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ORIGINAL STUDY

Medial pivot versus (cam post) posterior stabilised total knee arthroplasty, systematic review and meta-analysis of 3837 knees

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In the current literature, there is no consensus as to whether the medial pivot (MP) or posterior-stabilised (PS) knee provides the best result for the patient in the context of post-operative range of motion (ROM) and patient reported outcome measures (PROMs). The aim of this systematic review is to provide this equipoise with some clarity. We conducted this study following both the Preferred Reporting Items for Systematic Reviews and Meta-analyses Statement (PRISMA) and the Cochrane Handbook for systematic reviews and meta-analysis. Studies comparing the MP and PS knees from all regions and written in any language were included. Twenty-one studies were included in this meta-analysis. They were prepared and analysed using Review Manager V5.0 [Computer Program] (RevMan5). We calculated the risk ratio to measure the treatment effect, taking the heterogeneity of the studies into consideration. Random-effect models were also utilised. MP knees were found to have a significant advantage over PS knees in terms of WOMAC score at the midterm follow up, and insignificant advantages over PS knees in terms of ROM and FJS at one and two years follow-up. Additionally, the PS knees demonstrated an in significantly higher Knee Society Score (KSS) at short and midterm follow up. In terms of ROM, KSS, OKS and FJS this meta-analysis suggests a non-significant advantages for the MP knee compared with the PS prothesis in the short term. The MP implant also showed a significantly superior WOMAC score at short-term follow-up. An extended follow-up period is required to evaluate whether the MP knee is superior than the PS in the long-term.

Keywords: Medial pivot; posterior stabilised; total knee arthroplasty; meta-analysis.

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INTRODUCTION

Total knee arthroplasty (TKA) is commonly performed surgery for management of end stage knee osteoarthritis (OA) with a prosthesis survival rate of 92% at 16 years *(1)*. Despite the high survival rates of the implants, only 82% to 89% of the patients are satisfied with the overall outcome *(2)*. Researchers of the kinematics of the native knee have advocated for altering the joint congruity of TKA implants in order to replicate the medial pivoting of the native knee *(3)*. The inability to mimic the normal physiological knee kinematics may play an important role in patient dissatisfaction post-operatively *(4-5)*. Modern bicondylar TKAs are often designed using a dished bearing surface or a cam-post mechanism as these concepts help to recreate tibiofemoral rollback and stability in the sagittal plane *(6-8)*. Posterior stabilized (PS) TKAs utilise the cam-post mechanism whereby the cam-post articulates with the tibial post improving femoral rollback and at the same time providing sagittal stability *(8-12)*. Despite this it is associated with central tibial impingement and increased bleeding intra-operatively secondary to the larger osteotomy *(13)*. Moreover, these alteration in the normal knee kinematic might contribute to the knee function and the survival of the prothesis. Additionally, the contradictory anterior femoral translation might negatively affect the extensor mechanism of the knee *(14)*. The medial pivoting mechanism in native knees stems from external rotation of the femur in relation to the tibia during the knee movement from full extension to mid-flexion *(15)*. MP TKAs are fixed bearing pivoting design prostheses. They designed with a congruent medial compartment to constrain the translation in the sagittal plane medially, and a non-congruent lateral compartment to allow femoral rollback on the lateral side of the knee *(16)*. A systematic review performed by Young et al. *(17)* was unable to establish any clinical advantage of MP over non-MP TKAs due to the limited number of studies included. To our knowledge no published systematic reviews have comparatively evaluated MP and PS TKAs in the context of Patient Reporting Outcome Measures (PROMs) and post-operative ROM. This study aims to use meta-analysis and systematic review techniques to evaluate the ROM and PROM associated with MP and PS TKAs.

MATERIALS AND METHODS

We performed this study following both the Preferred Reporting Items for Systematic Reviews and Meta-analyses Statement (PRISMA) and the Cochrane Handbook for systematic reviews and meta-analysis *(18)*. We conducted an initial search using MEDLINE-OVID, Web of Science, PubMed, EMBASE-OVID, Google Scholar and Cochrane Library. Grey and unpublished literature were also explored by searching: Grey Matters BIOSIS Previews, International Clinical Trial Registry, UK Clinical Trials Gateway, ClinicalTrials. gov, Networked Digital Library of Theses and Dissertations, UK Clinical Research Network Study Portfolio, Open Grey and Grey Literature Report. We used the following keywords and their combinations: medial pivot, posterior stabilised, and total knee arthroplasty. Articles published up to January 2021 were included in our literature search and were limited to studies in human subjects published in any language. Additionally, we cross-referenced the bibliographies of retrieved articles and review papers to ensure that we captured all relevant studies.

We included all comparative studies (retrospective/prospective cohorts, RCTs) involving patients undergoing unilateral or bilateral TKAs which were of MP or PS design, and where outcomes were compared between the two designs. We excluded cadaveric, in vitro, or single arm studies. Conference abstracts, letters to editor, reviews were also excluded.

