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Infection and Instability Increasing the Risk of Patella Baja and Pseudo-Patella Baja after Revision Total Knee Arthroplasty

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Background: Patella baja with patellar tendon shortening due to traumatic or ischemic injury is a widely known complication after primary total knee arthroplasty (TKA). Pseudo-patella baja may arise from the elevation of the joint line after excessive distal femoral resection. The maintenance of original patellar height is important in revision TKA because postoperative patella baja and pseudo-patella baja can cause inferior biomechanical and clinical results. We investigated the incidence and risk factors of patella baja and pseudo-patella baja after revision TKA.

Methods: We retrospectively reviewed data for 180 revision TKAs. Patella baja was defined as a truly low-lying patella with an Insall-Salvati ratio (ISR) of < 0.8 and a Blackburne-Peel ratio (BPR) of < 0.54. Pseudo-patella baja was defined as a relatively low-lying patella compared to the joint line within the normal range of ISR and with a BPR of < 0.54. Clinically, the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) and range of motion (ROM) were evaluated. Risk factors increasing the incidence of patella baja and pseudo-patella baja after revision TKA were evaluated using multiple regression analysis.

Results: Before revision TKA, 169 knees did not exhibit patella baja or pseudo-patella baja, while 9 knees showed patella baja and 2 knees exhibited pseudo-patella baja. At 2 years after revision TKAs, 25 knees (13.9%) showed patella baja and 23 knees (12.8%) exhibited pseudo-patella baja. Despite no differences in the postoperative WOMAC score between groups with and without patella baja and pseudo-patella baja, the postoperative ROM was significantly smaller in the group with patella baja (113.3°) or pseudo patella baja (110.5°) than in the normal group (122.0°). Infection as the cause of revision TKA increased the risk of patella baja (odds ratio, 10.958; $p < 0.001$), and instability increased the risk of pseudo-patella baja (odds ratio, 11.480; $p < 0.001$).

Conclusions: Infection and instability resulted in increases in the incidence of patella baja and pseudo-patella baja after revision TKA. Information about the risk factors of patella baja and pseudo-patella baja will help TKA surgeons plan the height of the patella after revision TKA and improve clinical outcomes.

Keywords: *Knee, Arthroplasty, Patella*

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The purpose of primary and revision total knee arthroplasty (TKA) is to correct deformities, appropriately position all components, align extremities, balance soft tissue, and restore the joint line.[1-3] In addition, the maintenance of original patellar height is important because patella baja may be associated with limited range of motion (ROM), anterior knee pain, crepitus, peripatellar impingement, de-

creased lever arm, and lag of extensor.[4]

Patella baja with patellar tendon shortening due to traumatic or ischemic injury, contracture of peripatellar fat pad, and postoperative arthrofibrosis is a widely known complication after primary TKA with an incidence up to 34%.[5,6] Pseudo-patella baja refers to a situation in which the patellar tendon is not shortened and the height of the patella changes. Pseudo-patella baja may arise from an excessive soft-tissue release, elevation of the joint line after excessive distal femoral resection, and inferiorly located patellar component.[7-9] This complication leads to inferior biomechanical and clinical results similar to patella baja.[10] Patella baja can be detected using the Insall-Salvati ratio (ISR) or modified ISR, whereas pseudo-patella baja can be diagnosed using the Blackburne-Peel ratio (BPR) or Caton-Deschamps ratio (CDR).[9] All indices are decreased in patella baja, but only indices using the tibial plateau as a reference such as BPR and CDR are decreased in pseudo-patella baja.[9] Patella baja and pseudo-patella baja may occur more frequently after revision TKA,[7] but their incidences have not been reported in the literature.

Revision TKA using a nonarticulating spacer for prevention of infection results in a higher incidence of decreased ROM and patella baja.[7] Obese patients undergoing primary TKA have a higher rate of preoperative patella baja than non-obese patients and show greater changes in ISR.[11] To our knowledge, there are no previous studies attempting to define the risk factors that influence the incidence of patella baja or pseudo-patella baja after revision TKA according to patient demographics and causes of revision TKA.

The purpose of the present study was to investigate the incidence and risk factors of patella baja and pseudo-patella baja after revision TKA. We hypothesized that the incidence of patellar baja and pseudo-patella baja after revision TKA would be significant and that certain factors would increase the incidence.

