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Comparison of Survival Rate between Posterior-Stabilized and Constrained Condylar Articulations in Revision Total Knee Arthroplasty: A Minimum 5-Year Follow-up Analysis

Woo-Kyoung Kwak, MD, Jong-Keun Seon, MD

Department of Orthopedic Surgery, Chonnam National University Hospital, Chonnam National University Medical School, Hwasun, Korea

Background: Revision total knee arthroplasty (RTKA) is a technically demanding procedure for failed primary TKA. Posterior-stabilized (PS) and constrained condylar knee (CCK) articulations are commonly used for RTKA, but comparison of these articulations in RTKA is scarce. The aim of this study was to compare survival rates and clinical outcomes of RTKAs using PS articulation and CCK articulation.

Methods: This study conducted a retrospective analysis of 86 RTKAs (PS, n = 41; CCK, n = 45) with a mean follow-up of 9.15 ± 2.79 years. Clinical outcomes were evaluated using the Hospital for Special Surgery score, Knee Society Score, and The Western Ontario and McMaster Universities Osteoarthritis Index at final follow-up. The survival rate of each group was analyzed by Kaplan-Meier survival analysis and Cox-hazard progression model.

Results: Clinical outcomes were improved in both groups without significant difference. Twelve patients had orthopedic complications (4 in PS group and 8 in CCK group). Eight of them underwent re-RTKA (3 in PS group and 5 in CCK group). The articulation design did not influence the failure. The estimated 10-year survival rate was 92.7% in the PS group and 88.2% in the CCK group with no significant difference (p = 0.60). Also in septic failure, there was no significant difference in survival rate (92.7% in PS group and 92.5% in CCK group, p = 0.87). The hazard ratio in the PS group was not significantly different (p = 0.607).

Conclusions: In RTKA, both PS and CCK showed similar survival rates and clinical outcomes at a mean follow-up of 9.2 years. Implant articulation did not affect the outcomes when properly indicated.

Keywords: *Arthroplasty, Replacement, Knee, Reoperation, Survival rate, Prosthesis design*

Knee osteoarthritis is a common cause of disability due to pain and limitations in mobility in the older population.[1] Total knee arthroplasty (TKA), which is aimed at relieving pain and improving joint function and mobility, is the main surgical alternative in this patient population.[2] The survivorship of TKA exceeds 90% in the second decade.[3] However, TKA has many complications such as infection, loosening, periprosthetic fracture, osteolysis, and polyethylene (PE) wear. In these cases, revision TKA (RTKA), a technically challenging procedure, is performed.[4]

As the number of TKAs in South Korea continues to increase, so does the number of RTKAs.[5] Posterior-stabilized (PS) and constrained condylar knee (CCK) articulations are commonly used for RTKA. The decision to use either PS or CCK articulation in RTKA has traditionally been based on surgeon's preference and knee stability.[6,7] In PS articulation, a cam is used on the femur to engage to

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Correspondence to: Jong-Keun Seon, MD
Department of Orthopedic Surgery, Chonnam National University Hospital, Chonnam National University Medical School, 42 Jebong-ro, Dong-gu, Gwangju 61469, Korea
Tel: +82-62-670-9475, Fax: +82-62-670-9476
E-mail: seonbell@chonnam.ac.kr

the back of the tibial post to push the femorotibial contact point posteriorly during knee flexion.[8] The CCK articulation increases the width of the post on the PE insert to partially or fully engage the femoral implant box, thereby increasing stability in the coronal plane. This mechanism is an internal brace and reduces coronal motion.[9]

RTKA may need a more constrained prosthesis design due to bony defect or residual ligament instability prior surgical intervention or implant removal during revision. So, the CCK articulation is considered the ideal choice for severe deformities resulting from ligament laxity. However, the CCK articulation has been associated with some complications such as premature component loosening, PE wear, and limited range of motion (ROM) and may also result in increased forces transmitted to the bone-cement-implant interface.[10] Hence, a less constrained prosthesis is preferred for revision TKA. Nevertheless, there are occasions where an unconstrained prosthesis such as the PS type cannot provide sufficient stability; therefore, a more constrained prosthesis is commonly needed.[11]

Despite the wide use of these two types of articulations in RTKA, information about the survival rate and clinical outcomes of patients who underwent RTKA using these articulations are not well known. An understanding of the revision articulation that results in better long-term survivorship and clinical outcomes is important to maximize patient satisfaction and quality of life. However, there are few studies that investigated this controversial issue, and these studies have short follow-up periods.[12,13] Thus, this subject should be investigated using data from longer follow-up.

