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ORIGINAL PAPER

Factors affecting the choice of constrained prostheses when performing revision total knee arthroplasty

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Abstract

Purpose The purposes of the present study were to assess the levels of prosthetic constraint chosen during revision total knee arthroplasty (TKA) and to identify factors influencing the choice of a constrained prosthesis.

Methods We retrospectively reviewed data on 274 revision TKAs. The mean follow-up period after revision TKA was 7.2 years. The femorotibial angle (FTA), joint line height (JLH), and Insall–Salvati ratio (ISR) were radiographically evaluated. Factors affecting the extent of constraint chosen were evaluated in terms of age, gender, body mass index, primary diagnosis, the cause of revision TKA, the Anderson Orthopedic Research Institute (AORI) classification, and changes in the JLH and ISR.

Results Totals of 247 (90.1%), 11 (4.0%), and 9 (3.4%) knees received posteriorly stabilized prostheses, constrained condylar knees, and rotating hinge prostheses, respectively. On multivariate analysis, the cause of revision TKA including loosening and instability and the changes in the JLH and ISR affected independently the choice of a constrained prosthesis.

Conclusions The frequency of implantation of constrained prostheses was 7.4% in the present study. Consideration of various factors including the cause of revision TKA and changes in the JLH and ISR will aid the TKA surgeon in selecting prostheses with appropriate constraints when performing revision TKAs.

Keywords Knee · Arthroplasty · Revision · Constraint

Introduction

The goal of revision total knee arthroplasty (TKA) is to stabilize the knee joint, align the extremities, and position all components appropriately [1–3]. Joint stability may be attained after revision TKA when the remained ligaments are balanced, and when constrained prostheses are placed as necessary [4–6]. Various levels of prosthetic constraint are required to achieve these goals. One example of a modern, linked constrained prosthesis is the rotating hinge (RH), and an example of a popular nonlinked prosthesis is the constrained condylar knee (CCK) [7, 8]. Constraint implies restriction of rotational or translational movement, increasing torque-induced stress at bone-cement and implant-cement interfaces, thus potentially increasing wear and loosening [4, 9]. The basic principle is to choose a prosthesis featuring the minimum extent of constraint necessary to deal with the instability. Only a few studies have explored how often constrained prostheses are required when performing revision TKAs [10–14]. In one study of 125 revision TKAs, 34% (42 knees) received a posteriorly stabilized (PS) prosthesis, 63% (79 knees) received CCKs, and 3% (4 knees) received RH prostheses [14]. In another study of 365 revision TKAs, 82% received unconstrained prostheses, 10% required CCKs, and 8% RH prostheses [10].

If surgeons seek to prepare for every prostheses varying in constraint level for each patient, a severe burden would be placed on the operative team and surgical efficiency would be compromised [10]. It would be useful to predict and prepare an appropriately constrained prosthesis, prior to performing revision TKA.

The clinical results according to constraint level required during revision TKA remains controversial. Hass et al. [11] and Hwang et al. [15] reported that clinical outcomes using PS prostheses were better when those using constrained

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prostheses were used. However, Worhacz et al. [16] and Shen et al. [3] found that the clinical results were poor when unconstrained prostheses were used.

To our knowledge, no previous study has sought to precisely define factors influencing the extent of constraint required for pre-operative preparations of revision TKA.

The purpose of our present study was to determine how frequently constrained prostheses were placed during revision TKA, and to compare the clinical and radiographic results of those in whom less-constrained and constrained prostheses were placed. Also, we sought to define factors that could affect the selection of constrained prostheses. We hypothesized that certain factors could influence the frequency of choice of constrained prostheses.

Materials and methods

Materials

We retrospectively reviewed data on 274 revision TKAs performed on 239 patients between 1990 and 2014. Two different prostheses (the P.F.C.®/Press Fit Condylar prosthesis; Depuy; Johnson & Johnson, Warsaw, IN, USA, and the NexGen® prosthesis; Zimmer Biomet, Warsaw, USA) were placed. The P.F.C.® prostheses were placed in 263 knees (7 cruciate retaining (CR), 247 posterior stabilized (PS), 9 constrained condylar knee (CCK)), and the NexGen® prostheses were placed in 11 knees (2 Legacy® CCK (LCCK) and 9 rotating hinge (RH)). The study was approved by our institutional review board (authority KHUHMDIRB 1111-02). Nineteen patients (24 knees) were lost to follow-up within two post-operative years. The inclusion criterion was performance of revision TKA using either of the two prostheses mentioned above. Exclusion criteria were exchange of only the polyethylene insert or revision of only the patellar component. Data from all 274 knees were used to analyze factors affecting the chosen extent of constraint, and data from 250 knees were used to evaluate the clinical and radiological results.

