META-ANALYSIS

Posterior Cruciate-Retaining vs Posterior Cruciate-Stabilized Prosthesis in Total Knee Arthroplasty: A Meta-Analysis

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ABSTRACT

Objective • To evaluate the clinical and imaging results of posterior cruciate-retaining vs the posterior cruciate-stabilized method in total knee arthroplasty (TKA).

Methods • PubMed, EMbase and Cochrane Library databases were used to retrieve randomized controlled trials (RCTs) concerning the posterior cruciate-retaining vs posterior cruciate-stabilized method in TKA. Determination of study quality and data extraction were performed by 2 reviewers. Study heterogeneity was assessed by ReviewManager (RevMan) software and meta-analysis was conducted.

Results • A total of 15 RCTs were finally included in our meta-analysis. The results showed that no significant differences were found in the American Knee Society Score (AKSS) (MD = 0.13; 95% CI, -0.73 to 1.00), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) (MD = 0.59; 95% CI, 0.00-1.18), knee extension range of motion (MD = 0.10; 95% CI, -0.30 to 0.51)] or posterior tibial slope (MD = -0.09; 95% CI, -0.52-0.33) after surgery between the 2 groups. Compared with the posterior cruciate-retaining prosthesis group, in the posterior cruciate-stabilized prosthesis group the active knee joint range of motion was significantly increased (MD = -6.99; 95% CI, -9.17 to -4.81), knee flexion was significantly increased (MD = −4.22; 95% CI, -6.03 to -2.41) and the mechanical tibial angle was closed to 6° (MD = 0.85; 95% CI, 0.46-1.25). There were no significant differences in residual knee pain (OR = 1.26; 95% CI, 0.57-2.78), infection rate at the surgical site (OR = 0.50, 95% CI, 0.13-1.88) or revision rate (OR = 0.59; 95% CI, 0.15-2.32) between the 2 groups. Funnel plot revealed no significant bias in the included studies.

Conclusions • In summary, patients who received a posterior cruciate-stabilized prosthesis had better knee joint active range of motion, knee flexion and mechanical femorotibial angle than patients who received a posterior cruciate-retaining prosthesis. Due to the surgical difficulty involved in a posterior cruciate-retaining prosthesis, junior doctors should choose a posterior cruciate-stabilized prosthesis first, and senior doctors should choose the prosthesis according to the patient's condition and the surgeon's proficiency at performing the surgery in question. (*Altern Ther Health Med.* 2023;29(7):191-197).

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INTRODUCTION

Osteoarthritis (OA) is one of the most common degenerative lesions of the joints. It is a chronic disease characterized by articular cartilage degeneration and destruction, bone hyperplasia and narrowing of the joint space.[1] OA is common in elderly patients; more so in women than in men. Epidemiological investigations show that the prevalence of the disease is 50% to 60% and increases year by year.[2] OA has become an important cause of human disability, lowering quality of life (QoL), increasing medical expenses and even affecting national productivity. Weight-bearing joints are more prone to be affected, such as in the knees, spine (lumbar and cervical vertebrae), hips and ankles.[3] Current treatments for OA include non-drug, drug and surgical therapy. In the long-term treatment of knee OA, a reasonable and effective efficacy evaluation is needed, which could not only guide the doctor's next treatment plan, but also increase patient compliance.[4] We reviewed the efficacy evaluation of knee OA before and after treatment based on the literature and clinical experience, so as to provide more diversified and convenient methods for clinical diagnosis and treatment.

The improvement in surgical techniques and instruments in total knee arthroplasty (TKA) has gradually become a solution to relieve pain, correct deformity and improve QoL

in end-stage knee OA.[5] TKA arthroplasty prostheses currently in clinical use include posterior cruciate-retaining prosthesis and posterior cruciate-stabilized prosthesis, both of which can achieve ideal therapeutic effects in long-term postoperative follow-up.[6] Studies have reported that the use of a posterior cruciate ligament (PCL) retaining prosthesis in knee joint surgery results in favorable postoperative proprioception and range of motion.[7] In addition, it has been reported that the use of a posterior cruciate-stabilized prosthesis in knee joint surgery leads to improved postoperative mobility and facilitates easier achievement of soft tissue balance during surgery.

