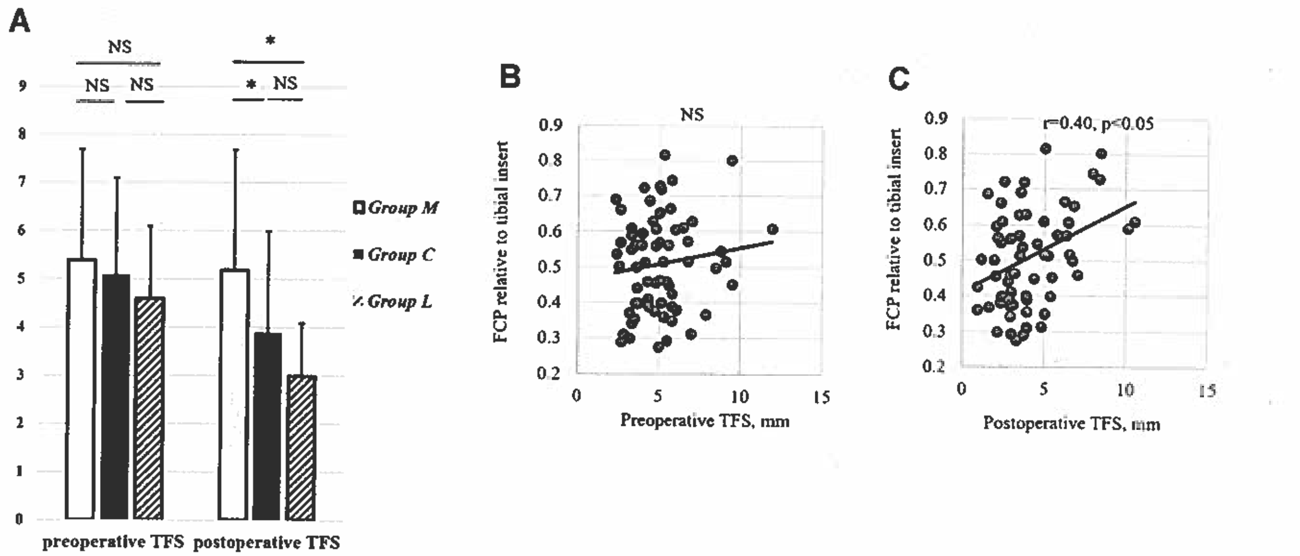

Fig. 5. Results of TFS. (A) Comparison of preoperative and postoperative TFS among the 3 groups. (B) Correlation of preoperative TFS with femoral component positions relative to the tibial insert. (C) Correlation of postoperative TFS with femoral component positions relative to the tibial insert. TFS, tibiofemoral subluxation.

varus/valgus alignment and posterior slope and femoral component varus/valgus alignment and flexion/extension (Table 2).

Postoperative Posterior Condylar Offset Ratio

No significant differences in the postoperative posterior condylar offset ratio among the 3 groups were noted (0.46 ± 0.04 in group M, 0.47 ± 0.03 in group C, and 0.47 ± 0.03 in group L).

Postoperative Coronal Limb Alignment

No significant difference in the postoperative coronal limb alignment among the 3 groups was noted (3.3° ± 2.7° in group M, 2.8° ± 2.0° in group C, and 3.0° ± 2.4° in group L).

TFS

TFS was corrected significantly from 5.1 mm (range, 2.3-12.0 mm) preoperatively to 4.0 mm (range, 0.9-10.5 mm) postoperatively (paired t test, $P < .05$). Preoperative TFS did not significantly differ among the 3 groups, and no significant correlation between preoperative TFS and FCP relative to the tibial insert was noted (Fig. 5A and B). However, the postoperative values were higher in group M (5.2 mm [range, 2.0-10.5 mm]) than in groups C (3.8 mm [range, 1.1-6.7 mm]) and L (3.0 mm [range, 0.9-4.9 mm]) ($P < .01$) (Fig. 5A), showing significant positive correlation with FCP relative to the tibial insert ($r = 0.40$, $P < .05$; Fig. 5C).

