Painful Patellar Clunk or Crepitation of Contemporary Knee Prostheses

Won Chul Choi MD, PhD, Keun-Jung Ryu MD,
Sahnghoon Lee MD, PhD, Sang Cheol Seong MD, PhD,
Myung Chul Lee MD, PhD

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Abstract

Background Painful patellar clunk or crepitation (PCC) is a resurgent complication of contemporary posterior-stabilized TKA. The incidence, time to presentation, causes, and treatment of PCC still remain controversial.

Questions/purposes We therefore (1) compared the incidence of PCC with five contemporary TKA designs, (2) evaluated the time to presentation, (3) identified possible etiologies, and (4) determined recurrence rate and change in knee functional scores after treatment for PCC.

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

This work was performed at Seoul National University College of Medicine, Seoul, Korea.

W. C. Choi, K.-J. Ryu
Department of Orthopaedic Surgery, CHA Bundang Medical
Center, CHA University School of Medicine, Seongnam, Korea

S. Lee, S. C. Seong, M. C. Lee (✉)
Department of Orthopaedic Surgery, Seoul National University
College of Medicine, 101 Daehang-ro, Jongno-gu,
Seoul 110-744, Korea
e-mail: leemc@snu.ac.kr

Methods We reviewed 580 patients who had 826 posterior-stabilized TKAs involving five different designs. The incidences of PCC were compared among the prostheses. The knees were divided into two groups depending on the development of PCC, and possible etiologic factors of PCC, including prosthesis design and surgical or radiographic variables, were compared between groups. We investigated the onset time of PCC and evaluated treatment results by knee outcome scores. Minimum followup was 2.0 years (mean, 3.9 years; range, 2.0–9.8 years).

Results The PCC incidence was higher in the Press-Fit Condylar® Sigma® Rotating Platform/Rotating Platform-Flex Knee System (11 of 113 knees, 9.7%) than in the others (seven of 713 knees, 1.0%). Increased risk of PCC was associated with using a specific prosthesis and patellar retention. PCC occurred in all cases within a year after TKA (mean, 7.4 months). Arthroscopic treatment (16 knees) and patellar replacement (two knees) improved knee scores, with no recurrence observed over an average followup of 29 months.

Conclusions Prosthesis design and patellar retention were associated with PCC. Surgery resolved the PCC.

Level of Evidence Level III, therapeutic study. See Instructions to Authors for a complete description of levels of evidence.

Introduction

Painful patellar clunk or crepitation (PCC) reportedly occurs in 0% to 20% of patients after TKA [2, 15, 21]. Although some authors have suggested the evolution of TKA designs and surgical techniques had largely eliminated PCC [8, 14, 27, 29], several studies have reported

incidences with the recently developed posterior-stabilized TKA designs ranging from 12% to 17% [14, 15, 17]. Patellar clunk typically develops within a year postoperatively [3, 18, 22, 24, 28, 29]; however, late cases up to even 6 years after TKA have been reported [3, 11, 38].

PCC is presumed to result from soft tissue impingement after TKA [18] and specifically the overgrowth of a fibrous nodule at the attachment of the extensor mechanism to the superior aspect of the patella [3, 21, 28, 32]. The fibrous tissue engages the intercondylar box of the femoral component and results in painful catching while the knee is moving from a flexed to an extended position [18, 20]. This complication occurs particularly after posterior-stabilized TKA [1–3, 8, 18, 21, 25, 27, 32, 38, 39], although it might occur after cruciate-retaining TKA [30, 36].

Numerous factors, including femoral component design [1, 2, 8, 15, 22, 25, 27, 29], postoperative patellar positioning [10, 13, 15, 18, 39], patellar thickness [13, 18], joint line level [3, 13, 18], femoral component position [10, 13], increased knee flexion [35], and a history of previous knee surgeries [10], have all been associated with the occurrence of PCC. However, the relative risks of these various factors are unclear.

Recently, some surgeons have recommended arthroscopic excision of the nodule [9, 11, 15, 24, 26, 28] rather than nonoperative treatment [3, 21] or open arthrotomy with or without revision of patellar component [2, 3, 13, 18] as a treatment option for PCC. However, even arthroscopic treatment is not free from recurrence [3, 29] and the clinical results of each treatment option, including recurrence of symptoms and change in knee outcome scores, are not clearly known yet.

We therefore (1) determined and compared the incidence of PCC in different contemporary posterior-stabilized TKA designs, (2) evaluated the time to presentation, (3) identified possible etiologic factors of PCC, and (4) determined recurrence of symptom and changes in knee scores after surgery for PCC.

