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Comparison of Patellofemoral-Specific Clinical and Radiographic Results after Total Knee Arthroplasty Using a Patellofemoral Design-Modified Prosthesis and Its Predecessor

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Background: One recently developed total knee arthroplasty (TKA) prosthesis was designed to alter the patellofemoral geometry and optimize patellar tracking compared to its predecessor. Despite an expectation that the improved design would contribute to optimal patellofemoral compatibility, its effect has not been confirmed with patellofemoral-specific clinical scoring systems and radiographic parameters. Our purpose was to compare patellofemoral-specific clinical and radiographic results after TKA using a patellofemoral design-modified prosthesis and its predecessor.

Methods: The results of 200 TKAs with Attune (group A) were compared to those of 200 TKAs with PFC Sigma (group B). Clinically, the presence of anterior knee pain (AKP), patellar crepitation, and Kujala score were checked. Radiographically, anterior femoral offset (AFO), posterior femoral offset (PFO), position of patellar ridge, and patellar tilt and translation were compared.

Results: In group A, AKP and patellar crepitation occurred less frequently (AKP: 3% vs. 8%, $p = 0.028$; patellar crepitation: 2.5% vs. 9%, $p = 0.005$) and Kujala score was higher (81.8 vs. 77.9, $p < 0.001$), when compared to group B. The AFO decreased in group A postoperatively but increased in group B (–1.2 vs. 1.1 mm, $p < 0.001$). The change in PFO was smaller in group A than group B (–1.2 vs. –3.6 mm, $p < 0.001$). The change in patellar ridge after TKA was smaller in group A than group B (1.4% vs. 8.3%, $p < 0.001$). The postoperative patella of group A was more laterally tilted (5.9° vs. 2.2°, $p < 0.001$) and less laterally translated (0.9 vs. 2.6 mm, $p < 0.001$). The proportion of incompatible patella tilt angle (≥ ± 10°) was greater in group A than group B (21.7% vs. 4.5%, $p < 0.001$).

Conclusions: TKA using Attune provided better patellofemoral-specific clinical results and favorable radiographic parameters related with patellar ridge, AFO, and PFO than TKA using PFC Sigma did. However, the current prosthesis did not provide better radiographic patellar tracking, which might be due to the medial location of the patellar ridge.

Keywords: *Knee, Arthroplasty, Patellofemoral, Compatibility*

Although total knee arthroplasty (TKA) is the effective surgical option for end-stage osteoarthritis, residual pain after TKA, especially anterior knee pain (AKP), is still a matter of concern.[1] Abnormal patellofemoral joint loads and kinematics caused by patellar malalignment and overstuffing appear to play important roles in AKP after TKA.[2,3] Incompatibility between the femoral and patellar components may also cause various patellofemoral complications, including patellar crepitation and instability, and such complications can be affected by the design of each prosthesis.[4]

One recently developed TKA prosthesis (Attune; DePuy Synthes, Warsaw, IN, USA) was designed to alter the patellofemoral geometry and optimize patellar track-

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ing compared to its predecessor (Press Fit Condylar [PFC] Sigma, DePuy Synthes). The improved design features include a natural and proportional trochlear groove of the femoral component, a reduced femoral component profile, an extensive range of component size options, and a medialized ridge of the patellar component.[1,3,5] These features could contribute to optimal patellofemoral compatibility.[6] However, it has not been confirmed which radiographic parameters can be improved.

It is difficult to compare the outcomes related to patellofemoral compatibility according to prosthesis design factors because the patellofemoral behavior of a specific component directly depends on a number of variables. That is, the compatibility of the patellofemoral joint is influenced not only by the prosthesis but also by factors related to patient demographics and surgical techniques, such as the position and alignment of the components.[2,3,7,8] Furthermore, patellofemoral complications, such as AKP and crepitation, are poorly defined disease entities without precise diagnostic criteria.[9] Accordingly, it is necessary to use a patellofemoral-specific clinical scoring system for reasonable evaluation regarding patellofemoral outcomes.[10,11] Radiographically, the parameters influencing patellofemoral tracking, including joint line height, patellar thickness, patellofemoral joint offset, location of patellar ridge, patellar tilt, and patellar translation, require evaluation.[12,13]

To our knowledge, few previous studies have compared the outcomes related to patellofemoral compatibility after TKA using a patellofemoral design-modified prosthesis and its predecessor, taking the above confounding variables into consideration.[14,15] The present study was performed to compare the patellofemoral-specific clinical and radiographic results for a minimum 2-year follow-up after TKA using Attune and PFC Sigma prostheses with different patellofemoral design features. We tried to find out which patellofemoral specific parameters would be different between the two groups. It was hypothesized that the results of the current prosthesis would be better than those of its predecessor.

METHODS

This study was approved by Kyung Hee University Hospital Institutional Review Board (IRB No. KHUH 2017-05-062). Informed consent was obtained from all patients at an outpatient visit before analysis.