METHODS

This study was approved by the Institutional Review Board of Kyung Hee University Hospital (No. KHUH 2021-03-026). Informed consent was obtained from all patients before the study.

Materials

We retrospectively reviewed data on 180 revision TKAs (170 patients) performed between 2009 and 2018 and followed up for a minimal period of 2 years. Two prostheses were used: Press Fit Condylar (PFC) prosthesis (Depuy, Johnson & Johnson, Warsaw, IN, USA) and the NexGen prosthesis (Zimmer Biomet, Warsaw, IN, USA). PFC prosthesis was used in 172 knees (163 posterior stabilized [PS] and 9 constrained condylar knee [CCK]), and NexGen prosthesis was placed in 8 knees (4 Legacy CCK and 4 rotating hinge [RH]). Cases where only a polyethylene insert was replaced or only a patella component was revised were excluded.

The mean age at the time of revision surgery was 70.6 years (range, 39–93 years). One hundred forty-eight patients were female and 22 were male. Ninety-two knees were right-sided; 88 knees were left-sided. The average body mass index (BMI) was 26.2 kg/m^2 (range, 17.6–37.6 kg/m^2). The average duration between primary and revision TKA was 9.3 years (range, 0.1–28.3 years). The average follow-up period was 5.3 years (range, 2–10.8 years).

The diagnoses that led to primary TKA were degenerative osteoarthritis (160 knees, 88.9%), rheumatoid arthritis (6 knees, 3.3%), post-infectious arthritis (8 knees, 4.4%), hemophilic arthritis (3 knees, 1.7%), posttraumatic arthritis (2 knees, 1.1%), and Charcot joint (1 knee, 0.6%). The causes of revision TKA were infection (62 knees, 34.4%), loosening (57 knees, 31.7%), polyethylene wear and osteolysis (39 knees, 21.7%), instability (16 knees, 8.9%), periprosthetic fractures (4 knees, 2.2%), and stiffness (2 knees, 1.1%). In the cases with periprosthetic joint infection, two-stage revision TKA was performed. In the first operation, an antibiotic-loaded articulating spacer was inserted after implant removal and debridement so that weight-bearing and ROM were possible until the second operation was performed.[12]

Surgical Technique

The midline skin incision and the medial parapatellar approach used in primary TKA were performed. Techniques such as management of bone defect, restoration of limb alignment, soft-tissue balancing, cementation, and rehabilitation performed in general revision TKA were applied. Following the Anderson Orthopedic Research Institute classification, 109 knees had bone defects of grades greater than F2 or T2; 71 knees were of grades F1 and T1. Metal augmentation was performed, if necessary. Twenty-three knees (12.8%) received allografts in the proximal tibia, 18 knees (10.0%) in the distal femur, and 12 knees (6.7%) in both the proximal tibia and distal femur. In 108 cases (78.3%), both femoral and tibial stems were used, in 18 cases (10.0%) only tibial stems were used, and in 15 cases (8.3%) only femoral stems were used. We used the fully cemented technique to ensure stem fixation in 36 knees (20.0%), and the hybrid cemented technique in 105 knees

(58.3%).

Three levels of constraint including PS, CCK, and RH prosthesis were applied. The PS prosthesis was used in 163 knees (90.6%) with well-balanced flexion and extension gaps, good mediolateral stability, and intact collateral ligaments. The CCK prosthesis was used in 13 knees (7.2%) lacking sufficient mediolateral stability or with flexion-extension gap mismatches that might predispose the knee to cam dissociation of a standard PS insert. The RH prosthesis was placed in 4 knees (2.2%) with a completely inadequate isolated medial collateral ligament or a lateral collateral ligament or with genu recurvatum. A more constrained prosthesis was used only when unavoidable.

Radiographic Evaluation of Patellar Height

The ISR and BPR were radiographically measured to evaluate the height of the patella on lateral knee radiographs before revision TKA and at postoperative 2 years (Fig. 1).[9] Patella baja was defined as a truly low-lying patella due to shortening of the patellar tendon, with ISR of < 0.8 and BPR of < 0.54. Pseudo-patella baja was defined as a relatively low-lying patella compared to the joint line, with a normal range of ISR (0.8–1.2) and a BPR of < 0.54.