The average patient age at the time of revision surgery was 66.7 years (range, 31–86 years). In terms of gender, 217 patients were female and 22 male. A total of 140 knees were right-sided; 134 knees were left-sided. The average body mass index (BMI) was 26.1 kg/m^2 (range, 17.6–34.6 kg/m^2). The mean interval between primary and revision TKA was 10.6 years (range, 0.1–27.6 years). The mean follow-up period after revision TKA was 7.2 years (range, 2.0–26.3 years). The mean follow-up period after revision TKA was 7.0 years (range, 2.0–24.0 years) in the less-constrained group and 7.4 years (range, 2.0–26.3 years) in the constrained group.

Diagnoses triggering primary TKA were degenerative osteoarthritis (219 knees, 79.9%), rheumatoid arthritis (29 knees, 10.6%), postinfectious arthritis (15 knees, 5.5%), haemophilic arthritis (5 knees, 1.8%), a Charcot joint (4 knees, 1.5%), and osteonecrosis (2 knees, 0.7%). The causes of revision TKA included polyethylene wear and osteolysis (199 knees, 72.6%), loosening (19 knees, 6.9%), infection (27 knees, 9.9%), instability (7 knees, 2.6%), stiffness (2 knees, 0.7%), and periprosthetic fractures (20 knees, 7.3%).

Using the Anderson Orthopedic Research Institute (AORI) classification, 151 knees had bone defects of grades greater than F2 or T2; 123 knees were of grades F1 and T1.

Methods

Evaluation of the extents of constraint

The extent of constraint was recorded on operative records; all patients were divided into a less-constrained and a constrained group. The former group included knees in which CR or PS prostheses were placed during revision TKA. The constrained group included knees in which CCK or RH prostheses were placed (Table 1).

Clinical evaluation

The Knee Society knee and function scores [13] and the Western Ontario and McMaster Universities Osteoarthritis (WOMAC) score [14] were used to evaluate pain and function both pre-operatively and at the last follow-up; data were compared using paired *t* tests. Flexion contracture, further flexion, and range of motion (ROM) of the knee were measured using a long-armed goniometer.

Radiographic evaluation

Serial pre-operative and post-operative anteroposterior and lateral radiographs, and orthoroentgenograms, were used to assess limb alignment. Measurements were made on these images using a picture-acquiring communication system (PACS) (INFINITT, Seoul, Korea). The femorotibial angle (FTA) is defined as the angle between the femoral and tibial intramedullary axes. The joint line height (JLH) was measured from the fibular head on the anteroposterior view of the standing X-ray (Fig. 1) [13, 15]. The Insall–Salvati ratio (ISR) (the ratio of the length of the patellar tendon to the length of the patella on a lateral X-ray) was also measured (Fig. 2) [17].

Statistical analysis

The knee and function scores, the WOMAC score, and the ROM, calculated pre-operatively and at the last follow-up, were compared between those with constrained and less-constrained prostheses (Student's *t* test). The FTA, JLH, ISR, and changes therein were also compared between the two groups (Student's *t* test).

Table 1 Demographic data on patients between less-constrained and constrained groups

Group	Less constrained	Constrained	*p* value
Number of knees	254	20	
Number of patients	221	18	
CR/PS/CCK/RH[a]	7/247/0/0	0/0/11/9	
Age (years)	66.7 ± 10.3 (31–86)	65.3 ± 10.1 (47–83)	0.525
Female/male	200/21	17/1	0.605
Right/left	130/124	10/10	0.919
Body mass index (kg/m^2)	26.2 ± 3.5 (17.6–34.6)	26.4 ± 4.1 (20.2–33.8)	0.695
Follow-up period (years)	7.0 ± 4.4	7.4 ± 8.5	0.135

[a] CR/PS/CCK/RH: the types of prostheses placed, including those restraining and substituting for the posterior cruciate ligament and constraining the condylar and rotation hinges

To reduce observational bias, all radiographic measurements were performed by two independent investigators. The intra-observer and inter-observer reliabilities of all measurements were assessed by calculating intraclass correlation coefficients (ICCs). The ICCs for all intra-observer and inter-observer reliabilities were > 0.8. All statistical analyses were performed using SPSS software (ver. 20.0; SPSS, Inc., Chicago, IL, USA); $p < 0.05$ was considered to indicate statistical significance.

Factors affecting the level of constraint

We explored whether age, gender, BMI, the diagnosis at the time of primary TKA, the cause of revision TKA, the Anderson Orthopedic Research Institute (AORI) classification [18], and changes in the JLH and ISR influenced the choice of constrained prostheses.

Continuous variables, including age and BMI, were compared between the less-constrained and constrained groups (Student's *t* test). Noncontinuous variables (gender, primary diagnosis, the cause of revision TKA, and AORI classification) were compared using the chi-squared (χ^2) test. Changes in the JLH and ISR were also compared between the two groups (Student's *t* test). All variables were subjected to linear regression analysis and multivariable regression modeling to identify factors independently influencing the use of constrained prostheses in revision TKAs.