Patients and Methods

We retrospectively reviewed 647 patients treated with 948 primary posterior-stabilized TKAs involving five different designs between January 2000 and December 2006. We reviewed all medical records to identify patients with painful PCC for which surgery was performed. PCC was defined as a disabling clunk or painful crepitation that occurred during knee motion. A painless clunk or crepitation was not documented as a complication and was not treated. The indications for surgery were patients (1) with an audible PCC of the patellofemoral joint, (2) with persistent PCC after nonoperative management with antiinflammatory

medication, activity modification, or physical therapy, and (3) who agreed to undergo the operation. The contraindications were patients (1) with identifiable cause of knee pain other than PCC and (2) who refused to have surgery. We excluded 67 patients with knees diagnosed as having inflammatory arthritides ($n = 39$ knees), who were lost before the 2-year followup had lapsed ($n = 68$ knees), or without clinical outcome details ($n = 15$ knees). These exclusions left 580 patients with 826 TKAs with a minimum followup of 2.0 years (mean, 3.9 years; range, 2.0–9.8 years). Eighteen knees had PCC while 808 did not. Of the 18 knees with PCC, 10 showed a definite clunk and eight suffered from painful patellofemoral crepitation without an obvious clunking sound. Of the 826 knees, 424 were implanted with the NexGen[®] Legacy[®] Posterior Stabilized-Flex Knee System (NexGen LPS-flex) (Zimmer Inc, Warsaw, IN, USA), 135 with the Scorpio[®] Posterior Stabilized Knee System (Scorpio PS) (Stryker Orthopaedics, Mahwah, NJ, USA), 113 with the Press-Fit Condylar[®] Sigma[®] Rotating Platform/Rotating Platform-Flex Knee System (PFC RP/RPF) (DePuy Orthopaedics, Inc, Warsaw, IN, USA), 96 with the Genesis[™] II Posterior Stabilized Knee System (Genesis II PS) (Smith & Nephew, Inc, Memphis, TN, USA), and 58 with the e.motion[®] Total Knee System (e.motion PS) (B Braun Aesculap, Tuttlingen, Germany) (Table 1). The selection of prosthesis was at the surgeon's discretion without applying any selection criteria. No patients were recalled specifically for this study; all data were obtained from medical records and radiographs. We obtained prior institutional review board approval.

A single surgeon (MCL) performed all surgeries. The primary TKAs were performed using a conventional technique, except for the 58 e.motion PS TKAs, during which an image-free navigation system (OrthoPilot[®]; B Braun Aesculap) had been used. After an anterior midline skin incision, a standard medial parapatellar arthrotomy was performed. The PCLs were resected in all cases. Fixed-bearing tibia inserts were implanted for NexGen LPS-flex, Scorpio PS, and Genesis II PS knees, while rotating-platform tibia inserts were used for PFC RP/RPF and e.motion PS knees. Most patellae were resurfaced (766 knees, 92.7%); however, the normally shaped small patellae with no eburnated bone and congruent patellofemoral tracking were retained selectively (60 knees, 7.3%). The synovial lining on the undersurface of the quadriceps tendon in the suprapatellar region was excised. All prostheses were inserted with cement.

Postoperatively, all patients underwent similar, standardized rehabilitation programs. The knees were immobilized for the first 24 hours and continuous passive motion was started on the first postoperative day. Patients were encouraged to perform isometric quadriceps strengthening and straight-leg raises on the first postoperative day. Patients began walking

Table 1. Demographics

Prosthesis	Number of knees	Age (years)*	Sex (female/male) (number of knees)	Followup (years)*
NexGen® Legacy® Posterior Stabilized-Flex Knee System	424 (51.3%)	67.8 ± 6.6 (43–84)	407/17	4.0 ± 1.4 (2.1–8.9)
Scorpio® Posterior Stabilized Knee System	135 (16.3%)	67.8 ± 8.1 (41–83)	123/12	4.8 ± 1.7 (2.3–9.8)
Press-Fit Condylar® Sigma™ Rotating Platform/Rotating Platform-Flex Knee System	113 (13.7%)	66.2 ± 6.4 (47–82)	109/4	2.8 ± 1.0 (2.0–5.0)
Genesis™ II Posterior Stabilized Knee System	96 (11.6%)	67.4 ± 6.7 (49–83)	91/5	4.7 ± 1.8 (2.2–8.0)
e.motion® Total Knee System	58 (7.1%)	70.8 ± 6.0 (43–84)	48/10	2.4 ± 0.6 (2.0–4.2)
Total	826	68.0 ± 6.8 (41–84)	778/48	3.9 ± 1.6 (2.0–9.8)

* Values are expressed as mean ± SD, with range in parentheses.

with use of a walker on the second postoperative day. The next day, they started active and passive ROM exercises under the supervision of a physical therapist twice a day during the 2-week hospitalization period.