The present study was conducted with a retrospective, matched case-control design. All consecutive patients undergoing primary TKA using the current prosthesis (Attune) performed by a senior surgeon (SJS) between January and December 2015 were reviewed (group A). During this period, 200 arthroplasties using this prosthesis were performed in 182 patients. No patients were lost to follow-up before 2 years and all patients agreed to participate in the study. Then, we matched control patients from our patient database, who had undergone primary TKA with the predecessor prosthesis (PFC Sigma) between December 2013 and December 2014 (group B). Matching was performed according to age, sex, body mass index (BMI), diagnosis, preoperative range of motion (ROM), and severity of preoperative deformity. We excluded patients with (1) TKAs using other prostheses and TKAs with patellar non-resurfacing, (2) patellofemoral instability or history of patellofemoral ligament injury or reconstructive surgery for the stable patellofemoral joint, (3) a history of infection, fracture, and dislocation, or previous high tibial osteotomy, and (4) extra-articular deformity.

With the exception of the follow-up period, the demographics were not different significantly (Table 1). The follow-up period was inevitably longer in group B because we mainly used the Attune prosthesis instead of the PFC sigma prosthesis after the introduction of the recent prosthesis.

Surgical Technique and Rehabilitation

All TKAs were performed with a general principle of using all-cemented and posterior-stabilized prostheses with patellar resurfacing. The medial parapatellar approach was used with a midline skin incision. Bone resection was performed with a measured resection technique. The transepicondylar axis was used for femoral component rotation. The size of the femoral component was selected considering the anteroposterior (AP) length of the lateral femoral condyle and the mediolateral length of the original distal femur. Tibial resection was set to a posterior slope of 3° in the sagittal plane. Any contracted medial or lateral soft tissue was evaluated carefully and released selectively where required.

All patellae were resurfaced to a thickness equal to or slightly thinner (0.5 mm) than the thickness of the original patella. The uncovered lateral cut surface was beveled using an electric saw and rasp. A patellar component with medialized dome was used for group A and a patellar component with oval dome was used for group B. The patellar component was placed as medial as possible on the resected bone surface without overhang after removal of osteophytes. The patellofemoral articulation was carefully evaluated with the no thumb technique. Lateral retinacular release was performed when patellar tracking was not

Table 1. Comparison of Patient Demographics between the Groups Using a Modified Prosthesis and Its Predecessor

Variable	Group A	Group B	*p*-value
Knee (patient)	200 (178)	200 (182)	-
Age (yr)	68.8 ± 7.4	67.9 ± 6.7	0.233
Female : male	194 : 6	195 : 5	1.000
Right : left	99 : 101	102 : 98	0.842
Body mass index (kg/m^2)	26.1 ± 3.5	26.2 ± 3.4	0.721
OA : RA : other*	193 : 5 : 2	198 : 1 : 1	0.262
Range of motion (°)	119.1 ± 22.2	120.2 ± 20.6	0.625
Preoperative mechanical axis (°)	11.7 ± 6.9 Varus	12.0 ± 7.2 Varus	0.656
Follow-up period (yr)	2.8 ± 0.5	3.1 ± 0.8	< 0.001

Values are presented as mean ± standard deviation.
Group A: patients who received the Attune prosthesis, Group B: patients who received the PFC Sigma prosthesis, OA: osteoarthritis, RA: rheumatoid arthritis.
*Preoperative diagnosis included degenerative OA, RA, and other (posttraumatic arthritis or infection sequelae).

appropriate; in 2 knees in each group.

The postoperative rehabilitation protocol was similar between the groups.[12] There were no knees in which manipulation was required under anesthesia postoperatively.

Clinical Evaluation

For clinical evaluation, the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) was used to evaluate pain and function preoperatively and at the latest follow-up. The ROM was assessed preoperatively and at the last follow-up using a long-armed goniometer.

The patients were carefully evaluated for signs of patellofemoral complications at each follow-up visit. The presence of AKP, patellar crepitation, patellar instability, and patellar clunk syndrome were checked. Due to the absence of precise diagnostic criteria,[9] it was determined that AKP and crepitation were present when they were found simultaneously by two independent investigators (DUS and CHP). Feller[10] and Kujala[11] scores were used to assess the patellofemoral-specific clinical outcomes objectively.

Radiographic Evaluation

Pre- and postoperative AP, lateral, and axial radiographs, and orthoroentgenograms (full-length standing AP radiographs) were obtained to assess limb alignment and component position. Measurements were made on these images using a picture archiving and communication system (PACS; Infinitt Healthcare, Seoul, Korea). The quality of radiographic evaluation could be improved by standardization of the position of the knee and use of an identical distance between the X-ray beam and cassette. The images were transferred digitally to the PACS and were then manipulated. Assessment was performed on a 61-cm (24-inch) monitor (SyncMaster 2494HMN; Samsung, Seoul, Korea) in portrait mode using the PACS software (Infinitt Healthcare). The software was capable of detecting minimum differences of 0.1° in angle and 0.1 mm in length.