In the current study, we aimed to compare survivorship and clinical outcomes of RTKA with a PS articulation and RTKA with a CCK articulation. It was hypothesized that CCK in RTKA would have more complications such as aseptic loosening and periprosthetic fracture due to mechanical characteristics of the design and survival would be lower in RTKA with a CCK articulation than in RTKA with a PS articulation.

METHODS

Patient Selection

This retrospective study received approval from the Chonnam National University Hospital Institutional Review Board (No. CNUH-2020-279) and informed consent was obtained from all patients. The clinical results of 222 RTKAs performed between March 2004 and December 2017 were reviewed. All the patients received RTKA by two senior surgeons (EKS and JKS) in a single large orthopedic department of a university hospital. The inclusion criteria were patients who underwent RTKA with a CCK articulation (LCCK; Zimmer, Warsaw, IN, USA) or a PS articulation (LPS, Zimmer). The exclusion criteria were patients with other types of prosthesis or prosthesis from other manufacturers (n = 51, triathlon, 34; rotating hinge knee, 11; and cruciate retaining, 6) and patients who were followed up for less than 5 years (n = 85) (Fig. 1).

Surgical Procedure

In all cases, a standard medial parapatellar approach was used whenever possible. Extensive approaches such as quadriceps snip and tibial tuberosity osteotomy were performed when sufficient exposure could not be accomplished with the standard medial parapatellar approach. The tibial tuberosity osteotomy was performed when there was severe restriction of flexion, patella infra, or a need to conserve quadriceps strength. Intraoperatively, the stability of knee joints was evaluated with a PS trial. When the surgeon encountered an imbalanced gap, the CCK prosthesis was chosen instead of the PS prosthesis. Instability was checked by the senior surgeons (EKS and JKS) by stressing the prosthesis with a lift-off test, varus and valgus stress after trial insertion. In the lift-off test, with the knee in flexion, the anterior tibial tray-bone interface is examined. The test is positive if the test lifts off the tibial surface anteriorly. Bone defects were managed according to the Anderson Orthopaedic Research Institute bone defect

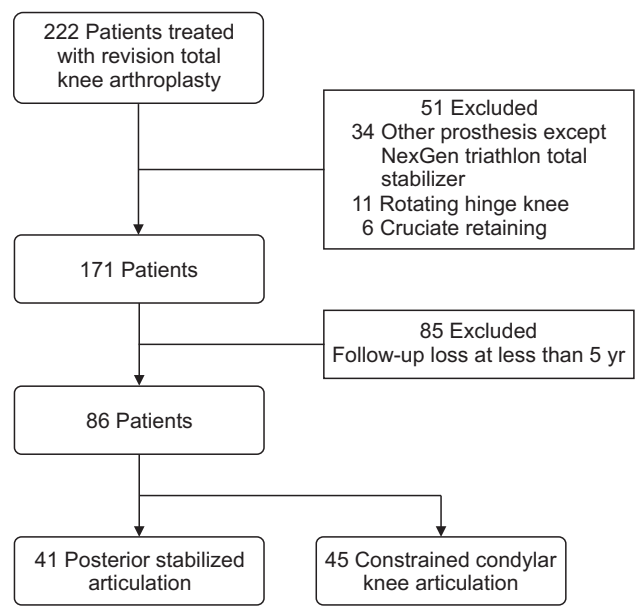

Fig. 1. Flowchart showing reasons for exclusion.