We followed patients with clinical and radiographic reviews at 2 weeks, 6 weeks, 3 months, and 1 year after the surgery and annually thereafter. The active maximum knee flexion angles were measured using a goniometer with the patient in the supine position preoperatively and at each postoperative followup times. All patients were rated preoperatively and postoperatively at 6 weeks, 3 months, 1 year, and annually using the American Knee Society (AKS) [19], Hospital for Special Surgery (HSS) [34], and WOMAC [4] scoring systems. Plain radiographs, including full-length standing AP radiographs of the lower extremity, true-lateral view radiographs with the knee in 30° of flexion, and Merchant view radiographs, were acquired preoperatively and at each postoperative followup visits. Since 2006, we have routinely recommended CT scans to patients who consented to them at a followup visit to evaluate the postoperative rotational alignments of prostheses. In particular, patients suspected of having PCC were highly recommended to have the CT scans before surgery. We reviewed patients' clinical records and radiographs and compared possible etiologic factors of PCC between the groups. We recorded the following clinical variables: patient demographics (sex, age, BMI, followup years), design of implanted prosthesis, patellar resurfacing state, preoperative and postoperative maximum knee flexion angles, history of previous knee surgeries, and time to presentation of symptoms.

Two of us (WCC, SL), who were not treating surgeons, measured radiographs for tibiofemoral angle, patellar height, posterior femoral condylar offset, femoral component flexion angle, posterior tibial slope, patellar thickness, absolute value of patellar tilt, and joint line level. The preoperative and postoperative tibiofemoral angles were

measured using full-length standing AP radiographs. We assessed the patellar height by calculating the Insall-Salvati ratio [16] and Blackburne-Peel ratio [7] in preoperative and postoperative true-lateral view radiographs with the knee in 30° of flexion (Fig. 1). Posterior femoral condylar offset [5] (Fig. 2), femoral component flexion angle [12], and posterior tibial slope [12] were also measured from postoperative lateral views (Fig. 3). Merchant view was used to evaluate the absolute values of patellar tilt [6, 15] and patellar thickness [23] (Fig. 4). In the postoperative standing AP view, the joint line level was determined by measuring the distance between the proximal end of the fibula and the distal end of the femoral prosthesis [27] (Fig. 5). Postoperative CT scans were obtained from 201 knees (16 in the PCC group, 185 in the non-PCC group) and the absolute value of rotational deviation of the femoral component from the transepicondylar axis was measured (Fig. 6). We found interobserver reliability using intraclass correlation coefficient values ranging from 0.82 to 0.94 for the following variables: tibiofemoral angle, patellar thickness, Insall-Salvati ratio, Blackburne-Peel ratio, rotational deviation of the femoral component from the transepicondylar axis, patellar tilt, posterior femoral condylar offset, femoral component flexion angle, posterior tibial slope, and joint line level (Table 2).

All continuous variables were tested for normality using the Kolmogorov-Smirnov test. We divided the knees into two groups (PCC versus non-PCC groups) and determined intergroup differences in variables. We determined differences in variables, including sex (female/male), patellar resurfacing status, and history of previous knee surgery, between the groups using the Fisher's exact test. We determined differences in prosthesis design between the groups using the chi-square test. Differences in continuous variables that could be assumed to have normal distribution, including BMI, duration of followup, postoperative knee flexion, tibiofemoral angle, patellar thickness, Insall-Salvati ratio,

Fig. 1 A radiograph demonstrates the Insall-Salvati ratio (A/B) and Blackburne-Peel ratio (C/D).

Fig. 2 A radiograph demonstrates measurement of posterior femoral condylar offset.

Blackburne-Peel ratio, rotational deviation of the femoral component, patellar tilt, posterior femoral condylar offset, posterior tibial slope, and joint line level, between the groups were determined using Student's t-test. Intergroup difference in preoperative knee flexion angle was determined using Mann-Whitney U test since it could not be assumed to have normal distribution. Differences in knee outcome scores, including AKS knee, AKS function, HSS, and

Fig. 3A–B A radiograph demonstrates measurement of femoral component flexion (A) and posterior tibial slope (B).

Fig. 4A–B A radiograph demonstrates measurement of patellar tilt (A) and patellar thickness (B).

Fig. 5 A radiograph demonstrates measurement of joint line level.

Fig. 6 A CT image demonstrates measurement of rotation of the femoral component using the transepicondylar and posterior prosthetic axes.

