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Review Article

Retention Versus Sacrifice of Posterior Cruciate Ligament During Mobile-Bearing Total Knee Arthroplasty: A Meta-Analysis

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Abstract

Background: Although the superiority of posterior cruciate ligament (PCL) for mobile-bearing (MB) TKA remains debated, there remains a lack of high-quality evidence based studies such as meta-analyses of comparative studies, so we performed a meta-analysis of comparative studies to determine whether there is a significant difference between PCL retention (CR) and PCL sacrifice (PS) mobile-bearing (MB) in terms of clinical and functional knee scores, kinematic function, rate of complications and revision.

Methods: We searched literatures comprehensively published by May 2020 in databases including MEDLINE, Cochrane databases and Embase, and the RevMan 5.3 was used to perform this meta-analysis.

Results: 6 RCTs and 6 comparative observational studies (Obs) on this topic were integrated. There were no significant differences between the two procedures in the Hospital for Special Surgery score (HSS), Knee Society Knee Score (KSS), Knee Society Functional score (KSFS), Western Ontario McMasters University index (WOMAC), knee range of motion (ROM)， and varus–valgus laxity. Even CR MB was slightly superior to PS MB regarding New Jersey Knee score (NJKS), PS MB was superior to CR MB with respect to complications rate and revision rate.

Conclusions: The meta-analysis revealed that CR MB and PS MB could achieve similar clinical outcomes, whereas the rate of complications and revision was significantly increased in CR MB. Based on the outcomes of this meta-analysis, the choice of the CR MB does not appear to be justified, and further studies of high methodological quality with long-term follow-up are required to confirm our conclusion.

Keywords: *Posterior cruciate ligament (PCL), Fixed-bearing (FB), Meta-analysis, Knee score system*

Introduction

The debate over the intervene of PCL during TKA has initially regarded fixed-bearing (FB), primary TKA for years, which still suggested no significant clinically relevant differences regarding prosthesis function or survivorship [1]. With the PCL retained, CR prosthesis was capable of retaining an adequate articular proprioception and increasing the ROM by retaining the physiological femoral rollback, thus keeping the motor function [2,3,4]. From a view of biomechanics, the PCL is able to relieve the stress imparted to the implant-bone interface which improves implant survivorship from minimize polyethylene wear [5]. However, others held that PS prosthesis can show better ROM [6], avoid excessive PCL laxity or tightness, and provide more reliable femoral rollback because of the post-cam mechanism [7,8]. It was found in a biomechanical study that when being elongated and changed tighten consistently along with high flexion of the knee, the PCL could inhibit further high flexion of the knee from a biomechanical study, which indirectly supported the PS prosthesis [9].

The patterns of movement of MB designs have changed from the transitions from pure rotation to pure translation, and then, combined rotation and translation. The first-generation MB prosthesis, called Low Contact Stress (LCS, DePuy, Warsaw, IN), were invented by Buechel and Pappas in 1977 [10]. Initially, the PCL-retaining, meniscal-bearing (MeBe) (LCS Meniscal-Bearing, DePuy, Warsaw, IN) and the PCL-sacrificing rotating-platform designs (LCS Rotating-Platform, DePuy, Warsaw, IN) were designed to provide mobility and congruity of the bearing surfaces, which reduces constraint force and contact stress to minimize the polyethylene wearing and implant loosening problems seen with earlier implant designs [11].

Furthermore, the axial rotation of the bearing enables a self-alignment of rotational malalignment of tibial component. Successively, in 1996, the second-generation LCS MB prosthesis, called anteroposterior gliding and rotation bearing (APGR), were designed to replicate normal knee kinematics by combining unconstrained anterior-posterior translation and rotation at the high conforming polyethylene bearing surface [12]. Later, other MB products were invented such as Press-fit Condylar（PFC）Sigma system (DePuy, Warsaw, IN, USA) [13], E-motion system (Braun Aesculap, Tuttlingen, Germany) [7] and Global Knee System (GKS)Prime (Permedica, Merate, Italy) [14], all of which included retained or sacrificed PCL subgroups. The MB products have been reported of good clinical outcomes and kinematic function [15,16,17], and there were no significant differences between FB and MB whether in clinical results or implant survivorship [18].

However, it is unclear whether there were differences between CR versus PS for MB TKA, since little literatures to suggest superiority of CR MB over PS MB [19, 20]. A meta-analysis from 2011 compared overall clinical outcomes of MB TKA and most of the studies included were one-armed test or indirect controlled test, resulting lack of sufficient data to directly compare the role of PCL between different types of MB prostheses [21]. Hence, to determine the clinically relevant difference between CR MB and PS MB, further studies would be needed, and since 2011, there were several RCTs and Obs published to directly compare CR MB and PS MB in postoperative outcome [7, 22, 23, 24]. To resolve this controversy, the purpose of this study is to directly compare the postoperative outcomes of retaining verse sacrificing the PCL in MB TKA.

Materials and Methods

Based on the PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-analyses) with a PRISMA checklist and algorithm, a meta-analysis of the current study was performed [25].

Eligibility criteria: (1) Participants underwent primary MB TKA. (2) RCTs and comparative Obs with more than 1 year' follow-up. (3) Vitro studies used biomechanical models were excluded. (4) The operations were performed with CR MB TKA verse PS MB TKA. (5) Outcomes were about clinical and functional knee scores, kinematic function, complications rate and revision rates.

We searched literatures published by May 2020 by means of MEDLINE, Cochrane databases and Embase. Key words such as "mobile-bearing", "total knee arthroplasty", "posterior cruciate ligament retaining", "posterior stabilization", "posterior cruciate ligament sacrificing", "rotating platform", "meniscal bearing", "anterior-posterior gliding rotation" and their synonyms were used to perform the retrieval work. Furthermore, in case literatures were lost, references of related reviews were also reviewed.

Two independent reviewers conducted all the screening works. When meeting disagreements, a consensus was made by a corresponding author. The initial screening was to rule out the obviously unrelated literatures across to review the title and abstract, and the remaining literatures would be further screened through the full text to insure whether they meet with the eligibility criteria mentioned above. In addition, to prevent data duplication, we selected the literature with most recent data and the longest follow-up if multiple literatures from the same author or institution reported data on the same patient group.