Table 1. Demographic Data (N = 86)

Variable	PS group (n = 41)	CCK group (n = 45)	*p*-value*
Age (yr)†	69.7 ± 7.6	75.0 ± 8.5	0.003
FU duration (yr)	9.7 ± 3.2 (5.33–18.16)	8.6 ± 2.2 (5.24–15.25)	0.068
Sex			1.000
Female	34 (82.9)	37 (82.2)	
Male	7 (17.1)	8 (17.8)	
Surgical limb			0.202
Right	18 (43.9)	27 (60.0)	
Left	23 (56.1)	18 (40.0)	
Reason of revision			0.096
Infection	14 (34.1)	28 (62.2)	
Aseptic loosening	16 (39.0)	8 (17.8)	
Periprosthetic fracture	2 (4.9)	2 (4.4)	
Instability	2 (4.9)	2 (4.4)	
PE problem	6 (14.6)	5 (11.1)	
Malalignment	1 (2.4)	0	
BMI (kg/m^2)	26.0 ± 3.5	25.5 ± 3.4	0.505
ASA class			0.334
1	1 (2.4)	5 (11.1)	
2	34 (82.9)	35 (77.8)	
3	6 (14.6)	5 (11.1)	
Comorbidity			
Hypertension	22 (53.7)	24 (53.3)	1.000
Diabetes mellitus	15 (36.6)	7 (15.6)	0.047
Gout	0	1 (2.2)	1.000
CKD	0	4 (8.9)	0.118
RA	3 (7.3)	1 (2.2)	0.344
DVT, PTE	1 (2.4)	0	0.477
Thyroid disease	4 (9.8)	2 (4.4)	0.418

Values are presented as mean ± standard deviation, mean ± standard deviation (range), or number (%).
PS: posterior stabilized articulation, CCK: constrained condylar knee articulation, FU: follow-up, PE: polyethylene, BMI: body mass index, ASA: American Society of Anesthesiologists Physical Status Classification, CKD: chronic kidney disease, RA: rheumatoid arthritis, DVT: deep vein thrombosis, PTE: pulmonary thromboembolism.
*The independent *t*-test was used to analyze differences in age and follow-up duration. The chi-square test was used to analyze differences in sex, surgical limb, hypertension, and diabetes mellitus. The Fisher's exact test was used to analyze differences in reason of revision, ASA class, gout, CKD, RA, DVT, PTE, and thyroid disease. A p-value < 0.05 was considered significant.

classification.[14] All infection cases underwent two-stage revisions, and the rest underwent single-stage revisions.

Clinical Outcomes

All the patients were evaluated using the Knee Society Score (KSS),[14] Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), Hospital for Special Surgery (HSS) score, and ROM preoperatively and at last follow-up. ROM assessments were conducted by senior surgeons (EKS and JKS) using a goniometer during the outpatient visits. For each measurement, the result was recorded in the outpatient medical record. Patients were considered to have attained the minimal clinically important difference (MCID) when their improvement in scores were greater than 5.4 for HSS,[15] 6.1 for KSS function,[16] and 17.0 for WOMAC.[17,18] The American Society of Anesthesiologists physical status classification system was used to assess the fitness of patients by anesthesiologists in the hospital for the prediction of anesthetic and surgical risks prior to the procedure.[19]

Comorbidities included general conditions that are considered to affect the patients' clinical functions, such as hypertension, diabetes, dyslipidemia, inflammatory arthritis (gout and rheumatoid arthritis), deep vein thrombosis, and thyroid disease. Complications included only orthopedic complications (PE wear, periprosthetic fracture, infection, etc.). The primary endpoint was re-RTKA due to implant-related complications or infection. So cases such as open reduction through plate fixation due to periprosthetic fractures were excluded from the primary endpoint analysis as further implant re-replacement was not required. When the cause of failure was infection, it was defined as septic failure, and in other cases, it was defined as aseptic failure. Instability was defined as an objective instability with pain without osteolysis, such as recurvatum, positive in a draw test. It was confirmed by physical examination before RTKA.