The debate regarding whether or not to retain the cruciate ligament in TKA has persisted despite more than 30 years of development history for the 2 types of prostheses. Moreover, previous studies have generally included a limited number of cases, leading to insufficient evidence for clinical decision-making. In order to address this gap, we aimed to conduct a systematic review and meta-analysis to assist healthcare professionals in making informed choices. In addition, most of the existing literature on systematic evaluations and meta-studies has been retrospective or non-randomized controlled trials (RCTs), with only a small number of studies included. Therefore, in our meta-analysis, we extensively reviewed high-quality RCTs from multiple centers. The purpose of this meta-analysis was to provide valuable insights in the selection of TKA prostheses.

MATERIALS AND METHODS

Search Strategy

Pubmed, EMbase and Cochrane Library databases were searched by 2 reviewers independently. Retrieval words included "posterior cruciate retaining," "posterior cruciate stabilizing" and "total knee arthroplasty."

Inclusion and Exclusion Criteria

Inclusion criteria: (1) patients received TKA for the first time; (2) the knee arthroplasty prosthesis accepted by the patient was the posterior cruciate-retaining prosthesis or the posterior cruciate-stabilized type; (3) outcome indicators included at least one of American Knee Society Score (AKSS), the Western Ontario and McMaster Universities arthritis index (WOMAC) score or postoperative knee range of motion and postoperative complications; (4) all included studies were RCTs; (5) all patients were followed up for 8 months or more.

Exclusion criteria: (1) non-RCTs; (2) studies had a lack of detailed data from required outcome indicators; (3) data extraction and statistics of repeatedly published studies were conducted according to the newest study; (4) reviews and case reports; (5) studies for which full text could not be obtained.

Data Extraction and Quality Assessment

A total of 2 reviewers independently extracted specific data from all the included studies and then cross-checked them. In the case of a disagreement between the 2 reviewers, a third reviewer decided whether or not to include the study in question. The extracted data included baseline characteristics and outcome indicators of the included studies.

We used the Jadad scale to evaluate the quality of the included studies.[8] The total possible study score is 7, and studies with scores ≥4 are considered high quality and those with scores <4 are considered low quality. Studies with too low quality (score 1-2) were excluded from the analysis.

Outcome indicators

The outcome indicators we analyzed were: (1) AKSS; (2) WOMAC score; (3) active range of motion of the knee joint; (4) knee extension range of motion; (5) knee flexion range of motion; (6) mechanical tibial angle; (7) posterior slope; (8) residual knee pain; (9) surgical site infection rate; (10) knee revision rate.

Statistical Analysis

We used RevMan 5.3 software (https://training.cochrane.org/online-learning/core-software/revman) for our analysis. Counting data were analyzed by calculating odds ratio (OR) and 95% CI. Measurement data were analyzed by calculating the mean difference (MD) and 95% CI. We used I^2 to assess the heterogeneity among studies. If I^2<50%, the heterogeneity was low and if >50% considered high. For results with low heterogeneity, we used the fixed-effect model to analyze them, and for the results with high heterogeneity, we used the random effect model for analysis. In addition, we created funnel plots to analyze the risk of bias in the included studies.

RESULTS

Study Selection and Characteristics

We initially retrieved 4340 studies and 15 studies[9-23] were finally included. The study screening process is shown in Figure 1, and baseline data for the included studies are shown in Table 1.

Figure 1. Study flow and selection diagram.