Clinical Outcomes

Preoperative maximum knee flexion angles did not significantly differ among the 3 groups (Fig. 6A). However, the maximum knee

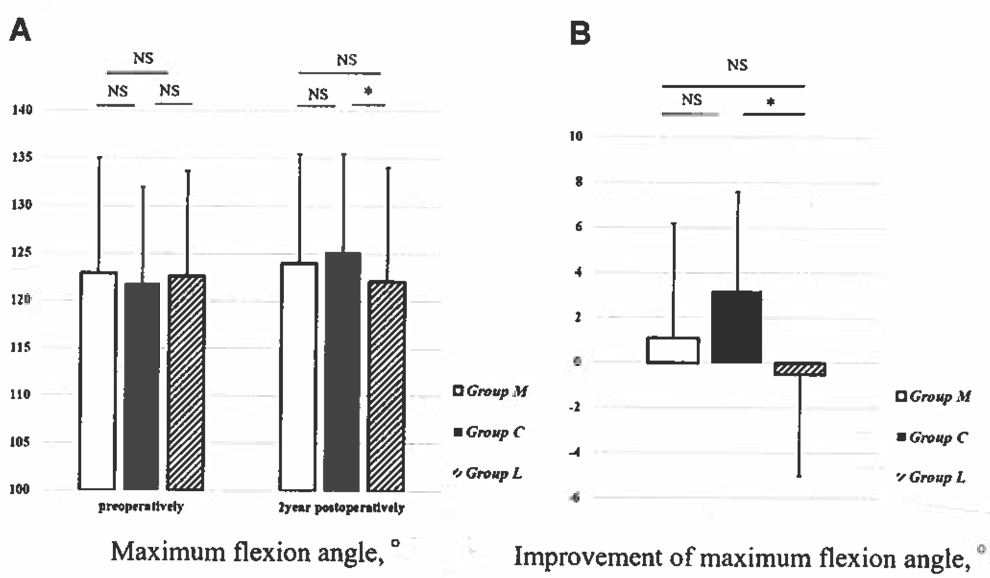

Fig. 6. Results of maximum knee flexion angle. (A) Comparison of preoperative and postoperative (2 years) maximum knee flexion angle among the 3 groups. (B) Comparison of the improvement in maximum knee flexion angle within 2 years among the 3 groups.

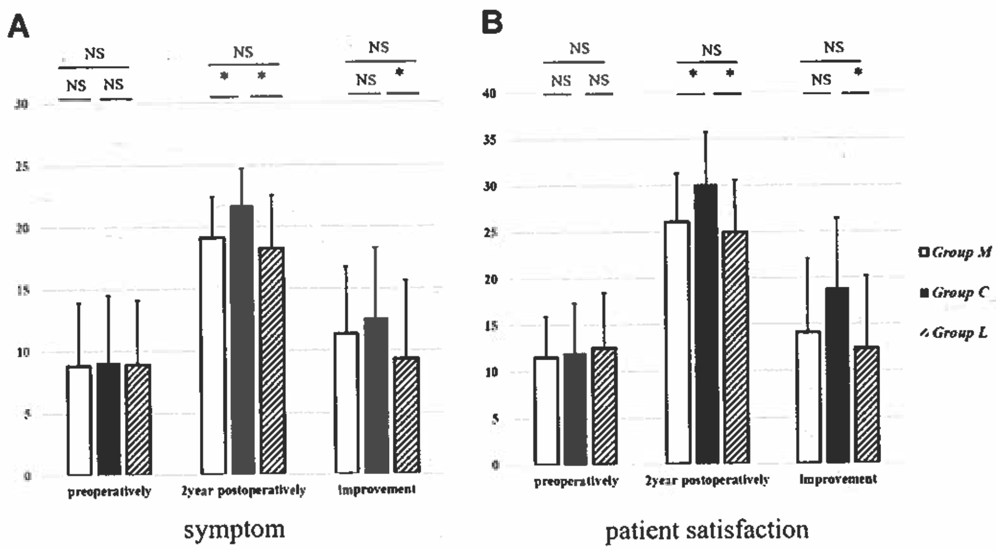

Fig. 7. Comparison of the "symptom" (A) and "patient satisfaction" (B) scores of the 2011 Knee Society Score (preoperatively and at 2 years postoperatively) and the score improvement within 2 years.

flexion angle and its improvement at 2 years postoperatively were significantly lower in group L than in groups M and C (Fig. 6A and B). Moreover, the average preoperative "symptom" and "patient satisfaction" scores of the 2011 KSS showed no significant differences among the 3 groups. However, both scores and their improvement were significantly better in group C than in groups M and L at 2 years after the operation (Fig. 7A and B). Scatter plots show the association of FCPs relative to the tibial insert with the "symptom" and "patient satisfaction" scores (Fig. 8A and B).