Pre- and postoperative mechanical axes were defined as the angle between femoral and tibial mechanical axes on orthoroentgenograms. Detailed analyses of the positions of femoral and tibial components were conducted to determine α, β, γ, and δ angles, using the Knee Society radiographic evaluation method.[16] The joint line height was defined as the shortest distance between the fibular head and lateral femoral condyle on AP radiographs.[17]

The patellofemoral joint offset, including anterior femoral offset (AFO; defined as the distance between the anterior femoral cortical margin and the anterior margin of the femoral condyle) and posterior femoral offset (PFO; defined as the distance between the posterior femoral cortical margin and the posterior margin of the femoral condyle), was measured on true lateral radiographs of the knee (Fig. 1).[13] Given that cartilage thickness could not be determined from the radiographs,[18] 2 mm for cartilage thickness was added to radiographic measurements of the AFO and PFO as this value corresponds to the approximate average cartilage thickness of the distal femur.[18] AFO and PFO ratios were also measured for more precise

evaluation with consideration of radiographic magnification.[19] The AFO ratio was defined as the value of the AFO divided by the distance from the tangent of the posterior femoral cortex to the anterior margin of the femoral condyle (Fig. 1). Similarly, the PFO ratio was calculated by dividing the PFO by the distance from the tangent of the anterior femoral cortex to the posterior margin of the femoral condyle (Fig. 1).

The radiographic parameters associated with patellofemoral compatibility were measured in Merchant view of the knee joint. The pre- and postoperative patellar thicknesses, defined as the thickness of the preoperative patella and that of the postoperative prosthesis-patellar component, respectively, were measured.[20] The location of the patellar component ridge was evaluated.[20] We measured the mediolateral length of the patella (L1) and the distance from the medial border of the patella to the point of the original patella ridge or the component ridge (L2) (Fig. 2). The location of the patellar component ridge was defined as the ratio between these two values: L2 / L1 × 100. Pre- and postoperative patellar tilt angles were measured; a positive value indicated opening toward the medial side of the patella.[12] Pre- and postoperative patellar translation was defined as translation of the ridge of the patella or patellar component compared to the trochlear sulcus of the femur or femoral component[12]; a positive value indicated lateral translation of the patella. The postoperative incompatible patellar position was defined as the patellar tilt of ≥ ± 10° and translation of ≥ ± 4 mm.[21]

To minimize any observation bias, two independent investigators (DUS and CHP) repeated all radiographic measurements with an interval of 2 weeks, and average values were used for analysis. The intra- and interobserver reliabilities of all measurements were assessed using the intraclass correlation coefficient. In this study, intraclass correlation coefficient values of all measurements were > 0.8 for both intra- and interobserver reliability.

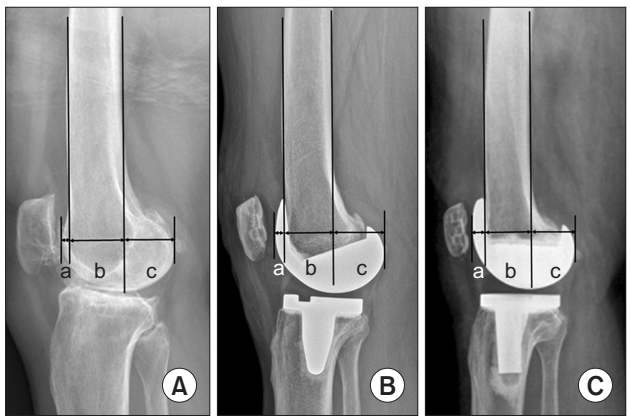

Fig. 1. Measurement of patellofemoral joint offset. a: distance between the anterior femoral cortical margin and the anterior margins of the femoral condyles, b: distance between the anterior and posterior femoral cortical margins, c: distance between the posterior femoral cortical margin and the posterior margin of the femoral condyle. (A) Preoperative lateral radiograph of the knee. A cartilage thickness of 2 mm was considered when evaluating the preoperative patellofemoral joint offset. Anterior femoral offset (AFO; mm) = a + 2. Posterior femoral offset (PFO; mm) = c + 2. AFO ratio (%) = [a + 2 / b + (a + 2)] × 100. PFO ratio (%) = [c + 2 / b + (c + 2)] × 100. (B) Lateral radiograph of Attune total knee arthroplasty (TKA). AFO (mm) = a. AFO ratio (%) = (a / a + b) × 100. PFO (mm) = c. PFO ratio (%) = (c / b + c) × 100. (C) Lateral radiograph of PFC Sigma TKA. AFO and PFO and their ratios were evaluated in the same manner as in Attune TKA.