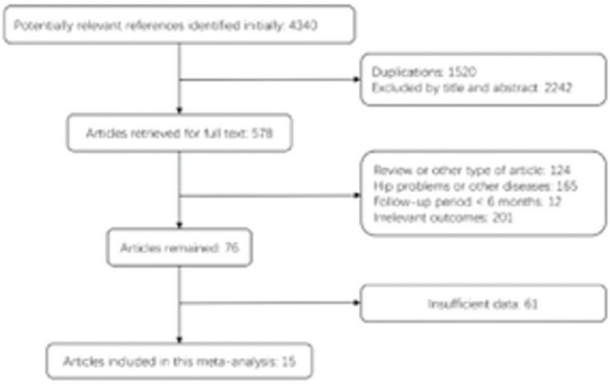


Table 1. Baseline Characteristics of Included Studies

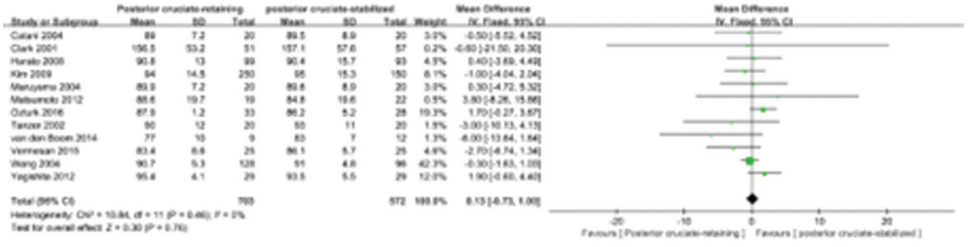
Study	Year	Region	n (PR/PS)	Mean age (yrs) (PR/PS)	Protopathy	Follow-up time (yrs)	Outcomes
Catani, et al.[9]	2004	Italy	20/20	70/71	Knee OA	2	acghij
Chaudhary, et al.[10]	2008	Canada	51/49	69.2/70.2	Knee OA	≥2	deij
Clark, et al.[11]	2001	America	51/57	71.8/71.2	Knee OA	≥2	abc
Harato, et al.[12]	2008	UK	99/93	70/71	Knee OA	≥5	aehij
Kim, et al.[13]	2009	Brazil	250/250	71.6/71.6	Knee OA	2.3	abcghi
Maruyama, et al.[14]	2004	Japan	20/20	65/65	Knee OA	≥2	adehij
Matsumoto, et al.[15]	2012	Japan	19/22	73.5/74.4	Knee OA	5	ae
Ozturk, et al.[16]	2016	Turkey	33/28	71.9/73.7	Knee OA	7	acde
Seon, et al.[17]	2011	Japan	48/47	68.2/69.2	Knee OA	≥2	befg
Tanzer, et al.[18]	2002	Canada	20/20	72.3/72.7	Knee OA	2	aehij
Thomsen, et al.[19]	2013	Denmark	36/36	69/69	Knee OA	1	e
van den Boom, et al.[20]	2014	Netherlands	9/12	72/72	Knee OA, malformation ≤15°	1	abcde
Vermesan, et al.[21]	2015	Romania	25/25	68.8/68.4	Knee OA, malformation≤15°	1	acgh
Wang, et al.[22]	2004	China	157/110	57/66	Knee OA	≥2	af
Yagishita, et al.[23]	2012	Japan	29/29	74.3/74.3	Knee OA	5	acdefhi

Abbreviations: PR, posterior cruciate-retaining; PS, posterior cruciate-stabilized; (a) American Knee Society Score (AKSS); (b) Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) score; (c) Active range of motion of the knee joint; (d) Extension range of motion of the knee; (e) Flexion range of motion of the knee; (f) Mechanical tibial angle; (g) Posterior slope; (h) Residual knee pain rate; (i) Surgical site infection rate; (j) Knee revision rate.

American Knee Society Score

A total of 12 studies[9,11-16,18,20-23] reported postoperative AKSS, including 703 patients in the posterior cruciate-retaining prosthesis group and 572 patients in the posterior cruciate-stabilized prosthesis group. A heterogeneity test showed that $P = .46$ and $I^2 = 0\%$. There was no significant homogeneity among the 12 included studies, so the fixed effect model was applied. Meta-analysis results were: MD = 0.13; 95% CI, -0.73 to .00), suggesting that there was no significant difference in the AKSS between the 2 groups (Figure 2).