Statistical Analyses

All statistical tests were performed using R Project 3.6.1 (R Foundation, Vienna, Austria; http://www.R-project.org/). A p-value < 0.05 was considered to indicate statistical significance. Continuous data are presented as mean values with standard deviations. Categorical data are presented in frequency with percentage. An independent t-test was used to compare parametric continuous data, and the chi-square and Fisher exact tests were used to compare categorical data. An analysis of covariance (ANCOVA) was performed to identify the difference in the improvement of clinical outcomes between the groups.

The Kaplan-Meier survival analysis was used to estimate the 10-year survival rate in each articulation group. It was used to plot the survival rates with 95% confidence intervals, and a log-rank test was used to compare the survival curves. In addition, Cox proportional hazards regression was used to adjust for other factors that affect survival in the articulation survival analysis, such as sex, age, comorbidity, and reason for revision.

RESULTS

A total of 86 patients (41 PS and 45 CCK) with a mean age of 72 ± 8.5 years and follow-up of 9.15 ± 2.79 years (range, 5.24–18.16 years) were included in the study. Of the patients, 71 (82%) were women. At the final follow-up, 41 patients underwent RTKA with a PS articulation, while 45 underwent RTKA with a CCK articulation. No significant difference in preoperative baseline characteristics was found between the two groups, except for age and diabetes mellitus (Table 1).

There was a significant difference between the groups in the reason for RTKA, including infection, periprosthetic fracture, instability, aseptic loosening, PE problems (PE dislocation and PE wear), and malalignment (p = 0.096). Infection and aseptic loosening were the most common reasons for RTKA in the CCK group (n = 28, 62.2%) and PS group (n = 16, 39.0%), respectively (Table 1).

Of the 12 cases of complication, 4 patients (9.8%) in PS group and 8 patients (17.8%) in CCK group had orthopedic complications (Table 2). Infection was the most common complication in both groups. Three patients in PS group (infection, n = 3) and 5 patients in CCK group (infection, n = 3; aseptic loosening, n = 2) underwent re-RTKA. Regarding the 6 patients who developed infection following RTKA, the causes of the primary RTKA were infection in 5 patients (2 in PS group and 3 in CCK group)

Table 2. Complications

Event	PS group	CCK group
Infection	3 (7.3)	3 (6.7)
Aseptic loosening	0	2 (4.4)
Periprosthetic fracture	1 (2.4)	2 (4.4)
Patella tendon rupture	0	1 (2.2)
Total	4 (9.8)	8 (17.8)

Values are presented as number of knees (%).
PS: posterior-stabilized articulation, CCK: constrained condylar knee articulation.

