

Long-Term Outcomes of Single-Radius Total Knee Arthroplasty in an Asian Population: A Comparison of Cruciate-Retaining and Posterior-Stabilized Designs

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Abstract

Background

Single-radius total knee arthroplasty (TKA) has demonstrated favorable clinical outcomes and survivorship; however, long-term comparative data between cruciate-retaining (CR) and posterior-stabilized (PS) designs within a single-radius system remain limited, particularly in Asian populations. This study aimed to evaluate the long-term clinical and radiologic outcomes and survivorship of single-radius TKA and to compare CR and PS designs in an Asian population.

Methods

This retrospective study included 222 knees (152 patients) who underwent primary TKA using a single-radius prosthesis between 2006 and 2015, with a minimum follow-up of 10 years. There were 112 CR knees and 110 PS knees. Clinical outcomes were assessed using the Knee Society Score, Western Ontario and McMaster Universities Osteoarthritis Index, and Forgotten Joint Score. Radiologic outcomes were also evaluated. Kaplan–Meier survivorship analysis was performed using revision for all cause and aseptic revision as endpoints. Inverse probability of treatment weighting (IPTW) was applied to adjust for baseline differences between groups.

Results

At a mean follow-up of 13.16 ± 2.78 years, significant improvements were observed in all clinical outcomes compared with preoperative values (all $p < 0.001$). At final follow-up, no significant differences were found between the CR and PS groups in clinical outcomes, radiologic parameters, except for a greater posterior tibial slope in the CR group ($p < 0.001$). These findings remained consistent after IPTW adjustment. Revision surgery was performed in 6 of 222 knees (2.7%), with no difference between groups ($p = 0.44$). In the overall cohort, the 15-year Kaplan–Meier survivorship free from revision for all cause was 96.2% (95% CI, 93.2–99.4). The estimated 15-year aseptic revision-free survivorship was 98.9% (95% CI, 96.9–100) in the CR group and 95.6% (95% CI, 91.4–100) in the PS group. Survivorship did not differ between CR and PS groups for either all-cause or aseptic revision (log-rank $p = 0.99$ and $p = 0.999$, respectively).

Conclusions

Single-radius TKA demonstrated favorable long-term clinical outcomes and high survivorship in an Asian population. Comparable outcomes were observed between CR and PS designs when used according to appropriate clinical indications, despite more severe preoperative deformity in the PS group.

Introduction

The single-radius design of total knee arthroplasty (TKA) has been developed to optimize knee function, and prior studies have demonstrated favorable clinical outcomes and long-term survivorship [1–5]. Meanwhile, many mid- to long-term comparative studies and meta-analyses have reported no significant differences in outcomes between cruciate-retaining (CR) and posterior-stabilized (PS) designs [6–10]. In single-radius TKA, both CR and PS designs are also widely used [1, 2, 5]; however, it remains unclear whether preserving or sacrificing the posterior cruciate ligament (PCL) leads to meaningful differences in long-term outcomes within a single-radius design [6, 10]. This is because long-term comparative evidence specific to the single-radius design is limited [6] and to our knowledge, no studies have compared CR and PS designs using a single-radius design with long-term follow-up in an Asian population. Because of the different lifestyles between Asians and Westerners, such as high-flexion activities, it remains unclear whether differences exist in terms of clinical outcomes or long-term survivorship in Asian populations [11–13]. Therefore, this study aimed to evaluate the long-term outcomes and survivorship of single-radius TKA and to compare CR and PS groups with a minimum follow-up of 10 years. We hypothesized that there would be favorable long-term outcomes in single-radius TKA and no differences in survivorship between the two designs in an Asian population.

Materials and Methods

Patient Selection

This retrospective study included consecutive patients who underwent primary TKA using a single-radius design at our institution between July 2006 and December 2015. The inclusion criterion was primary TKA performed for primary osteoarthritis using the single-radius implant system. Exclusion criteria included diagnoses other than primary osteoarthritis and patients who died or were lost to follow-up before 10 years. After applying the criteria, 222 knees (152 patients) were finally enrolled. Of these, there were 112 knees (50.5%) with the CR design and 110 knees (49.5%) with the PS design (Fig. 1). Baseline demographic and clinical variables were collected through a retrospective review of medical records and preoperative radiographs. The study protocol was approved by the institutional review board of the participating institution (approval number blinded for review).

A total of 385 total knee arthroplasties (TKAs) performed using a single-radius prosthesis between July 2006 and December 2015 were assessed for eligibility. After exclusion of 40 knees with diagnoses other than primary osteoarthritis and 123 knees because of death or loss to follow-up before 10 years, 222 knees were included in the final analysis. The final cohort comprised 112 cruciate-retaining and 110 posterior-stabilized TKAs. OA, osteoarthritis; TKA, total knee arthroplasty; CR, cruciate-retaining; PS, posterior-stabilized.

Surgical Procedures

All surgeries were performed by a single senior surgeon who performed more than 200 primary TKAs annually, using the single-radius Triathlon (Stryker, Mahwah, NJ) prosthesis system. A mini-mid vastus approach was used for all surgeries [14]. A modified gap technique was used for gap and soft tissue balancing [15]. The PS design was used in patients with a coronal deformity of $> 15^\circ$, a fixed flexion contracture of $> 20^\circ$, or PCL insufficiency [16–19]. In addition, if residual flexion contracture or recurvatum persisted, or if the flexion gap remained tight despite adjustment of posterior tibial slope or PCL release during an attempted CR procedure, the implant was converted to the PS type [16, 20, 21]. Posterior tibial slope was targeted at 5° for the CR design and 3° for the PS design, in accordance with established technical considerations for each design [22, 23]. Postoperative pain management and rehabilitation protocols were identical for all cases.