WOMAC scores, before and after surgical treatment of PCC were determined by paired t-test. In addition, the differences in the knee outcome scores between PCC and non-PCC groups were compared using Student's t-test. To include the prosthesis design as a binary variable in univariate and multivariate analyses, knees were classified as PFC RP/RPF or non-PFC RP/RPF designs. Thereafter, we included all variables in the multivariate models and performed regression analysis in a stepwise manner to identify factors influencing the occurrence of PCC. All statistical analyses were performed using two-tailed tests. The statistical software MedCalc® (Version 11.6; MedCalc Software, Mariakerke, Belgium) and R (Version 2.12; Comprehensive

Table 2. Interobserver reliabilities for radiographic measurements

Measurement	ICC	95% CI
Preoperative tibiofemoral angle	0.90	0.79–0.95
Postoperative tibiofemoral angle	0.92	0.89–0.95
Preoperative patellar thickness	0.82	0.70–0.91
Postoperative patellar thickness	0.89	0.84–0.93
Preoperative Insall-Salvati ratio	0.82	0.78–0.88
Postoperative Insall-Salvati ratio	0.83	0.76–0.90
Preoperative Blackburne-Peel ratio	0.84	0.79–0.89
Postoperative Blackburne-Peel ratio	0.84	0.76–0.90
Rotational deviation of the femoral component from the transepicondylar axis	0.94	0.87–0.97
Patellar tilt	0.89	0.79–0.95
Femoral component flexion angle	0.88	0.76–0.94
Posterior femoral condylar offset	0.90	0.85–0.95
Posterior tibial slope	0.87	0.81–0.91
Joint line level	0.90	0.81–0.95

ICC = intraclass correlation coefficient.

R Archive Network, Boston, MA, USA) were used for all statistical analyses.

Results

Of the 826 TKAs reviewed, 18 knees (2.2%) underwent surgical intervention for PCC after TKA. PCC occurred in six knees (1.4%) implanted with NexGen LPS-flex, 11 knees (9.7%) with PFC RP/RPF, and one knee (1.0%) with Genesis II PS. However, PCC did not occur in the 135 and 58 knees implanted with Scorpio PS and e.motion PS, respectively. The incidence of PCC was higher ($p < 0.001$) in knees with PFC RP/RPF prostheses (11 of 113 knees, 9.7%) than in knees with non-PFC RP/RPF designs (seven of 713 knees, 1.0%).

The mean onset time for symptom was 7.4 months (range, 3–12 months) after TKA, and the mean time between the onset of symptoms and surgical treatment for PCC was 4.9 months (range, 0–13 months).

There were no differences in patient demographics and clinical or radiographic parameters between the PCC and non-PCC groups, with the exception of prosthesis design and patellar resurfacing state (Table 3). The knees with PFC RP/RPF prostheses ($p < 0.001$) and a retained patella ($p = 0.003$) had increased risks of PCC occurrence with odds ratios of 11.3 and 5.7, respectively (Table 4). McFadden's pseudo R^2 value for the multivariate regression analysis was 0.362 and R^2 values of 0.2 to 0.4 are considered satisfactory.

The symptoms were alleviated without recurrence over a mean followup of 29 months (range, 11–67 months) after operative treatment for PCC. All 18 knees underwent an

Table 3. Comparison of demographics and clinical or radiographic variables between PCC and non-PCC groups