Figure 2. Forest plot for comparison of American Knee Society Score between the 2 groups.



Western Ontario and McMaster Universities Osteoarthritis Index Score

A total of 4 studies[11,13,17,20] reported a postoperative WOMAC score, including 358 patients in the posterior cruciate-retaining prosthesis group and 366 patients in the posterior cruciate-stabilized prosthesis group. A heterogeneity test showed that $P = .90$ and $I^2 = 0\%$. There was no significant

Figure 3. Forest plot for comparison of WOMAC score between the 2 groups.

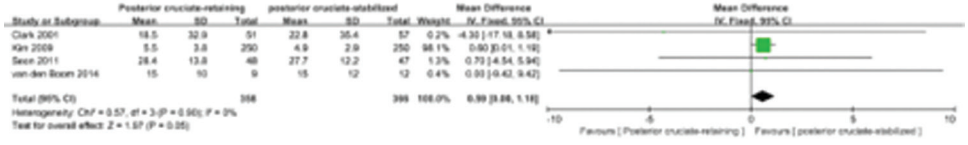


Figure 4. Forest plot for comparison of active range of motion of the knee joint between the 2 groups.

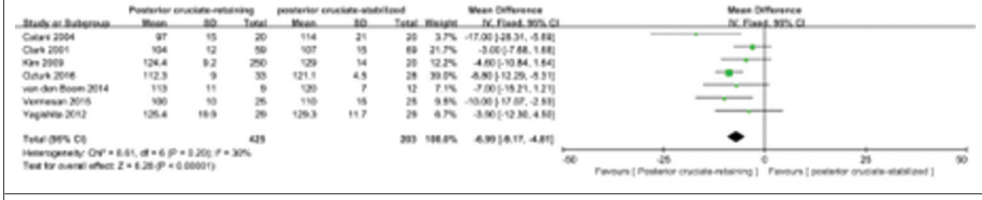


Figure 5. Forest plot for comparison of extension range of motion of the knee between the 2 groups.

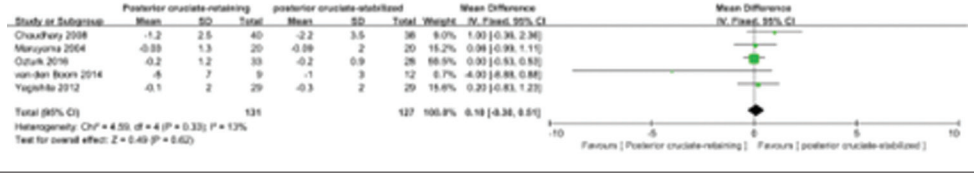


Figure 6. Forest plot for comparison of flexion range of motion of the knee between the 2 groups.

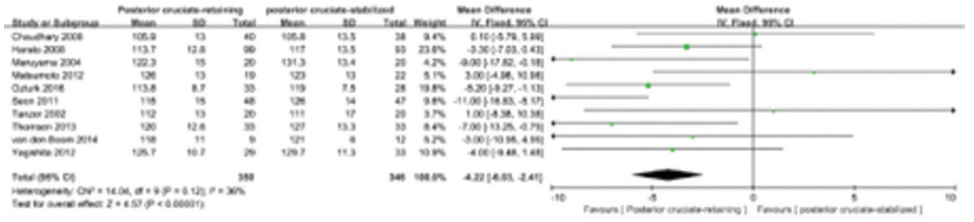


Figure 7. Forest plot for comparison of mechanical tibial angle between the 2 groups.