Clinical and Radiologic Evaluations

Clinical and radiologic outcomes were assessed and compared between the CR and PS groups. Clinical evaluations were conducted preoperatively, at 6 weeks, 3 months, 6 months, 1 year, and annually thereafter, and at the final follow-up, using the Knee Society Knee Score (KSKS) and the Knee Society Function Score (KSFS) [24]. The primary clinical outcome was the KSFS. At the final follow-up, patient-reported outcome measures included the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) and the Forgotten Joint Score (FJS) [25, 26]. Flexion contracture (FC) and range of motion (ROM) of the knee were measured in the supine position using a goniometer [27]. The minimal clinically important difference (MCID) values for the KSKS and KSFS and patient-acceptable symptom state (PASS) threshold for the FJS were adopted to assess clinically meaningful improvement, and achievement rates were compared between the groups [28, 29].

Radiologic evaluations included long-leg standing radiographs from the pelvis to the ankle joint, as well as weight-bearing anteroposterior and lateral views. The alignment of the lower limb was assessed using the hip-knee-ankle angle (HKAA) [30]. Implant alignment was assessed on standing radiographs using component alignment angles in accordance with the Knee Society radiographic evaluation system [31]. Prosthesis loosening was defined by intraoperative confirmation or radiographic evidence, such as changes in implant position or the presence of a progressive radiolucent line at the bone-cement or bone-implant interface [32].

Complications and Revisions

All intraoperative, early, and late postoperative complications were recorded by review of the medical records and operative notes. Complications were classified according to the standardized list and definitions proposed by the Knee Society [32].

Revision surgery was defined as any subsequent operation involving exchange, removal, or addition of one or more prosthetic components, including the femoral component, tibial component, and polyethylene (PE) insert [33]. In cases of revision surgery, the causes of failure and the time to revision were recorded.

Survivorship

Kaplan–Meier survivorship analysis was performed to generate survivorship curves with 95% confidence intervals (CIs). Time-to-event was calculated from the date of the index primary TKA to the date of revision surgery, or to the date of the final follow-up for censored cases. Implant survivorship at 15 years was evaluated using revision for all cause as the primary endpoint. The secondary endpoint was aseptic revision, defined as revision excluding infection, with aseptic causes analyzed separately [34]. Patients who underwent revision surgery before 10 years of follow-up were not excluded. Instead, they were retained in the cohort and counted as events at the time of revision [35].

Data Analyses

A power analysis based on the available sample size was performed using G*Power (version 3.1.9.7). The effect size was estimated from a previous long-term comparative study of CR and PS TKA, which reported between-group differences in KSFS at a minimum of 10 years [36]. With 112 knees in the CR group and 110 knees in the PS group, the present study had 93.6% power ($\alpha = 0.05$, $\beta = 0.064$) to detect an effect size of Cohen's $d = 0.47$ for between-group comparisons of continuous clinical outcomes. Categorical variables were compared using the chi-square test or Fisher's exact test, as appropriate. For continuous variables, the Student's t-test was employed for normally distributed data and the Mann–Whitney U test was employed for non-normally distributed data. Changes from preoperative to the final follow-up in the overall cohort were assessed using paired t-tests for normally distributed variables and Wilcoxon signed-rank tests for non-normally distributed variables as appropriate. To adjust for baseline

imbalances between the CR and PS groups, inverse probability of treatment weighting (IPTW) was applied. Propensity scores were estimated using a logistic regression model including age, sex, BMI, HKAA, KSKS, KSFS, FC, maximum flexion, and ROM. Stabilized weights were used and truncated at the 1st and 99th percentiles to reduce the influence of extreme weights. Covariate balance after weighting was confirmed by standardized mean differences (SMDs) < 0.10 for all covariates. Outcomes were compared using weighted regression models with robust standard errors. Kaplan–Meier survivorship curves were compared using the log-rank test. A p-value < 0.05 was considered statistically significant. Statistical analyses were performed using SPSS software version 23 (IBM Corp, Armonk, NY).

Results

In the overall cohort, the mean age at surgery was 67.66 ± 6.37 years, and the mean follow-up duration was 13.16 ± 2.78 years. Baseline demographic and preoperative clinical characteristics according to prosthesis design are presented in Tables 1 and 2. The mean follow-up period was 13.48 ± 2.61 years in the CR group and 12.83 ± 2.91 years in the PS group ($p = 0.142$) (Table 1). Preoperatively, the KSKS was higher in the CR group than in the PS group ($p < 0.001$). The CR group also showed greater ROM compared with the PS group ($p < 0.001$). The HKAA was more varus in the PS group than in the CR group ($p = 0.028$). No significant differences were observed in other baseline characteristics between the two groups (Table 2). Given these baseline imbalances, IPTW was applied. After weighting, covariate balance improved substantially, with SMDs < 0.10 for all covariates (Fig. 2 and Table 3).