Methodological quality of each study included was evaluated according to a Modified Coleman Methodology Score (MCMS), which was initially adopted to evaluate the quality of a RCT about treatment for lateral epicondylitis [26], and its subsections were on the basis of the CONSORT statement (for RCT) but were set to the compatibility for other study designs such as case-controlled study (CCS) and cohort study (CS). Based on 15 criteria, the MCMS system employed a total score from 0 to 100 to evaluate the methodological quality of study. A study with a high score indicates that it owes a robust design so to largely avoid confounding factors and various biases. The grading evaluation was considered to be excellent if the score is between 85 and 100 points, good if it is between 70 and 84 points, fair if it is between 55 and 69 points, and poor if it is less than 54 points.

For another, the levels of evidence of included studies were graded using the 2011 Oxford Centre for Evidence-Based Medicine Levels of Evidence [27]. These levels are essentially designated as: I= systematic review of RCTs; II = RCT or Obs with significant effect size; III= non-randomized controlled cohort or follow-up study; IV= case-control studies, case-series and historically controlled studies.

In order to extract as much information as we can, each included study was reviewed thoroughly. Basic characteristics of studies included name of first author, study design, the brand of the prosthesis, race, follow-up time, number of patients, number of implanted knees, and patient demographics (e.g., gender, age, BMI). Furthermore, outcomes of studies included the clinical and functional knee scores (KSS, KSFS, NJKS, WOMAC, HSS), kinematic function (ROM, knee flexion, flexion contracture and varus–valgus laxity), and rate of complications and revision at final follow-up were within the range of the current study. When meeting with incomplete data in the included studies (e.g., only median, extremes or quartiles), only if we fail to contact the corresponding authors for original data we needed, we attempted to estimate the mean and standard deviation of the sample from the incomplete data mentioned above [28].

The RevMan 5.3 was used to perform this meta-analysis. With the funnel plot of this software, publication bias can be visually inspected according to a scatterplot. Heterogeneity tests for pooled results were performed with heterogeneity index such as I^2 and Chi^2. The data of the CR MB or PS MB of different brands were grouped and analyzed together by means of a similar mode of way of dealing with PCL, therefore, the PCL-retaining MeBe design, PCL-retaining APGR design and other mobile-bearing design that retain the PCL were categorized as the CR MB group.

For continuous data like clinical scores and functional scores, we used Fixed Effect (FE) model and Inverse Variance method. For dichotomous data like rate of complications, the FE model and Mantel-Haenszel method were used. If sensitivity analysis and subgroup analysis cannot settle heterogeneity incident, Random Effects (RE) model was used. Mean difference（MD）was used to compare the relative effects of CR MB minus PS MB, and Odds Ratio（OR）was used to compare the relative effects of CR MB divide PS MB. For each analysis, 95% CI and p value were calculated, and $p<0.05$ was considered statistically significant.

Results

The basic characteristics of included studies were summarized in Table 1. Totally 1040 articles were searched from MEDLINE, Cochrane and Embase databases initially. According to inclusion and excluding criteria, the screening flow diagram was available in Fig 1. At last, we incorporated 12 studies with 961 knees underwent CR MB prosthesis TKA and 887 knees with PS MB prosthesis TKA.

Table 1: Basic characteristics of included studies.

Authors	Year	Country	Sample size			TKA type		Mean age		Males (%)		Mean BMI		Follow-up(years)	
			Patients	Knees	OA (%)	CR	PS	CR	PS	CR	PS	CR	PS	CR	PS
Aigner [1]	2004	Australia	46	46	100	20	26	69.1±7	70.0±7	17	22	28.8±4.4	29.5±2.6	1.0	1.0
Kim YH [36]	2004	Korea	190	380	85.26	190	190	64(47-76)	64(47-76)	5.79		ND	ND	6.4(5-7)	6.4(5-7)
Matsuda [40]	2005	Japan	80	80	100	40	40	70	72	15	5	ND	ND	1.0	1.0
Takeda [59]	2011	Japan	60	60	100	30	30	70±6	72±6	20	16.67	ND	ND	6.3	6.5
Roh [48]	2012	Korea	86	86	100	42	44	69.±4.7	71.±4.9	4.76	6.81	26.5±3.2	26.4±4.0	2.3±0.3	2.7±0.4
Yoshinori [31]	2018	Japan	51	102	100	51	51	81±8	81±8	13.73		26.0±4.0		9.1±3.8	9.0±3.3
Hooper [20]	2009	New Zealand	186	192	87.63	110	82	66.9(29-87)	66.9(29-87)	56.45		ND	ND	10.0	10.0
Stiehl [55]	1999	America	191	191	82.72	147	44	69	64	35.08		ND	ND	5.7(5-9.3)	5.7(5-9.3)
Huang [22]	2003	China	406	495	98.69	228	267	62(29-74)	62(29-74)	16.75		ND	ND	12(10-15)	12(10-15)
Buechel [9]	2002	America	94	94	ND	47	47	67(30-86)	67(23-87)	40.96	27.08	28.99	28.99	12.0±1.5	12.4±1.8
D.Eneal [14]	2015	Italy	88	102	ND	46	56	70.2±7.6	68.6±6.7	39.13	30.36	30.7±4.8	28.8±4.2	5.3±1.7	5.3±2.4
Murakamo[44]	2017	Japan	17	20	100	10	10	73.8±5.9	72.3±6.8	11.11	25.00	26.8±2.6	27.1±2.3	1.5±0.4	4.3±1.3

BMI, Body Mass Index; CR, PCL-retaining group; PS, PCL-substituting group; ND, no data or unclear.

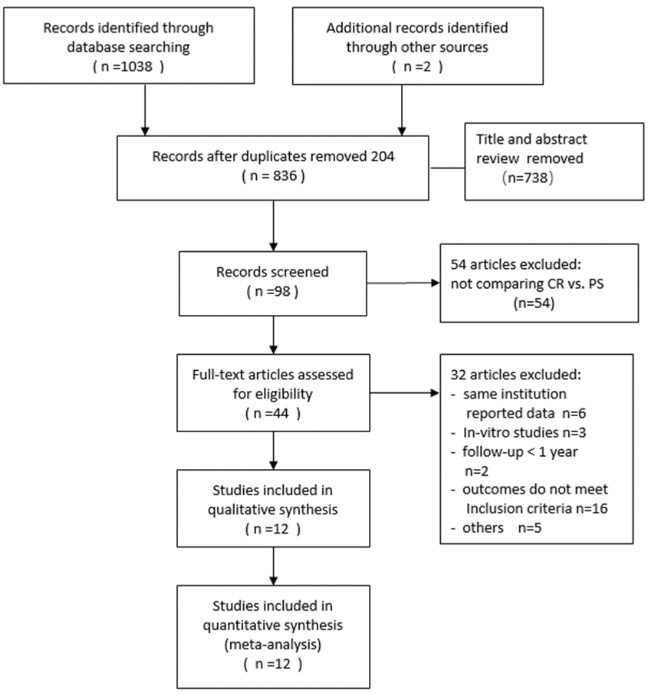


Figure 1: *Flow diagram for the meta-analysis of included studies.*

According to the detail for each judgement of MCMS, the mean MCMS was 52.83 (range, 35-67) for the 12 included studies, and 5 studies were scored fair, and 7 were poor. The MCMS of each study was shown in Table 2.

