The Journal of Arthroplasty xxx (2021) 1–7

Contents lists available at ScienceDirect

The Journal of Arthroplasty

journal homepage: www.arthroplastyjournal.org

# No Difference in Postoperative Knee Flexion and Patient Joint Awareness Between Cruciate-Substituting and Cruciate-Retaining Medial Pivot Total Knee Prostheses: A 10-Year Follow-Up Study

Hideki Ueyama, MD, PhD [a, b, c, *], Narihiro Kanemoto, MD [b], Yukihide Minoda, MD, PhD [c], Nobuo Yamamoto, MD [c], Yoshiki Taniguchi, MD [b], Hiroaki Nakamura, MD, PhD [c]

[a] Department of Orthopedic Surgery, Osaka Rosai Hospital, Sakai, Osaka, Japan
[b] Department of Orthopedic Surgery, Tanabe Central Hospital, Tanabe, Wakayama, Japan
[c] Department of Orthopedic Surgery, Osaka City University Graduate School of Medicine, Osaka City, Japan

ARTICLE INFO

*Article history:*
Received 14 September 2021
Received in revised form
3 November 2021
Accepted 8 November 2021
Available online xxx

*Keywords:*
medial pivot
total knee arthroplasty
survival rate
cruciate retaining
cruciate substituting

ABSTRACT

*Background:* This study aimed to clarify differences in clinical results, including in patients' joint awareness, between cruciate-substituting (CS) and cruciate-retaining (CR) medial pivot total knee arthroplasty (TKA) over a 10-year follow-up.
*Methods:* A total of 333 TKAs were included in this study. There were 257 cases of CS and 76 cases of CR TKAs. Knee range of motion, Knee Society Score, and radiological outcomes were assessed. The patients' joint awareness was evaluated using the Forgotten Joint Score-12 at the final follow-up. The survival rate with respect to reoperation or revision was analyzed.
*Results:* The mean follow-up period was 10 ± 1.7 years, and the loss to follow-up was 5.4%. All clinical outcomes improved significantly after surgery in both groups ($P < .001$). Postoperative knee flexion was 118° ± 13° in the CS group and 116° ± 10° in the CR group ($P = .10$). The mean Forgotten Joint Score-12 scores were 57 ± 27 points in the CS group and 56 ± 28 points in the CR group ($P = .59$). Ten years after the operation, the survival rates for reoperation were 96.3% in the CS group and 94.2% in the CR group ($P = .61$), and those for revision were 98.4% and 98.7% in the CS and CR groups, respectively ($P = .87$). Other postoperative clinical results did not differ between the 2 groups.
*Conclusion:* In this 10-year follow-up study, medial pivot TKA, regardless of polyethylene insert type, showed a high survival rate and good patient awareness of the prosthetic joint.


The medial pivot total knee arthroplasty (TKA) was developed to mimic natural knee kinematics, with a single radius curvature, high conformity of the medial compartment, and an unrestricted lateral compartment [1]. These features reproduce the natural rollback of the femur during flexion and achieve good anteroposterior knee stability [2]. The medial pivot design has good longevity and high patient satisfaction after TKA [1,3].

Recently, patient-reported outcome measurements (PROMs) have been commonly used to assess the postoperative clinical results of TKA [4,5]. Joint awareness in everyday life was developed as a PROM to evaluate clinical results, especially those related to patient satisfaction [6,7]. Awareness was evaluated using the Forgotten Joint Score-12 (FJS-12), which is an excellent tool for the assessment of joint satisfaction [6]. According to a previous report, the medial pivot prosthesis is likely to have a higher FJS-12 than other designed prostheses [3]. However, the difference in joint awareness between different types of medial pivot prostheses remains unknown.

The medial pivot prosthesis ADVANCE (MicroPort Orthopedics Inc, Arlington, TN) has shown good clinical results, with a long-term survival rate of 96.4%-98.8% [1,8]. This prosthesis has 2 different designs: a cruciate-substituting (CS) type and cruciate-retaining (CR) type. The CS type has a complete ball-and-socket

Present address: Nobody moved since the work described.

No author associated with this paper has disclosed any potential or pertinent conflicts which may be perceived to have impending conflict with this work. For full disclosure statements refer to https://doi.org/10.1016/j.arth.2021.11.016.

* Address correspondence to: Hideki Ueyama, MD, PhD, 1179-3 Nagasonecho, Kitaku, Sakai, Osaka, 591-8025 Japan.