Variable	PCC group (n = 18)	Non-PCC group (n = 808)	p value
Sex (female/male) (number of knees)	17/1	762/46	> 0.99
Age (years)	66.4 ± 5.5 (63.7–69.2)	68.1 ± 6.6 (67.6–68.6)	0.295
BMI (kg/m ²)	28.1 ± 3.7 (26.4–29.8)	26.4 ± 3.2 (26.2–26.6)	0.185
Followup (years)	3.6 ± 1.5 (2.8–4.4)	4.0 ± 1.5 (3.9–4.1)	0.284
Prosthesis design (PFC RP/RPF/non-PFC RP/RPF) (number of knees)	11/7	102/706	< 0.001
Patellar resurfacing status (retention/resurfaced) (number of knees)	4/14	56/752	0.036
History of previous knee surgery (yes /no) (number of knees)	4/14	161/647	0.955
Preoperative knee flexion (°)*	135 (130–140)	130 (130–135)	0.082
Postoperative knee flexion (°)	132.2 ± 7.3 (128.6–135.9)	128.3 ± 11.8 (127.5–129.1)	0.158
Preoperative tibiofemoral angle (°)	Varus 5.6 ± 3.5 (varus 7.4 to varus 3.9)	Varus 4.3 ± 5.1 (varus 4.7 to varus 4.0)	0.278
Postoperative tibiofemoral angle (°)	Valgus 4.4 ± 1.8 (valgus 3.5 to valgus 5.3)	Valgus 4.6 ± 2.1 (valgus 4.5 to valgus 4.8)	0.629
Preoperative patellar thickness (mm)	21.2 ± 2.2 (21.1–21.4)	20.7 ± 1.9 (19.8–21.7)	0.318
Postoperative patellar thickness (mm)	21.5 ± 2.4 (21.3–21.6)	21.3 ± 1.8 (20.4–22.2)	0.731
Preoperative Insall-Salvati ratio	1.11 ± 0.19 (1.10–1.13)	1.12 ± 0.20 (1.02–1.22)	0.812
Postoperative Insall-Salvati ratio	1.06 ± 0.14 (0.99–1.13)	1.11 ± 0.18 (1.09–1.12)	0.260
Preoperative Blackburne-Peel ratio	0.86 ± 0.25 (0.73–0.98)	0.87 ± 0.34 (0.84–0.89)	0.929
Postoperative Blackburne-Peel ratio	0.77 ± 0.17 (0.69–0.86)	0.85 ± 0.28 (0.83–0.86)	0.288
Absolute value of rotational deviation of the femoral component from the transepicondylar axis (°) [†]	1.3 ± 1.4 (0.6–2.0)	1.6 ± 1.2 (1.4–1.8)	0.514
Absolute value of patellar tilt (°)	2.3 ± 2.5 (1.1–3.6)	2.4 ± 2.2 (2.2–2.5)	0.953
Femoral component flexion angle (°)	2.1 ± 1.5 (1.4–2.9)	2.2 ± 1.8 (2.1–2.3)	0.809
Posterior femoral condylar offset (mm)	0.6 ± 3.5 (–1.1 to 2.3)	1.7 ± 3.3 (1.5–1.9)	0.178
Posterior tibial slope (°)	3.8 ± 1.4 (3.1–4.5)	3.5 ± 1.5 (3.4–3.6)	0.495
Joint line level (mm)	15.7 ± 2.1 (14.7–16.8)	16.6 ± 3.4 (16.3–16.8)	0.306

Values are expressed as mean ± SD, with 95% CI in parentheses, unless otherwise indicated; * values are expressed as median, with 95% CI in parentheses; [†] measured from postoperative CT scans of 201 knees (16 in PCC group, 185 in non-PCC group); PCC = patellar clunk or crepitation; PFC RP/RPF = Press-Fit Condylar[®] Sigma[®] Rotating Platform/Rotating Platform-Flex Knee System.

Table 4. Results of stepwise multivariate regression analysis for the development of PCC

Variable	Standardized coefficient	p value	Odds ratio	95% CI
Constant	–4.888			
Implantation of PFC RP/RPF	2.429	< 0.001	11.347	4.229–30.449
Patellar retention	1.749	0.003	5.748	1.84–17.944

PCC = patellar clunk or crepitation; PFC RP/RPF = Press-Fit Condylar[®] Sigma[®] Rotating Platform/Rotating Platform-Flex Knee System.

arthroscopic examination first. Hypertrophied synovial tissues located adjacent to the superomedial aspect of the patella were identified in 16 knees and excised arthroscopically. Open synovectomy and patellar replacement were performed to treat painful patellar clunk of two PFC

RP/RPF knees with retained patellae. Characteristically, patellar cartilage was peeled off in a fan shape and hypertrophied peripatellar synovial lining was identified. The mean ± SD AKS knee, AKS function, HSS, and WOMAC scores all showed improvement (all $p < 0.001$) after treatment (Table 5). The knee outcome scores were similar in the knees with and without PCC at last followup (Table 6).

Discussion

Painful PCC is one of the few recurrent complications related to the posterior-stabilized TKA. The characteristics of PCC, including the incidence, etiologies, onset time, and treatment outcomes, are unclear. We therefore (1) determined and compared the incidence of PCC in different contemporary

Table 5. Comparison of preoperative and latest knee scores after surgery for PCC

Score	Preoperative	Latest	p value
AKS knee score (points)	67.4 ± 12.9 (61.4–73.4)	92.5 ± 5.3 (90.1–94.9)	< 0.001
AKS function score (points)	50.5 ± 10.8 (45.5–55.5)	82.8 ± 11.1 (77.7–87.9)	< 0.001
HSS score (points)	62.1 ± 7.0 (58.9–65.3)	90.8 ± 4.5 (88.7–92.9)	< 0.001
WOMAC score (points)	32.7 ± 9.3 (27.1–38.8)	13.0 ± 8.2 (8.0–17.9)	< 0.001

Values are expressed as mean ± SD, with 95% CI in parentheses; PCC = patellar clunk or crepitation; AKS = American Knee Society; HSS = Hospital for Special Surgery.