On the basis of the 2011 Oxford Centre for Evidence-Based Medicine Levels of Evidence, level of evidence was rated for each study, in which 6 studies evidence level of II, 3 studies evidence level of III, and 3 studies evidence level of IV (Table 2).

Table 2: Outcomes of included studies.

Authors	Study design	Level of Evidence	MCMS	Brand of prostheses	Outcomes	Complications		Revision rate	
						CR	PS	CR	PS
Aigner [1]	RCT	II	67	LCS-Universal system (APGR vs RP)	HSS ROM Flexion	1 Deep infection	0 Deep infection	2	0
Kim [36]	RCT	II	49	LCS-Universal system (APGR vs RP)	KSS HSS	ND	ND	0	0
Matsuda [40]	Quasi-RCT	II	53	LCS prosthesis system (MeBe vs RP)	ROM Varus/valgus laxity	ND	ND	0	0
Takeda [59]	RCT	II	58	LCS-Universal system (MeBe vs RP)	HSS Varus/valgus laxity	ND	ND	ND	ND
Roh [48]	RCT	II	57	E-motion TKA system (Retained vs sacrifice PCL)	KSS KSFS HSS WOMAC ROM Flexion Flexion contracture	1 Dislocation 2 Loosening	0 Dislocation 0 Loosening	3	0
Yoshinori [31]	Quasi-RCT	II	66	LCS prosthesis system (MeBe vs RP)	HSS ROM	ND	ND	ND	ND
Hooper [20]	CS	III	40	LCS prosthesis system (MeBe vs RP)	KSS KSFS NJKS WOMAC	5 Osteolysis 3 Wearing	2 Osteolysis 0 Wearing	ND	ND
Stiehl JB [55]	CS	III	35	LCS prosthesis system (MeBe vs RP)	ROM	1 Fracture	0 Fracture	5	0
Huang [22]	CCS	IV	47	LCS prosthesis system (MeBe vs RP)	ND	3 Dislocation 12 Osteolysis 28 Wearing	7 Dislocation 8 Osteolysis 13 Wearing	ND	ND
Buechel [9]	CCS	IV	53	LCS prosthesis system (MeBe vs RP)	NJKS ROM	ND	ND	ND	ND
D. Enea [14]	CCS	IV	57	GKS Prime (Retained vs sacrifice PCL)	KSS KSFS ROM Flexion Flexion contraction	1 Loosening	2 Loosening	3	2
Murakamoi[44]	CS	III	53	PFC Sigma RP (Retained vs sacrifice PCL)	KSFS Flexion Flexion contracture Varus/valgus laxity	ND	ND	ND	ND

Quasi-RCT, quasi- randomized controlled study.

LCS prosthesis system, Low Contact Stress mobile-bearing knee prosthesis (DePuy, Warsaw, Indiana).

LCS-Universal system, Low Contact Stress mobile-bearing knee prosthesis（DePuy, Johnson and Johnson company, Warsaw, Indiana）.

MeBe, PCL-retaining meniscal-bearing; RP, PCL-substituting rotating-platform.

APGR, PCL-retaining anterior-posterior glide and rotation bearing.

E-motion TKA system, Ultracongruent mobile polyethylene insert (B. Braun Aesculap, Tuttlingen, Germany).

GKS Prime, fully conforming, mobile-bearing knee prosthesis (Permedica, Merate, Italy).

PFC Sigma RP, Press Fit Condylar Sigma rotating platform (Depuy, Warsaw, IN, USA).

The ROM data included 7 of 12 studies and covered the maximum analysis so that it was used to generate the funnel plot to inspect the publication bias, and the Fig 2 showed asymmetry for the ROM data (I2 = 78%, P< 0.00001). Thus, the RE model was used for statistical analysis.

The clinical and functional knee scores were reported in 9 studies [7, 12, 14, 15, 19, 22, 23, 24, 29], including KSS [7, 14,19, 29], KSFS [7, 41, 19, 23], NJKS [15, 19], WOMAC score [7, 19] as well as HSS [7, 12, 22, 24, 29], were shown in Fig 3.

As mentioned in the Fig 3.E, the meta-analysis of the HSS (Fig 3.E HSS Total) showed striking heterogeneity ($Chi^2 = 14.23$, $I^2 = 72\%$, $p = 0.007$) and RE model was employed. Subgroup and sensitivity analyses showed that the study of Aigner [12] is the main source of heterogeneity, and the heterogeneity shows ($Chi^2 = 0.60$, $I^2 = 0\%$, $p = 0.90$) after we removed the study of Aigner [12] (Fig 3.E HSS Subgroup).

After reviewing thoroughly, the study of Aigner [12], we found that maybe it was the shortest follow-up time that led the HSS of the study of Aigner [12] to be lower than other studies about HSS. The CR MB were slightly better than PS MB about the NJKS (FE, MD = 2.58, 95% CI 0.25 to 4.90, p = 0.68), however, no apparent differences were found between CR MB and PS MB among the HSS (RE, MD =-0.23, 95% CI -1.86 to 1.40, p = 0.007), KSS (FE, MD =1.15, 95% CI -0.31 to 2.62, p = 0.98), KSFS (FE, MD = 0.72, 95% CI -3.66 to 5.10, p = 0.90) and WOMAC (FE, MD = -0.69, 95% CI -3.92 to 2.55, p = 0.75).