https://doi.org/10.1016/j.arth.2021.11.016
0883-5403/

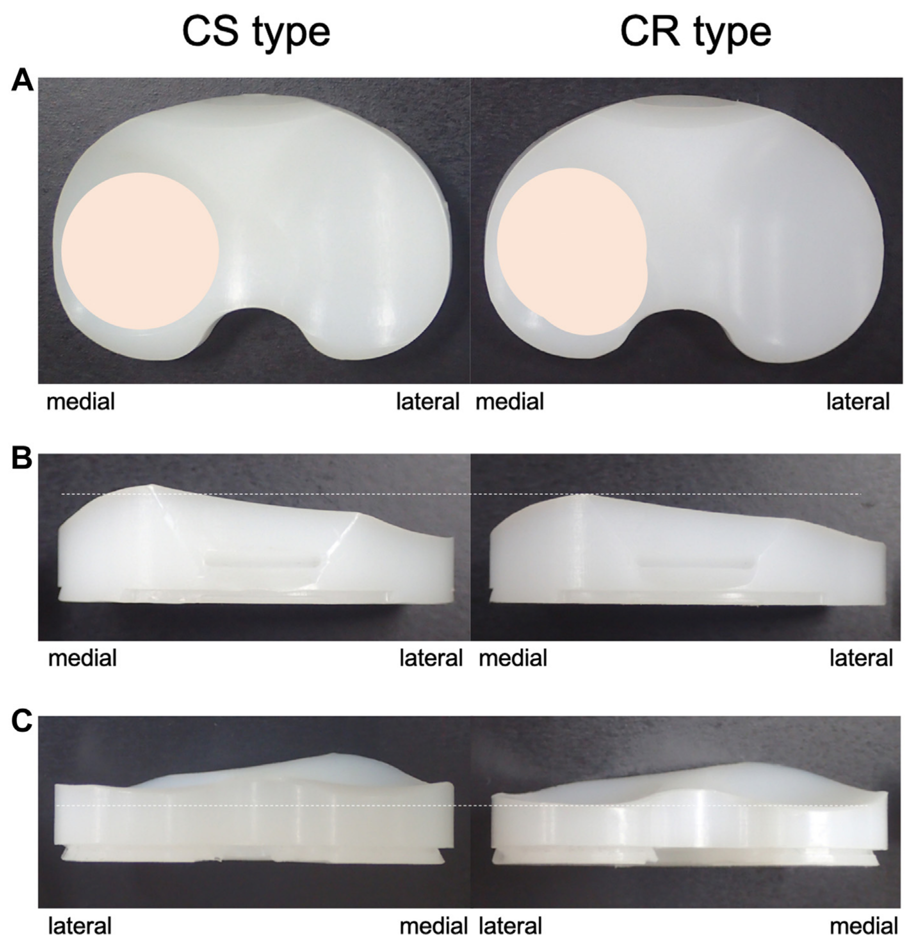


**Fig. 1.** Schema of the difference between CS-type and CR-type medial pivot prostheses. CS-type and CR-type inserts of the same size are shown. The CS-type insert has a complementary ball-and-socket joint surface with anterior and posterior lips on the medial side, while the CR type insert has slightly reduced lips to allow better knee flexion by femoral rollback. Overviews from the proximal side of the contact surface of the CS type and CR type are shown in orange. The CR type has a wider contact area between the femoral component and the polyethylene insert (A). The polyethylene insert of the CS type has higher lips at the anterior (B) and posterior (C) than the CR type. CS, cruciate substitution; CR, cruciate retaining.

on the medial side with higher anterior and posterior polyethylene lips, whereas the CR type has slightly reduced anterior and posterior polyethylene lips to allow greater knee flexion and rollback motion (Fig. 1). The difference in general clinical results between the CS and CR types has been found to be not significant [9]. However, the differences in joint awareness and FJS-12 according to prosthesis design remain unknown.

Therefore, this study aimed to clarify the differences in joint awareness and other clinical results between CS-type and CR-type inserts of medial pivot prostheses in a long-term observational

**Table 1**
Patient Demographics.

| Parameters | Total (n = 333) | CS Type (n = 257) | CR Type (n = 76) | *P* Values |
|---|---|---|---|---|
| Age at operation (y) | 75.9 (7.3, 53-88) | 76.2 (7.3, 53-88) | 74.6 (7.3, 57-88) | .13 |
| Woman, n (%) | 308 (92.5) | 241 (93.8) | 67 (88.2) | .13 |
| Height (cm) | 151.3 (6.2, 138-168) | 151.5 (6.2, 138-168) | 150.7 (5.9, 139-165) | .38 |
| Weight (kg) | 53.74 (8.7, 38-80) | 53.9 (8.1, 38-80) | 53.2 (10.0, 38-80) | .58 |
| BMI (kg/m$^2$) | 23.39 (3.0, 18.3-32.0) | 23.4 (2.9, 18.3-32.0) | 23.3 (3.4, 18.3-32.0) | .78 |
| Deformity, n (%) | | | | .36 |
| Valgus knee | 4 (1.2) | 2 (0.7) | 2 (2.6) | – |
| Neutral knee | 37 (11.1) | 28 (10.9) | 9 (11.8) | – |
| Varus knee | 292 (87.7) | 227 (88.3) | 65 (85.6) | – |
| Disease, n (%) | | | | .13 |
| Osteoarthritis | 318 (95.5) | 244 (87.2) | 74 (97.4) | – |
| Rheumatoid arthritis | 10 (3.0) | 10 (3.9) | 0 (0) | – |
| Osteonecrosis | 5 (1.5) | 3 (1.2) | 2 (2.6) | – |
| Follow-up period (y) | 10.1 (1.7, 7.3-13.6) | 10.1 (1.7, 7.0-13.6) | 10.0 (1.7, 7.0-12.9) | .56 |

Mean, standard deviation, and range were provided, or number and percentage were provided. PCL was resected in CS type. PCL was retained in CR type. *P* values were assessed between CS type and CR type groups.
CS, cruciate substitute; CR, cruciate retaining; BMI, body mass index; PCL, posterior cruciate ligament.

**Table 2**
Clinical and Radiological Parameters at Preoperation and Final Follow-Up.

| Parameters | Preoperation (n = 333) | Final Follow-Up (n = 333) | *P*-Value |
|---|---|---|---|
| Clinical outcomes | | | |
| KSS knee score (points) | 39.4 ± 4.6 (28-55) | 87.6 ± 4.9 (74-100) | <.001 |
| KSS function score (points) | 41.5 ± 4.9 (30-60) | 90.1 ± 5.2 (75-100) | <.001 |
| Knee extension (°) | −2.5 ± 4.7 (−20 to 0) | −0.2 ± 1.6 (−10 to 5) | <.001 |
| Knee flexion (°) | 113 ± 12.7 (85-135) | 118 ± 9.8 (85-135) | <.001 |
| VAS for knee pain (points) | 8.0 ± 1.0 (4-10) | 1.9 ± 1.1 (0-5) | <.001 |
| FJS-12 total score (points) | NA | 58.32 ± 29.2 (0-100) | NA |
| Radiological outcomes | | | |
| Femorotibial angle (°) | 184.8 ± 3.6 (169.9-195.4) | 176.1 ± 1.0 (172.9-179.8) | <.001 |
| Prosthetic alignment | | | |
| α (°) | NA | 94.8 ± 7.3 (90.4-98.5) | NA |
| β (°) | NA | 90.5 ± 1.2 (87.2-94.3) | NA |
| γ (°) | NA | 2.4 ± 1.1 (−1.5 to 6.6) | NA |
| δ (°) | NA | 4.0 ± 1.5 (−1.0 to 10.4) | NA |
| Radiolucent line, n (%) | NA | 36 (10.8%) | NA |
| Aseptic loosening, n (%) | NA | 0 (0%) | NA |