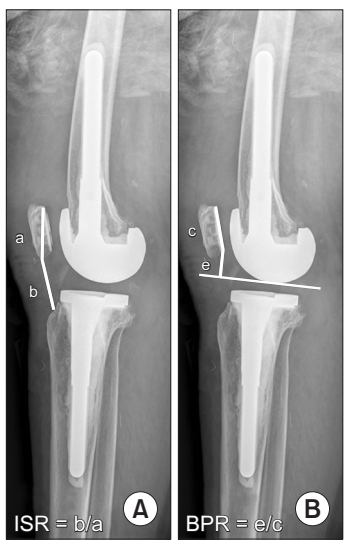

Fig. 1. Evaluation of patellar height to determine the presence of patella baja and pseudo-patella baja. (A) Insall-Salvati ratio (ISR) = b/a. (B) Blackburne-Peel ratio (BPR) = e/c. a, longest (diagonal) length of patella; b, length of patellar tendon; c, length of patellar articular surface; e, distance between patellar articular surface and perpendicular distance to tangent along tibial plateau. Patella baja was defined as a truly low-lying patella due to shortening of the patellar tendon, associated with an ISR of < 0.8 and a BPR of 0.54. Pseudo-patella baja was defined as a relatively low-lying patella compared to the joint line, which is associated with a normal range of ISR (0.8–1.2) and a BPR of < 0.54.

Clinical Evaluation

The clinical scores recorded in our database were retrospectively analyzed. The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) score[13] was used to evaluate pain and function before revision TKA and at postoperative 2 years. The ROM of the knee was measured using a long-armed goniometer before revision TKA and at postoperative 2 years.

Other Radiographic Evaluations

Serial preoperative and postoperative anteroposterior (AP) and lateral radiographs and orthoroentgenogram were used to assess limb alignment. Measurements were made on these images using a picture archiving and communication system (Infinitt, Seoul, Korea). The mechanical axis (MA) and the positions of components including α, β, γ, and δ angles were measured according to the Knee Society radiological evaluation method.[14] The joint line height was measured from the medial femoral epicondyle and from the fibular head on AP radiographs (Fig. 2).[15]

Causes of Revision TKA

Causes of revision TKA were classified according to the general method employed[16-19] and categorized as polyethylene wear and osteolysis, loosening, infection, instability, periprosthetic fracture, or stiffness. Causes were determined by chart review, citing laboratory tests, joint fluid analyses, radiographs, and intraoperative findings. When

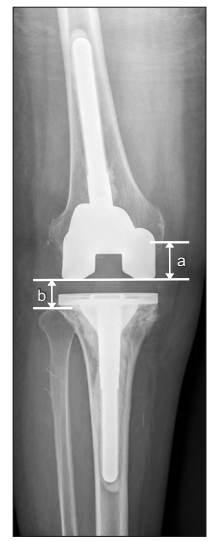

Fig. 2. Measurement of the joint line. Joint line height (JLH) was measured from the medial femoral epicondyle (a) or the fibular head (b) on an anteroposterior standing X-ray, with the knee in a fully extended neutral position. JLHs were similar before and after revision total knee arthroplasty.

multiple causes of revision TKA were noted, a senior surgeon (SJS) determined the predominant cause.

Statistical Analysis

Clinical and radiographic results were compared between groups with normal patellar height and with patella baja or pseudo-patella baja (independent *t*-test). Risk factors that increase the incidence of patella baja and pseudo-patella baja after revision TKA were evaluated in terms of age, sex, BMI, cause of revision TKA, patella baja before revision TKA, bone defect, and prosthesis constraint (logistic regression analysis). The incidence of patella baja and pseudo-patella baja after revision TKA were compared according to the cause of revision TKA (chi-square test). All statistical analyses were performed using IBM SPSS ver. 20.0 (IBM Corp., Armonk, NY, USA); $p < 0.05$ indicates statistical significance. Two investigators (JWL and HWL) performed radiographic measurements to reduce observational bias. The intra- and inter-observer reliabilities were assessed by calculating intraclass correlation coefficients, which were greater than 0.8.

To check whether the sample has sufficient power to detect a significant difference, post hoc power analysis was performed and the alpha value was set to 0.05. Power > 80% was considered sufficient, and all significant variables met the criteria.