Surgical technique

Tourniquets were applied to all knees. The prior midline skin incision was used; a medial parapatellar approach was adapted. The basic principles of revision TKA were followed in terms of restoration of limb alignment, soft tissue balancing, antibiotic prophylaxis, cementation, and rehabilitation. However, various surgical strategies were required to manage bone defects. Appropriate thickness of metal augmentation was performed when necessary. A total of 235 knees (85.8%) received prostheses with long extended stems, 191 (69.7%) prostheses with both femoral and tibial stems, 24 (8.8%) only tibial stems, and 20 knees (7.3%) only femoral stems. In terms of cementation to ensure stem fixation, we used the fully cemented technique on 115 knees, the hybrid cemented technique on 101, and the uncemented technique on 19. The latter technique used cement fixation of only the cut surface. A total of 100 knees (36.5%) received bulk allografts

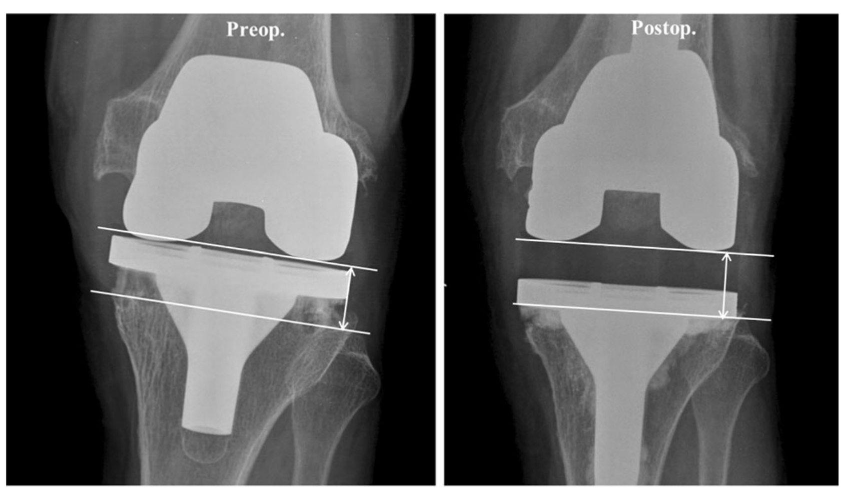

Fig. 1 Joint line height (JLH) was measured from the fibular head on the anteroposterior view of a standing X-ray, with the knee in a fully extended neutral position. The JLHs were similar both pre-revision and post-revision total knee arthroplasty (TKA)

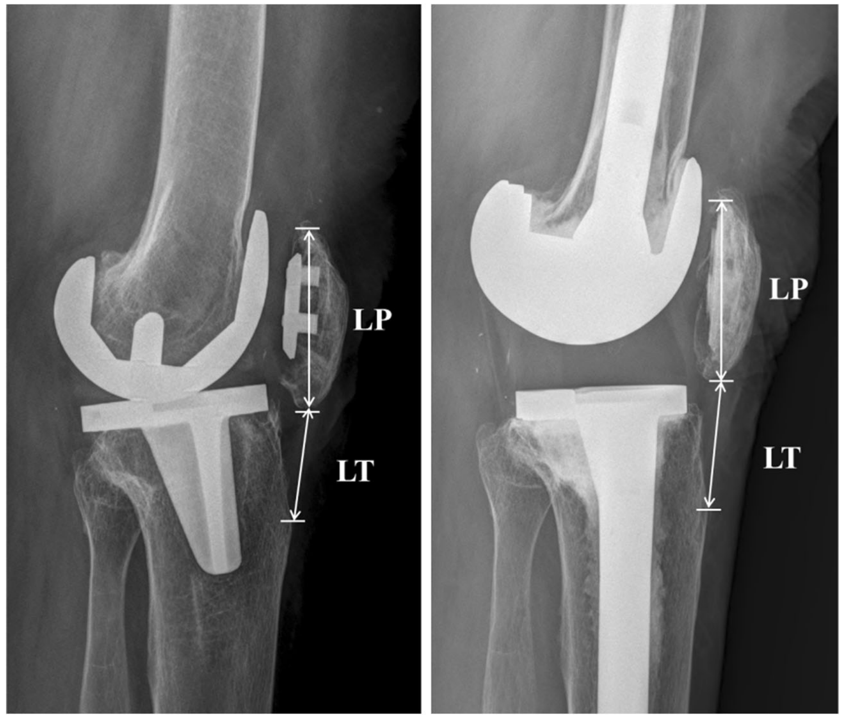

Fig. 2 Insall–Salvati ratio (ISR) from a lateral X-ray. The ISR is the ratio of the length of the patellar tendon to the length of the patella (denoted by LT/LP)

to deal with bone defects. Thirty-eight knees received allografts in the proximal tibia, 28 allografts in the distal femur, and 34 allografts in both the proximal tibia and distal femur.