Mean, standard deviation, and range or number and percentage were provided. *P* values were calculated between preoperation and final follow-up groups.
KSS, Knee Society Score; VAS, Visual Analog Scale; FJS, Forgotten Joint Score; NA, not applicable.

study. We hypothesized that there are no differences in clinical results, including PROMs, following TKA between the CS-type and CR-type inserts.

## Materials and Methods

In total, 442 consecutive TKAs performed between January 2006 and January 2012 were enrolled in this retrospective cohort study. The inclusion criteria of this study were patients who underwent TKA, as performed by a senior surgeon (N.K.), using the ADVANCE knee system at our joint clinic center and who were followed up at our outpatient department at the research time point. The exclusion criteria were patients who underwent TKA using other prostheses or who were operated on by fellows or resident surgeons working in the short term at our hospital. Eighty-three TKAs were excluded according to the following criteria: 36 TKAs used other prostheses and 47 TKAs were performed by junior surgeons. Medial pivot prosthesis was excluded from cases requiring stem extension or augmentation due to large bone defect or requiring constraint-type TKA due to severe instability. Fourteen patients died due to other medical issues during the follow-up period, and 19 patients (5.4%) were lost to follow-up. A total of 333 TKAs were analyzed in this study.

### *Operative Technique and Postoperative Treatment*

A total of 257 CS-type prostheses and 76 CR-type prostheses were used for TKA. The prosthetic designs of the femoral and tibial components were identical. All surgeries were performed using the same operative technique, except for resection of the posterior cruciate ligament (PCL). Briefly, a medial parapatellar approach was used, with resection of the PCL for the CS type or with preservation of the PCL for the CR type. An intramedullary rod for the femoral component and an extramedullary rod for the tibial component were used for bone resections, and the prostheses were fixed using bone cement. Bone resection was performed using the measured resection technique, and the goal of prosthetic alignment was perpendicular to mechanical alignment [10]. All patellae were resurfaced using a polyethylene prosthesis. Postoperative pain control and physical therapy were identical in all cases, following the institutional clinical pathway. The polyethylene insert selection was determined according to the PCL status during the operation.

**Table 3**
Clinical and Radiological Parameters at Preoperation and Final Follow-Up Between CS and CR Types.

| Parameters | Preoperation | | | Final Follow-Up | | |
|---|---|---|---|---|---|---|
| | CS Type (n = 257) | CR Type (n = 76) | *P*-Value | CS Type (n = 257) | CR Type (n = 76) | *P*-Value |
| Clinical outcomes | | | | | | |
| KSS knee score (points) | 39.7 (28-55) | 39.1 (30-51) | .18 | 87.8 (75-100) | 87.0 (74-95) | .23 |
| KSS function score (points) | 41.5 (35-60) | 41.8 (35-50) | .71 | 90.3 (75-100) | 90.0 (745-95) | .38 |
| Knee extension (°) | −2.4 (−20 to 0) | −2.9 (−20 to 0) | .39 | −0.1 (−10 to 5) | −0.2 (−10 to 5) | .72 |
| Knee flexion (°) | 114 (90-135) | 113 (85-135) | .61 | 118 (85-135) | 116 (85-135) | .10 |
| VAS for knee pain (points) | 8.0 (4-10) | 8.2 (4-10) | .47 | 1.6 (0-4) | 2.1 (0-5) | .06 |
| Radiological outcomes | | | | | | |
| Femorotibial angle (°) | 183.8 (169.9-195.4) | 182.7 (170.0-192.1) | .09 | 176.2 (172.9-179.8) | 176.1 (173.6-178.7) | .40 |
| Prosthetic alignment | | | | | | |
| α (°) | – | – | NA | 94.1 (91.1-97.3) | 94.0 (90.4-98.5) | .30 |
| β (°) | – | – | NA | 90.7 (87.3-94.3) | 90.4 (86.3-93.6) | .16 |
| γ (°) | – | – | NA | 2.7 (−1.5 to 5.6) | 2.4 (−1.0 to 6.6) | .68 |
| δ (°) | – | – | NA | 4.0 (−0.8 to 8.6) | 4.2 (−1.0 to 10.4) | .27 |
| Radiolucent line, n (%) | – | – | NA | 29 (11.3) | 8 (10.8) | .99 |
| Aseptic loosening, n (%) | – | – | NA | 0 (0) | 0 (0) | NA |

Mean, standard deviation, and range or number and percentage were provided. *P* values were calculated between CS and CR type inserts group.
CS, cruciate substitution; CR, cruciate retaining; KSS, knee society score; VAS, visual analog scale; NA, not applicable.