Table 1
Demographic Data

Demographic	CR	PS	p-value
Knees (n)	112	110	
Age (years, mean $\pm$ SD)	67.09 ± 6.54	68.24 ± 6.16	0.180
Follow-up period (years, mean $\pm$ SD)	13.48 ± 2.61	12.83 ± 2.91	0.142
Sex (male: female)	4:108	6:104	0.724
Body mass index (mean $\pm$ SD)	28.05 ± 3.44	28.03 ± 3.93	0.839
HKAA (degree, mean $\pm$ SD)	-8.13 ± 4.93	-9.39 ± 5.30	0.028*
CR = cruciate-retaining, PS = posterior-stabilized, HKAA = hip-knee-ankle angle (negative values indicating varus alignment), SD = standard deviation. * Statistically significant with $p < 0.05$			

Table 2
Preoperative Clinical Scores and Range of Motion

Preoperative Clinical Scores and ROM	CR	PS	p-value
KSKS (mean $\pm$ SD)	51.92 ± 16.32	43.05 ± 16.69	< 0.001*
KSFS (mean $\pm$ SD)	50.78 ± 13.11	47.10 ± 14.88	0.220
Flexion contracture (degree, mean $\pm$ SD)	5.86 ± 5.69	9.86 ± 8.74	< 0.001*
Maximum flexion (degree, mean $\pm$ SD)	131.53 ± 9.79	126.06 ± 14.80	0.010*
ROM (degree, mean $\pm$ SD)	125.71 ± 12.96	116.06 ± 18.72	< 0.001*
CR = cruciate-retaining, PS = posterior-stabilized, KSKS = Knee Society knee score, KSFS = Knee Society function score, ROM = range of motion, SD = standard deviation. * Statistically significant with $p < 0.05$			

Absolute standardized mean differences for baseline covariates are presented before and after inverse probability of treatment weighting (IPTW). The vertical dashed line indicates the prespecified threshold of 0.10 for acceptable covariate balance. After weighting, all baseline covariates were below this threshold. IPTW, inverse probability of treatment weighting; ROM, range of motion; KSKS, Knee Society Knee Score; KSFS, Knee Society Function Score; HKAA, hip-knee-ankle angle; BMI, body mass index.

Table 3
Covariate Balance Before and After Inverse Probability of Treatment
Weighting

Covariate	Unweighted SMD	IPTW Weighted SMD
ROM	0.559	0.054
Flexion contracture	0.529	0.052
KSKS	0.506	0.051
Maximum flexion	0.386	0.020
KSFS	0.256	0.012
HKAA	0.239	0.018
Age at operation	0.201	0.010
Sex (Male)	0.024	0.001
BMI	0.017	0.022

SMD, standardized mean difference; IPTW, inverse probability of treatment weighting; ROM, range of motion; KSKS, Knee Society Knee Score; KSFS, Knee Society Function Score; HKAA, hip-knee-ankle angle; BMI, body mass index. Absolute SMDs are presented for each covariate before and after IPTW. An absolute SMD < 0.10 was considered indicative of acceptable covariate balance.

At final follow-up, the overall cohort showed significant improvements in KSKS, KSFS, and ROM compared with preoperative values (all $p < 0.001$). Specifically, the KSKS increased from 47.79 ± 16.89 preoperatively to 82.08 ± 14.56 at final follow-up, and the KSFS increased from 49.03 ± 14.10 to 80.89 ± 20.57 . ROM increased from $121.02 \pm 16.79^\circ$ to $138.02 \pm 9.37^\circ$. There were no statistically significant differences in clinical outcomes between the CR and PS groups (all $p > 0.05$) (Table 4). Furthermore, no significant between-group differences were found in MCID or PASS achievement rates for any clinical outcome (all $p > 0.05$) (Fig. 3). Radiologically, no significant differences were found in the HKAA, α angle, β angle, or γ angle (all $p > 0.05$) between the groups. Only the posterior tibial slope (δ angle) was significantly larger in the CR group ($4.48 \pm 2.15^\circ$) than in the PS group ($3.26 \pm 1.64^\circ$) ($p < 0.001$). These results were consistent after IPTW adjustment, with no significant differences between the two groups in clinical outcomes and the δ angle remaining the only parameter showing a significant difference (Table 4).

Overall complications are summarized in Table 5. Total complications occurred in 5 of 112 knees (4.5%) in the CR group and 10 of 110 knees (9.1%) in the PS group, with no significant difference between the groups ($p = 0.191$). Revision surgery was performed in 6 of 222 knees (2.7%). There were 2 knees (1.8%) in the CR group and 4 knees (3.6%) in the PS group that required revision surgery, with no significant difference between groups ($p = 0.44$). Aseptic revision cases (excluding infection) are summarized in Table 6.

Bar plots show the achievement rates of clinically meaningful outcomes in the cruciate-retaining and posterior-stabilized groups: (a) minimal clinically important difference (MCID) for the Knee Society Knee Score (KSKS), (b) MCID for the Knee Society Function Score (KSFS), and (c) patient-acceptable symptom state (PASS) for the Forgotten Joint Score (FJS). No statistically significant between-group differences were identified in any of these outcomes. CR, cruciate-retaining; PS, posterior-stabilized; MCID, minimal clinically important difference; PASS, patient-acceptable symptom state; KSKS, Knee Society Knee Score; KSFS, Knee Society Function Score; FJS, Forgotten Joint Score.

Table 4
Comparison of Clinical and Radiologic Outcomes Between CR and PS Designs : unweighted and IPTW-weighted comparisons