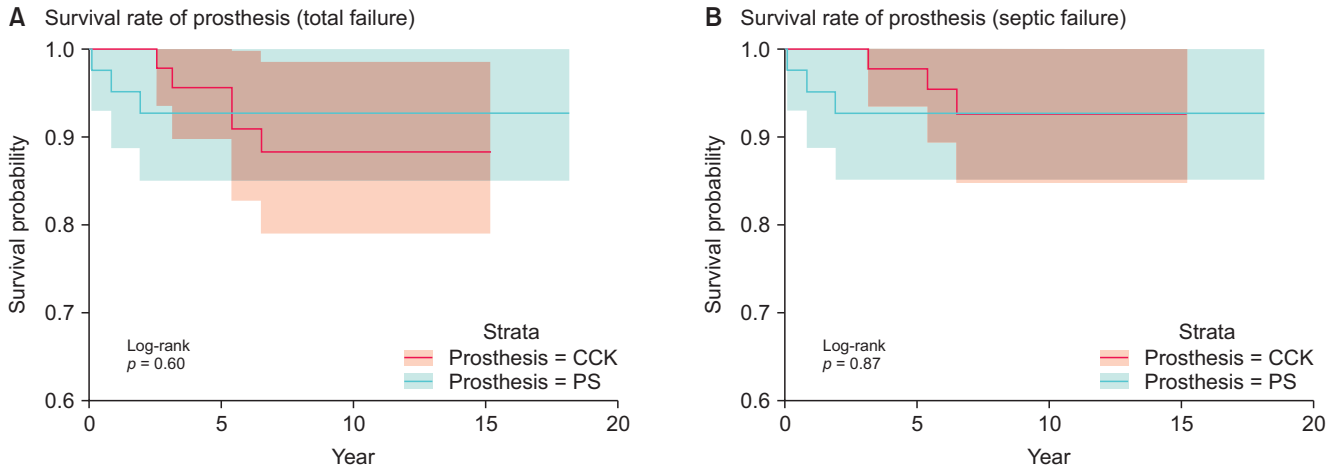

Fig. 2. Kaplan-Meier survival curve. Kaplan-Meier analysis of cumulative survival for all-cause failure of the posterior-stabilized and constrained condylar articulation. (A) Failure due to all complications. (B) Septic failure (due to infection). Colored area: upper and lower limits of 95% confidence intervals. Log-rank test was used to analyze differences in survival curve. A *p*-value < 0.05 was considered significant. CCK: constrained condylar knee articulation, PS: posterior-stabilized articulation.

Table 3. Cox Proportional Hazard Models with HR of PS to CCK

Failure	Without adjustment			With adjustment		
	HR*	95% CI	*p*-value†	HR*	95% CI	*p*-value†
Total failure	0.69	0.16–2.87	0.605	1.53	0.30–7.78	0.607
Septic failure	1.14	0.23–5.56	0.872	2.94	0.44–19.68	0.266

HR: hazard ratio, PS: posterior-stabilized articulation, CCK: constrained condylar knee articulation, CI: confidence interval.
*Age, sex, body mass index, comorbidity, and reason of revision were adjusted. †A *p*-value < 0.05 was considered significant.

and periprosthetic fracture in 1 patient (CCK group). Complications at follow-up less than 5 years were not associated with re-RTKA. There were wound dehiscence cases (2 in PS group and 3 in CCK group) and patellar tendon rupture (0 in PS group and 1 in CCK group).

The survival rates at the 10-year follow-up were 92.7% and 88.2% in the PS group and CCK group, respectively. The survival rates in septic failure were also calculated. In septic failure, the respective 10-year survival rate was 92.7% in the PS group and 92.5% in the CCK group. A log-rank test was performed to analyze the difference in survival curve between the groups and no statistically significant difference was found ($p = 0.60$ in total failure and $p = 0.87$ in septic failure) (Fig. 2). When the factors affecting the occurrence of complications such as age, sex, comorbidity, and reason for revision were corrected using the Cox proportional hazard model, a significant difference in survival rate in total or septic failure was not observed. The hazard ratio in the PS group was not significantly different from that in the CCK group (Table 3).

At the final follow-up, both patient groups demonstrated statistically significant improvements over MCID in most clinical outcomes as compared with the preoperative baseline values (Table 4). Regarding the postoperative clinical outcomes, neither the clinical scores nor the improvement of clinical outcomes showed significant differences between the PS group and CCK group (Table 5).

DISCUSSION

In RTKA, both PS and CCK showed similar survival rates and clinical outcomes at a mean follow-up of 9.2 years; implant articulation did not affect the outcomes. PS and CCK articulations are commonly used for RTKA. Despite the wide use of these two types of articulations, information about the survival rates and clinical outcomes of patients who underwent RTKA using these articulations are not well known. Although there are some comparison studies, many are based on data concerning the failure rates after primary TKA[20-22] and only a few reports have described RTKA.[12,13,19] In our study, there was no statistically significant difference in the 10-year survival rate between the PS and CCK groups.