Table 6. Comparison of the latest knee scores between PCC and non-PCC groups

Score	PCC group (n = 18)	Non-PCC group (n = 808)	p value
AKS knee score (points)	92.5 ± 5.3 (90.1–94.9)	92.2 ± 9.7 (91.5–92.9)	0.834
AKS function score (points)	82.8 ± 11.1 (77.7–87.9)	87.8 ± 11.5 (87.0–88.6)	0.207
HSS score (points)	90.8 ± 4.5 (88.7–92.9)	90.6 ± 6.7 (90.1–91.1)	0.909
WOMAC score (points)	13.0 ± 8.2 (9.2–16.8)	12.7 ± 11.3 (11.9–13.5)	0.923

Values are expressed as mean ± SD, with 95% CI in parentheses; PCC = patellar clunk or crepitation; AKS = American Knee Society; HSS = Hospital for Special Surgery.

TKA designs, (2) evaluated the time to presentation, (3) identified possible etiologic factors of PCC, and (4) determined recurrence of symptoms and change in knee scores after surgery for PCC.

Our study has certain limitations. First, we excluded patients lost before the 2-year followup (n = 68 knees) or without clinical outcome details (n = 15 knees). It is possible those patients might have had PCC and affected the study results. Second, followup duration was relatively short (mean, 3.9 years) with a minimum followup of 2 years. A higher incidence of PCC might be observed in a long-term study since late onset of PCC of up to 6 years after TKA has been reported [3, 11, 38]. Third, our findings may not be generalizable due to the low incidence of PCC combined with inadequate patient numbers. Sample size could not be determined a priori due to the retrospective nature of the study. This limits the power of the study and increases the risk of a Type II error in presuming some factors are not associated with PCC; that is, some of these factors might be associated with PCC with greater numbers of patients. However, a retrospective case study is often the most feasible method for risk factor identification and quantification in the surgical literature because randomized controlled trials are mostly not possible. In addition, a post hoc power analysis with the numbers available showed this study had an 89.8% power to detect a significant difference between groups (PCC versus non-PCC), assuming an alpha error level of confidence of 5% and prosthesis design as the primary dependent variable. Finally, the scores that specifically address the anterior knee pain after TKA were unavailable in this study. However, the knee scores used in this study are validated for evaluating TKA outcomes and

are comprised of indirect measures for examining the patellofemoral joint status.

The reported incidence of PCC varies in the literature (Table 7). Patellar clunk syndrome was considered resolved with the evolution of posterior-stabilized TKA designs [2, 8, 27, 29]. However, the PFC RP/RPF design used in this study is reportedly susceptible to PCC. Recently, high rates of patellar clunk after PFC RPF TKAs were reported: 11 of 71 TKAs (16.7%) [17] and 15 of 113 PFC RP TKAs (13.3%) [15]. Our findings of a higher incidence of PCC in the PFC RP/RPF prostheses (9.7%) than in the other four contemporary posterior-stabilized TKAs (1.0%) concur with those results. In contrast, a low incidence of patellofemoral crepitation was reported in fixed-bearing Press-Fit Condylar® Sigma® posterior-stabilized (PFC PS) TKAs (two of 135 knees, 1.5%), while 12% of PFC RP knees had crepitation [33]. Similar findings of no patellar clunk in 106 fixed-bearing PFC PS TKAs were also reported [32]. It is notable the identical femoral component is used for rotating-platform and fixed-bearing PFC Sigma® TKAs. This finding raises the possibility that using a rotating-platform bearing increases PCC occurrence in PFC Sigma® TKAs. However, Frye et al. [14], studying 244 PFC PS TKAs, found bearing type was not associated with PCC development.

Numerous clinical and radiographic variables have been proposed as etiologic factors for developing PCC (Table 8). Prosthesis design has been regarded as a major etiologic factor causing patellar clunk [1, 2, 8, 15, 22, 25, 27, 29]. We found a specific prosthesis (PFC RP/RPF) was a factor associated with PCC. Several studies have suggested certain characteristics of prosthesis design have an increased