Outcomes	Unweighted		IPTW-Weighted					
	CR	PS	Mean Difference (PS - CR, 95% CI)	P-value	CR	PS	Mean Difference (PS - CR, 95% CI)	P-value
Clinical Outcomes								
FC (degree)	-0.86 ± 2.22	-0.61 ± 1.78	0.25 (-0.29, 0.79)	0.299	-0.75 ± 2.30	-0.91 ± 2.11	-0.16 (-0.89, 0.58)	0.676
Maximum flexion (degree)	137.34 ± 8.71	137.10 ± 8.38	-0.24 (-2.53, 2.05)	0.885	137.02 ± 9.02	137.67 ± 8.09	0.65 (-1.89, 3.18)	0.615
ROM (degree)	138.20 ± 9.67	137.71 ± 8.99	-0.49 (-2.99, 2.02)	0.924	137.77 ± 10.05	138.57 ± 9.02	0.80 (-2.09, 3.70)	0.586
KSKS	83.54 ± 13.94	80.53 ± 15.03	-3.01 (-6.90, 0.87)	0.125	84.21 ± 13.81	81.29 ± 14.75	-2.92 (-7.17, 1.33)	0.176
KSFS	82.72 ± 20.18	79.38 ± 20.53	-3.34 (-8.79, 2.11)	0.162	82.07 ± 21.48	81.05 ± 19.10	-1.02 (-7.24, 5.21)	0.747
WOMAC	32.41 ± 30.88	31.69 ± 26.97	-0.71 (-10.29, 8.86)	0.510	33.81 ± 31.60	28.66 ± 25.50	-5.15 (-15.91, 5.61)	0.346
FJS	78.35 ± 18.81	78.85 ± 15.73	0.50 (-5.43, 6.42)	0.954	78.20 ± 18.58	79.49 ± 13.76	1.29 (-4.68, 7.26)	0.670
Radiologic Outcomes								
HKAA (degree)	-0.16 ± 2.60	-0.66 ± 2.48	-0.50 (-1.18, 0.18)	0.117	-0.41 ± 2.76	-0.50 ± 2.41	-0.09 (-0.90, 0.71)	0.819
α angle (degree)	95.77 ± 1.84	96.01 ± 2.06	0.23 (-0.40, 0.87)	0.467	95.62 ± 1.77	96.04 ± 2.00	0.42 (-0.25, 1.08)	0.220
β angle (degree)	88.88 ± 1.33	88.82 ± 1.89	-0.06 (-0.60, 0.49)	0.306	88.96 ± 1.42	88.89 ± 1.98	-0.07 (-0.72, 0.58)	0.829
γ angle (degree)	2.87 ± 2.12	3.26 ± 2.37	0.39 (-0.30, 1.09)	0.175	2.81 ± 2.18	3.16 ± 2.38	0.36 (-0.42, 1.13)	0.366
δ angle (degree)	4.48 ± 2.15	3.26 ± 1.64	-1.23 (-1.74, -0.72)	< 0.001*	4.39 ± 2.14	3.34 ± 1.55	-1.05 (-1.60, -0.50)	< 0.001*

Data are presented as mean ± standard deviation unless otherwise indicated. Mean differences were calculated as PS minus CR and are presented with 95% confidence intervals. After-IPTW estimates were obtained using inverse probability of treatment weighting. CR, cruciate-retaining; PS, posterior-stabilized; IPTW, inverse probability of treatment weighting; FC, flexion contracture; ROM, range of motion; KSKS, Knee Society Knee Score; KSFS, Knee Society Function Score; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index; FJS, Forgotten Joint Score; HKAA, hip-knee-ankle angle; CI, confidence interval; SD, standard deviation. Negative HKAA values indicate varus alignment. *Statistically significant at $p < 0.05$.

Table 5
Complications

Complications	Number
Aseptic tibial loosening	3 (3 PS)
Instability	2 (1 CR, 1 PS)
Stiffness (required MUA)	4 (2 CR, 2 PS)
PJI	1 (1 CR)
Periprosthetic fracture	5 (1 CR, 4 PS)
Distal femur	3 (1 CR, 2 PS)
Patella	2 (2 PS)
CR = cruciate-retaining, PS = posterior-stabilized, PJI = periprosthetic joint infection, MUA = manipulation under anesthesia	

Table 6
Aseptic Revision Cases After Single-radius Total Knee Arthroplasty

Design	Time to Revision (Year)	Reason for Revision	Surgical Procedure
PS	4.9	Aseptic tibial loosening	Tibial component revision
PS	6.1	Aseptic tibial loosening	Tibial component revision
PS	10.7	Aseptic tibial loosening	Tibial component revision
PS	10.1	Instability	Polyethylene change
CR	10.1	Instability	Polyethylene change
CR = cruciate-retaining, PS = posterior-stabilized			

In the overall cohort, the 15-year Kaplan–Meier survivorship with revision for all cause was 96.2% (95% CI, 93.2–99.4). The estimated 15-year all-cause revision-free survivorship was 97.0% (95% CI, 92.9–100) in the CR group and 95.6% (95% CI, 91.4–100) in the PS group, and aseptic revision-free survivorship was 98.9% (95% CI, 96.9–100) for the CR group and 95.6% (95% CI, 91.4–100) for the PS group. Kaplan–Meier survivorship analysis showed no significant differences between the two groups at 15 years for all-cause revision or aseptic revision (Fig. 4).

Kaplan–Meier curves compare revision-free survivorship between the cruciate-retaining and posterior-stabilized designs using (a) revision for all cause and (b) aseptic revision as endpoints. No statistically significant between-group differences were observed for revision for all cause (log-rank $p = 0.99$) or aseptic revision (log-rank $p = 0.999$). CR, cruciate-retaining; PS, posterior-stabilized.

Discussion

The current study evaluated the long-term outcomes of single-radius TKA and compared CR and PS designs in an Asian population with a minimum follow-up of 10 years. The principal findings were that single-radius TKA showed favorable long-term clinical outcomes and high implant survivorship, and that no significant differences were observed between CR and PS groups in terms of clinical outcomes, radiologic parameters, complication rates, or survivorship, except for a greater posterior tibial slope in the CR group. These findings remained consistent after adjustment for baseline differences using IPTW. Considering the limited long-term comparative data specific to single-radius designs, particularly in Asian populations, this study provides clinically relevant long-term evidence regarding implant durability and PCL management.