Four levels of constraint (associated with the CR, PS, CCK, and RH prostheses) were applied; the two senior surgeons made their decisions intra-operatively. The prerequisites for use of a CR prosthesis were an intact posterior cruciate ligament (PCL), balanced collateral ligaments, and equal flexion and extension gaps. The PS prosthesis was used in patients with well-balanced flexion and extension gaps, good mediolateral stability, and intact collateral ligaments. A CCK was considered in cases lacking sufficient mediolateral stability, or with flexion-extension gap mismatches that might predispose to cam dissociation of a standard PS insert. RH prostheses were placed in a minority of cases in whom the isolated medial collateral ligament or lateral collateral ligament was completely inadequate, or in cases with genu recurvatum. More-constrained prostheses were considered only when less-constrained prostheses were not suitable.

Results

Constraint levels

Of the 274 knees of the present study, seven (2.5%), 247 (90.1%), 11 (4.0%), and nine (3.4%) received CR, PS, CCK, and RH prostheses, respectively (Figs. 3 and 4). The 20 knees that received CCK and RH prostheses were considered to be constrained.

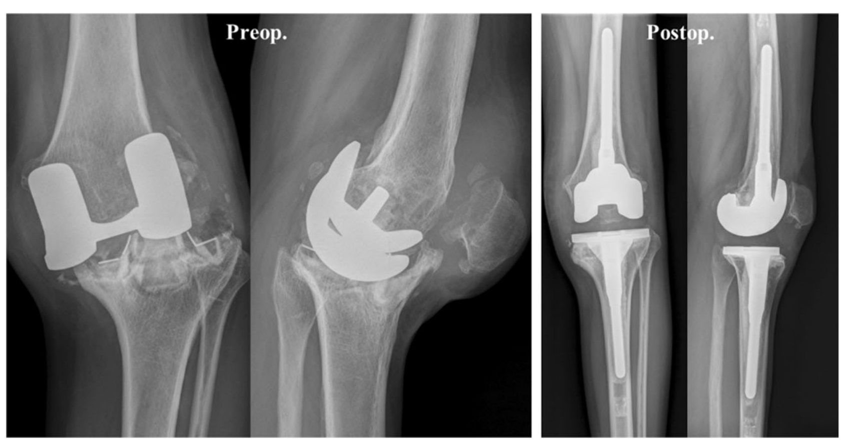

Fig. 3 Polyethylene insert wear, osteolysis, and loosening of the tibial component evident after TKA. The tibial bone defect was graded AORI T2B. Revision TKA was performed using a posteriorly stabilized prosthesis. Both autogenous and allogenous bone grafts were placed at the site of the bone defect in the tibia

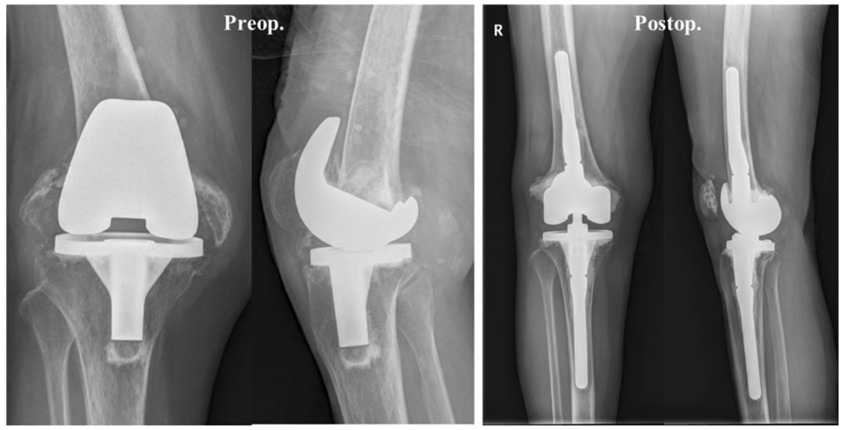

Fig. 4 Loosening after TKA, combined with a severe femoral bone defect of grade AORI F3. Revision TKA was performed using a constrained condylar knee prosthesis. Strut bone grafts were placed at both femoral condyles using allogenous femoral heads

Clinical results

In the less-constrained group, the average knee score increased from 49.8 to 90.9 at the last follow-up, and the average function score from 38.5 to 91.6 ($p < 0.001$) (Table 2). The average WOMAC score was 55.3 pre-operatively and 16.4 at the last follow-up ($p < 0.001$). The pre-operative ROM averaged 108.3° and increased to 115.1° at the last follow-up ($p < 0.001$).

In the constrained group, the average knee score increased from 44.2 to 86.0 at the final follow-up, whereas the average function score increased from 32.6 to 83.3 ($p < 0.001$) (Table 2). The average WOMAC score was 58.2 pre-operatively and 21.9 at the last follow-up ($p < 0.001$). The pre-operative ROM averaged 96.9° and increased to 109.5° at the last follow-up ($p < 0.001$).

The clinical score and ROM at the last follow-up after revision TKA were better in the less-constrained group, but there was no significant difference in the change of any knee or function score, the WOMAC score, or the ROM, between the two groups (Table 2).