RESULTS

Before revision TKA, there were no cases of patella baja and pseudo-patella baja in 169 knees, while 9 knees had patella baja and 2 knees had pseudo-patella baja (Table 1). After revision TKAs, 25 knees (13.9%) had patella baja and 23 knees (12.8%) had pseudo-patella baja (Table 1). Nine

Table 1. Incidence of Patella Baja and Pseudo-Patella Baja after Revision TKA

Variable	Post-revision TKA			
	Total	Normal	Patella baja*	Pseudo-patella baja†
Number of knees (%)	180	132 (73.3)	25 (13.9)	23 (12.8)
Pre-revision TKA				
Normal	169	132	15	22
Patella baja*	9	0	9	0
Pseudo-patella baja†	2	0	1	1

TKA: total knee arthroplasty.
*Patella baja: both modified Insall-Salvati ratio (< 0.8) and Blackburne-Peel ratio (< 0.54) are abnormally low. †Pseudo-patella baja: normal modified Insall-Salvati ratio (0.8–1.2) and low Blackburne-Peel ratio (< 0.54).

Table 2. Patellar Height Measurements in Patella Baja and Pseudo-Patella Baja after Revision TKA

Variable	Normal	Patella baja*	*p*-value	Pseudo-patella baja†	*p*-value
Number of knees (%)	132 (73.3)	25 (13.9)	-	23 (12.8)	-
Insall-Salvati ratio					
Preoperative	0.98 ± 0.13	0.75 ± 0.25	< 0.001	0.96 ± 0.13	0.428
Postoperative	0.95 ± 0.11	0.54 ± 0.14	< 0.001	0.92 ± 0.11	0.206
Blackburne-Peel ratio					
Preoperative	0.72 ± 0.15	0.53 ± 0.22	< 0.001	0.73 ± 0.15	0.743
Postoperative	0.65 ± 0.13	0.25 ± 0.12	< 0.001	0.29 ± 0.09	< 0.001

Values are presented as mean ± standard deviation.
TKA: total knee arthroplasty.
*Patella baja: both modified Insall-Salvati ratio (< 0.8) and Blackburne-Peel ratio (< 0.54) are abnormally low. †Pseudo-patella baja: normal modified Insall-Salvati ratio (0.8–1.2) and low Blackburne-Peel ratio (< 0.54).

knees with patella baja before revision TKA sustained patella baja after revision TKA (Table 1). The ISR and BPR were well preserved before and after revision TKA in the group with normal patellar height (Table 2, Fig. 3). In the group with patella baja, all were significantly smaller before revision TKA than those in the group with normal patellar height and decreased patellar height after revision TKA (Table 2). The group with pseudo-patella baja after revision TKA had a relatively low-lying patella compared to the joint line, which was associated with a normal range of ISR and small BPR (Table 2). No significant differences were observed in patient demographics, except for causes of revision TKA (Table 3).

Fig. 3. Normal patellar height after revision total knee arthroplasty. (A) Before total knee revision. (B) After total knee revision. ISR: Insall-Salvati ratio, BPR: Blackburne-Peel ratio.

There were no differences in WOMAC score after revision TKA between the group with normal patellar height and groups with patella baja or pseudo-patella baja. The average preoperative and postoperative ROM were significantly smaller in the group with patella baja than in the group with normal patellar height (p = 0.011 and p = 0.010), and the postoperative ROM was significantly smaller in the group with pseudo-patella baja than in the group with normal patellar height (110.5° vs. 122.0°, p < 0.001). In terms of change in ROM after revision TKA, 14.9° increase was observed in the normal patellar height group. In the patella baja group, ROM increased by 25.5° and in the pseudo-patella baja group, it increased by 2.6°. But there was no significant difference with wide range of change in ROM (Table 4).