In clinical series, single-radius TKA has been reported to provide favorable clinical outcomes, and long-term follow-up studies have demonstrated excellent implant survivorship exceeding 95% at 10 years [1, 2, 4, 37]. These findings support the theoretical advantages of a constant flexion–extension axis and improved extensor efficiency [38, 39]. However, the majority of long-term studies of the single-radius design have focused on Western populations [4–6]. Therefore, whether these findings can be generalized to Asian patients seems uncertain [11–13]. Differences in lifestyle, including frequent high-flexion activities such as squatting and floor sitting, as well as anatomical characteristics such as a higher prevalence of constitutional varus alignment, may influence joint kinematics, implant loading, and long-term durability [11, 13]. Given these considerations, long-term data on single-radius TKA in Asian populations remain limited [1, 2]. The current study further extends the evidence in an Asian population by evaluating both CR and PS designs in single-radius TKA and demonstrating favorable long-term outcomes and high 15-year revision-free survivorship comparable to those reported in Western cohorts [4].

Another important aspect of the current study is the comparison between CR and PS designs within a single-radius system under real-world clinical indications [18, 40]. In the present cohort, implant selection was based on preoperative and intraoperative findings, with PS designs preferentially used in knees with more severe deformity, flexion contracture, PCL insufficiency, or intraoperative tight flexion gap when the CR trial applied [16–19, 41]. As a result, the PS group had worse baseline clinical and radiologic characteristics than the CR group. Despite these differences, no significant differences were observed in long-term clinical outcomes after IPTW adjustment, suggesting that both designs can achieve reliable long-term outcomes when applied according to appropriate clinical indications. Recent long-term studies and meta-analyses have shown no consistent pattern regarding survivorship differences between CR and PS designs, although some registry-based analyses have suggested a higher risk of revision in PS designs, particularly due to aseptic loosening [6, 8, 10, 42, 43]. From a mechanistic perspective, all-cause revision may not fully reflect differences attributable to implant design, as certain failure modes, such as periprosthetic joint infection or traumatic periprosthetic fracture, are not necessarily attributable to implant design [32, 33, 44–46]. In this context, aseptic implant-related failure may represent a more relevant endpoint when comparing CR and PS designs [43, 47]. In the current study, although no statistically significant difference was observed in aseptic revision-free survivorship, no case of aseptic loosening occurred in the CR group, whereas loosening was observed only in the PS group (2.7%). However, given the small number of events and the limited statistical power of this retrospective study, this observation should be interpreted with caution. In addition, because the PS group included patients with more severe preoperative deformity, residual confounding cannot be excluded [48, 49]. Therefore, this finding should be considered exploratory rather than indicative of a definitive difference between the two designs.

From a surgical perspective, CR TKA is generally considered more technically demanding than PS TKA, as it requires preservation of the PCL while achieving appropriate gap balance and soft-tissue tension [22, 23, 41]. For this reason, PS design remains widely used in clinical practice, often to

achieve more predictable stability and technical reproducibility, particularly in severely deformed knees [17, 27, 41]. At the same time, the comparable outcomes achieved in the PS group, despite worse baseline conditions, support the role of PS designs as a reliable option in more challenging clinical scenarios [17, 41]. Meanwhile, recent advances in TKA have shifted the focus from conventional mechanical alignment toward more patient-specific approaches, including kinematic alignment, functional alignment, and robotic-assisted techniques [50–54]. These contemporary concepts aim to better restore native knee kinematics by preserving individual anatomy and soft-tissue balance [50, 51, 54]. In this context, CR designs have gained renewed interest, as preservation of more native knee kinematics, maintenance of PCL, and less bone resection may be more consistent with these principles [50, 55, 56]. In the current study, comparable long-term outcomes were observed between CR and PS groups, suggesting that the technical demands of CR TKA may be justified in appropriately selected patients. Accordingly, our long-term findings may provide a useful reference for interpreting future evidence as CR techniques continue to evolve and long-term successful outcomes of kinematically aligned CR TKA become available. Taken together, these findings suggest that while CR TKA may be conceptually aligned with evolving trends toward more physiologic reconstruction, both CR and PS designs remain valid options in contemporary practice [6, 8, 10]. Therefore, implant selection should be individualized, based on patient characteristics, deformity severity, as well as the surgeon's philosophy and proficiency [16, 41].

This study has several limitations. First, the retrospective design and indication-based selection of implant design may have introduced residual confounding, despite the use of IPTW. Second, the number of revision events was relatively small, limiting statistical power to detect differences in survivorship. Third, the predominance of female patients may affect generalizability. While the female predominance is common in Asian populations, differences in lifestyle and skeletal structure may limit the generalizability of our findings to Western populations [11, 12]. Fourth, loss to follow-up over a long observation period is unavoidable and may introduce selection bias. This is likely due to the high average age of our patients and the fact that they were recruited from all over the country to our institute. Finally, as the current study reflects a single, high-volume center experience using a specific implant system, caution is warranted when extrapolating the findings to other populations, institutions or implant designs.

Conclusions

Single-radius total knee arthroplasty demonstrated favorable long-term clinical outcomes and high survivorship in an Asian population. No significant differences were observed between CR and PS groups when used according to appropriate clinical indications. Notably, comparable outcomes were achieved despite more severe preoperative deformity in the PS group, suggesting that implant selection based on appropriate indications can yield reliable long-term results irrespective of design.