Radiographic results

The average pre-operative FTAs were 0.7° varus and 1.0° varus in the less-constrained and constrained groups, respectively ($p = 0.871$) (Table 3). The average post-operative FTA was 4.6° valgus in the less-constrained group and 6.3° valgus in the constrained group ($p = 0.358$). The JLH at the last follow-up was 20.8 mm in the less-constrained group and 23.1 mm in the constrained group (Table 3). The ISRs at the last follow-up were 1.16 and 1.30 in the less-constrained and constrained groups, respectively (Table 3). The changes in JLH and ISR differed significantly between the two groups ($p < 0.001$, $p = 0.009$) (Table 3).

Table 2 Clinical results between less-constrained and constrained groups

		Less constrained	Constrained	p value
Knee score	Pre-operative	49.8 ± 7.5	44.2 ± 14.6	0.158
	Last follow-up	90.9 ± 4.9	86.0 ± 6.6	0.018
	Change	41.1 ± 7.0	41.5 ± 10.7	0.900
Function score	Pre-operative	38.5 ± 11.0	32.6 ± 13.3	0.154
	Last follow-up	91.6 ± 5.2	83.3 ± 5.4	< 0.001
	Change	53.1 ± 12.2	50.3 ± 17.1	0.459
WOMAC	Pre-operative	55.3 ± 8.8	58.2 ± 11.1	0.174
	Last follow-up	16.4 ± 6.6	21.9 ± 8.7	0.008
	Change	−38.9 ± 9.5	−38.2 ± 14.7	0.824
Flexion contracture (°)	Pre-operative	2.8 ± 8.8	1.6 ± 4.1	0.545
	Last follow-up	0.9 ± 3.2	1.3 ± 2.2	0.624
Further flexion (°)	Pre-operative	104.3 ± 31.1	98.2 ± 35.2	0.414
	Last follow-up	116.0 ± 19.3	109.8 ± 17.1	0.160
Range of motion (°)	Pre-operative	108.3 ± 33.0	96.9 ± 37.8	0.538
	Last follow-up	115.1 ± 20.3	109.5 ± 17.1	0.248
	Change	13.2 ± 30.8	18.0 ± 39.9	0.567

Table 3 Radiographic results between less-constrained and constrained groups

		Less constrained	Constrained	p value
Femorotibial angle (°)	Pre-operative	Varus 0.7 ± 7.4	Varus 1.0 ± 5.3	0.871
	Post-operative	Valgus 4.6 ± 3.9	Valgus 6.3 ± 3.3	0.358
	Change	6.0 ± 8.1	7.0 ± 3.4	0.123
Joint line height (mm)	Pre-operative	16.2 ± 6.3	13.3 ± 6.6	0.158
	Post-operative	20.8 ± 6.1	23.1 ± 3.2	0.093
	Change	4.6 ± 5.0	8.9 ± 2.7	< 0.001
Insall–Salvati ratio	Pre-operative	1.10 ± 0.27	1.0 ± 0.19	0.402
	Post-operative	1.16 ± 0.26	1.30 ± 0.12	0.130
	Change	0.07 ± 0.20	0.28 ± 0.20	0.009

Factors affecting the choice of constrained prostheses

We found no significant difference in age, gender, or BMI between the less-constrained and constrained groups (Table 1). We found a significant between-group difference in terms of the diagnosis prior to primary TKA (Table 4). TKA using constrained prosthesis was more frequently performed in patients with primary diagnosis of rheumatoid arthritis and Charcot joint (Table 4). The odds ratio of a Charcot joint in the constrained group was 32.715, when comparing to the osteoarthritis ($p = 0.006$). We found a significant between-group difference in terms of the cause of revision TKA (Table 5). The odds ratios of aseptic loosening, prosthetic joint infection, and instability in the constrained group were 12.186, 7.634, and 11.681, respectively ($p = 0.004$, 0.014, and 0.017, respectively). We found a significant between-group difference in terms of the AORI classification (Table 6). The odds ratios of F2 and F3 bone defects in the constrained group were 4.472 and 10.276, respectively ($p =$ 0.047 and 0.020, respectively). The odds ratio of change in the JLH for the constrained group was 1.169 ($p = 0.021$). The odds ratio for change in the ISR was 61.318 for the constrained group ($p = 0.017$).

On multivariate analysis, the cause of revision TKA, and the changes in JLH and ISR, independently predicted the choice of a constrained prosthesis ($p = 0.008$, 0.021, and 0.017, respectively) (Table 7).

Discussion

The most important finding was that the frequency of use of constrained prostheses was considerably lower than reported by others [3, 14, 19] but in line with that of another study [20]. We consider it crucial to restore the original joint line via augmentation of the various bone defects, and to ensure accurate rotation of an appropriately sized femoral component, without unnecessary release of contracted soft tissue or unnecessary placement of over-thick polyethylene inserts or constrained prostheses.