Statistical Analysis

The pre- and postoperative clinical and radiographic results were compared between the groups (Student *t*-test). Preoperative clinical and radiographic results were compared to postoperative results (paired *t*-test). Differences in categorical variables, such as the rate of patellofemoral complications and proportion of incompatible patellar position, were compared by the chi-square test or Fisher's exact test. Relationships between two different variables, such as the location of the postoperative patellar component ridge and the postoperative patellar tilt angle, were

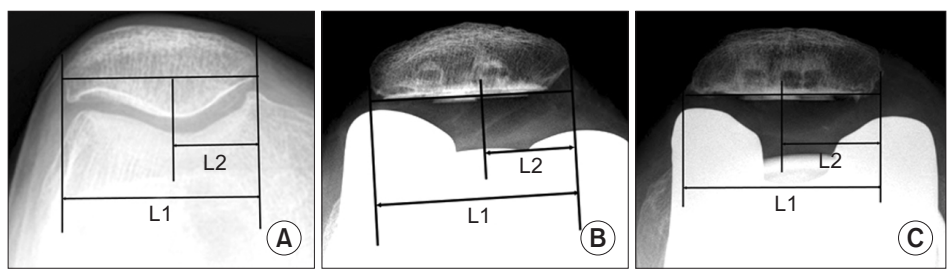

Fig. 2. Measurement of the locations of the original patellar ridge and patellar component ridge in the Merchant view. (A) Original patella. (B) Attune. (C) PFC Sigma. L1: mediolateral length of the patella, L2: distance from the medial border of the patella to the point of the original patellar ridge or the component ridge. The location of patellar component ridge was defined as the ratio between these two values (L2 / L1 × 100).

evaluated using Pearson's correlation analysis. Statistical analyses were performed using SPSS ver. 18.0 (SPSS Inc., Chicago, IL, USA), and a $p < 0.05$ was considered to indicate statistical significance.

To determine whether our sample had sufficient power to detect significant differences, we performed post hoc analyses of the *t*-tests and chi-square test using the significance levels set to an alpha of 0.05. A power > 80% was considered sufficient, and all of the variables, which were significantly different, met the criterion. Thus, we determined that our study was adequately powered.

RESULTS

The WOMAC and ROM improved significantly in both groups postoperatively ($p < 0.001$) (Table 2). The WOMAC at last follow-up was significantly better in group A than in group B (17.1 vs. 18.3, $p = 0.013$) (Table 2). The ROM at last follow-up was 131.5° in group A and 128.1° in group B ($p = 0.002$). AKP was observed in 6 knees (3%) in group A and in 16 knees (8%) in group B ($p = 0.028$). Patellar crepitation was observed in 5 knees (2.5%) in group A and in 18 knees (9%) in group B ($p = 0.005$). There was no patellar subluxation or patellar clunk in either group. The Feller and Kujala scores improved significantly in both groups ($p < 0.001$). The Feller score did not differ between the groups at last follow-up; however, the Kujala score at last follow up was 81.8 in group A and 77.9 in group B ($p < 0.001$).

Radiographically, the postoperative mechanical axis did not differ significantly between the groups (Table 3). The positions of components were appropriate in both groups. The joint line height and the patellar thickness were well preserved after TKA in both groups. The average AFO was decreased by 1.2 mm in group A, but increased by 1.1 mm in group B ($p < 0.001$) (Table 4). Similar to the change in AFO, the AFO ratio decreased in group A and increased in group B (−3.7% vs. 1.6%, $p < 0.001$). The PFO was decreased by 1.2 mm in group A and decreased by 3.6 mm in group B ($p < 0.001$). Similar to the change in PFO, the PFO ratio showed a smaller decrease in group A than in group B (−2.6% vs. −3.8%, $p < 0.033$).

The patellar component ridge was located at 43.2% in group A and at 49.4% in group B ($p < 0.001$), and it showed a closer match to the original patellar ridge in

Table 2. Comparison of Clinical Results between the Groups Using a Modified Prosthesis and Its Predecessor

Variable	Group A	Group B	*p*-value
WOMAC score			
Preoperative	71.4 ± 7.2	68.9 ± 6.2	< 0.001
Postoperative	17.1 ± 5.1	18.3 ± 4.6	0.013
Range of motion (°)			
Preoperative	119.2 ± 27.4	119.6 ± 19.8	0.850
Postoperative	131.5 ± 10.0	128.1 ± 12.1	0.002
Feller score			
Preoperative	14.7 ± 2.7	14.7 ± 2.8	0.959
Postoperative	25.1 ± 3.5	24.8 ± 3.3	0.400
Kujala score			
Preoperative	44.9 ± 4.1	44.8 ± 3.9	0.795
Postoperative	81.8 ± 5.7	77.9 ± 7.1	< 0.001

Values are presented as mean ± standard deviation.
Group A: patients who received the Attune prosthesis, Group B: patients who received the PFC Sigma prosthesis, WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index.