The pre- and postoperative MA and position of components did not differ between the group with normal patellar height and groups with patella baja or pseudo-pa-

Table 3. Comparison of Patient Demographics in Patella Baja and Pseudo-Patella Baja after Revision TKA

Variable	Normal	Patella baja*	Pseudo-patella baja†	*p*-value
Knee (patient)	132 (122)	25 (25)	23 (23)	-
Period of revision TKAs	2009–2018	2009–2018	2009–2018	-
Age (yr)	70.8 ± 8.6	68.2 ± 10.2	72.0 ± 8.0	0.167
Female : male	106 : 16	21 : 4	21 : 2	0.668
Right : left	64 : 68	15 : 10	13 : 10	0.807
Body mass index (kg/m^2)	26.1 ± 3.4	25.8 ± 3.2	26.8 ± 3.9	0.427
Causes of revision TKAs (wear & osteolysis : loosening : infection : instability : other‡)	34 : 46 : 39 : 7 : 6	2 : 5 : 18 : 0 : 0	3 : 5 : 2 : 11 : 2	< 0.001
PS : CCK : RH§	120 : 9 : 3	23 : 2 : 0	20 : 2 : 1	0.796
Period between primary and revision TKAs (yr)	9.5 ± 7.0	9.1 ± 6.4	7.9 ± 7.8	0.587
Follow-up period (yr)	3.2 ± 2.4	6.2 ± 2.6	5.3 ± 2.5	0.173

Values are presented as mean ± standard deviation.
TKA: total knee arthroplasty, PS: posterior stabilized, CCK: constrained condylar knee, RH: rotating hinge.
*Patella baja: both modified Insall-Salvati ratio (< 0.8) and Blackburne-Peel ratio (< 0.54) are abnormally low. †Pseudo-patella baja: normal modified Insall-Salvati ratio (0.8–1.2) and low Blackburne-Peel ratio (< 0.54). ‡Other: periprosthetic fracture and stiffness. §PS : CCK : RH: types of prostheses placed, including PS, constrained condylar, and rotation hinge knees.

Table 4. Comparison of Clinical Results between Groups with and without Patella Baja and Pseudo-Patella Baja at Postoperative 2 Years after Total Knee Arthroplasty

Variable	Normal	Patella baja*	*p*-value	Pseudo-patella baja†	*p*-value
Number of knees (%)	132 (73.3)	25 (13.9)	-	23 (12.8)	-
WOMAC score					
Preoperative	70.7 ± 5.6	71.8 ± 5.1	0.330	65.8 ± 11.9	0.066
Postoperative 2 yr	19.6 ± 6.1	19.4 ± 4.1	0.916	21.2 ± 12.5	0.553
Range of motion (°)					
Preoperative	107.1 ± 33.2	87.8 ± 39.2	0.011	107.9 ± 41.5	0.918
Postoperative 2 yr	122.0 ± 14.0	113.3 ± 20.8	0.010	110.5 ± 10.1	< 0.001
Change	14.9 ± 29.5	25.5 ± 35.4	0.112	2.6 ± 37.0	0.077

Values are presented as mean ± standard deviation.
WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index.
*Patella baja: both modified Insall-Salvati ratio (< 0.8) and Blackburne-Peel ratio (< 0.54) are abnormally low. †Pseudo-patella baja: normal modified Insall-Salvati ratio (0.8–1.2) and low Blackburne-Peel ratio (< 0.54).

Table 5. Comparison of Radiographic Results between Groups with or without Patella Baja and Pseudo-Patella Baja after Revision Total Knee Arthroplasty

Variable	Normal	Patella baja*	*p*-value	Pseudo-patella baja†	*p*-value
Number of knees (%)	132 (73.3)	25 (13.9)	-	23 (12.8)	-
Mechanical axis (°)					
Preoperative	–7.5 ± 7.7	–5.9 ± 8.3	0.337	–4.7 ± 8.6	0.117
Postoperative	–1.8 ± 3.6	–1.0 ± 3.2	0.327	–1.8 ± 2.5	0.927
Position of components (°)					
α angle	95.2 ± 8.3	96.2 ± 1.7	0.544	96.1 ± 2.0	0.617
β angle	90.2 ± 2.1	90.6 ± 2.1	0.426	90.9 ± 1.8	0.150
γ angle	4.1 ± 8.8	3.9 ± 4.5	0.938	2.8 ± 1.7	0.494
δ angle	86.6 ± 3.3	85.6 ± 2.4	0.186	85.7 ± 2.6	0.225
Restoration of joint line (mm)					
Medial femoral epicondyle-joint line					
Preoperative	26.8 ± 3.9	27.1 ± 1.7	0.794	27.6 ± 3.0	0.356
Postoperative	27.6 ± 3.5	27.3 ± 3.1	0.705	27.8 ± 2.2	0.729
Joint line-fibular head					
Preoperative	21.0 ± 5.4	19.4 ± 5.6	0.215	23.3 ± 5.0	0.061
Postoperative	24.9 ± 5.4	28.1 ± 7.2	0.021	30.7 ± 6.1	< 0.001