Increased articular constraint would theoretically increase load transmission to the component bone interface, which is associated with risks of early loosening and poor survival. The polyethylene post of the CCK prosthesis is intimately associated with the housing of the femoral component. This places considerable stress on the post and can trigger wear, fracture, or both [9, 21, 22]. Therefore, use of the least-constrained prosthesis possible is advised [8, 23]. Appropriate selection of an adequate constraint level during revision TKA is

Table 4 Numbers of knees of primary diagnosis between less-constrained and constrained groups

	Less constrained	Constrained	Frequency of use of constrained prostheses (%)
Degenerative osteoarthritis	205	14	6.4
Rheumatoid arthritis	25	4	13.8
Post-infectious arthritis	15	0	0
Hemophilia	5	0	0
Charcot joint	2	2	50
Osteonecrosis	2	0	0
			$P = 0.012$

Table 5 Numbers of knees of cause of revision between less-constrained and constrained groups

	Less constrained	Constrained	Frequency of use of constrained prostheses (%)
Wear/osteolysis	190	9	4.5
Aseptic loosening	16	3	15.8
Infection	24	3	11.1
Instability	5	2	28.6
Stiffness	2	0	0
Periprosthetic fracture	17	3	15.0
			$P = 0.043$

Table 6 Numbers of knees of AORI classification between less-constrained and constrained groups

	AORI classification	Less constrained	Constrained	Frequency of use of constrained prostheses (%)
Femur	1	112	3	2.6
	2	110	12	9.8
	3	32	5	13.5
Tibia	1	117	5	4.1
	2	114	12	9.5
	3	23	3	11.5
				$P = 0.036$

important to avoid instability, to increase component survival, and to avoid the risk of aseptic loosening.

The effects of different levels of constraint in terms of knee stability after revision TKA remain controversial. Hossain et al. [12] reported that various prostheses exhibiting incremental degrees of constraint afforded acceptable results that were remarkably similar in terms of functional outcome, ROM, and overall patient satisfaction. Other authors have also reported similar results [15, 19]. However, Haas et al. [11] found that the clinical outcomes of a PS group were better than those of a constrained group. Their pre-operative status of patients undergoing revision TKA with placement of prostheses of various constraint levels differed. Thus, both selection bias and the limitations inherent in a clinical study rendered it difficult to directly compare the outcomes afforded using prostheses with various levels of constraint. A comparative study on prostheses with different levels of constraint placed in patients with varying extents of bone defects showed that the PS prosthesis afforded superior knee scores in patients with AORI type 1 bone defects; an ultracongruent prosthesis was best for patients with type 2 and 3 aseptic loosening, and a hinge prosthesis was optimal for those with septic type 2 or 3 defects [3].

Few previous studies have sought to identify preoperative factors that might help surgeons choose appropriately constrained prostheses during revision TKA. The extent of constraint required depends on the state of the peripheral knee stabilizers (including the collateral ligaments) and the severity of bone loss [19]. In the present study, constrained prostheses were favoured when the diagnosis at the time of primary TKA was a Charcot joint; when the cause of revision TKA was loosening, infection, or instability; when the femoral bone defect was of type 2 or 3 according to the AORI classification; and when changes in the JLH and ISR were marked.

The technical challenges encountered during primary TKA of a Charcot joint happen to be repeated during revision TKA, including the need to augment bone defects, a requirement for meticulous cementation, and the need to balance soft tissue. Because these challenges may be aggravated during revision TKA, these problems must be solved more properly against a background of severe joint destruction, massive bone loss, and overstretched soft tissue. This explains why constrained prostheses were often used (in 50% of patients) upon revision TKA of Charcot joints. When the cause of revision TKA was loosening, major problems can be posed by the combination of gradual loss of soft tissue tone and bone defects (Fig. 5). This explains why constrained prostheses were often placed in such patients (odds ratio, 12.186) during revision TKA [24]. In the present study, infection also increased the use of constrained prostheses. Lau et al. [13] found that coronal subluxation of the articulating antibiotic spacer was associated with an increased need for constrained prostheses during second-stage revision TKAs treating prosthetic joint infections. They placed PSs in 69.4% of patients, CCKs in 26.4%, and RHs in 4.2%.

A recent report found that PS prostheses afforded superior knee scores in knees of AORI type I. Placement of CCK prostheses improved the WOMAC scores of aseptic AORI type 2 and 3 knees, and placement of RH prostheses improved the scores of septic AORI type 2 and 3 knees [3]. Although the severity of a bone defect influenced the choice of constraint, it is not immediately apparent why this should be so. Bone loss adds to the complexity of soft tissue balancing during revision TKA [13]. In patients with severe bone defects (AORI type 3), both the origin and insertion points of the medial and/or lateral collateral ligaments may be absent (associated with bone loss). Such deficiencies create gross instability; the patients may require RH prostheses. Many strategies (metal augmentation, allografting, placement of tantalum cones, and insertion of modular stems) can be used to treat bone defects discovered during revision TKA. Such a defect in the tibial metaphysis

Table 7 Comparison of various factors using multiple regression analysis between less-constrained and constrained groups ($R^2 = 0.215$)