Recently, Kim and Park[23] calculated survivorship of 114 RTKAs performed using the Zimmer CCK prosthesis as in our study. They reported good functionality, high satisfaction level, and 91% survival rate for a mean follow-up of 19.2 years, indicating the CCK articulation could be

Table 4. Clinical Outcomes

Variable	PS group (n = 41)			CCK group (n = 45)		
	Preoperative	Postoperative	*p*-value*	Preoperative	Postoperative	*p*-value*
Extension	3.3 ± 7.3	1.7 ± 5.2	0.113	6.0 ± 12.1	3.9 ± 5.9	0.113
Flexion	99.4 ± 39.3	111.5 ± 25.8	0.038	90.1 ± 33.6	107.1 ± 19.1	< 0.001
ROM	96.1 ± 41.3	109.8 ± 27.5	0.022	84.1 ± 37.8	103.2 ± 21.3	< 0.001
HSS score	57.8 ± 12.4	83.6 ± 12.0	< 0.001	46.2 ± 15.0	81.6 ± 10.7	< 0.001
KSS pain	24.3 ± 11.4	40.4 ± 7.2	< 0.001	25.4 ± 9.4	39.6 ± 5.9	< 0.001
KSS function	43.4 ± 18.7	79.0 ± 17.6	< 0.001	36.9 ± 25.3	78.4 ± 10.8	< 0.001
WOMAC	59.6 ± 17.7	18.4 ± 12.5	< 0.001	55.7 ± 20.0	21.2 ± 12.4	< 0.001

Values are presented as mean ± standard deviation.
PS: posterior-stabilized articulation, CCK: constrained condylar knee articulation, ROM: range of motion, HSS: Hospital for Special Surgery, KSS: Knee Society Score, WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index.
*The paired *t*-test was performed to identify the difference in clinical value. A *p*-value < 0.05 was considered significant.

Table 5. Comparison of Clinical Outcomes in PS and CCK Groups

Variable	Postoperative		*p*-value*	Improvement		*p*-value†
	PS group (n = 41)	CCK group (n = 45)		PS group (n = 41)	CCK group (n = 45)	
Extension	1.7 ± 5.2	3.9 ± 5.9	0.073	1.6 ± 6.3	2.1 ± 8.8	0.198
Flexion	111.5 ± 25.8	107.1 ± 19.1	0.381	12.1 ± 36.0	17.0 ± 25.9	0.752
ROM	109.8 ± 27.5	103.2 ± 21.3	0.225	13.7 ± 36.7	19.1 ± 28.1	0.603
HSS score	83.6 ± 12.0	81.6 ± 10.7	0.423	25.9 ± 18.7	35.5 ± 17.3	0.445
KSS pain	40.4 ± 7.2	39.6 ± 5.9	0.548	16.1 ± 12.5	14.1 ± 11.3	0.524
KSS function	79.0 ± 17.6	78.4 ± 10.8	0.856	35.6 ± 25.1	41.5 ± 27.0	0.900
WOMAC	18.4 ± 12.5	21.2 ± 12.4	0.332	41.2 ± 23.5	34.5 ± 20.9	0.288

Values are presented as mean ± standard deviation.
PS: posterior-stabilized articulation, CCK: constrained condylar knee articulation, ROM: range of motion, HSS: Hospital for Special Surgery, KSS: Knee Society Score, WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index.
*The independent *t*-test was used to analyze differences in clinical outcome. †Analysis of covariance was performed to identify the difference of each group's improvement in clinical outcomes. A *p*-value < 0.05 was considered significant.

excellent for RTKA; however, in the 10 re-revision cases, infection occurred in 4 patients (4%) and aseptic loosening occurred in 5 patients (5%). In our study, among the patients who underwent a revision in the CCK group, 3 (6.7%) had infections, 2 (4.4%) had periprosthetic fractures, and 2 (4.4%) had aseptic loosening. This result is similar with that of the study of Kim et al. On the contrary, when a PS articulation was used, 3 patients (7.3%) had an infection, 1 (2.4%) had a periprosthetic fracture, and none of them had loosening in our study. The statistical analysis revealed that the articulation design did not influence the likelihood of experiencing postoperative complications.