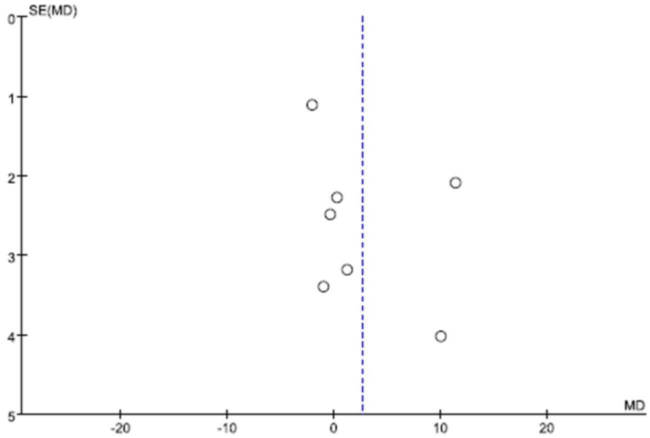
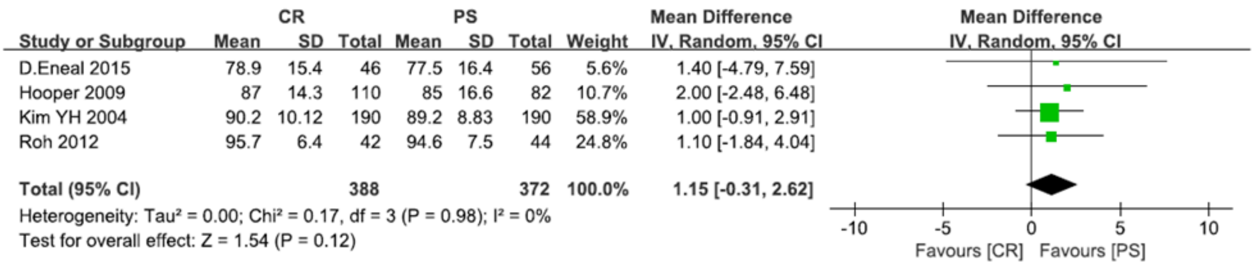
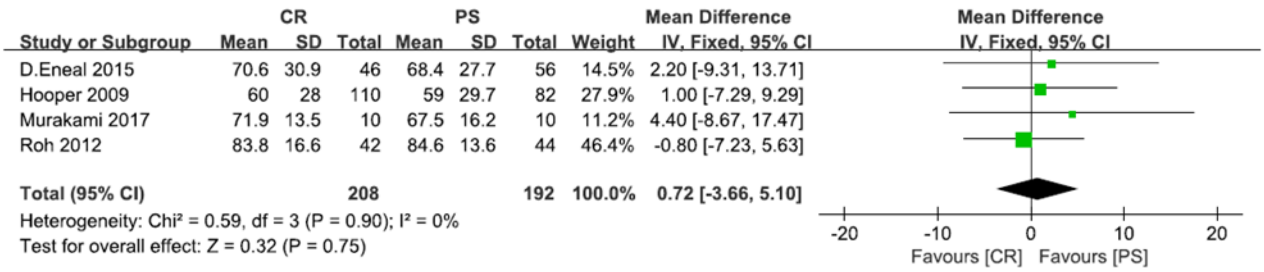


Figure 2: *The asymmetry funnel plot for the knee ROM data*

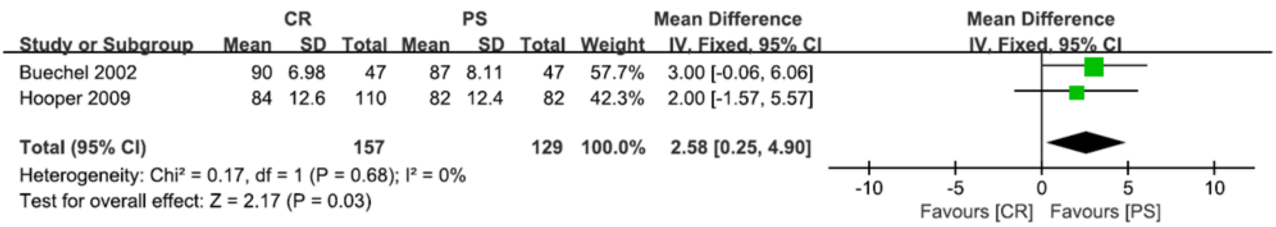
Fig 3. Forest plots of the clinical and functional scores (Panel A-E)