**Table 4**
Details of the FJS-12 Score.

| Question: Are You Aware of Your Artificial Joint When? | CS Type (N = 257) | CR Type (N = 76) | *P*-Value |
|---|---|---|---|
| Total score | 57 (SD 27; 35-75) | 56 (SD 28; 30-76) | .69 |
| Q1. In bed at night | 2.5 (1-4) | 2.3 (1-3) | .13 |
| Q2. Sitting in chair >1 h | 2.2 (1-3) | 2.1 (1-3) | .62 |
| Q3. Walking for >15 min | 2.7 (2-4) | 2.8 (2-4) | .96 |
| Q4. Taking a bath/shower | 2.3 (1-3) | 2.5 (1-3) | .32 |
| Q5. Traveling in a car | 2.3 (1-3) | 2.4 (1-3) | .53 |
| Q6. Climbing stairs | 3.0 (2-4) | 3.2 (1-5) | .30 |
| Q7. Walking on uneven ground | 3.1 (2-5) | 3.2 (2-5) | .73 |
| Q8. Standing from low sitting position | 3.2 (2-5) | 3.3 (2-5) | .73 |
| Q9. Standing for long periods of time | 3.3 (2-4) | 3.1 (2-4) | .52 |
| Q10. Doing housework/gardening | 2.9 (2-4) | 3.0 (2-3) | .82 |
| Q11. Taking a walk/hike | 3.0 (2-4) | 2.9 (2-4) | .52 |
| Q12. Doing your favorite sport | 2.6 (1-4) | 2.7 (1-4) | .58 |

Mean, standard deviation, and range are provided for the total FJS-12 score, with the mean and quartile (25%-75%) provided for each item. The range of each question is 1 (never aware) to 5 (mostly aware).
CS, cruciate substitution; CR, cruciate retaining; FJS, forgotten joint score; Q, question.

The CS type was selected based on surgeon preference. When the surgeon determined that the PCL was slightly degenerated during the operation, CS type was used [11].

### *Clinical Outcomes and Data Collection*

Knee range of motion and Knee Society Score (KSS) were evaluated preoperatively and at final follow-up [12]. The angles of the knee joint were measured with a standard clinical goniometer based on a previously established method [13]. The 12-item FJS-12 was used as a PROM at the final follow-up [6]. The raw FJS-12 score was transformed to a linearly scaled score from 0 to 100, using the following formula: Final total score = 100 − ([sum{1$^{st}$ item to 12$^{th}$ item} − 12]/48 × 100) [3]. Radiological outcomes were assessed with standing short-film radiographs of the knee taken preoperatively and at the final follow-up. Furthermore, postoperative prosthetic alignment using the KSS classification (α, β, γ, δ) [14] and preoperative and postoperative femorotibial angle were evaluated [15]. The radiolucent line (RLL) was evaluated based on the recommendation of a previous report [14]. The presence of 2 mm or more of RLL, migration of prosthesis, or prosthetic alignment change was defined as loosening [1]. The definition of reoperation and revision was based on the definition of the National Joint Registry for England and Wales [16]. Briefly, reoperation was defined as any additional surgery for the knee after TKA, such as debridement and irrigation, exchange of insert, or revision. Conversely, revision was defined as surgery performed to remove one or more components. The indication for reoperation was determined comprehensively by the surgeon who performed the TKA based on the patient's condition. All clinical outcomes were evaluated by an orthopedic surgeon who was not involved in the patients' treatment (H.U.) based on patient records and radiographs.

### *Statement of Ethics*

This study was approved by our institutional review board (approval number, 01,310,719). Informed consent was obtained from all the participants in this study. All methods involving human subjects were performed in accordance with the Declaration of Helsinki.

### *Statistical Analysis*

Univariate analyses were performed to evaluate differences before and after TKA among the same patients, using a paired *t*-test for continuous variables and chi-squared test for categorical variables. The differences in parameters between CS-type and CR-type prostheses were analyzed using Student's *t*-test for continuous variables and the chi-squared test for categorical variables. The survival rate of the prosthesis was evaluated using Kaplan-Meier analysis with a 95% confidence interval during the follow-up period [17,18]. The survival rates of the CS and CR types were compared using the log-rank test. The incidence of reoperation or revision for any reason was used as an endpoint. A power calculation was performed to determine the number of knees needed to detect a difference of approximately 15° (with a standard deviation of 15) on the range of motion or a difference of 30 points (standard

**Table 5**
Details of Reoperation and Revision.

| Reasons for Reoperation | N, % (Prosthetic Type) | Treatment (%; CS Cases, CR Cases) |
|---|---|---|
| Instability (including knee hyperextension) | 6, 1.8% (CS 4, CR 2) | Exchange insert (1.5%; CS 3, CR 2)<br>Revision of tibial components to constraint (0.6%; CS 1, CR 0) |
| Periprosthetic fracture | 5, 1.5% (CS 3, CR 2) | Open reduction and internal fixation (0.9%; CS 2, CR 1)<br>Revision of tibial components to constraint (0.6%; CS 1, CR 1) |
| Septic loosening | 2, 0.6% (CS 2, CR 0) | Two-stage revision of total components (0.6%; CS 2, CR 0) |
| Superficial surgical site infection | 1, 0.3% (CS 1) | Debridement and irrigation (0.3%; CS 1, CR 0) |
| Total reoperation | 14, 4.2% (CS 10, CR 4) | All of above |
| Total revision | 5, 1.5% (CS 4, CR 1) | Revisions of above |

The rate of each parameter was calculated from the total cases (n = 333). The rate was calculated from total number of reoperation or revision cases. Reoperation rate or revision rate was not statistically different between prosthetic types.
CS, cruciate substitution; CR, cruciate retaining.