Table 3. Comparison of Radiographic Results between the Groups Using a Modified Prosthesis and Its Predecessor

Variable	Group A	Group B	*p*-value
Mechanical axis (°)			
Preoperative	11.7 ± 6.9 Varus	12.0 ± 7.2 Varus	0.656
Postoperative	0.4 ± 2.6 Varus	0.7 ± 2.8 Varus	0.337
Position of components (°)			
α angle	95.4 ± 1.6	95.1 ± 1.7	0.165
β angle	90.7 ± 2.0	90.5 ± 2.2	0.374
γ angle	1.5 ± 2.8	1.5 ± 2.3	0.873
δ angle	88.4 ± 2.3	88.8 ± 2.2	0.105
Joint line height (mm)			
Preoperative	15.4 ± 4.6	15.8 ± 5.1	0.378
Postoperative	15.2 ± 4.1	15.4 ± 3.6	0.156
Change*	–0.2 ± 3.9	–0.4 ± 3.8	0.148
Patellar thickness (mm)			
Preoperative	23.3 ± 3.3	23.8 ± 3.1	0.133
Postoperative	23.7 ± 2.2	24.0 ± 2.5	0.358
Change*	0.4 ± 3.2	0.2 ± 3.5	0.449

Values are presented as mean ± standard deviation.
Group A: patients who received the Attune prosthesis, Group B: patients who received the PFC Sigma prosthesis.
*Changes in radiographic results before and after surgery.

Table 4. Comparison of Radiographic Results Associated with Patellofemoral Joint Offset between the Groups Using a Modified Prosthesis and Its Predecessor

Variable	Group A	Group B	*p*-value
Anterior femoral offset (mm)			
Preoperative	7.7 ± 1.8	8.0 ± 1.8	0.040
Postoperative	6.5 ± 1.9	9.1 ± 2.0	< 0.001
Change*	–1.2 ± 2.1	1.1 ± 2.4	< 0.001
Anterior femoral offset ratio (%)			
Preoperative	21.3 ± 6.2	24.7 ± 6.1	< 0.001
Postoperative	17.6 ± 5.5	26.3 ± 5.7	< 0.001
Change*	–3.7 ± 6.3	1.6 ± 7.7	< 0.001
Posterior femoral offset (mm)			
Preoperative	33.3 ± 4.9	37.2 ± 4.3	< 0.001
Postoperative	32.1 ± 5.4	33.6 ± 3.5	0.002
Change*	–1.2 ± 3.9	–3.6 ± 4.6	< 0.001
Posterior femoral offset ratio (%)			
Preoperative	53.6 ± 7.5	59.9 ± 6.6	< 0.001
Postoperative	51.0 ± 8.5	56.0 ± 6.1	< 0.001
Change*	–2.6 ± 6.3	–3.8 ± 7.9	0.033

Values are presented as mean ± standard deviation.
Group A: patients who received the Attune prosthesis, Group B: patients who received the PFC Sigma prosthesis.
*Changes in radiographic results before and after surgery.

Table 5. Comparison of Patellar Tracking-Associated Radiographic Results between the Groups Using a Modified Prosthesis and Its Predecessor

Variable	Group A	Group B	*p*-value
Location of original patellar ridge (%)			
Preoperative	41.8 ± 3.5	41.1 ± 3.5	0.036
Location of patellar component ridge (%)			
Postoperative	43.2 ± 3.2	49.4 ± 2.9	< 0.001
Change*	1.4 ± 4.3	8.3 ± 4.6	< 0.001
Patella tilt angle (°)			
Preoperative	5.2 ± 3.9	5.5 ± 3.0	0.512
Postoperative	5.9 ± 5.6	2.2 ± 5.1	< 0.001
Change*	0.7 ± 2.6	–3.3 ± 5.6	< 0.001
Patellar translation (mm)			
Preoperative	0.1 ± 2.6	0.2 ± 2.1	0.732
Postoperative	0.9 ± 2.8	2.6 ± 1.9	< 0.001
Change*	0.8 ± 2.8	2.4 ± 2.9	< 0.001

Values are presented as mean ± standard deviation.
Group A: patients who received the Attune prosthesis, Group B: patients who received the PFC Sigma prosthesis.
*Changes in radiographic results before and after surgery.