Abbreviations

TKA
Total knee arthroplasty
CR
Cruciate-retaining
PS
Posterior-stabilized
PCL
Posterior cruciate ligament
KSKS
Knee Society Knee Score
KSFS
Knee Society Function Score
WOMAC
Western Ontario and McMaster Universities Osteoarthritis Index
FJS
Forgotten Joint Score
ROM
Range of motion
HKAA
Hip-knee-ankle angle
FC
Flexion contracture
MCID
Minimal clinically important difference
PASS
Patient-acceptable symptom state
IPTW

Inverse probability of treatment weighting
SMD
Standardized mean difference
CI
Confidence interval
PE
Polyethylene
PJI
Periprosthetic joint infection
MUA
Manipulation under anesthesia

Declarations

Ethics approval and consent to participate

This retrospective study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Review Board. The requirement for informed consent was waived by the Institutional Review Board because of the retrospective nature of the study and the use of de-identified clinical data.

Consent for publication

Not applicable.

Author Contribution

Conceptualization: [Kang-II Kim], Methodology: [Kang-II Kim], Formal analysis and investigation: [Hyobeom Lee, Gi-Young Jang], Writing - original draft preparation: [Gi-Young Jang]; Writing - review and editing: [Kang-II Kim, Hyobeom Lee], Supervision: [Kang-II Kim].

Data Availability

The datasets used and/or analysed during the current study are not publicly available because they contain potentially identifiable clinical information, but are available from the corresponding author on reasonable request and subject to approval by the relevant institutional review board, where applicable.

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Figures

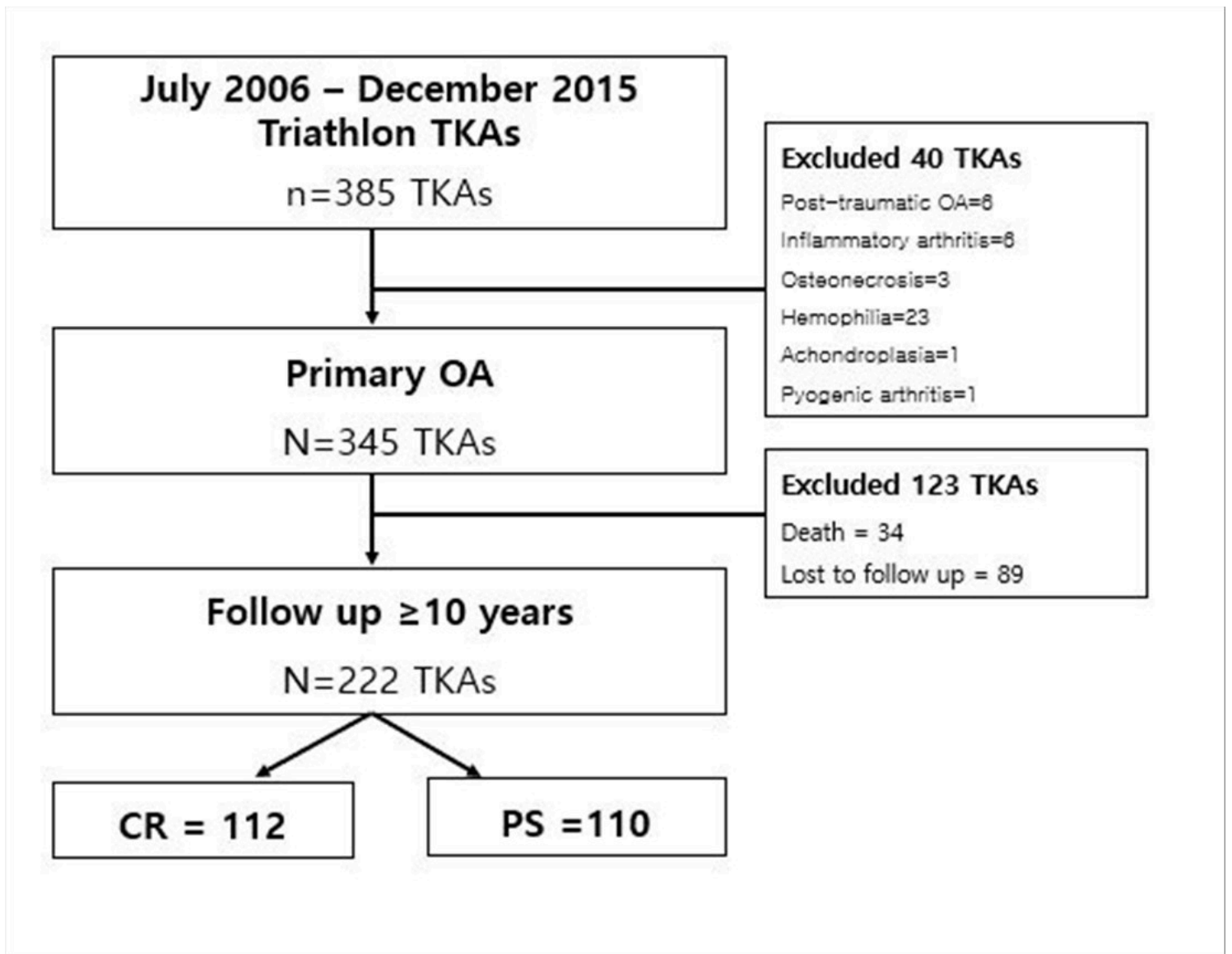


Figure 1

Flowchart of patient selection for the study cohort.

A total of 385 total knee arthroplasties (TKAs) performed using a single-radius prosthesis between July 2006 and December 2015 were assessed for eligibility. After exclusion of 40 knees with diagnoses other than primary osteoarthritis and 123 knees because of death or loss to follow-up before 10 years, 222 knees were included in the final analysis. The final cohort comprised 112 cruciate-retaining and 110 posterior-stabilized TKAs. OA, osteoarthritis; TKA, total knee arthroplasty; CR, cruciate-retaining; PS, posterior-stabilized.