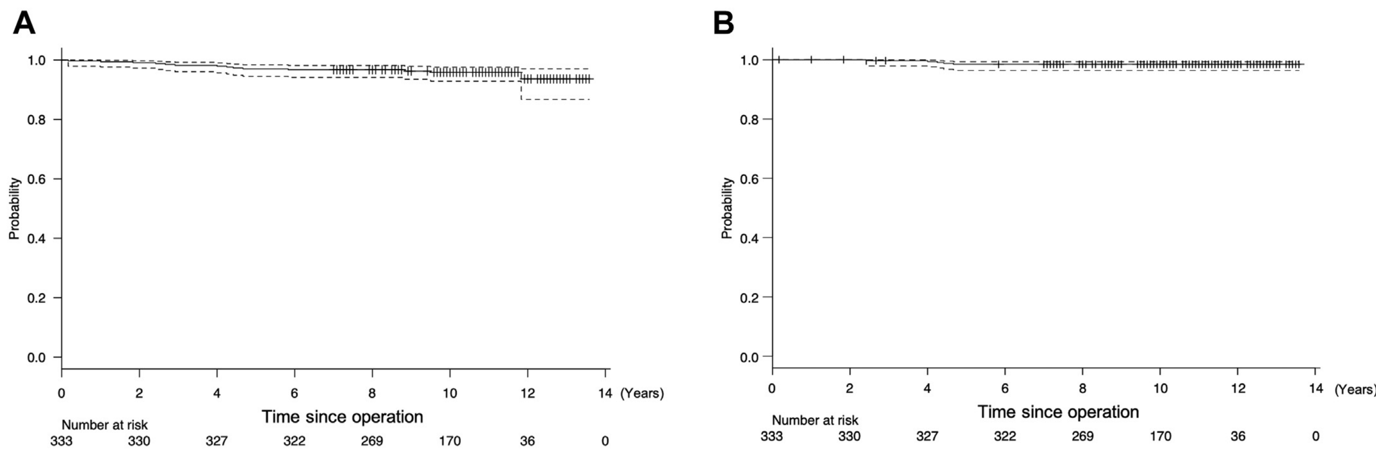


**Fig. 2.** Kaplan-Meier survivorship with all cases. Survival analysis of all patients who underwent medial pivot total knee arthroplasty in this study. The endpoints were reoperation for any reason (A) and revision for any reason (B). The Kaplan-Meier curve with 95% confidence intervals (dashed line) is shown. Censored patients are indicated with a tick mark on the survival curve. The number of cases every 2 years is indicated below the abscissa as the number at risk. The overall survival rates were 95.8% with reoperation and 98.5% with revision at 10 years postoperation.

deviation of 15) on the KSS, based on previous literature [1,8]. At least 24 knees or more were required to achieve a statistical power of 80%, with a 2-sided alpha set at 0.01. Statistical significance was defined as $P < .05$. Statistical analyses were performed using the R software package (version 3.1.1; R Core Team, 2014; R Foundation for Statistical Computing, Vienna, Austria).

## Results

The mean follow-up in this study was 10.1 ± 1.7 years (range 7.3-13.6). The mean age at operation was 75.9 ± 7.3 years, rate of woman was 92.5%, and body mass index was 23.4 ± 3.0 kg/$m^2$. The final analysis of 333 TKAs is presented in Table 1. The differences in patient characteristics between the CS and CR groups were not significant.

The clinical and radiological outcomes before TKA and at the final follow-up are shown in Table 2. The results of subgroup analyses between the CS and CR groups before TKA and at the final follow-up are shown in Table 3. The clinical outcomes improved after TKA in both groups. The RLLs of the femoral component were observed in 16 (6.2%) CS-type cases and 5 (6.6%) CR-type cases ($P = .99$). The RLLs of the tibial component were observed in 13 (5.1%) CS-type cases and 3 (3.9%) CR-type cases ($P = .99$). All femoral RLLs appeared at area-1 or area-2 (anterior parts) in the sagittal view, and all tibial RLLs appeared at area-1 or area-2 (medial parts) in the coronal view. More than 2 mm of radiolucency (aseptic loosening) was not observed in any case. No statistically significant differences were noted in both total and item-specific FJS-12 scores between the CS and CR types (Table 4).

Knee instability, such as hyperextension, was the main reason for reoperation (Table 5). The reoperation or revision rates did not significantly differ between the 2 groups. The overall survival rates with reoperation and revision as the endpoint were 95.8% and 98.5% at 10 years after TKA, respectively (Fig. 2A and B, Table 6). The survival rates did not differ significantly between the CS and CR groups (Fig. 3A and B, Table 7). Prosthetic type was not a risk factor for reoperation (Table 8).

## Discussion

The present study clarified that postoperative joint awareness after TKA did not differ between patients with CS and CR medial pivot prostheses. Moreover, this study found no difference in clinical outcomes, including knee flexion and survival rate, between the 2 designs over a mean follow-up period of 10 years.

Awareness of the operated joint is considered a reliable indicator of post-TKA patient satisfaction [6]. Critical factors affecting FJS-12 remain unclear; however, body mass index, age at operation, and gender have been identified as predictors by one study that first reported on FJS-12 [19]. Furthermore, another study has mentioned that postoperative knee stability on the medial side affected patients' joint awareness [20]. The CS-type insert has a higher conformity on the medial side than the CR-type; however, this variation was not associated with a difference in the FJS-12.

In this study, the design variation between the CS and CR types did not show significant postoperative knee flexion angle. A cadaver study has shown that the PCL preserved knee with CR type reproduced femoral rollback and the PCL resected knee with CS type reproduced medial pivot motion [21]. Anteroposterior translation of the femur was correlated positively with flexion knee angle; therefore, the CR type increasing femoral rollback may result in better knee flexion angle [22]. However, there was no clinical difference in actual. Eventually, to perform TKA following design concept, PCL resected in CS type or PCL preserved in CR type would lead to good knee flexion angle in both insert designs. It is similar with previous studies showing no differences in postoperative knee flexion among medial pivot prosthesis designs [9,23,24].

**Table 6**
Summary of Survival Rates for All Cases.

| Time (y) | Number at Risk | Survival Rate (%) | 95% CI |
|---|---|---|---|
| Reoperation for any reasons | | | |
| 2 | 330 | 98.8 | 96.8-99.5 |
| 4 | 327 | 97.9 | 95.6-99.0 |
| 6 | 322 | 96.7 | 94.1-98.2 |
| 8 | 269 | 96.3 | 93.5-97.9 |
| 10 | 170 | 95.8 | 92.8-97.6 |
| 12 | 36 | 93.6 | 86.7-97.0 |
| Revision for any reasons | | | |
| 2 | 330 | 99.7 | 97.9-99.9 |
| 4 | 327 | 98.8 | 96.8-99.5 |
| 6 | 322 | 98.5 | 96.4-99.4 |
| 8 | 269 | 98.5 | 96.4-99.4 |
| 10 | 170 | 98.5 | 96.4-99.4 |
| 12 | 36 | 98.5 | 96.4-99.4 |

CI, confidence interval.