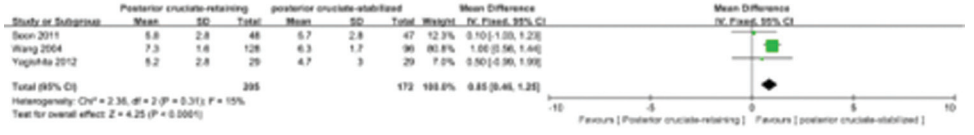


Figure 8. Forest plot for comparison of posterior slope between the 2 groups.

homogeneity among the 4 included studies, so the fixed effect model was applied. Meta-analysis results were: MD = 0.59; 95% CI, 0.00-1.18, suggesting that there was no significant difference in WOMAC score between the 2 groups (Figure 3).

Active Range of Motion of the Knee Joint

A total of 7 studies[9,11,13,16,20,21,23] reported the postoperative active range of motion of the knee joint, including 425 patients in the posterior cruciate-retaining prosthesis group and 203 patients in the posterior cruciate-stabilized prosthesis group. Heterogeneity test showed that $P = .20$ and $I^2 = 30\%$. There was no significant homogeneity among the 7 included studies, so the fixed effect model was applied. Meta-analysis results were: MD = -6.99; 95% CI, -9.17 to -4.81), suggesting that active range of motion of the knee joint in the posterior cruciate-stabilized prosthesis group was larger than that in the posterior cruciate-retaining prosthesis group (Figure 4).

Knee Extension Range of Motion

A total of 5 studies[10,14,16,20,23] reported the postoperative knee extension range of motion, including 131 patients in the posterior cruciate-retaining prosthesis group and 127 patients in the posterior cruciate-stabilized prosthesis group. A heterogeneity test showed that $P = .33$ and $I^2 = 13\%$. There was no significant homogeneity among the 5 included studies, so the fixed effect model was applied. Meta-analysis results were: MD = 0.10; 95% CI, -0.30 to 0.51, suggesting that there was no significant difference in knee extension range of motion between the 2 groups (Figure 5).

Knee Flexion Range of Motion

A total of 10 studies[10,12,14-20,23] reported the postoperative knee flexion range of motion, including 350 patients in the posterior cruciate-retaining prosthesis group and 346 patients in the posterior cruciate-stabilized prosthesis group. A heterogeneity test showed that $P = .12$ and $I^2 = 36\%$. There was no significant homogeneity among the 10 included studies, so the fixed effect model was applied. Meta-analysis results were: MD= -4.22; 95% CI, -6.03 to -2.41, suggesting that knee flexion range of motion in the posterior cruciate-stabilized prosthesis group was larger than that in the posterior cruciate-retaining prosthesis group (Figure 6).

Mechanical Tibial Angle

A total of 3 studies[17,22,23] reported postoperative mechanical tibial angles, including 205 patients in the posterior cruciate-retaining prosthesis group and 172 patients in the posterior cruciate-stabilized prosthesis group. A heterogeneity test showed that $P = .31$ and $I^2 = 15\%$. There was no significant homogeneity among the 3 included studies, so the fixed effect model was applied. Meta-analysis results were: MD = 0.85; 95% CI, 0.46 to 1.25, suggesting that the mechanical tibial angle in the posterior cruciate-stabilized prosthesis group was smaller than that in the posterior cruciate-retaining prosthesis group (Figure 7).

Posterior Slope

A total of 4 studies[9,13,17,21] reported the postoperative posterior slope, including 347 patients in the posterior cruciate-retaining prosthesis group and 346 patients in the posterior cruciate-stabilized prosthesis group. A heterogeneity test showed that $P = .23$ and $I^{2v} = 30\%$. There was no significant homogeneity among the 4 included studies, so the fixed effect model was applied. Meta-analysis results were: MD = -0.09; 95% CI , -0.52 to 0.33, suggesting that there was no significant difference in the posterior slope between the 2 groups (Figure 8).

Residual Knee Pain Level

A total of 7 studies[9,12-14,18,21,23] reported the level of postoperative residual knee pain, including 463 patients in the posterior cruciate-retaining prosthesis group and 457 patients in the posterior cruciate-stabilized prosthesis group. A heterogeneity test showed that $P = .69$ and $I^2 = 0\%$. There was no significant homogeneity among the 7 included studies, so the fixed effect model was applied. Meta-analysis results were: MD = 1.26; 95% CI, 0.57-2.78, suggesting that there was no significant difference in the level of residual knee pain between the 2 groups (Figure 9).