Five authors independently screened all titles and abstracts identified by the initial search to assess their eligibility for inclusion. We then did a full screening of each manuscript and conducted a final assessment of the eligibility for all included studies. The same reviewers performed the data extraction. Any discrepancies found after data collection were resolved by discussion between all reviewers. The collected information included first author, year, country, study design, study length, number of participants, age, gender, and Body Mass Index (BMI).

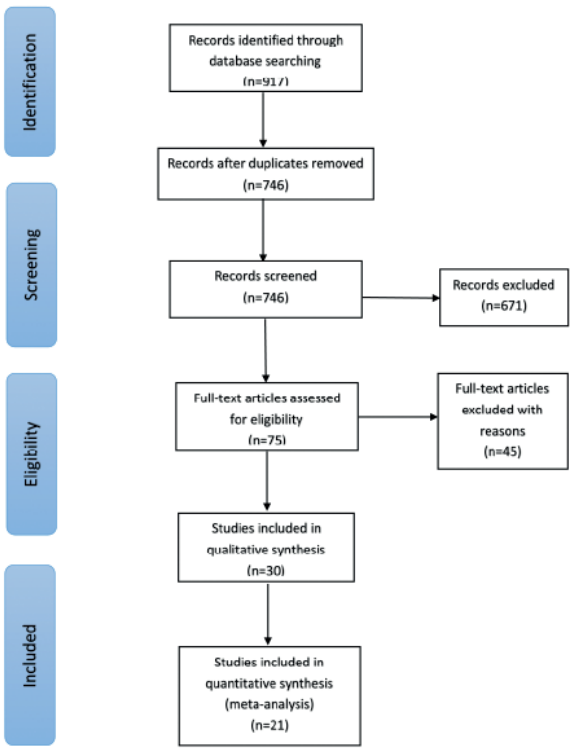

Figure 1. — Preferred reporting items for systematic reviews and meta-analyses (PRISMA) flow chart.

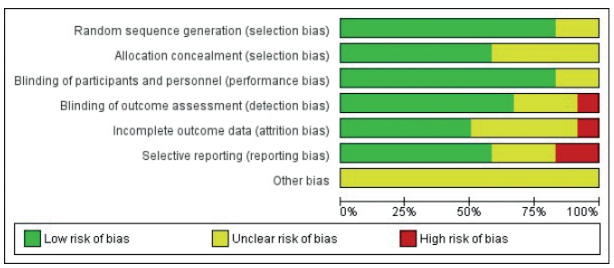

Figure 2. — Risk of bias graph: Review authors' judgements about each risk of bias item presented as percentages across all included studies.

Figure 3. — Risk of bias summary: Review authors' judgements about each risk of bias item for each included study.

We assessed the risk of bias for RCTs by using the Cochrane risk of bias criteria (Fig. 2 and 3) *(18)* and the non randomized cohort studies using Newcastle-Ottawa Scale *(19)*. Five reviewers independently crossed-checked the quality of the included studies. Disagreements were resolved through discussion.

Twelve RCTs *(14,20-30)*, were assessed for potential bias using Cochrane risk of bias tool. Randomization was performed in ten studies *(20-25,27-30)*, and use of randomization was unclear in two studies *(25,26)*. Use of patient blinding was unclear in two studies *(23,25)*. Quality assessment of 18 non-randomized cohort studies using Newcastle-Ottawa Scale showed that 13 studies were of high quality while five studies *(31-35)* were of moderate quality (Table 3).

The primary outcome of interest was ROM. Secondary outcomes were Knee Society Score(KSS) *(36)*, Forgotten Joint Score (FJS) *(37)*, Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) *(38)*, and Oxford Knee Score (OKS) *(39)*.

We conducted a statistical analysis by using Review Manager (RevMan), version 5.3 (The Nordic Cochrane Centre, The Cochrane Collaboration, 2009, Copenhagen, Denmark) *(40)*. Heterogeneity