No patients experienced any failures and revision in the postoperative courses.

Comparison of Osteoarthritis Severity in the Lateral Tibiofemoral and PF Compartments

Radiographic grade of osteoarthritis in both lateral tibiofemoral and PF compartments showed no significant differences in distribution among the 3 groups (Table 3).

Comparison of Implant Size Among the 3 Groups

There were no significant differences among the 3 groups regarding the implant size in both the tibial and femoral components (Table 4).

Discussion

The main finding of this study was that central implantation of the femoral component relative to the tibial insert plays a significant role in decreasing pain and could result in a deeper flexion angle and better patient satisfaction at 2 years after fixed-bearing UKA. Furthermore, the FCP relative to the tibial insert is closely correlated with the FCP relative to the distal femur. To the best of our knowledge, this is the first study to report the role of FCP of clinical results, with quantitative evaluation in fixed-bearing UKA.

Our results showed that patients whose femoral component is set at the center relative to the tibial insert (group C) tend to have less postoperative pain, better patient satisfaction, and higher active knee flexion angle at 2 years after fixed-bearing UKA than those whose femoral component is set at the medial or lateral positions. This supports the hypothesis that the positive biomechanical effect of the central implantation of the femoral component could improve clinical outcomes [11]. In addition, our study examined anatomical mediolateral component positions (ml-TCP and ml-FCP) as factors that could affect the FCP relative to the tibial insert. We found that, by contrast to ml-FCP, ml-TCP showed no significant correlation with FCP relative to the tibial insert, which could be attributed to the smaller variance in ml-TCP (SD of 0.037) than in ml-FCP (SD of 0.072). This suggests that FCP relative to the

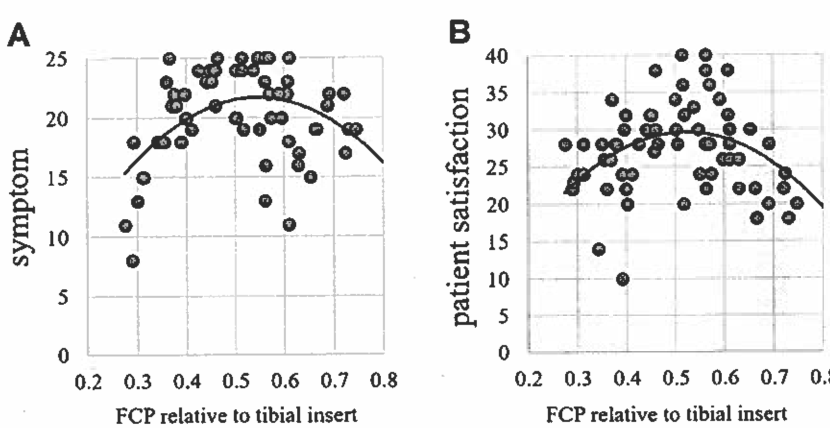

Fig. 8. Plot representing the association of femoral component position relative to tibial insert to the "symptom" (A) and "patient satisfaction" (B) scores with trend lines.

Table 3
Comparison of Postoperative Osteoarthritis Severity.

Criteria	Lateral Tibiofemoral Compartment				Patellofemoral Compartment			
	Group M	Group C	Group L	*P* Value	Group M	Group C	Group L	*P* Value
Kellgren								
None	7/18 (39%)	14/30 (47%)	8/18 (44%)	NS	7/18 (39%)	10/30 (33%)	6/18 (33%)	NS
Doubtful	9/18 (50%)	11/30 (37%)	8/18 (44%)	NS	9/18 (50%)	13/30 (47%)	8/18 (44%)	NS
Minimal	2/18 (11%)	3/30 (10%)	2/18 (11%)	NS	2/18 (11%)	7/30 (23%)	3/18 (17%)	NS
Moderate	-	2/30 (7%)	-	NS	-	-	1/18 (6%)	NS
Severe	-	-	-	-	-	-	-	-

Group M, patients whose femoral component position relative to the tibial insert was more than 0.6; group C, cases in which the values were within the range from 0.4 to 0.6; group L, cases in which the values at both flexion and extension or either were less than 0.4.
NS, not significant.

tibial insert is most affected by FCP relative to the distal femur (ml-FCP). Moreover, our results indicated that the femoral component in group C was placed centrally relative to the distal femur (mean value of ml-FCP; 0.50). This finding suggests that surgeons should aim to achieve anatomically adequate implantation of the femoral component with smaller variance for a better clinical outcome after fixed-bearing UKA.