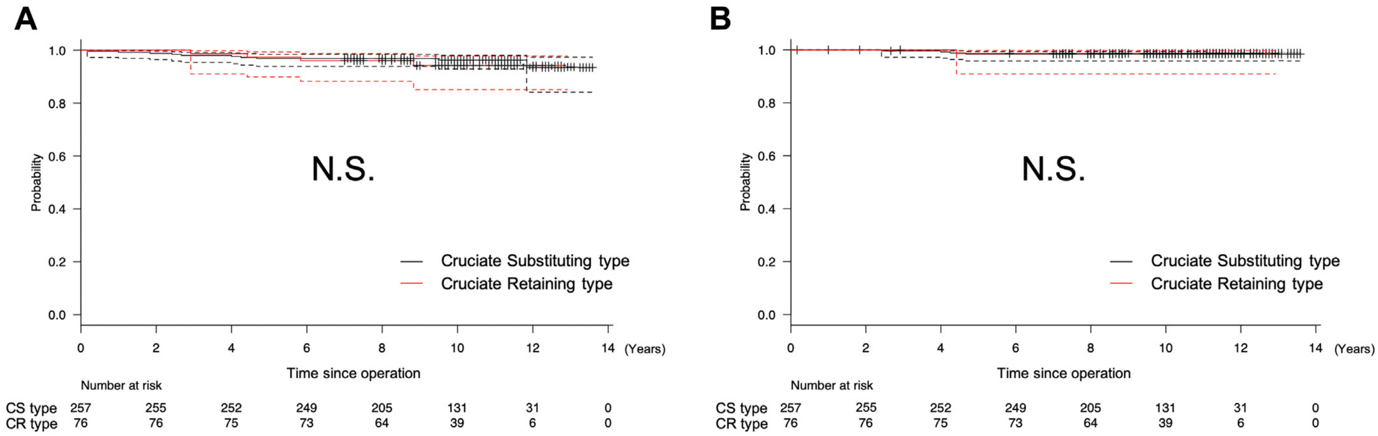


**Fig. 3.** Kaplan-Meier survivorship between CS type or CR type. Breakdown of survival analysis for cases operated using CS-type or CR-type prostheses. The endpoints were reoperation for any reason (A) and revision for any reason (B). The black and red lines indicate the CS- and CR-type, respectively. The Kaplan-Meier curve with 95% confidence intervals (dashed line) is shown. Censored patients are indicated with a tick mark on the survival curve. The number of cases every 2 years is indicated below the abscissa as the number at risk. The survival rate after reoperation was 96.3% in the CS type and 94.2% in the CR type 10 years after the operation ($P = .61$). The survival rates with revision were 98.4% for the CS type and 98.7% for the CR type at 10 years after the operation ($P = .87$).

The 10-year survival rates in this study were not statistically different between the CS and CR types. The 10-year survival rates (revision, 98.4% in CS type and 98.7% in CR type) of this study were high and comparable to those of previous medial pivot prosthesis reports [8,25]. Biomechanics studies have shown that the mechanical stress on the articular surface is lower in high conformity insert than in standard conformity insert [26,27]. The CS-type insert was designed to have a higher articular conformity than the CR-type insert; however, the rates of RLLs around the components were not statistically different. This suggests that other factors, such as gap tension during surgery, affect the patient more than the difference in prosthetic designs [28,29]. The wear particles of medial pivot prostheses in vivo have been shown to be fewer and rounder than those of other prostheses [30]. Lesser and smoother morphology of wear particles is less likely to promote biological reactions that cause osteolysis than wear particles that are not [31,32]. In this study, no aseptic loosening was observed for a maximum of 14 years after the operation; therefore, the medial pivot prosthesis could be a favorable design for aseptic loosening by wear particles regardless of design.

The advantages of this study are as follows: first, the clinical outcomes, including joint awareness of CS and CR medial pivot prostheses, were assessed over a mean follow-up period of 10 years with a low loss to follow-up (5.4%). Second, the operation was performed by a single surgeon in a particular institution using a specified operative technique. This consistency could be useful to exclude bias due to differences in actual treatment, such as operations and perioperative management.

This study had limitations as well. First, the study design was retrospective. However, the inclusion and exclusion criteria were defined clearly, and multivariable statistical analysis was performed to remove bias as much as possible. Second, there were relatively fewer CR than CS cases (76 vs 257 cases, respectively). However, because the power for statistical analysis was sufficient, the conclusions of this study could be reasonable. Third, the usage rate of CS inserts was slightly higher in the early phase, in 2006, of the observation period. There is a possibility of getting used to