Table 7. Reported incidences of PCC after posterior-stabilized TKA

Study	Year	Country of study subjects	Prosthesis	Bearing type	Number of knees	Number of knees with PCC (%)	Number of knees that underwent surgery due to PCC
Ip et al. [21]	2004	Hong Kong	Insall-Burstein [®] II	Fixed	80	7 (8.8%)	0 (0%)
			Anatomic Modular Knee [®]	Fixed	60	2 (3.3%)	1 (1.7%)
			Low Contact Stress [®] Rotating Platform	Mobile	106	0 (0%)	
Maloney et al. [29]	2003	USA	Insall-Burstein [®] II	Fixed	179	7 (3.9%)	5 (2.8%)
			Advance [®] Posterior Stabilized	Fixed	210	0 (0%)	
Yau et al. [39]	2003	Hong Kong	Insall-Burstein [®] II	Fixed	124	10 (8.1%)	Unidentified
			Anatomic Modular Knee [®]	Fixed	112	17 (15.2%)	
Lonner et al. [27]	2007	USA	Insall-Burstein [®] II	Fixed	150	6 (4%)	6 (4%)
			NexGen [®] Legacy [®] Posterior Stabilized	Fixed	150	0 (0%)	
Clarke et al. [8]	2006	USA	NexGen [®] Legacy [®] Posterior Stabilized	Fixed	238	0 (0%)	
Fukunaga et al. [15]	2009	Japan	Press-Fit Condylar [®] Sigma [®]	Mobile	113	15 (13.3%)	5 (4.4%)
Hamilton et al. [17]	2011	USA	Press-Fit Condylar [®] Sigma [®]	Mobile	71	2 (3.2%)	1 (1.6%)
				Mobile (flex type)	71	11 (16.7%)	2 (3.2%)
Frye et al. [14]	2012	USA	Press-Fit Condylar [®] Sigma [®]	Mobile or fixed	108	13 (12.0%)	4 (3.7%)
Ranawat et al. [33]	2006	USA	Press-Fit Condylar [®] Sigma [®]	Fixed	135	2 (1.5%)	0 (0%)
				Mobile	162	19 (12%)	2 (1%)
Pollack et al. [32]	2002	USA	Anatomic Modular Knee [®]	Fixed	212	8 (3.8%)	8 (3.8%)
			Anatomic Modular Knee [®] -Congruency [®]	Fixed	141	19 (13.5%)	19 (13.5%)
			Press-Fit Condylar [®] Sigma [®]	Fixed	106	0 (0%)	
Current study		Korea	NexGen [®] Legacy [®] Posterior Stabilized-Flex	Fixed	424	6 (1.4%)	6 (1.4%)
			Scorpio [®] Posterior Stabilized	Fixed	135	0 (0%)	
			Press-Fit Condylar [®] Sigma [®]	Mobile	113	11 (9.7%)	11 (9.7%)
			Genesis [™] II Posterior Stabilized	Fixed	96	1 (1.0%)	1 (1.0%)
			e.motion [®]	Mobile	58	0 (0%)	

PCC = patellar clunk or crepitation.

association with the development of patellar clunk, including femoral box designs with a sharp transition into the intercondylar notch [3, 28, 35] and proximally positioned or wide femoral box designs [32, 35, 36]. Fukunaga et al. [15] found the intercondylar box ratio (ratio between the length of the intercondylar box and the AP dimension of the femoral component) of the PFC RP unit was similar to those of older TKA designs with high incidences of patellar clunk and suggested the larger intercondylar box ratio of the PFC RP might be one of the reasons for the higher incidence of patellar clunk. In accordance with their results, we found the intercondylar box ratio of the PFC RP/RPF (0.85–0.87) was

higher than those of the NexGen LPS-flex, Scorpio PS, Genesis II PS, and e.motion PS (0.56–0.59, 0.52–0.59, 0.59–0.61, 0.68–0.75, respectively). In addition, Frye et al. [14] recently reported decreased incidence of PCC (from 12% to 0%) after changing the shape of the trochlear groove and intercondylar box of the PFC PS knee. These findings support the notion that the prosthesis design plays a substantial role in the development of PCC. In addition, we found knees with retained patellae were associated with a higher incidence of PCC while other variables were not. However, four cases of PCC developed in 10 PFC RP/RPF knees with retained patellae, while PCC did not occur in 50

Table 8. Factors associated with the development of PCC: comparison of published reports and current series

Study	Year	Mean followup (years)	Prosthesis design	Patellar height	Patellar tilt	Patellar thickness	Joint line level	History of previous knee surgery	Postoperative knee flexion	Patellar resurfacing status	Posterior femoral condylar offset	Component size
Ip et al. [21]	2004		S									
Maloney et al. [29]	2003	≥ 2	S									
Anderson et al. [2]	2002	1.2	S									NS
Pollack et al. [32]	2002		S	NS			NS					
Lonner et al. [27]	2007		S	NS			NS		NS			
Fukunaga et al. [15]	2009	2.3	S	NS	S							
Frye et al. [14]	2012	1.5	S	NS	S		NS		S			S
Figgie et al. [13]	1986	3.5		S			S					
Beight et al. [3]	1994	3.5		S			S					
Yau et al. [39]	2003			S			NS					
Schroer et al. [35]	2009			NS	NS				S			
Dennis et al. [10]	2011			S	NS	S	NS	S	NS		S	S
Current study		3.9	S	NS	NS	NS	NS	NS	NS	S	NS	