Surgical Site Infection Rate

A total of 7 studies[9,10,12-14,18,23] reported postoperative surgical site infection rates, including 486 patients in the posterior cruciate-retaining prosthesis group and 475 patients in the posterior cruciate-stabilized prosthesis group. A heterogeneity test showed that $P = .71$ and $I^2 = 0\%$. There was no significant homogeneity among the 7 included studies, so the fixed effect model was applied. Meta-analysis results were: MD = 0.50; 95% CI, 0.13-1.88, suggesting that there was no significant difference in the surgical site infection rate between the 2 groups (Figure 10).

Knee Revision Rate

A total of 5 studies[9,10,12,14,18] reported the knee revision rate, including 207 patients in the posterior cruciate-retaining prosthesis group and 196 patients in the posterior cruciate-stabilized prosthesis group. A heterogeneity test showed that $P = .54$ and $I^2 = 0\%$. There was no significant homogeneity among the 5 included studies, so the fixed effect model was applied. Meta-analysis results were: MD = 0.59; 95% CI, 0.15-2.32, suggesting that there was no significant difference in the knee revision rate between the 2 groups (Figure 11).

Publication bias and quality assessment

We drew the funnel plot corresponding to the results of the AKSS. As shown in Figure 12, the funnel plot had good symmetry, suggesting that no obvious publication bias was found. The quality assessment of the included studies is shown in Table 2. The quality score of all the studies was ≥4, indicating that the included studies were of good quality.

DISCUSSION

In recent years, with the accelerated aging worldwide, the prevalence of knee OS has been steadily increasing. In the advanced stages of the disease, it can lead to a high rate of disability and have a significant impact on patients' QoL Therefore, selecting an appropriate treatment approach at this stage is crucial. In addition, with the development of surgical techniques and equipment for TKA, it has become, by consensus among orthopedic surgeons, the most effective

Figure 9. Forest plot for comparison of residual knee pain rate between the 2 groups.

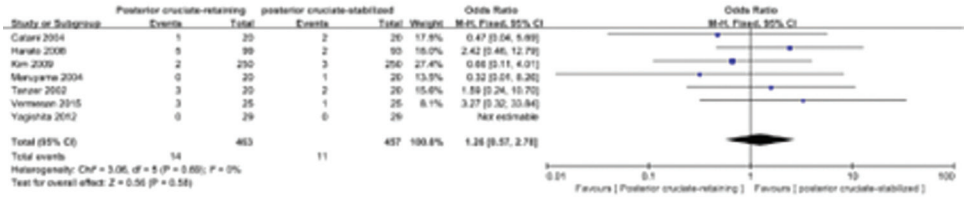


Figure 10. Forest plot for comparison of surgical site infection rate between the 2 groups.

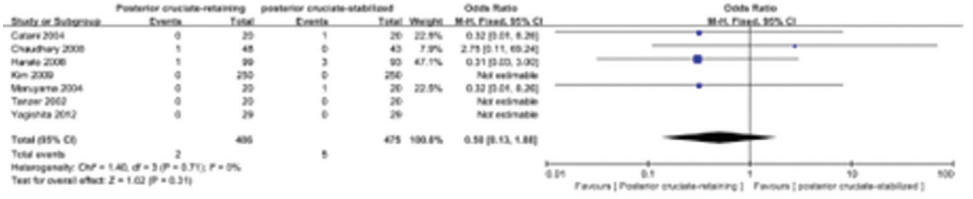


Figure 11. Forest plot for comparison of knee revision rate between the 2 groups.