**Table 7**
Summary of Survival Rates for CS and CR Type Prostheses.

| Time (y) | Prosthetic Types | Number at Risk | Survival Rate (95% CI) | P Value[a] |
|---|---|---|---|---|
| Reoperation for any reasons | | | | |
| 2 | CS | 255 | 98.8% (96.4-99.6) | .612 |
| | CR | 76 | 100% (NA) | |
| 4 | CS | 252 | 97.7% (94.9-98.9) | |
| | CR | 76 | 98.7% (91.0-99.8) | |
| 6 | CS | 249 | 97.3% (94.4-98.7) | |
| | CR | 73 | 96.1% (88.3-98.7) | |
| 8 | CS | 205 | 96.9% (93.9-98.4) | |
| | CR | 64 | 96.1% (88.3-98.7) | |
| 10 | CS | 131 | 96.3% (92.9-98.1) | |
| | CR | 39 | 94.2% (85.1-97.8) | |
| 12 | CS | 31 | 93.5% (84.1-97.4) | |
| | CR | 6 | 94.2% (85.1-97.8) | |
| Revision for any reasons | | | | |
| 2 | CS | 255 | 99.6% (97.2-99.9) | .874 |
| | CR | 76 | 100% (NA) | |
| 4 | CS | 252 | 99.2% (96.9-99.8) | |
| | CR | 75 | 98.7% (90.9-99.8) | |
| 6 | CS | 249 | 98.4% (95.9-99.4) | |
| | CR | 73 | 98.7% (90.9-99.8) | |
| 8 | CS | 205 | 98.4% (95.9-99.4) | |
| | CR | 64 | 98.7% (90.9-99.8) | |
| 10 | CS | 131 | 98.4% (95.9-99.4) | |
| | CR | 39 | 98.7% (90.9-99.8) | |
| 12 | CS | 31 | 98.4% (95.9-99.4) | |
| | CR | 6 | 98.7% (90.9-99.8) | |

CS, cruciate substitution; CR, cruciate retaining; CI, confidence interval; NA, not applicable.
[a] Log-rank test.

**Table 8**
Multiple Logistic Regression Model for Risk Factors of Reoperation.

| Variables | Odds Ratio (95% CI) | P-Value |
|---|---|---|
| Age at operation | 0.99 (0.87-1.12) | .89 |
| Gender (male) | 0.61 (0.06-6.41) | .68 |
| Operation side (left) | 0.33 (0.06-1.68) | .18 |
| Body mass index | 0.87 (0.63-1.09) | .18 |
| Preoperative VAS for knee pain | 0.79 (0.36-1.74) | .56 |
| Preoperative femorotibial angle | 1.13 (0.91-1.40) | .27 |
| Preoperative KSS knee score | 0.81 (0.64-1.02) | .08 |
| Preoperative KSS function score | 1.06 (0.86-1.30) | .61 |
| Preoperative knee extension | 1.19 (0.97-1.46) | .11 |
| Preoperative knee flexion | 1.03 (0.94-1.12) | .54 |
| Prosthetic type (CS) | 2.16 (0.45-3.91) | .19 |

$P$ value of this model was .04. Total of 271 cases was estimated in this model.
VAS, visual analog scale; KSS, knee society score; CS, cruciate substitution; CI, confidence interval.

handling the model, that is, the learning curve bias between the 2 groups.

## Conclusion

Regardless of polyethylene insert type, medial pivot prostheses had a high survival rate and good patient awareness of the prosthetic joint over a mean follow-up of 10 years.