Unidentified or not applicable data are left blank; PCC = patellar clunk or crepitation; S = significant; NS = not significant.

non-PFC RP/RPF knees without patellar resurfacing. A similar finding was reported by Shoji and Shimozaki [36], who performed 275 TKAs using AGC® prostheses (Biomet, Inc, Warsaw, IN, USA) and reported 11 cases of patellar clunk in 192 knees without patellar resurfacing but none among the remaining 83 knees that underwent patellar resurfacing. However, in their study, no patellar clunk was encountered among 372 Y/S II TKAs (Biomet, Inc) regardless of patellar resurfacing. Based on these findings, we assume the effect of patella retention on the development of the complication may be exacerbated by the TKA design specifics. It is noteworthy all of our patients were Korean. In Asian populations, daily activities are frequently carried out

on the floor and full flexion of the knee is often necessary to perform activities such as kneeling, squatting, and sitting with both legs crossed [31, 37]. Increased postoperative knee flexion has been implicated as a risk factor of patellar clunk syndrome [14, 35], and it is possible different kinematics or demands on the patellofemoral joint unique to our study population may have resulted in the relatively high incidence of PCC in our study. In this study, there was a tendency for increased ($p = 0.158$) mean knee flexion in patients with PCC (132.2°) compared to those without PCC (128.3°).

There have been various reports on the time to presentation and the recurrence rate, pain relief, or functional improvement after treatment for PCC (Table 9). In our

Table 9. Reported treatment outcome of PCC

Study	Year	Number of knees	Onset time after TKA (months)*	Treatment method	Followup (months)*	Outcome	Number of patients with recurrences
Dajani et al. [9]	2010	15	20	Arthroscopic treatment	41 (24–75)	Improvement in AKS score	2 (13%)
Koh et al. [24]	2008	12	10.2 (3–21)	Arthroscopic treatment	13.4 (12–17)	Improvement in AKS score	0 (0%)
Maloney et al. [29]	2003	5	(3–11)	Arthroscopic treatment	Unidentified	Improvement in pain	2 (40%)
Pollack et al. [32]	2002	27	7 (2–13)	Arthroscopic treatment	Unidentified	Improvement in pain	1 (3.7%)
Lucas et al. [28]	1999	32	12 (3–47)	Arthroscopic treatment	12	Improvement in AKS score	0 (0%)
Lintner et al. [26]	1994	14	Unidentified	Arthroscopic treatment	56 (37–91)	Improvements in pain and knee ROM	1 (7%)
Ip et al. [21]	2004	9	7 (4–11)	Nonoperative treatment (8) Arthroscopic treatment (1)	57 (36–70)	50% of patients have persistent symptom after nonoperative treatment	Not applicable
Beight et al. [3]	1994	20	10	Nonoperative treatment (6) Arthroscopic treatment (11) Open débridement and patellar replacement (3)	42 (11–67)	Improvement in pain	4 (20%)
Current study		18	7.4 (3–12)	Arthroscopic treatment (11) Open débridement and patellar replacement (2)	29 (11–67)	Improvements in AKS, HSS, and WOMAC scores	0 (0%)

*Values are expressed as mean, with range in parentheses; PCC = patellar clunk or crepitation; AKS = American Knee Society; HSS = Hospital for Special Surgery.

study, all PCC occurred within 1 year of the primary TKA, which corresponded well with previous studies [21, 24, 28, 29, 35]. Furthermore, arthroscopic synovectomy and patellar replacement were both satisfactory and no recurrence occurred over an average followup of 29 months. These findings indicate PCC occurs during the early post-operative period after primary TKA and may not affect the overall outcome of TKA with the appropriate treatment. Nevertheless, a longer-term followup is warranted considering the effect of this complication on TKA survival is indistinct and a clunk has been reported to recur at 4 years after the arthroscopic treatment [3, 11, 38].

The risk of PCC has not been eliminated in contemporary posterior-stabilized knee prostheses. We found prosthesis design plays a substantial role in the development of PCC after TKA. Consideration should be given to prosthesis choice, as the intercondylar box design of certain prosthesis may trigger PCC development. Although other known

clinical or radiographic factors were not associated with PCC development in our study, those possible etiologic factors should not be overlooked since our findings may be unique to the study population or a function of our sample size. We believe the risk of PCC can be reduced or eliminated by proper surgical technique, including accurate positioning of TKA components and careful débridement of the peripatellar synovial lining.

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