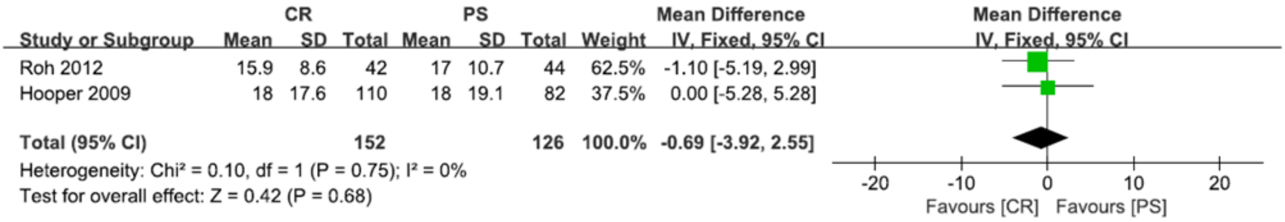
3A. *The meta-analysis of KSS.*



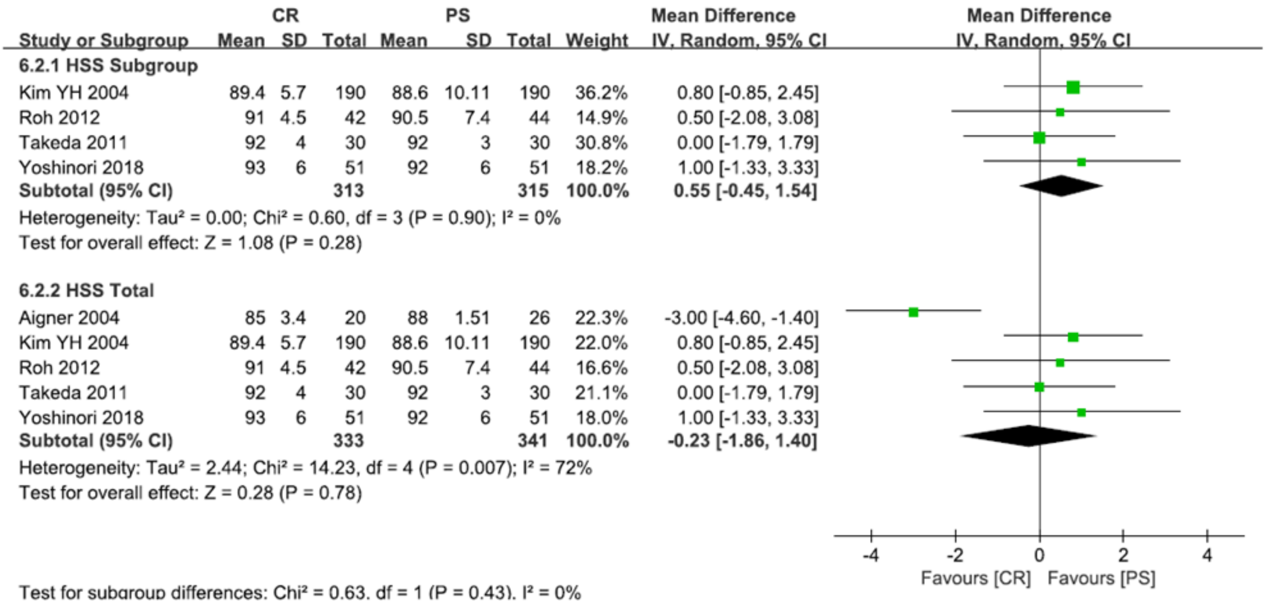
3B. *The meta-analysis of KSFS.*



3C. *The meta-analysis of NJKS.*



3D. The meta-analysis of WOMAC.



3E. The meta-analysis, subgroup and sensitivity analyses of HSS.

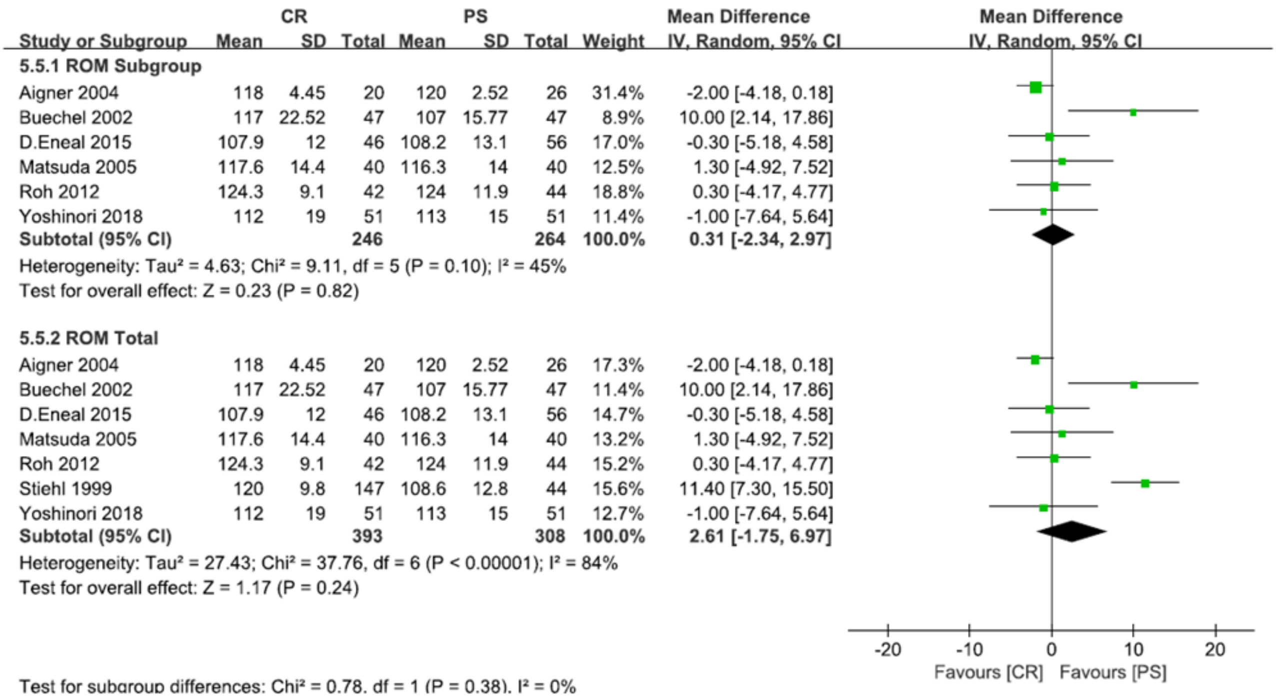
The kinematic function were reported in 9 studies [7, 12, 14, 15, 20, 22, 23, 24, 30], including ROM [7, 12, 14, 15, 20, 22,30], flexion [7, 12, 14, 23], flexion contracture [7, 14, 23,] and varus–valgus laxity [22, 23, 24, 30], shown in Fig 4. The Fig 4 revealed that obvious heterogeneity among the ROM (Chi^2 = 37.76, I^2 =84%, P< 0.00001) (Fig 4.A ROM Total) and flexion (Chi^2 = 11.93, I^2 =75%, P= 0.008) (Fig 4.B Flexion Total) analysis, for which RE model was employed. Subgroup and sensitivity analyses showed that the study of Stiehl [20] was the main source of heterogeneity of the ROM analysis, and the heterogeneity turned to (Chi2 = 9.11, I2 = 45%, p = 0.10) after we removed the study of Stiehl [20] (Fig 4.A ROM Subgroup). In the study of Stiehl [20], the final evaluation of the post-operative ROM for CR group was 120±9.8, versus 108±14.3 for PS group, and the MD was 11.4, which is significantly higher than other studies with respect to ROM.

At the same time, we used the same way to find that the study of D. Eneal [14] is the main source of heterogeneity of the Flexion analysis, and the heterogeneity shows (Chi2 = 4.26, I2 = 53%, p = 0.12) (Fig 4.B Flexion Subgroup) after we removed it. In the study of D. Eneal [14], we founded that the brand of prostheses is G.K.S. Prime, which is different from other studies in regard to the flexion analysis. Different prosthesis designs might lead to different post-operative effect, hence the unique prosthesis design of D. Eneal [14] is likely to make it the main source of heterogeneity of the Flexion analysis.