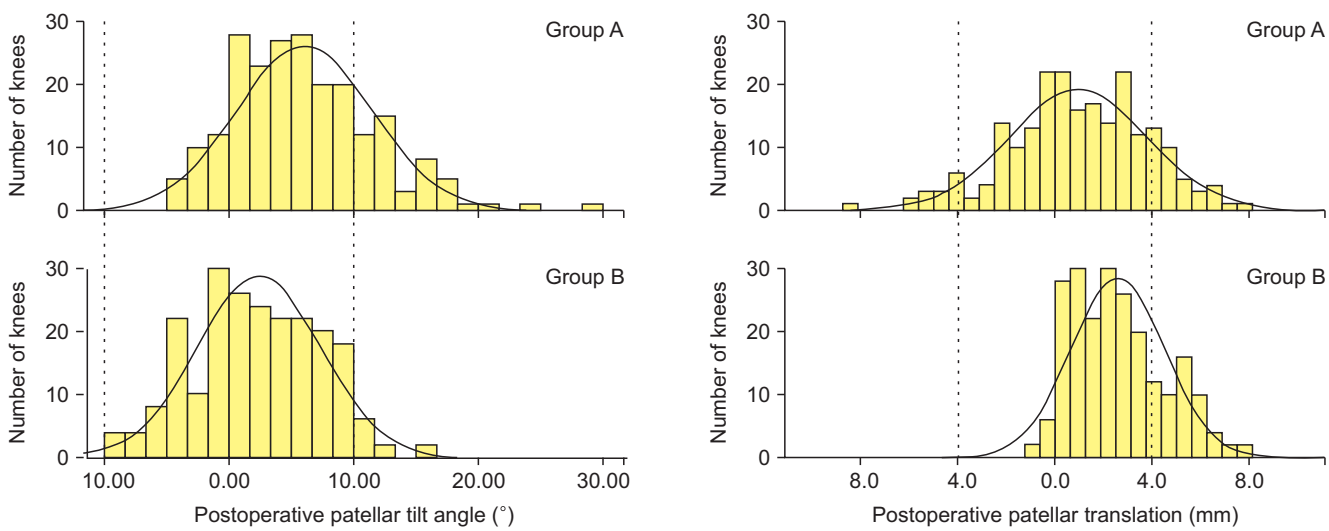

Fig. 3. The proportion of the incompatible patellar tilt and translation in group A using Attune and group B using PFC Sigma. The postoperative incompatible patellar position was defined as a patellar tilt of ≥ ± 10° and translation of ≥ ± 4 mm. The proportion of incompatible patellar tilt angle was greater in group A than group B (21.7% vs. 4.5%, $p < 0.001$); that of incompatible patellar translation was not different statistically significantly between groups (20.9% vs. 23.7%, $p = 0.492$).

group A (Table 5). The preoperative patellar tilt angle and translation were not different. The average postoperative patellar tilt angle was 5.9° in group A and 2.2° in group B ($p < 0.001$). Patellar translation of group A was 0.9 mm and that of group B was 2.6 mm ($p < 0.001$). The proportion of incompatible patellar tilt angle was greater in group A (21.7% vs. 4.5%, $p < 0.001$); that of incompatible patellar translation was not different (20.9% vs 23.7%, $p = 0.492$) (Fig. 3).

There was a negative correlation between the location of the patellar component ridge and postoperative patellar tilt angle ($r = -0.371$, $p < 0.001$). The negative correlation was found in both groups A and B (Fig. 4). These postoperative findings indicate that the more the patellar component was medialized, the more the lateral tilt was increased postoperatively. There was no correlation between the location of the patellar ridge and postoperative patellar translation ($r = 0.001$, $p = 0.905$).

DISCUSSION

The most important finding of the present study was that the patellofemoral-specific clinical results were more favorable with the patellofemoral design-modified prosthesis (Attune) than its predecessor (PFC Sigma). With regard to the radiographic results, the medialized dome patellar components of the current prosthesis better reproduced the original patellar ridge with changes in patellar ridge of 1.4% in group A and 8.3% in group B (Table 5). The different height of anterior flange in the femoral component decreased the AFO in the current prosthesis and increased the AFO in the previous prosthesis. The extensive size option of the femoral component in the current prosthesis reduced the change in the PFO, compared with its predecessor. However, the current prosthesis did not provide better patellar tracking-associated radiographic parameters, such as patellar tilt, which might be due to the medial location of the patellar ridge.

A few previous studies have compared the patellofemoral-specific clinical outcomes between the two prostheses. Ranawat et al.[1] reported a lower incidence of AKP with Attune compared with PFC Sigma at 2 years postoperatively (12.5% vs. 25.8%). The occurrence of patellar crepitation was also lower with the current pros-