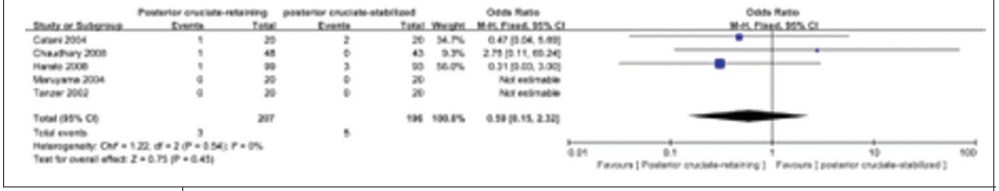


Figure 12. Funnel plots for publication bias assessment.

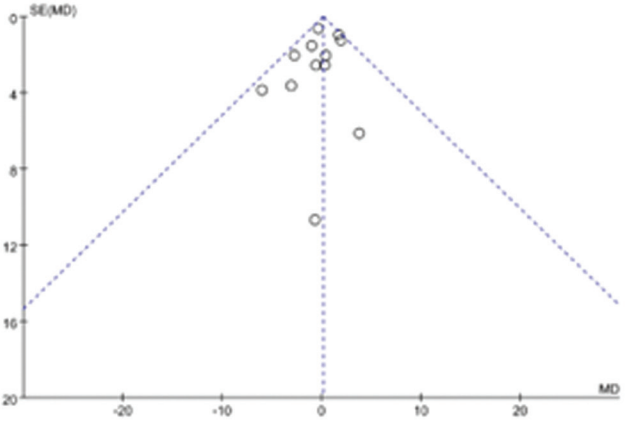


Table 2. Modified Jadad Scale

Studies	Year	Blinding	Randomization	Concealment allocation	Withdrawal	Total scores
Catani, et al.[9]	2004	2	1	2	1	6
Clark, et al.[11]	2001	0	1	2	1	4
Harato, et al.[12]	2008	1	2	2	1	6
Kim, et al.[13]	2009	1	1	2	1	5
Maruyama, et al.[14]	2004	0	2	1	1	4
Matsumoto, et al.[15]	2012	2	1	2	1	6
Ozturk, et al.[16]	2016	2	2	2	1	7
Tanzer, et al.[18]	2002	0	1	2	1	4
van den Boom, et al.[20]	2014	2	2	1	2	6
Vermesan, et al.[21]	2015	0	2	1	1	4
Wang, et al.[22]	2004	2	1	2	1	6
Yagishita, et al.[23]	2012	2	2	1	1	6

treatment for severe knee OA. It offers several advantages, including effective pain relief, correction of deformities and improvement in patients' QoL.[24] However, there is still controversy regarding whether or not to retain the posterior cruciate ligament (PCL) in TKS. Studies have reported that the use of a posterior cruciate-retaining prosthesis can theoretically increase the effectiveness of femoral rolling with a flat tibial articular surface, which may result in an improved flexion range. Retaining the bone in this type of prosthesis is also believed to have potential benefits for future revisions or renovations.[25] In addition, the implant-bone-cement-bone interface could also reduce stress concentration and probability of loosening. However, there are also studies indicating that posterior cruciate ligament-retaining implants are prone to posterior tibial translation and could not be used in patients with cruciate ligament damage.[26] The applicable scope is relatively small. In order to retain the PCL prosthesis, it needed to be released or shifted back to obtain a sufficient degree of buckling. Therefore, the difficulty of the intraoperative surgery was increased and the learning curve was steep.[27] Supporters of the procedure suggested that a posterior cruciate-stabilized prosthesis could play a role in the movement of the knee joint due to its column structure, thus correcting more severe knee joint deformities. As the posterior cruciate-stabilized prosthesis allows for a slight change in the joint line position, it can avoid collision with the condyle and reduce wear on the prosthesis.[28] Furthermore, this surgical procedure is relatively simple and does not affect postoperative activities after degradation of the cruciate ligament. Some studies have pointed out the disadvantages of the posterior cruciate-stabilized prosthesis, such as the concentration of stress at the interface between the prosthesis, bone cement and bone tissue. There is also a high probability of prosthesis loosening. In addition, the femoral distal osteotomy volume is significantly higher compared with the posterior cruciate-retaining prosthesis, and there is a high risk for the development of patella impingement syndrome.[29]

The retention of the cruciate ligament after TKA remains a controversial topic, and there are few relevant meta-analyses addressing this issue. Therefore, this meta-analysis aimed to gather relevant clinical studies in order to explore the clinical and radiographic outcomes of posterior cruciate-retaining and posterior cruciate-stabilized prosthesis after TKA arthroplasty.