To sum up, postoperative ROM (RE, MD = 2.61, 95% CI -1.75 to 6.97, p<0.00001), knee flexion (RE, MD =2.57, 95% CI -1.45 to 6.59, p = 0.008), knee flexion contracture (FE, MD = -0.18, 95% CI -0.77 to 0.42, p = 0.61), varus–valgus laxity ((varus laxity (FE, MD = -0.41, 95% CI -0.92 to 0.11, p = 0.33), valgus laxity (FE, MD = 0.11, 95% CI -0.27 to 0.50, p = 0.16, and test for subgroup differences: Chi^2 = 2.52, I^2 = 60.2%) showed that there were no significant difference between the two groups.

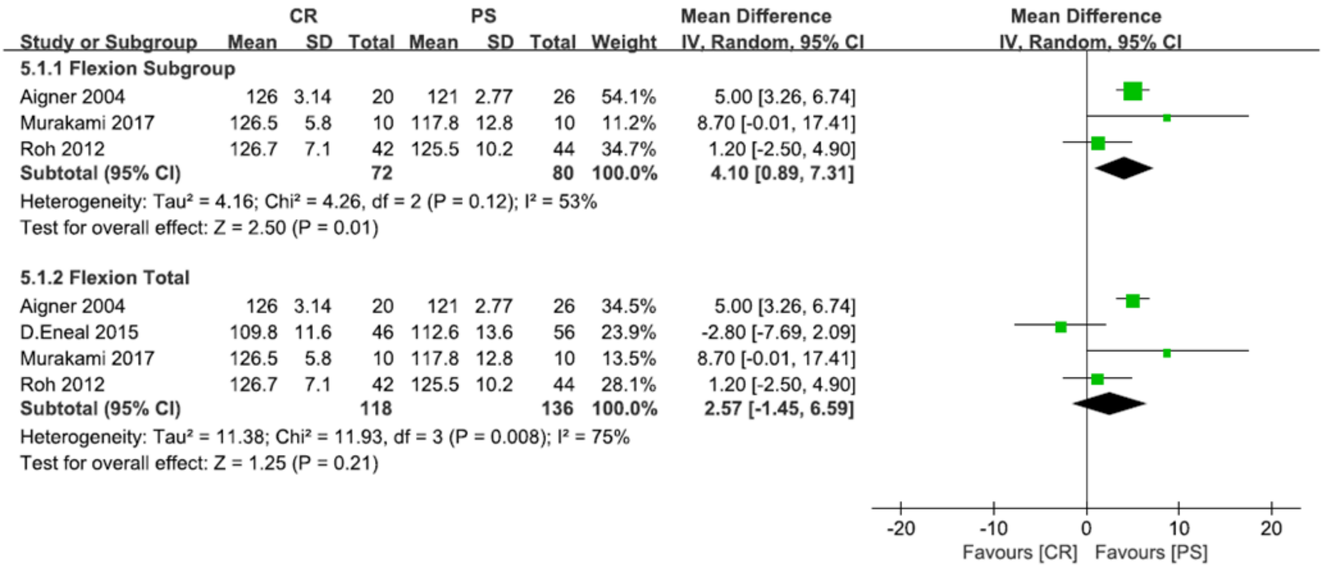
The complications rate was reported in 6 studies [7, 12, 14, 16, 19, 20] and revision rate was reported in 6 studies [7, 12, 14, 20, 29, 30]. The odds ratio of complications rate between CR MB and PS MB was 2.09(Fig 5.A;p<0.05, 95% CI 1.32 to 3.29) and that of revision rate was 3.69(Fig 5.B;p<0.05, 95% CI 1.32 to 3.29), the significant differences indicate that PS MB was superior to CR MB according to complications rate (FE, OR =2.09,95% CI 1.32 to 3.29, p = 0.89) and revision rate (FE, OR = 3.69, 95% CI 1.08 to 12.25, p =0.82).

Fig 4. Forest plots of kinematic function (Panel A-D).



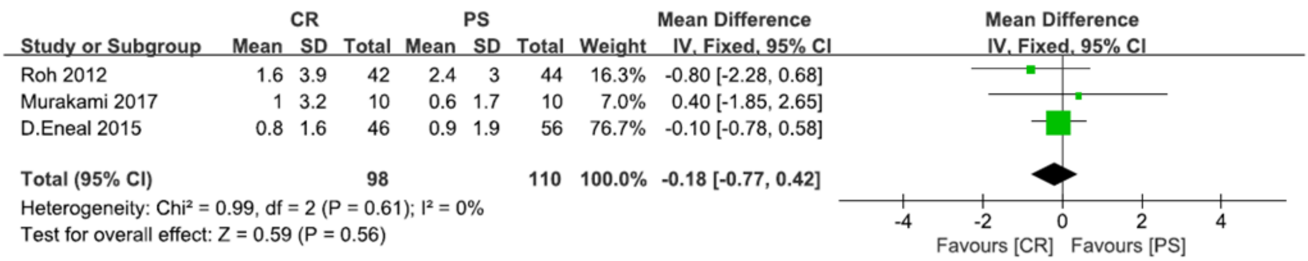
Study or Subgroup	CR Mean	CR SD	CR Total	PS Mean	PS SD	PS Total	Weight	Mean Difference IV, Random, 95% CI
5.5.1 ROM Subgroup								
Aigner 2004	118	4.45	20	120	2.52	26	31.4%	-2.00 [-4.18, 0.18]
Buechel 2002	117	22.52	47	107	15.77	47	8.9%	10.00 [2.14, 17.86]
D.Eneal 2015	107.9	12	46	108.2	13.1	56	17.0%	-0.30 [-5.18, 4.58]
Matsuda 2005	117.6	14.4	40	116.3	14	40	12.5%	1.30 [-4.92, 7.52]
Roh 2012	124.3	9.1	42	124	11.9	44	18.8%	0.30 [-4.17, 4.77]
Yoshinori 2018	112	19	51	113	15	51	11.4%	-1.00 [-7.64, 5.64]
Subtotal (95% CI)			**246**			**264**	**100.0%**	**0.31 [-2.34, 2.97]**
Heterogeneity: Tau² = 4.63; Chi² = 9.11, df = 5 (P = 0.10); I² = 45%								
Test for overall effect: Z = 0.23 (P = 0.82)								
5.5.2 ROM Total								
Aigner 2004	118	4.45	20	120	2.52	26	17.3%	-2.00 [-4.18, 0.18]
Buechel 2002	117	22.52	47	107	15.77	47	11.4%	10.00 [2.14, 17.86]
D.Eneal 2015	107.9	12	46	108.2	13.1	56	14.7%	-0.30 [-5.18, 4.58]
Matsuda 2005	117.6	14.4	40	116.3	14	40	13.2%	1.30 [-4.92, 7.52]
Roh 2012	124.3	9.1	42	124	11.9	44	15.2%	0.30 [-4.17, 4.77]
Stiehl 1999	120	9.8	147	108.6	12.8	44	15.6%	11.40 [7.30, 15.50]
Yoshinori 2018	112	19	51	113	15	51	12.7%	-1.00 [-7.64, 5.64]
Subtotal (95% CI)			**393**			**308**	**100.0%**	**2.61 [-1.75, 6.97]**
Heterogeneity: Tau² = 27.43; Chi² = 37.76, df = 6 (P < 0.00001); I² = 84%								
Test for overall effect: Z = 1.17 (P = 0.24)								
Test for subgroup differences: Chi² = 0.78, df = 1 (P = 0.38), I² = 0%								