Values are presented as mean ± standard deviation.
*Patella baja: both modified Insall-Salvati ratio (< 0.8) and Blackburne-Peel ratio (< 0.54) are abnormally low. †Pseudo-patella baja: normal modified Insall-Salvati ratio (0.8–1.2) and low Blackburne-Peel ratio (< 0.54).

tella baja (Table 5). The distances between the medial femoral epicondyle and joint line were not different between the normal patellar height group and groups with patella baja or pseudo-patella baja before and after revision TKA (26.8 mm vs. 27.1 mm vs. 27.6 mm and 27.6 mm vs. 27.3 mm vs. 27.8 mm, respectively) (Table 5). The distances between the fibular head and joint line were significantly greater in the groups with patella baja and pseudo-patella baja than in the group with normal patellar height (28.1 mm vs. 30.7 mm vs. 24.9 mm) (Table 5).

Fig. 4. Patella baja after revision total knee arthroplasty due to infection. (A) Before total knee revision. (B) After total knee revision for infection. ISR: Insall-Salvati ratio, BPR: Blackburne-Peel ratio.

On the logistic regression analysis, infection as the cause of revision TKA increased the risk of patella baja (odds ratio, 10.958; $p < 0.001$) (Fig. 4), and instability increased the risk of pseudo-patella baja (odds ratio, 11.480; $p < 0.001$) (Table 6, Fig. 5). The presence of patella baja before revision TKA was also an independent factor that increased the risk of patella baja after revision TKA (odds ratio, 90.249; $p < 0.001$) (Table 6).

Patella baja occurred frequently after revision TKA when infection was the cause of revision TKA ($p = 0.001$), and pseudo-patella baja occurred frequently when instability was the cause of revision TKA ($p < 0.001$) (Table 7).

DISCUSSION

The incidences of patella baja and pseudo-patella baja after revision TKA were 13.9% and 12.8%, respectively, which were considerably lower than those reported in previous studies.[7,10] In a study by Han et al,[10] the incidences of patella baja and pseudo-patella baja were 19.9% and 54.2%, respectively, after revision TKA. In order to prevent the

Table 6. Multiple Regression Analysis of Possible Factors Contributing to Development of Patella Baja and Pseudo-Patella Baja after Revision Total Knee Arthroplasty

Variable	Patella baja OR (95% CI)	*p*-value	Pseudo-patella baja OR (95% CI)	*p*-value
Age	0.971 (0.910–1.037)	0.378	1.014 (0.950–1.082)	0.684
Sex	1.630 (0.353–7.515)	0.531	1.694 (0.286–8.532)	0.607
Body mass index	0.997 (0.844–1.177)	0.967	1.015 (0.883–1.166)	0.833
Cause of revision TKA				
Wear	0.251 (0.056–1.120)	0.070	0.432 (0.121–1.547)	0.197
Loosening	0.467 (0.165–1.327)	0.153	0.660 (0.243–1.789)	0.414
Infection	10.958 (3.168–37.904)	< 0.001	0.662 (0.230–1.910)	0.446
Instability	-	-	11.480 (3.702–35.597)	< 0.001
Patella baja before revision TKA	90.249 (8.631–943.672)	< 0.001	-	-
AORI* greater than F2	2.684 (0.885–8.142)	0.081	3.028 (0.729–12.949)	0.135
AORI* greater than T2	1.379 (0.187–10.188)	0.753	0.362 (0.084–1.556)	0.172
PS/CCK or RHK†	1.003 (0.163–6.180)	0.997	1.359 (0.286–6.791)	0.681

OR: odds ratio, CI: confidence interval, TKA: total knee arthroplasty, AORI: Anderson Orthopedic Research Institute, PS: posterior stabilized, CCK: constrained condylar knee, RHK: rotating hinge knee.
*Bone defect according to the AORI classification. †Types of prostheses placed, PS knee compared to CCKs or rotation hinge knees.

occurrence of patella baja and pseudo-patella baja, it is important to maintain the original joint line and to position the femoral component of an appropriate size with correct rotation. Khakharia and Scuderi[20] reported using bone stock and distal femoral augments to restore the distal joint line during revision TKA to maintain normal patellar height. In our study, the joint line from the medial femoral epicondyle was well preserved with appropriate management of bone defects using metal augments or allografts.