## References

[1] Karachalios T, Varitimidis S, Bargiotas K, Hantes M, Roidis N, Malizos KN. An 11- to 15-year clinical outcome study of the Advance Medial Pivot total knee arthroplasty. Bone Joint J 2016;98-B:1050–5. https://doi.org/10.1302/0301-620X.98B8.36208.
[2] Atzori F, Salama W, Sabatini L, Mousa S, Khalefa A. Medial pivot knee in primary total knee arthroplasty. Ann Transl Med 2016;4:4–7. https://doi.org/10.3978/j.issn.2305-5839.2015.12.20.
[3] Samy DA, Wolfstadt JI, Vaidee I, Backstein DJ. A retrospective comparison of a medial pivot and posterior-stabilized total knee arthroplasty with respect to patient-reported and radiographic outcomes. J Arthroplasty 2018;33:1379–83. https://doi.org/10.1016/j.arth.2017.11.049.
[4] Liddle AD, Pandit H, Judge A, Murray DW. Patient-reported outcomes after total and unicompartmental knee arthroplasty: a study of 14 076 matched patients from the national joint registry for EngLand and Wales. Bone Joint J 2015;97-B:793–801. https://doi.org/10.1302/0301-620X.97B6.35155.
[5] Ramkumar PN, Harris JD, Noble PC. Patient-reported outcome measures after total knee arthroplasty. Bone Joint Res 2015;4:120–7. https://doi.org/10.1302/2046-3758.47.2000380.
[6] Behrend H, Giesinger K, Giesinger JM, Kuster MS. The "forgotten joint" as the ultimate goal in joint arthroplasty. J Arthroplasty 2012;27:430–6.e1. https://doi.org/10.1016/j.arth.2011.06.035.
[7] Thompson SM, Salmon LJ, Webb JM, Pinczewski LA, Roe JP. Construct validity and test re-test reliability of the forgotten joint score. J Arthroplasty 2015;30:1902–5. https://doi.org/10.1016/j.arth.2015.05.001.
[8] Macheras GA, Galanakos SP, Lepetsos P, Anastasopoulos PP, Papadakis SA. A long term clinical outcome of the medial pivot knee arthroplasty system. Knee 2017;24:447–53. https://doi.org/10.1016/j.knee.2017.01.008.
[9] Ishida K, Matsumoto T, Tsumura N, Iwakura T, Kubo S, Iguchi T, et al. No difference between double-high insert and medial-pivot insert in TKA. Knee Surgery. Sport Traumatol Arthrosc 2014;22:576–80. https://doi.org/10.1007/s00167-012-2314-x.
[10] Dennis DA, Komistek RD, Kim RH, Sharma A. Gap balancing versus measured resection technique for total knee arthroplasty. Clin Orthop Relat Res 2010;468:102–7. https://doi.org/10.1007/s11999-009-1112-3.
[11] Song SJ, Park CH, Bae DK. What to know for selecting cruciate-retaining or posterior-stabilized total knee arthroplasty. Clin Orthop Surg 2019;11:142–50. https://doi.org/10.4055/cios.2019.11.2.142.
[12] Insall JN, Dorr LD, Scott RD, Scott WN. Rationale of the knee society clinical rating system. Clin Orthop Relat Res 1989:13–4. https://doi.org/10.1097/00003086-198911000-00004.
[13] Kim Y-H, Sohn K-S, Kim J-S. Range of motion of standard and high-flexion posterior stabilized total knee prostheses. A prospective, randomized study. J Bone Joint Surg Am 2005;87:1470–5. https://doi.org/10.2106/JBJS.D.02707.
[14] Ewald FC. The knee society total knee arthroplasty roentgenographic evaluation and scoring system. Clin Orthop Relat Res 1989;96:9–12. https://doi.org/10.1016/j.otsr.2010.06.008.
[15] Bauer GC, Insall J, Koshino T. Tibial osteotomy in gonarthrosis (osteo-arthritis of the knee). J Bone Joint Surg Am 1969;51:1545–63. https://doi.org/10.5035/nishiseisai.21.87.
[16] Liebs TR, Splietker F, Hassenpflug J. Is a revision a revision? An analysis of national arthroplasty registries' definitions of revision. Clin Orthop Relat Res 2015;473:3421–30. https://doi.org/10.1007/s11999-015-4255-4.
[17] Cool P, Ockendon M. The use of plots in orthopaedic literature. Bone Joint J 2015;97-B:1593–603. https://doi.org/10.1302/0301-620X.97B12.36167.
[18] Pocock SJ, Clayton TC, Altman DG. Survival plots of time-to-event outcomes in clinical trials: good practice and pitfalls. Lancet 2002;359:1686–9. https://doi.org/10.1016/S0140-6736(02)08594-X.
[19] Behrend H, Zdravkovic V, Giesinger J, Giesinger K. Factors predicting the forgotten joint score after total knee arthroplasty. J Arthroplasty 2016;31:1927–32. https://doi.org/10.1016/j.arth.2016.02.035.
[20] Kamenaga T, Muratsu H, Kanda Y, Miya H, Kuroda R, Matsumoto T. The Influence of postoperative knee stability on patient satisfaction in cruciate-retaining total knee arthroplasty. J Arthroplasty 2018;33:2475–9. https://doi.org/10.1016/j.arth.2018.03.017.
[21] Omori G, Onda N, Shimura M, Hayashi T, Sato T, Koga Y. The effect of geometry of the tibial polyethylene insert on the tibiofemoral contact kinematics in Advance Medial Pivot total knee arthroplasty. J Orthop Sci 2009;14:754–60. https://doi.org/10.1007/s00776-009-1402-3.
[22] Ishii Y, Noguchi H, Sato J, Sakurai T, Toyabe S. Anteroposterior translation and range of motion after total knee arthroplasty using posterior cruciate ligament-retaining versus posterior cruciate ligament-substituting prostheses. Knee Surg Sports Traumatol Arthrosc 2017;25:3536–42. https://doi.org/10.1007/s00167-016-4257-0.
[23] Karachalios T, Roidis N, Giotikas D, Bargiotas K, Varitimidis S, Malizos KN. A mid-term clinical outcome study of the Advance Medial Pivot knee arthroplasty. Knee 2009;16:484–8. https://doi.org/10.1016/j.knee.2009.03.002.
[24] Bae DK, Song SJ, Do Cho S. Clinical outcome of total knee arthroplasty with medial pivot prosthesis. J Arthroplasty 2011;26:693–8. https://doi.org/10.1016/j.arth.2010.04.022.
[25] Chinzei N, Ishida K, Tsumura N, Matsumoto T, Kitagawa A, Iguchi T, et al. Satisfactory results at 8years mean follow-up after ADVANCE® medial-pivot total knee arthroplasty. Knee 2014;21:387–90. https://doi.org/10.1016/j.knee.2013.10.005.
[26] Stukenborg-Colsman C, Ostermeier S, Hurschler C, Wirth CJ. Tibiofemoral contact stress after total knee arthroplasty: comparison of fixed and mobile-bearing inlay designs. Acta Orthop Scand 2002;73:638–46. https://doi.org/10.1080/000164702321039598.
[27] Galvin AL, Kang L, Udofia I, Jennings LM, McEwen HMJ, Jin Z, et al. Effect of conformity and contact stress on wear in fixed-bearing total knee prostheses. J Biomech 2009;42:1898–902. https://doi.org/10.1016/j.jbiomech.2009.05.010.
[28] Nakamura S, Minoda Y, Nakagawa S, Kadoya Y, Takemura S, Kobayashi A, et al. Clinical results of alumina medial pivot total knee arthroplasty at a minimum follow-up of 10 years. Knee 2017;24:434–8. https://doi.org/10.1016/j.knee.2016.12.011.
[29] Dehl M, Bulaïd Y, Chelli M, Belhaouane R, Gabrion A, Havet E, et al. Total knee arthroplasty with the Medial-Pivot knee system: clinical and radiological outcomes at 9.5 years' mean follow-up. Orthop Traumatol Surg Res 2018;104:185–91. https://doi.org/10.1016/j.otsr.2017.10.016.
[30] Minoda Y, Kobayashi A, Iwaki H, Miyaguchi M, Kadoya Y, Ohashi H, et al. Polyethylene wear particles in synovial fluid after total knee arthroplasty. Clin Orthop Relat Res 2003;410:165–72. https://doi.org/10.1097/01.blo.0000063122.39522.c2.
[31] Sieving A, Wu B, Mayton L, Nasser S, Wooley PH. Morphological characteristics of total joint arthroplasty-derived ultra-high molecular weight polyethylene (UHMWPE) wear debris that provoke inflammation in a murine model of inflammation. J Biomed Mater Res A 2003;64:457–64. https://doi.org/10.1002/jbm.a.10368.
[32] Kobayashi A, Freeman MA, Bonfield W, Kadoya Y, Yamac T, Al-Saffar N, et al. Number of polyethylene particles and osteolysis in total joint replacements. A quantitative study using a tissue-digestion method. J Bone Joint Surg Br 1997;79:844–8. https://doi.org/10.1302/0301-620x.79b5.7602.