	Exp (β)	95% confidence interval	Standard error	p value
Primary diagnosis	1.335	0.864 to 2.063	0.222	0.193
Cause of revision	1.466	1.107 to 1.940	0.143	0.008
AORI (femur)	1.909	0.774 to 4.709	0.461	0.160
AORI (tibia)	1.883	0.699 to 5.073	0.506	0.211
Change of joint line height	1.169	1.024 to 1.335	0.068	0.021
Change of Insall–Salvati ratio	61.318	2.089 to 180.139	1.724	0.017

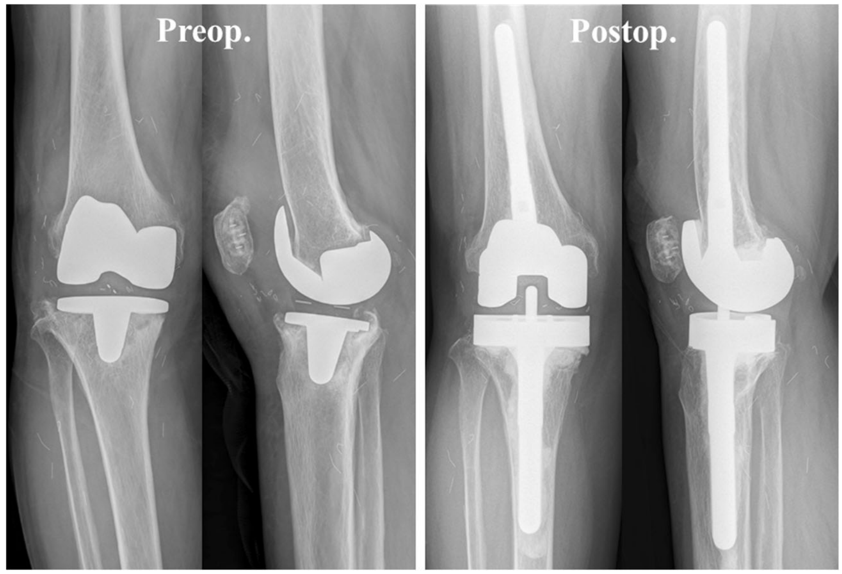

Fig. 5 Loosening of tibial component after TKA with the combined instability. The femoral and tibial bone defect was graded AORI F2BT2B and managed with metal augmentations. However, a constrained condylar knee prosthesis was required in spite of appropriate management for bone defect

affects both the flexion and extension gaps. Appropriate augmentation renders it possible to not increase the constraint level unnecessarily. Our multiple regression analysis showed that a bone defect itself did not directly affect the constraint level chosen during revision TKA (Table 7). Any bone defect evident during revision TKA must be first corrected by bone grafting or metal augmentation, and any persistent laxity only then subjected to prosthetic constraint.

We found that changes in the JLH and ISR independently affected the extent of prosthetic constraint required. It might be thought that a constrained prosthesis is appropriate when the JLH is elevated and relative mediolateral instability is evident only in extension (Fig. 4). On the other hand, an exceptionally large flexion gap would require placement of a thick polyethylene insert, elevating the JLH from the fibular head or tibial tuberosity. Changes in the JLH could be either cause or result of instability after revision TKA (Fig. 6), but we could not distinguish them in the present retrospective study. In most revision situations, bone loss is apparent in both the distal and posterior aspects of the femur. This may be caused by component removal, movement of a loose implant, or osteolysis [10]. Appropriate distal positioning of the femoral component, together with metal or allograft augmentation, is required to restore the joint line if distal bone loss has occurred. If not, the joint line can be elevated after revision TKAs. Global instability or genu recurvatum can be properly treated by using a constrained prosthesis; the patellar height may increase post-operatively (Fig. 7). It is practically