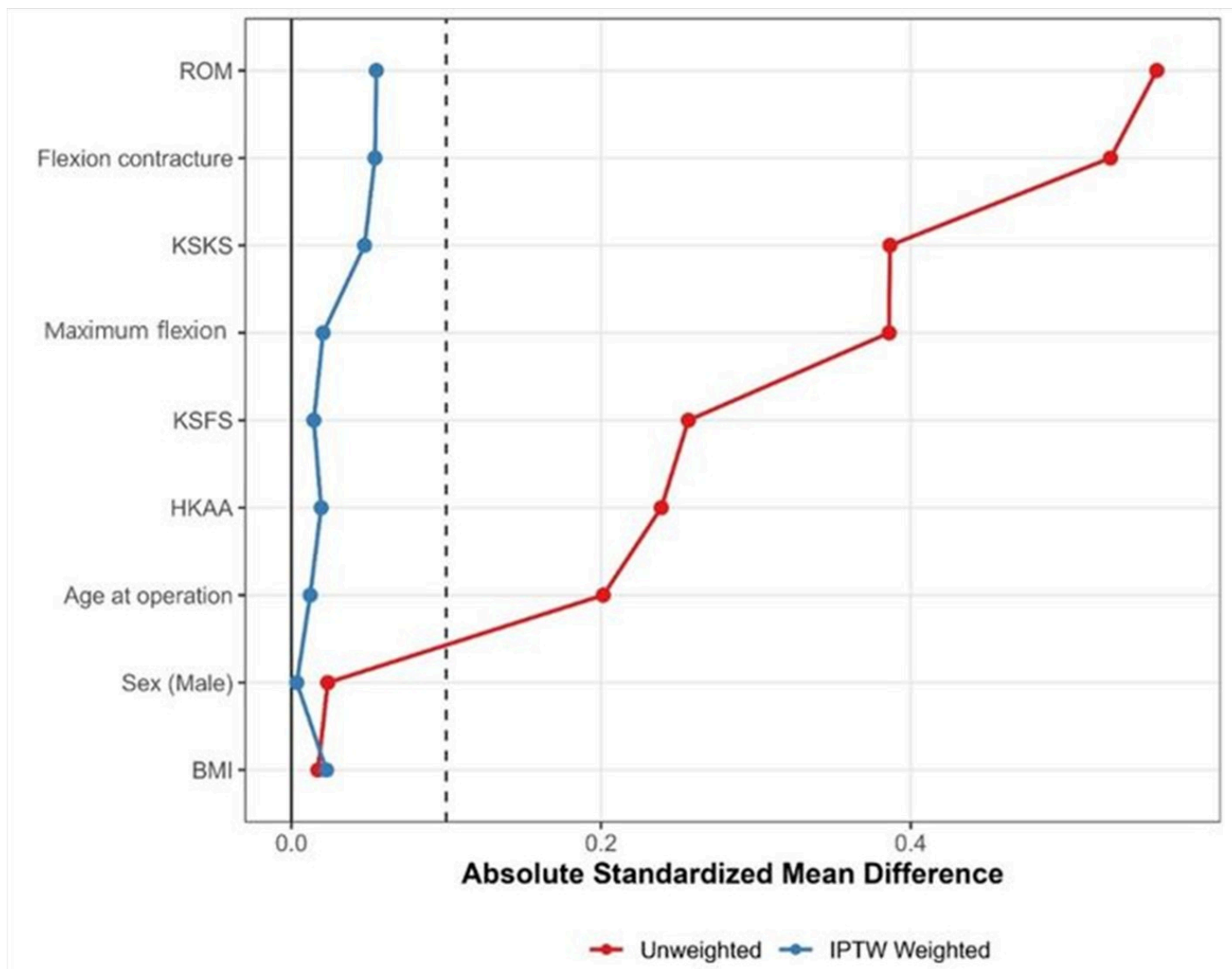


Figure 2

Covariate balance before and after inverse probability of treatment weighting.

Absolute standardized mean differences for baseline covariates are presented before and after inverse probability of treatment weighting (IPTW). The vertical dashed line indicates the prespecified threshold of 0.10 for acceptable covariate balance. After weighting, all baseline covariates were below this threshold. IPTW, inverse probability of treatment weighting; ROM, range of motion; KSKS, Knee Society Knee Score; KSFS, Knee Society Function Score; HKAA, hip-knee-ankle angle; BMI, body mass index.