Despite the lack of statistical significance and the possibility of selection bias due to the nonrandom assignment of the articulations, the frequency of loosening was greater in the CCK group than in the PS group. Kunze et al.[12] also reported the incidence of postoperative aseptic failure was 8.8% in the revision CCK group and 6.6% in the revision PS group ($p = 0.14$). It can be inferred that RTKA with a CCK articulation is associated with a higher incidence of loosening due to many constraints as initially hypothesized: the use of a more constrained CCK resulted in increased stress transfer to the fixation interface and thus loosening of the bone-cement-implant interface.[10]

The Kaplan-Meier survival curve indicated that the 10-year survival rate was 92.7% in the PS group and 88.2% in the CCK group. However, no statistically significant difference was found between the two survival curves in the log-rank test ($p > 0.05$). In addition, this was similar in septic failure. After the factors affecting the incidence of complications were corrected, the hazard ratio in the PS group was not significantly different with that in the CCK group. Kunze et al.[12] reported that the use of the PS articulation conferred a lower likelihood of re-revision (odds ratio, 0.3; $p = 0.001$). Their Cox regression model included only age, sex, body mass index, and articulation type, and the mean follow-up duration was short (3.5 ± 1.3 years). However, in our study, age, sex, body mass index, comorbidities, and reason for revision were additionally adjusted to compare the two articulation types. In addition, products from the same manufacturer were compared. The mean follow-up duration was midterm (9.15 ± 2.78 years). In the Cox proportional hazard model, the hazard ratio between the PS and CCK groups was not significantly different not only in total failure, but also in septic failure. It could be interpreted that the operator may be able to select CCK in RTKA without worrying about the survival rate. But studies analyzing several complications in more samples will be needed to determine the hazard ratio accurately.

After revision surgery, all the clinical outcomes were improved in both groups in our study. Lee et al.[24] reported there were no significant differences in postoperative ROM and clinical scoring between two groups. Hwang et al.[13] also reported no significant difference in postoperative KSS for physical function between the PS and CCK groups. On the contrary, Kunze et al.[12] reported that PS articulation had superior postoperative KSS for physical function and ROM. The PS group had greater postoperative knee flexion (6.4°, $p = 0.01$) and higher KSS for physical function (10.0, $p = 0.002$). They used a multivariate linear regression analysis to compare the results. However, to demonstrate that RTKA using a PS articulation has a better clinical outcome than RTKA using a CCK articulation, whether the difference between preoperative and postoperative functions was significant in the two groups had to be analyzed. Thus, in our study, an ANCOVA was performed and the amount of function improved by operation was not found significantly different.

This study has some limitations. First, it has the inherent weaknesses associated with its retrospective design. The fact that the CCK articulation was used only in cases where imbalance was not resolved during surgery suggests that the CCK articulation was used in more complicated groups in general, and the preference of the operator may have influenced the choice of type of prosthesis, which might have caused a selection bias. Second, the sample size of the study was small. Since this was only for single-center long-term follow-up patients, only 38.7% of 222 patients were analyzed. A multi-center study is likely necessary in the future. Third, regarding the demographic characteristics, there were significant differences in age and diabetes mellitus between PS and CCK groups. In addition, regarding the cause of revision, infection was 62.2% in the CCK group and 34.1% in the PS group. Such difference in preoperative baseline characteristics could contribute to complication and survivorship. However, there was no statistic difference. This might be due to low statistical power. Fourth, PS group in this study did not have aseptic loosening. It is obvious that aseptic loosening occurs in the PS group, but it did not occur in our patient group, so it was not reflected in the statistics. So larger case-control studies will be needed in the future for clear comparison of aseptic loosening between the groups.

In RTKA, both PS and CCK showed similar survival rates and clinical outcomes at a mean follow-up of 9.2 years. Implant articulation did not affect the outcomes when properly indicated. Thus, when choosing the articulation type for RTKA, CCK can be used without concern about prognosis for cases with appropriate indications.

CONFLICT OF INTEREST

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

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ORCID

Jong-Keun Seon https://orcid.org/0000-0002-6450-2339
Woo-Kyoung Kwak https://orcid.org/0000-0001-6342-1185

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