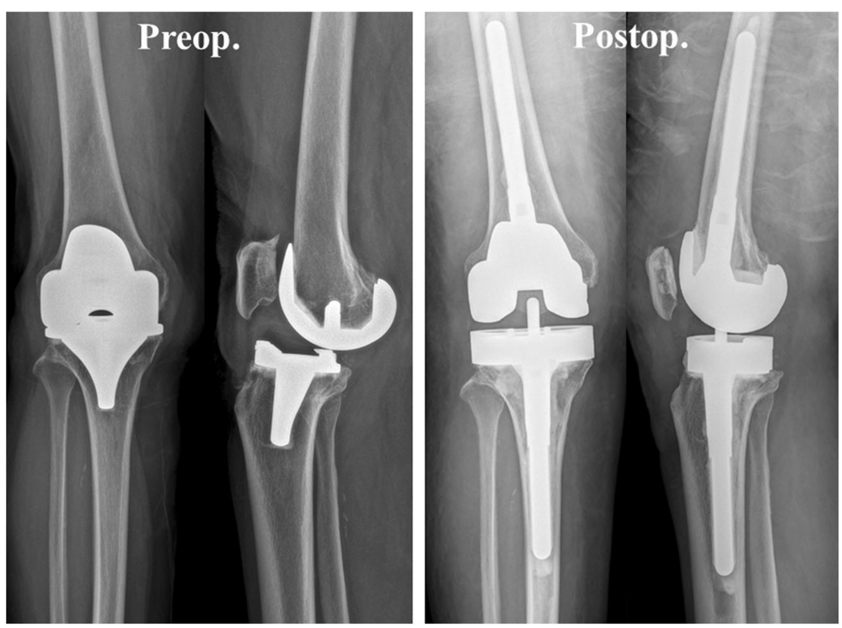

Fig. 6 Instability after cruciate retaining TKA. Revision TKA was performed with a constrained condylar knee prosthesis due to remained medio-lateral instability in spite of achieving flexion stability with the appropriate metal augmentation

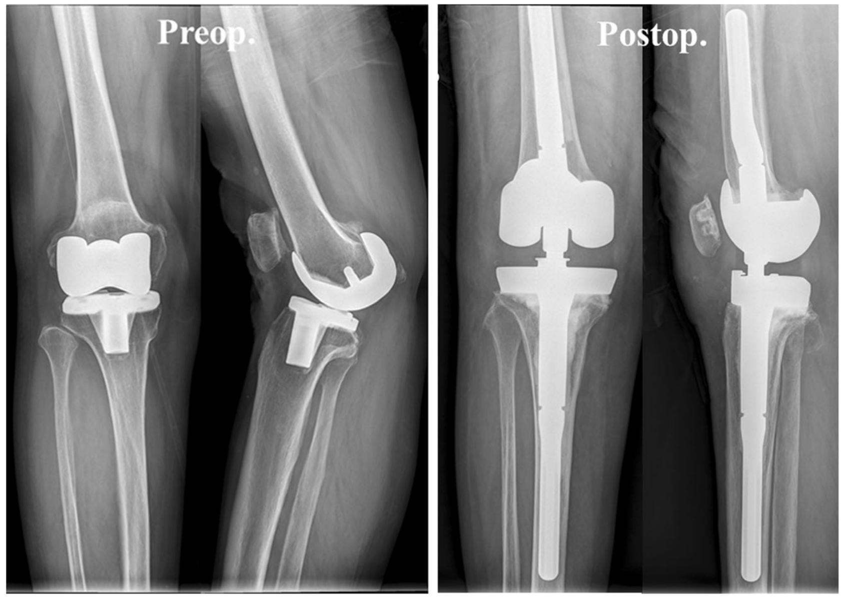

Fig. 7 Global instability after posterior stabilized TKA. The patient had experienced the quadriceps muscle weakness and genu recurvatum. Revision TKA was performed with a rotating hinge knee prosthesis. Insall–Salvati ratio increased from 0.79 to 1.08 post-operatively

impossible to achieve stability in severe unstable TKA with PS prosthesis which only substitutes for the posterior cruciate ligament [25]. Prudhon et al. [26] reported that TKA showing increase of patellar height seems to have lower functional results when using PS prosthesis. Boelch et al. [27] reported that rotating hinge prostheses provide significant improvement in pain and function scores at post-operative 12-month follow-up in 51 revision TKAs for gross instability.

Vasso et al. [19] devised a simple algorithm allowing the extent of constraint of a revision implant to be calculated by reference to the state of the ligaments and bone defects. PS prostheses were chosen for knees with intact ligaments and bone defects of AORI type 1; CCK prostheses were selected for knees with inadequate ligaments and type 2 defects, and RH prostheses were used for knees in which the ligaments were absent or disrupted and that also exhibited a type 2 or 3 bone defect. However, many factors affect the balance between the mediolateral and flexion/extension gaps during revision TKA; all must be considered. The clinical relevance of our present study is that we show that various factors, apart from the state of the collateral ligaments and bone defects, could affect the selection of a prosthesis for revision TKA. Consideration of such factors should ensure stable knee reconstruction, thus helping the revision TKA surgeon to select a prosthesis that applies an appropriate degree of constraint.

The principal limitation of our present study is the retrospective nature of the work; we studied a nonrandomized, consecutive case series. We focused primarily on the frequency of placement of constrained prostheses, exploring various factors potentially influencing the choice of the extent of constraint. Understandably, other factors will also be in play, including component size and position. However, not all possible variables can be controlled in clinical settings such as ours. A more sophisticated, randomized prospective study is required. Another limitation was that most patients were females of low BMI. A combination of osteoarthritis and low BMI is common in Korean females [28]. This means that caution must be exercised when seeking to extrapolate our findings to other populations.

Conclusion

The frequency of placement of constrained prostheses (CCKs and RHs) was 7.4% in the present study. Surgeons should not automatically choose a constrained prosthesis when revision TKA is planned. The need for a constrained prosthesis increases when the cause of revision is loosening, infection, or instability and when changes in the JLH or the ISR are greater than in other patients. Consideration of such factors will assist the revision TKA surgeon in selecting the prosthesis that applies the appropriate extent of constraint.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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