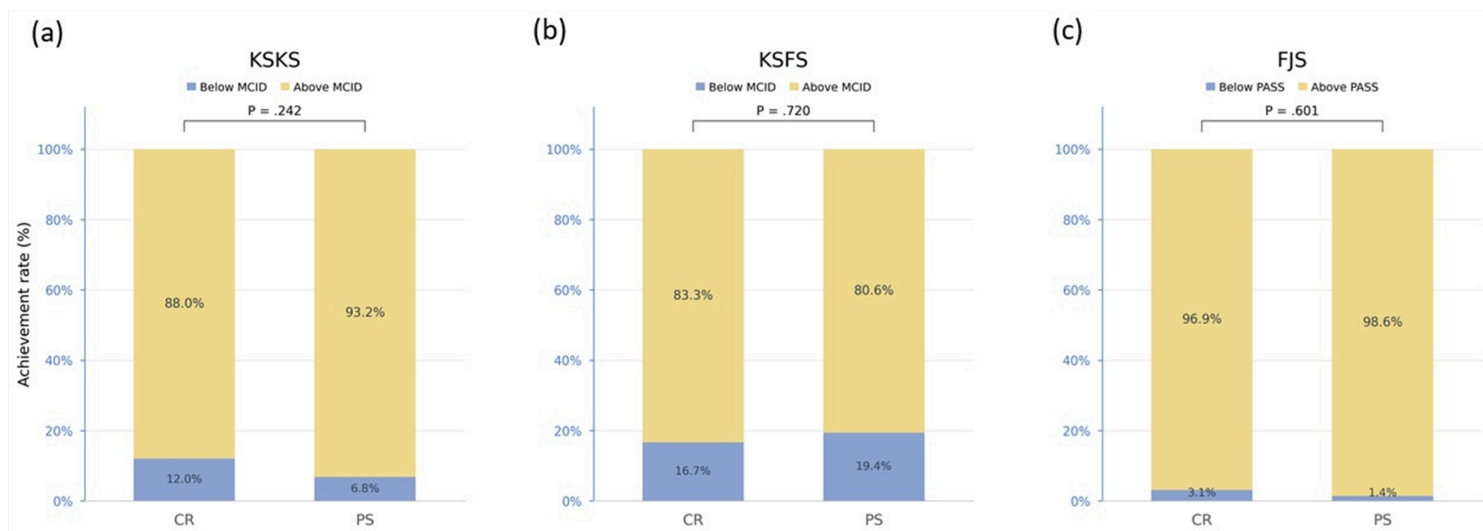


Figure 3

Achievement of clinically meaningful outcomes at final follow-up.

Bar plots show the achievement rates of clinically meaningful outcomes in the cruciate-retaining and posterior-stabilized groups: (a) minimal clinically important difference (MCID) for the Knee Society Knee Score (KSKS), (b) MCID for the Knee Society Function Score (KSFS), and (c) patient-acceptable symptom state (PASS) for the Forgotten Joint Score (FJS). No statistically significant between-group differences were identified in any of these outcomes. CR, cruciate-retaining; PS, posterior-stabilized; MCID, minimal clinically important difference; PASS, patient-acceptable symptom state; KSKS, Knee Society Knee Score; KSFS, Knee Society Function Score; FJS, Forgotten Joint Score.

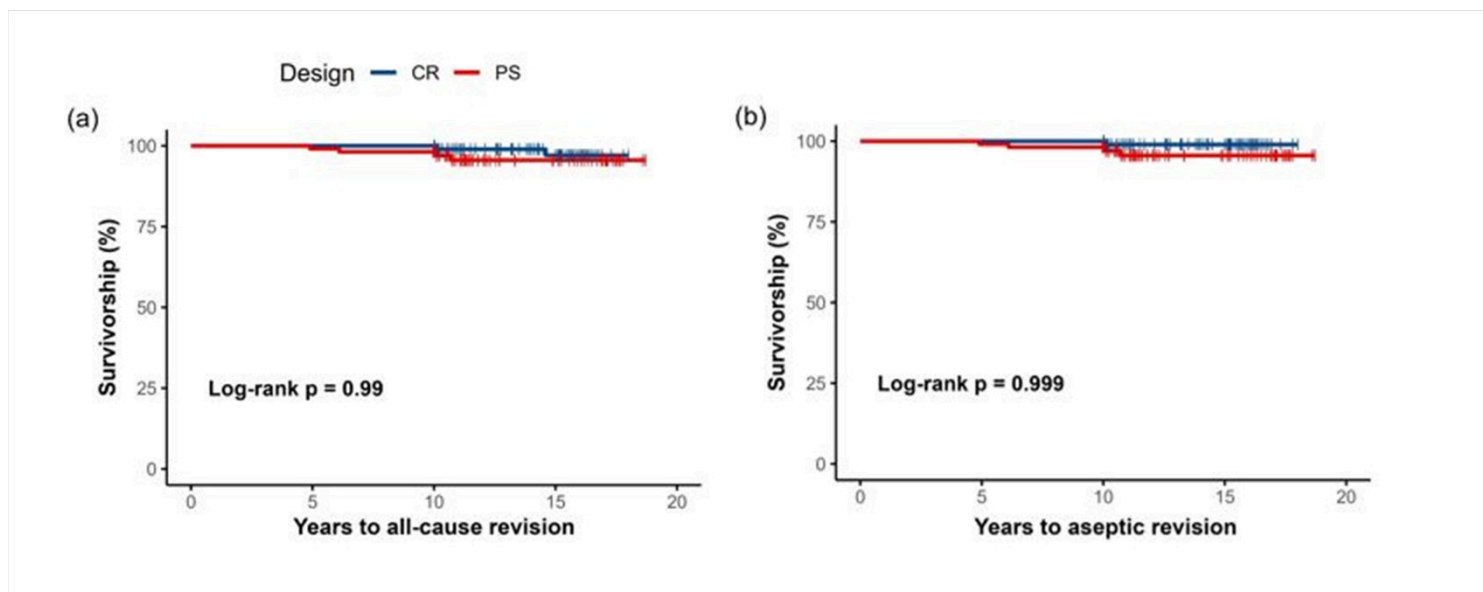


Figure 4

Kaplan–Meier survivorship curves comparing cruciate-retaining and posterior-stabilized designs.

Kaplan–Meier curves compare revision-free survivorship between the cruciate-retaining and posterior-stabilized designs using (a) revision for all cause and (b) aseptic revision as endpoints. No statistically significant between-group differences were observed for revision for all cause (log-rank $p = 0.99$) or aseptic revision (log-rank $p = 0.999$). CR, cruciate-retaining; PS, posterior-stabilized.