4A. *The meta-analysis, subgroup and sensitivity analyses of ROM.*



Study or Subgroup	CR Mean	CR SD	CR Total	PS Mean	PS SD	PS Total	Weight	Mean Difference IV, Random, 95% CI
5.1.1 Flexion Subgroup								
Aigner 2004	126	3.14	20	121	2.77	26	54.1%	5.00 [3.26, 6.74]
Murakami 2017	126.5	5.8	10	117.8	12.8	10	11.2%	8.70 [-0.01, 17.41]
Roh 2012	126.7	7.1	42	125.5	10.2	44	34.7%	1.20 [-2.50, 4.90]
Subtotal (95% CI)			**72**			**80**	**100.0%**	**4.10 [0.89, 7.31]**
Heterogeneity: Tau² = 4.16; Chi² = 4.26, df = 2 (P = 0.12); I² = 53%								
Test for overall effect: Z = 2.50 (P = 0.01)								
5.1.2 Flexion Total								
Aigner 2004	126	3.14	20	121	2.77	26	34.5%	5.00 [3.26, 6.74]
D.Eneal 2015	109.8	11.6	46	112.6	13.6	56	23.9%	-2.80 [-7.69, 2.09]
Murakami 2017	126.5	5.8	10	117.8	12.8	10	13.5%	8.70 [-0.01, 17.41]
Roh 2012	126.7	7.1	42	125.5	10.2	44	28.1%	1.20 [-2.50, 4.90]
Subtotal (95% CI)			**118**			**136**	**100.0%**	**2.57 [-1.45, 6.59]**
Heterogeneity: Tau² = 11.38; Chi² = 11.93, df = 3 (P = 0.008); I² = 75%								
Test for overall effect: Z = 1.25 (P = 0.21)								

4B. *The meta-analysis, subgroup and sensitivity analyses of knee flexion.*

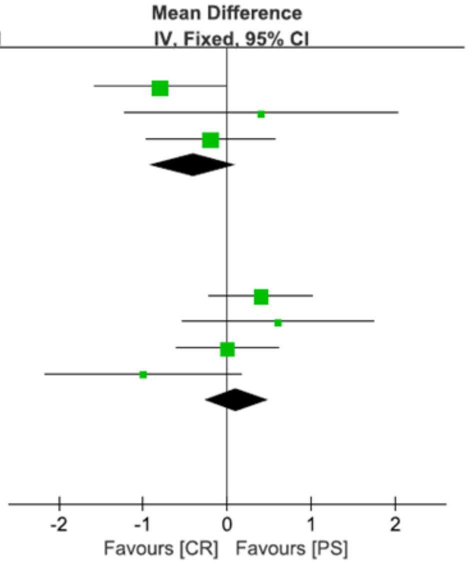


Study or Subgroup	CR Mean	CR SD	CR Total	PS Mean	PS SD	PS Total	Weight	Mean Difference IV, Fixed, 95% CI
Roh 2012	1.6	3.9	42	2.4	3	44	16.3%	-0.80 [-2.28, 0.68]
Murakami 2017	1	3.2	10	0.6	1.7	10	7.0%	0.40 [-1.85, 2.65]
D.Eneal 2015	0.8	1.6	46	0.9	1.9	56	76.7%	-0.10 [-0.78, 0.58]
Total (95% CI)			**98**			**110**	**100.0%**	**-0.18 [-0.77, 0.42]**
Heterogeneity: Chi² = 0.99, df = 2 (P = 0.61); I² = 0%								
Test for overall effect: Z = 0.59 (P = 0.56)								

4C. *The meta-analysis of flexion contracture.*

Study or Subgroup	CR Mean	CR SD	CR Total	PS Mean	PS SD	PS Total	Weight	Mean Difference IV, Fixed, 95% CI
9.3.1 Varus laxity								
Matsuda 2005	3.9	1.2	40	4.7	2.2	40	44.3%	-0.80 [-1.58, -0.02]
Murakami 2017	5.2	1.7	10	4.8	2	10	10.1%	0.40 [-1.23, 2.03]
Takeda 2011	4.2	1.3	30	4.4	1.7	30	45.6%	-0.20 [-0.97, 0.57]
Subtotal (95% CI)			**80**			**80**	**100.0%**	**-0.41 [-0.92, 0.11]**
Heterogeneity: Chi² = 2.21, df = 2 (P = 0.33); I² = 9%								
Test for overall effect: Z = 1.54 (P = 0.12)								
9.3.2 Valgus laxity								
Matsuda 2005	4	1.4	40	3.6	1.4	40	38.7%	0.40 [-0.21, 1.01]
Murakami 2017	3.7	1.3	10	3.1	1.3	10	11.2%	0.60 [-0.54, 1.74]
Takeda 2011	3.6	1.1	30	3.6	1.3	30	39.3%	0.00 [-0.61, 0.61]
Yoshinori 2018	4	3	51	5	3	51	10.8%	-1.00 [-2.16, 0.16]
Subtotal (95% CI)			**131**			**131**	**100.0%**	**0.11 [-0.27, 0.50]**
Heterogeneity: Chi² = 5.18, df = 3 (P = 0.16); I² = 42%								
Test for overall effect: Z = 0.59 (P = 0.56)								

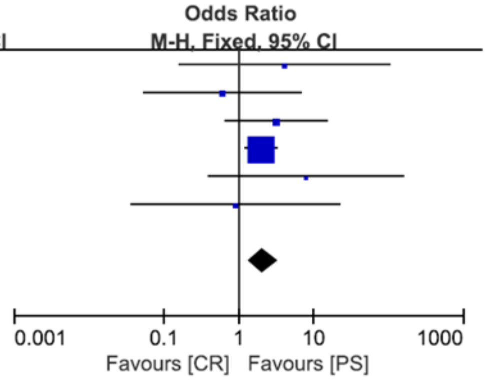
Test for subgroup differences: Chi² = 2.52, df = 1 (P = 0.11), I² = 60.2%



4D. The meta-analysis and subgroup analyses of varus–valgus laxity.