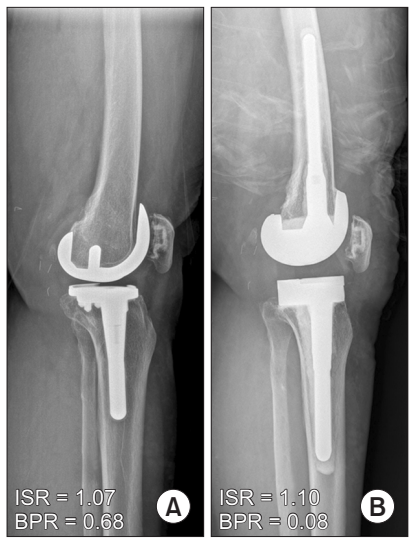

Fig. 5. Pseudo-patella baja after revision total knee arthroplasty due to instability. (A) Before total knee revision. (B) After total knee revision for instability. ISR: Insall-Salvati ratio, BPR: Blackburne-Peel ratio.

We believe that adequate restoration of femoral bone defects lowered the incidence of patella baja and pseudo-patella baja in the present study, compared to previous studies. However, the joint line from the fibular head was increased in several cases, as noted during the selection of polyethylene inserts of appropriate thickness after soft-tissue balancing in revision TKA (Table 5). Patella baja and pseudo-patella baja may not be avoidable in such cases, although the joint line was well restored from the medial femoral epicondyles.

The other important finding in this study is that when infection was the cause of revision TKA, it increased the risk of patella baja, while instability increased the risk of pseudo-patella baja after revision TKA. A previous study reported that revision TKA performed for septic causes using a nonarticulating spacer resulted in an incidence of patella baja of 58.8%.[7] Although we used antibiotic-loaded articulating spacers for two-stage revision TKA, 18 knees (29.0%) had patella baja after revision TKA (Table 7). Among them, 6 knees had patella baja before revision TKA (Table 7). We suggest that ongoing processes in infected knees contribute to patella baja, including infection-related peripatellar scar formation and arthrofibrosis due to pain and prolonged immobilization.[7] Laudermilch et al.[21] reported that patients who underwent septic revision required more surgical procedures, resulting in longer surgical time, which in turn affected scar formation.

In the present study, instability was associated with the risk of pseudo-patella baja after revision TKA (Tables 6

Table 7. Incidences of Patellar Baja and Pseudo-Patella Baja According to the Causes of Revision TKA

Variable	Total (N)	Osteolysis*	Loosening	Infection	Instability	Others†	*p*-value
Knee	180	39 (21.7)	57 (31.7)	62 (34.4)	16 (8.9)	6 (3.3)	
Normal							
Preoperative	169	38 (22.5)	53 (31.4)	56 (33.1)	16 (9.5)	6 (3.6)	0.811
Postoperative	132	34 (25.8)	46 (34.8)	39 (29.6)	7 (5.3)	6 (4.5)	0.092
Patella baja							
Preoperative	9	0	3 (33.3)	6 (66.7)	0	0	0.760
Postoperative	25	2 (8.0)	5 (20.0)	18 (72.0)‡	0	0	0.001
Pseudo-patella baja							
Preoperative	2	1 (50)	1 (50)	0	0	0	0.744
Postoperative	23	3 (13.1)	6 (26.1)	5 (21.7)	9 (39.1)‡	0	< 0.001

Values are presented as number (%).
TKA: total knee arthroplasty.
*Wear of polyethylene insert and osteolysis. †Periprosthetic fracture and stiffness. ‡Post hoc test $p < 0.05$.

and 7). Thicker polyethylene inserts were frequently used to overcome global or flexion instability, which resulted in elevation of the joint line from the fibular head or tibial tuberosity. Surgeons should be aware that global instability or genu recurvatum can be treated by using a constrained prosthesis, which can provide stability without requiring a thick polyethylene insert.[22] Otherwise, patellar height may increase postoperatively (Fig. 5).