A total of 15 randomized controlled trials (RCTs) were included in this meta-analysis. The results indicated that, compared with the posterior cruciate-retaining prosthesis, use of the posterior cruciate-stabilized prosthesis resulted in greater postoperative active range of motion and flexion range of motion of the knee joint. However, the difference in the postoperative straight range of motion of the knee joint was not significant. This is not consistent with the theory that the posterior cruciate-retaining prosthesis has a smoother tibial articular surface and greater active range of motion and flexion range of motion, but it is consistent with the results of previous multi-center RCTs.[30] The increased active mobility observed in the posterior cruciate-stabilized prosthesis is thought to be due to the enhanced buckling activity, while no significant difference is found in straight activity. This observation suggests that the improvement in cruciate ligament and soft tissue balance may play a role in these outcomes.

In order to obtain near-normal PCL tension, the accuracy of the PCL needs to reach 1 mm. The osteotomy accuracy of the posterior cruciate-stabilized prosthesis is considered lower than the posterior cruciate-retaining prosthesis. However, achieving a proper soft tissue balance is relatively easier with the posterior cruciate-stabilized prosthesis.[31] Moreover, the presence of the post axle device in the posterior cruciate-stabilized prosthesis helps prevent abnormal femoral forward movement that may occur due to relaxation or tension of the posterior cruciate-retaining prosthesis after surgery. The results of this study suggested that there was no significant difference in the AKSS between the 2 groups. The follow-up time of the included study was basically 2 years or more, which was also consistent with the previous conclusions: the posterior cruciate-retaining prosthesis had a higher functional score in the first 6 months after the surgery and there was no significant difference in the functional score 2 years after surgery. Although the posterior cruciate-stabilized prosthesis provides greater mobility, the difference in activity between the 2 types of prostheses fluctuates within a range of 5° to 10°. Previous studies have not indicated the difference has a larger clinical effect on patients. The research results showed the posterior cruciate-stabilized prosthesis achieves a smaller mechanical tibial angle compared with the posterior cruciate-retaining prosthesis.. There was no significant difference observed in the postoperative tibial angle, which agreed with previous RCTs. In addition, this meta-analysis found no significant differences between the groups in terms of the postoperative residual knee pain rate, surgical site infection rate, knee revision rate and other aspects.

Study Limitations

This meta-analysis also had some limitations. First, although the included studies were all RCTs, it is important to note that 4 of them did not utilize a double-blind design, which introduces the potential for bias in patient selection, allocation and evaluation of study results.[11,14,18,21] Another limitation was the variation in follow-up time among the included studies; 3 studies had a follow-up time of <2 years, which could have an impact on the homogeneity between studies and potentially affect the results. In addition, the follow-up time for assessing the postoperative revision rate of the knee joint was not long enough, which may have introduced outcome bias. It is also important to note that long-term randomized RCTs are needed in the future to compare the long-term knee function outcomes between the use of the posterior cruciate-retaining prosthesis and the posterior cruciate-stabilized prosthesis after TKA.

CONCLUSIONS

The findings of this meta-analysis demonstrate that, compared with the posterior cruciate-retaining prosthesis, the posterior cruciate-stabilized prosthesis offers significant advantages in terms of achieving a larger active range of motion and flexion range of motion of the knee, as well as a smaller mechanical tibial angle.

These results provide valuable insights for orthopedic surgeons and clinicians in making informed decisions regarding the selection of prostheses for TKA, ultimately improving patient outcomes and enhancing the overall quality of care in knee OA treatment.

CONFLICT OF INTEREST

None.

FUNDING

None.

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