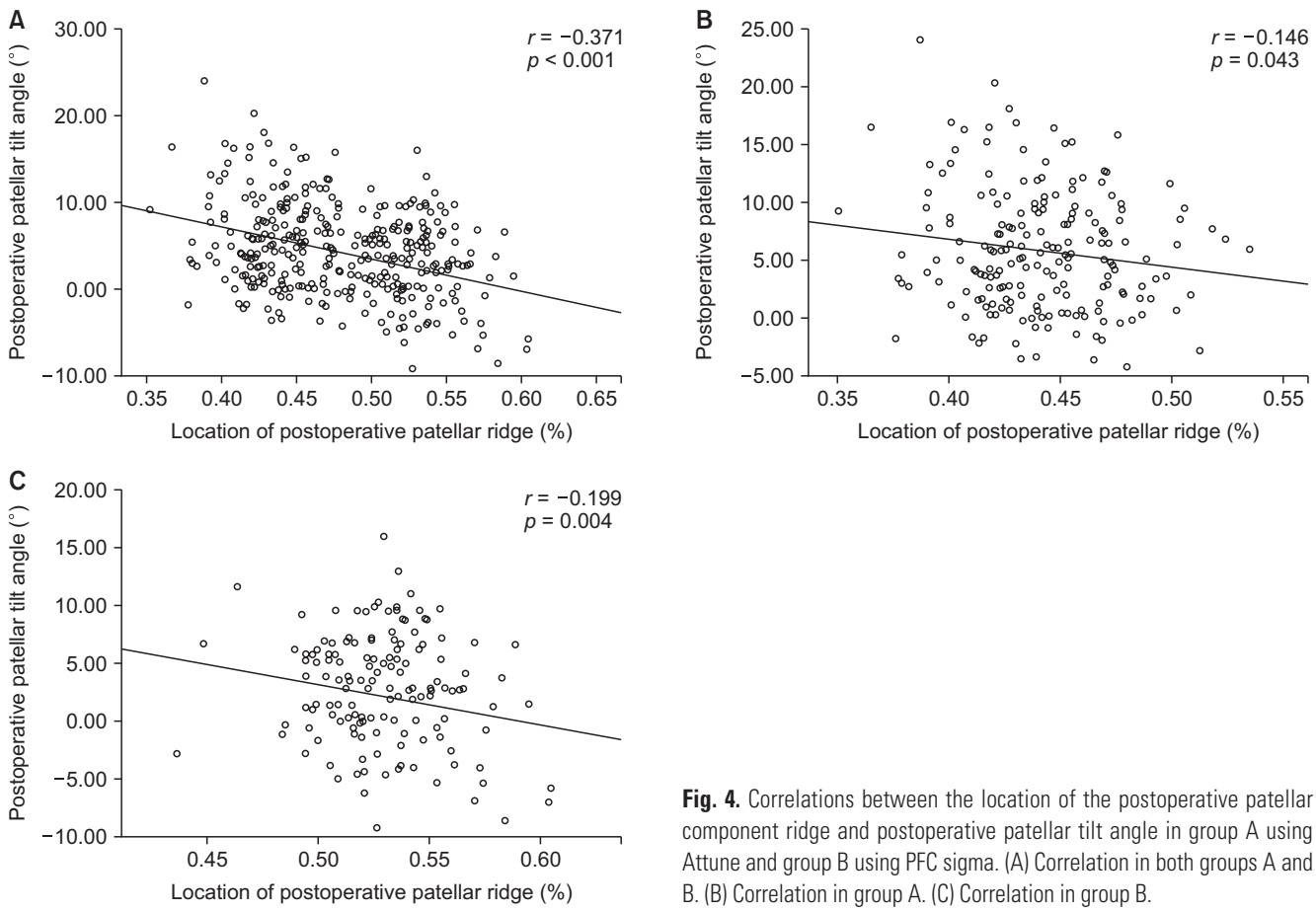

Fig. 4. Correlations between the location of the postoperative patellar component ridge and postoperative patellar tilt angle in group A using Attune and group B using PFC sigma. (A) Correlation in both groups A and B. (B) Correlation in group A. (C) Correlation in group B.

thesis (17.7% vs. 30.9%). Martin et al.[5] also reported a low incidence of patellar crepitus in the Attune group compared with the PFC Sigma group at 1 year (0.55% vs. 6.3%) and 2 years postoperatively (0.83% vs. 9.4%). In the present study, the incidence of AKP in groups A and B was 3% and 8%, respectively, and the incidence of patellar crepitus in groups A and B was 2.5% and 9%, respectively, at a minimum of 2 years postoperatively. The incidences of AKP and patellar crepitus in our study were lower than those reported by Ranawat et al.[1] and higher than those in the study of Martin et al.[5] This may have been due to the ill-defined diagnostic criteria for AKP and patellar crepitation. In addition, these complications are influenced by various factors, such as the surgical technique and preoperative condition. Accordingly, we investigated the clinical rating systems related to patellofemoral outcomes to allow more objective comparison of the clinical outcomes. The postoperative Kujala score was better in group A than in group B (81.8 vs. 77.9).

It was difficult to predict which radiographic parameters could result in better patellofemoral-specific clinical outcomes based on previous studies of Ranawat et al.[1] and Martin et al.[5] Various prosthesis- and surgical technique-related parameters could influence patellofemoral tracking, including joint line height, patellar thickness, patellar tilt, patellar translation, location of patellar ridge, and patellofemoral joint offset.[12,13] Therefore, we compared these parameters between the two groups. Surgical factors, such as mechanical axis, component positions, joint line height, and patellar thickness did not differ between the two groups in the present study.