Preexisting patella baja was the major predisposing factor for patella baja after revision TKA. Proximalization of the tibial tubercle can solve preexisting patella baja,[4] but we used the medial patellar approach in revision TKA due to the possibility of delayed union or nonunion of the osteotomy and resultant delayed rehabilitation and extensor lag. The presence of patella baja or pseudo-patella baja alter patellofemoral kinematics and can cause several functional problems,[5,8,23] as well as impingement, peripatellar pain, and decreased ROM.[4,5,24] In our study, postoperative ROM was significantly lower in groups with patella baja and pseudo-patella baja than in the group with normal patellar height (Table 4). A previous study reported significant differences in ROM between patients with and without patella baja after revision TKA (95.1° vs. 106.8°, $p = 0.04$).[7] Behrend et al.[25] and Kazemi et al.[26] identified an association between pseudo-patella baja and decreased ROM. Surgeons should try to avoid them after revision TKA as much as possible.

In the patella baja group, ROM increased by 25.5° (from 87.8° to 113.3°), which is thought to be due to the smaller preoperative ROM compared to the other groups. In addition, the cause of revision was infection in 72% of patients in the patella baja group. The preoperative ROM was limited due to severe effusion and pain, but it is thought that ROM improved remarkably when the symptoms of infection were relieved after the revision TKA.[27] The use of an articulating spacer in the two-stage revision TKA for infection is also considered to have influenced this finding.[28]

Contrary to our expectation, there were no differences in postoperative WOMAC scores among the group with normal patellar height and the groups with patella baja or pseudo-patella baja after revision TKA in the present study. Several reasons for the no difference could be assumed as follows: The first reason is that there were various factors affecting the clinical outcomes. It may be difficult to predict outcomes only with the presence or absence of patella baja and pseudo patella baja. Second, the average age of the patients in the present study was 71 years. Functional abilities were low in these elderly patients, so the patellar height might not have had much influence on the clinical result. Last, the ceiling effect of our clinical rating system and bias due to the small numbers of subjects in groups with patella baja or pseudo-patella baja could be assumed.[29]

Several limitations of the present study should be noted. First, we measured the position of the patella on a lateral radiograph in full extension using ISR and BPR. In general, patellar position is measured at a knee flexion angle of 30° to ensure that the patellar tendon is stretched appropriately.[30,31] However, a previous study reported that varying the degree of knee flexion (0°, 30°, and 60°) did not produce clinically important effect in measurement of patellar position.[32] Another study reported that there was no clinically significant difference in patellar tendon length evaluated on weight-bearing lateral radiographs at 0° and 30° flexion.[33] We thought that our method of measuring the patellar height when the knee is fully extended in standing was reasonable in terms of cost-effectiveness and convenience because maintaining the flexion angle of 30° might cause pain in patients requiring revision TKA.[34] It was also useful to take a radiograph in a fully extended position in terms of reproducibility. The second limitation is the retrospective nature of the work, as we studied a nonrandomized, consecutive case series. We included every consecutive revision TKA to avoid unexpected omission of patella baja or pseudo-patella baja in the specific group. We focused primarily on the incidence of patella baja and pseudo-patella baja, exploring various factors potentially influencing these conditions. Understandably, other factors may also be in play, including component size and rehabilitation protocol. However, we could not control for all possible variables in a clinical setting such as ours. A more sophisticated, randomized, prospective study is required to explore these questions further. The third limitation is that most of our patients were female and had low BMI. The combination of osteoarthritis and low BMI is common in Korean women.[35] The revision TKA procedures were performed by an experienced senior surgeon at a tertiary medical center with extensive experience in performing revision TKAs. This means that caution must be exercised when seeking to extrapolate our findings to other populations and to general hospitals. The fourth limitation is that many patients requiring TKA revision due to infection underwent primary TKA at other hospitals, and many already had patella baja before TKA revision.

Among the causes of revision TKA, infection and instability resulted in increases in the incidences of patella baja and pseudo-patella baja after revision TKA. Considering the risk factors for patella baja and pseudo-patella baja would help surgeons performing TKA to better plan

the height of the patella after revision TKA in ways that lead to better clinical outcomes.

CONFLICT OF INTEREST

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

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