In this study, TFS was corrected significantly from 5.1 ± 2.0 mm preoperatively to 4.0 ± 2.2 mm postoperatively, which was nearly consistent with the findings of a previous study [24]. This study showed that group M had significantly larger postoperative TFS than did group C with significantly higher postoperative pain and lower patient satisfaction at 2 years after fixed-bearing UKA. Postoperative TFS has been hypothesized to increase the incidences of intercondylar notch impingement and component edge loading and hasten polyethylene wear [2,27]. This may in turn worsen the postoperative clinical outcome. However, the direct relationship between TFS and clinical outcome was not proven in our study. Hence, future studies should investigate the effect of TFS on clinical outcomes and explore the development of surgical techniques that could improve TFS in UKA.

Furthermore, our results showed that patients with lateral installation of the femoral component relative to the tibial insert (group L) had significantly lower postoperative knee flexion angle as well as lower knee flexion angle improvement than did patients in the other groups (ie, groups M and C). Recent studies [21,28] using mobile-bearing prosthesis found that the relative lateral positioning of the femoral component could lead to abnormal bearing movement and bearing impingement with the tibial component. These findings suggest that, in fixed-bearing UKA, we can easily imagine that too-lateral implantation of the femoral component relative to the tibial insert may result in impingement with the intercondylar notch, as seen in Figure 2C. Based on our results, such impingement may cause discomfort and/or pain, preventing the knee from achieving deep flexion, and resulting in poor patient satisfaction.

Table 4
Comparison of Implant Size Selection.

Size	Group M	Group C	Group L	*P* Value
Femur				
A	-	-	-	-
B	5/18 (27%)	10/30 (33%)	6/18 (29%)	NS
C	6/18 (33%)	10/30 (33%)	5/18 (38%)	NS
D	7/18 (36%)	10/30 (33%)	7/18 (33%)	NS
E	-	-	-	-
Tibia				
1	1/18 (6%)	2/30 (7%)	1/18 (6%)	NS
2	9/18 (50%)	15/30 (50%)	8/18 (44%)	NS
3	6/18 (33%)	10/30 (33%)	8/18 (44%)	NS
4	2/18 (11%)	3/30 (10%)	1/18 (6%)	NS
5	-	-	-	-

Group M, patients whose femoral component position relative to the tibial insert was more than 0.6; group C, cases in which the values were within the range from 0.4 to 0.6; group L, cases in which the values at both flexion and extension or either were less than 0.4.
NS, not significant.

This study has several limitations. First, this was a retrospective analysis involving only one type of prosthesis. Additional prospective comparative studies of matched-paired groups using multiple implant designs are necessary to further examine FCP influence. Second, this study mainly focused on the ML position of the components and its relationship with the clinical outcome; a comprehensive large-scale study including the evaluation of other positional parameters, such as varus/valgus alignment and flexion/extension, should be considered in the future. However, our study revealed no significant differences in other prosthesis positional parameters (varus/valgus and sagittal alignment), postoperative posterior condylar offset, coronal limb alignment, osteoarthritis grade of lateral tibiofemoral and PF compartments, or implant size selection, which could affect clinical outcomes. This suggests that FCP relative to the tibial insert may be an independently related factor that significantly affects patient-reported scores and knee flexion angle, even when other confounding factors are considered. Third, there were very few obese patients with an above 30 BMI in our country unlike North America thus constituting a low proportion of obese patients and a low average of BMI compared to another knee arthroplasty cohort in another country. Therefore, further studies on different populations with a wide BMI range are necessary. Fourth, although the radiographic technique was standardized and all radiographs were taken in the same manner in this study, the relative orientation of the tibial implant in space (slope, varus/valgus, and rotation) could affect radiographic outcomes. Three-dimensional evaluations under weight-bearing and knee flexion are ideal and should be considered in the future. Despite the above limitations, this study is the first to discuss the effect of positional relationships of the femoral and tibial components on clinical outcome, thereby providing new insights into the importance of adequate positioning of the femoral component.

In conclusion, central implantation of femoral components relative to the tibial insert plays a significant role in decreasing pain potentially resulting in improved patient satisfaction and higher active knee flexion at 2 years after fixed-bearing UKA.

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