In the present study, the AFO decreased in group A (−1.2 mm) but increased in group B (1.1 mm). The change in AFO ratio was similar to the change in AFO (−3.7% vs. 1.6%). The increase in AFO could induce overstuffing of the patella, resulting in increased contact pressure and shear force on the patellar component, occurrence of AKP, and restriction of ROM.[13] In contrast, the decrease in AFO could result in weakness of the extensor in the knee joint due to a decrease in the lever arm of the quadriceps.[9] It is known that avoidance of overstuff in the anterior femoral flange is one of the factors that contribute to the optimal patellar compatibility of Attune.[6] We thought that this design modification might reduce the incidence of AKP and patellar crepitation and provide better patellofemoral-specific clinical results in the present study.

The Attune knee system provides more extensive size options of the femoral component than the PFC system does. Specifically, PFC Sigma provides a total of 8 femoral component sizes from 1 to 6, while Attune has a total of 14 sizes from 1 to 10, including narrow sizes (3N–6N) of mostly used sizes of components. These extensive femoral component size options in Attune could increase the possibility of better implementation of the original distal femur, avoiding the change in PFO. In the present study, group A showed better restoration of the original distal and posterior femur; the changes in PFO and PFO ratio were smaller in group A than in group B (−1.1 vs. −3.6 mm; −2.6% vs. −3.8%). Small changes in PFO and PFO ratio might improve not only ROM, but also WOMAC and Kuala score in group A.[22,23] Kang et al.[24] reported that an excessive change in PFO may lead to quadriceps weakness and can influence contact stresses on the polyethylene insert and patellar component and concluded that orthopedic surgeons should be careful in intraoperative conservation of PFO.

Previous studies indicated advantages of medialization of the patellar component, which reduced lateral retinacular tension and patellofemoral contact force.[7,25] Hofmann et al.[26] reported a lower incidence of lateral retinacular release in TKAs that reproduced the original patellar ridge compared to those with a centralized patellar component (17% vs. 45.5%). However, reproduction of the original patellar ridge with an oval or round patellar component can be difficult due to overhang of the component or lateral bony impingement, especially in patients with a small patella.[27,28] In the present study, the patellar component ridge was closer to the original patellar ridge in group A than in group B. Although the oval dome patellar component was placed as medial as possible on the resected bone surface in group B, the postoperative medialization of the patellar component ridge and restoration of the original patellar ridge were not sufficient when measured from the medial border of the patella (Fig. 1). The patellar component in Attune has a medialized offset ridge of approximately 3 mm compared to that in PFC Sigma. This medialized offset ridge of the patellar component could contribute to better implementation of the original patellar ridge.

The patellar tilt and translation have been measured for evaluation of patellofemoral compatibility after TKA.[12,29] In the present study, the patella was more laterally tilted and less laterally translated in group A than in group B postoperatively (Table 5). These findings may be explained by the medialized ridge of Attune. It has been reported that the patella was tilted laterally and translated medially by medial placement of the patellar component postoperatively.[20,25,28,30] Biomechanically, medialization of the patellar component may create a lateral tilting moment by off-centering of the quadriceps tendon force.[28] We also

found that medialization of the component ridge was correlated with increased postoperative lateral tilt of the patella; this coincided with the results of previous studies.[20,31] Interestingly, there was more proportion of incompatible patellar tracking in group A, despite the better patellofemoral-specific clinical results. It has not yet been clarified that conventional radiographic values representing patellar tracking affect clinical outcomes of TKA. Van Houten et al.[21] reported that patellar position as represented by patellar tilt and displacement was not a determinant for AKP after TKA. Campbell et al.[32] also reported that the incidence of AKP was not affected by radiographic patellar tilt after TKA. As a wide range of diverse factors affect patellofemoral clinical outcomes, more sophisticated research for confounding factors will be required.

There are several limitations of the present study. First, this is a retrospective study with a relatively short follow-up period. However, the data were collected prospectively in a clinical database, although the review of the clinical data and radiographic analysis were performed retrospectively. And the minimum 2-year follow-up was sufficient to evaluate the postoperative patellofemoral-specific radiographic measurements. Second, patellar tracking was not assessed by patella kinematic analysis during ROM but only with patellar tilt and translation in the Merchant view taken at 45° knee flexion. The patellofemoral articulation is so complex that it is difficult to assess patellar tracking with only two measurements from simple radiographs. Further biomechanical and kinematic studies are needed to compare the patellofemoral compatibility between the two prostheses. Third, there was a possibility of radiographic measurement error. Radiographic standardization was performed to improve the quality of measurement. To minimize measurement error and observation bias, the intra- and interobserver reliabilities of all measurements were assessed using the intraclass correlation coefficient. Finally, most patients in the present study were women with low BMI. Such sex distribution of osteoarthritis and low BMI are common findings in our ethnic group. These differences should be taken into consideration to extrapolate our findings to other populations.

In conclusion, TKA using Attune provided better patellofemoral-specific clinical results and favorable radiographic parameters related to patellar ridge, AFO, and PFO than TKA using PFC Sigma did. However, the current prosthesis did not provide better radiographic patellar tracking, which might be due to the medial location of the patellar ridge.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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