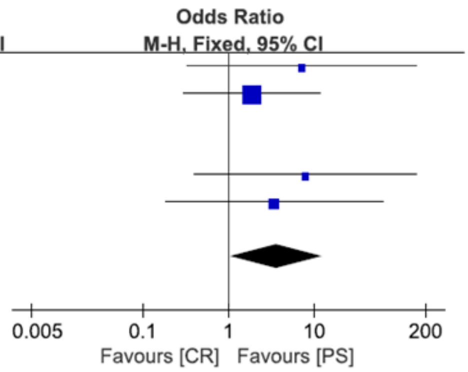
Fig 5. Forest plots of complications rate and revision rate. (Panel A-B).

Study or Subgroup	CR Events	CR Total	PS Events	PS Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Aigner 2004	1	20	0	26	1.5%	4.08 [0.16, 105.52]
D.Eneal 2015	1	46	2	56	6.7%	0.60 [0.05, 6.83]
Hooper 2009	8	110	2	82	8.0%	3.14 [0.65, 15.18]
Huang 2003	43	228	28	267	79.2%	1.98 [1.19, 3.31]
Roh 2012	3	42	0	44	1.7%	7.89 [0.39, 157.45]
Stiehl 1999	1	147	0	44	2.9%	0.91 [0.04, 22.76]
Total (95% CI)		**593**		**519**	**100.0%**	**2.09 [1.32, 3.29]**
Total events	57		32			
Heterogeneity: Chi² = 2.48, df = 5 (P = 0.78); I² = 0%						
Test for overall effect: Z = 3.16 (P = 0.002)						



5A. The meta-analysis of complications rate.

Study or Subgroup	CR Events	CR Total	PS Events	PS Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Aigner 2004	2	20	0	26	11.8%	7.16 [0.32, 158.02]
D.Eneal 2015	3	46	2	56	51.7%	1.88 [0.30, 11.78]
Kim YH 2004	0	190	0	190		Not estimable
Matsuda 2005	0	40	0	40		Not estimable
Roh 2012	3	42	0	44	13.8%	7.89 [0.39, 157.45]
Stiehl 1999	5	147	0	44	22.7%	3.44 [0.19, 63.35]
Total (95% CI)		**485**		**400**	**100.0%**	**3.69 [1.08, 12.55]**
Total events	13		2			
Heterogeneity: Chi² = 0.94, df = 3 (P = 0.82); I² = 0%						
Test for overall effect: Z = 2.09 (P = 0.04)						



5B. The meta-analysis of revision rate.

Discussion

The current study included totally 12 directly comparative studies, with at least 5 more studies [7, 14, 22, 23, 24] to synthetically compare CR MB verse PS MB than the former meta-analyses on this topic directly [21]. Clinical and functional scores, kinematic function, rates of complications and revision were extensively applied in evaluating the effectiveness of primary TKA in both clinical practice and medical science research. To sum up, this meta-analysis showed that there were no significant differences in HSS, KSS, KSPS, WOMAC, ROM, knee flexion, flexion contracture and varus–valgus laxity, although CR MB had slightly higher scores in NJKS, the PS MB did provide a significant superiority than CR MB in the aspect of complications rate and revision rate, which is the most important results of this meta-analysis.

After TKA treatment, rate of postoperative complications and revision is another important index when we evaluate the long-term effect in clinical practice. Previously, a Kaplan-Meier analysis from the study of Buechel reported that the 16-year survival rate of the LCS cementless MeBe prosthesis was 83% and the 20-year survival rate for the LCS cemented RP prosthesis was 97.7% [15], moreover, the 15-year survival rate was 83% of the LCS MeBe prosthesis and 92.1% for the LCS RP prostheses in the study of Huang [16], both of these two studies were in line with the meta-analysis of postoperative complications and revision rate in the current study, where the PS MB provided a significant superiority than CR MB in the aspect of postoperative complications rate and revision rate. However, both the differences in follow-up times and the underreporting of the important expected results might influenced the final analytical results. For instance, some included studies did not report the rates of complications and revision adequately, onlyreporting the number of complications in all prosthesis instead of specifying how many occurred in either the CR MB or PS MB subgroup [15, 22, 23, 24, 29, 30].

The current study has several advantages. Firstly, we comprehensively searched articles in database include MEDLINE, Cochrane databases and Embase up to May 2020, almost covering all the latest related English databases. Secondly, only studies that directly compare CR MB and PS MB were included, studies such as one-armed test and indirect controlled studies, which were included in previous study [21] were excluded. Lastly, this meta-analysis covered data such as clinical and functional scores, kinematic characteristics, rates of complications and revision of MB TKA, which compared CR MB and PS MB exhaustively and comprehensively.

Nevertheless, there are some defects in our research. First, not every study included in our meta-analysis had high-quality evidence, so that the inclusion of cohort studies and retrospective control studies making the current meta-analysis failed to provide the least biased evidence and was constrained to the limitations found within this level of evidence. In addition, we might miss some related non-English high-quality studies and have selection bias in language since the included study was limited to the studies published in English, but fortunately, the samples of included studies almost cover different regions all over the world, such as Australia, Korea, Japan, China, New Zealand, Italy and America. Last but not least, different literatures focused on different way of comparison, for instance, from some included studies [22, 30], comparison were done within simultaneous bilateral MB TKA, that is to say, on the same patient, one knee underwent PS MB TKA and the other knee underwent CR MB TKA, it might be difficult to evaluated because these kind of patients lacked of a natural lower limbs to support the postoperative lower limbs.

Conclusion

Based on all current research evidence, this meta-analysis concluded that there were no significant differences between CR MB and PS MB as regards knee score system and kinematic characteristics. However, PS MB did provide a significant superiority than CR MB about the rate of complication especially the rate of revision. Therefore, the choice of CR MB, especially the LCS MeBe prosthesis does not seem justified, and we need more long-term follow-up high-quality RCTs to clarify a preferred alternative.

Conflict of Interest

The authors declare no conflict of interest.

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