Table 1. — Patient demographics by study

Study ID	Age (year)		BMI (kg/m2)		Gender (female percentage)	
	MP	PS	MP	PS	MP	PS
Samy et al. 2017	64.4 ± 10.5	66.7 ± 8.61	29.7 ± 5.24	31.3 ± 8.2	47 (61.8%)	54 (61.4%)
Papagiannis et al. 2016	70.25 ± 1.96	72.92 ± 1.46	NA		NA	
Lin et al. 2020	70.38 ± 6.37	70.98 ± 7.29	NA		33 (32%)	222 (82%)
Kulshrestha et al. 2020	63.8 ± 6.8	65.97 ± 6.7	27.34 ± 5.1	26.64 ± 4.3	29 (72.5%)	23 (57.5%)
Lee et al. 2020	70 ± 7	70 ± 7	27.4 ± 4	27.4 ± 4	32 (69.6%)	32 (69.6%)
Hossain et al. 2011	72.5 ± 9.7	68.9 ± 12.1	28.9 ± 6.2	29.5 ± 8.1	31 (77.5%)	22 (55%)
Gray et al. 2020	67.3 ± 6.44	66.8 ± 7.34	33.8 ± 4.6	30.9 ± 4.5	14 (53.85%)	9 (39.13%)
Gill et al. 2019	68.86 ± 2.67	68.6 ± 2.09	NA		22 (62.9%)	24 (68.6%)
Esposito et al. 2020	73.3 ± 3.5	70.5 ± 4.7	31 ± 3	30.9 ± 3.6	11 (55%)	8 (40%)
Edelstein et al 2019	67 ± 8	64 ± 7	32.8 ± 5.82	34.2 ± 5.81	18 (72%)	15 (60%)
Dowsey et al. 2020	66 ± 6.8	65.7 ± 7.7	32.5 ± 3.6	30.7 ± 3.8	15 (51.7%)	11 (42.3%)
Benjamin et al. 2018	62.4 (54 - 71)	64.8 (58 - 73)	NA		4 (40%)	3 (30%)
Bae et al. 2016	66.7 ± 7.1	66.7 ± 6.5	26.4 ± 3.2	25.9 ± 4.4	120 (96.8%)	136 (98.6%)
Anderson et al. 2002	70 (47 - 84)	69 (38 - 89)	NA		11 (55%)	14 (70%)
Minoda et al. 2003	67 ± 2.3	63.8 ±2.1	NA		NA	
Indelli et al. 2018	67.3(53 -77)	67.6 (46 - 86)	34.6(23.7- 42.4)	34.4 (25.7 - 53.8)	3 (7%)	4 (8%)
Wautier et al. 2016	72 ± 11	69.5 ± 9.5	33 ± 5	28± 4.8	6 (60%)	13 (65%)
Beach et al. 2019	66.7 ± 5.6	69.1 ± 6.4	32.3 ± 3.9	30.1 ± 5.4	NR	
Vanduren et al. 2007	75.2 (68 - 78)	72.4 (64 - 78)	NA		NR	
Zhang et al. 2020	67.5 ± 6.5	65.4 ± 6.2	27.3 ± 3	27.6 ± 3	74 (76%)	80 (73.4%)
Yuan et al. 2019	69.43 ± 5.97	69.63 ± 5.72	27.81 ± 5.17	27.59 ± 4.86	26 (54%)	28 (55%)
Shi et al. 2020	74.5 ± 6.97	75.4 ± 5.7	27.89 ± 3.65	27.43 ± 3.51	228 (78.6%)	169 (71.3%)
Shakespeare et al. 2006	76	78	NA		49%	52%
Schütz et al. 2019	68.8 ± 9.9	69 ± 6.5	25.4 ± 3.7	27.6 ± 3.5	8 (80%)	5 (50%)
Pritchett et al. 2012	66.4	69.6	NA		NA	
Pritchett et al. 2011	NA		NA		NA	
Hosseininasab et al. 2019	68.8 ± 9.9	69 ± 6.5	25.4 ± 3.7	27.6 ± 3.5	8 (80%)	5 (50%)
Batra et al. 2020	61.7 ± 6.88	61.7 ± 6.88	28.3 ± 3.4	28.3 ± 3.4	42 (79.2%)	42 (79.2%)
Wang et al. 2021	66.92 ± 5.60	67.15 ± 6.01	27.74 ± 4.63	27.90 ± 4.39	102 (81%)	104 (82.5%)
Bianchi et al. 2021	72 (CI95%: 68-76)	71 (CI95%: 69-74)	NA		8 (50%)	7 (43.75%)

SD: standard deviation, NA: Not applicable, BMI: Body Mass Index.

between studies was assessed by the I^2 statistic and a c^2 of <0.05 was used to define the significance of the heterogeneity among the included studies. Ranges of 0-24%, 25-74% and 75-100% were used to define minor, moderate and major heterogeneity respectively *(18)*. Mean differences and standard deviations (SDs) were used for continuous variables. We used the Mantel-Haenszel random-effects model in our meta-analysis. We illustrated the results using forest plots, which used a 95% confidence interval (CI) for each study and a cumulative weighted Mean Differences (MD) for all the included studies *(18)*.

RESULTS

Our literature search returned 746 articles after removal of duplicates. Title and abstract screening revealed 75 articles that were eligible for full text screening. Forty-five articles were subsequently excluded for not meeting selection criteria leaving 30 articles that were included for qualitative review. Twenty-one of these articles were included in the meta-analysis. A flow chart demonstrating the study selection process is provided (Fig 1). Twelve studies were randomized clinical trials (RCTs), five were prospective cohort studies and thirteen

Table 2. — Summary of included studies characteristics

Prosthesis used									
Study ID	**Study design**	**Study country**	**Follow up duration**	**Sample size**	**Medial pivot**	**PCL retained or sacrificed**	**Posterior stabilized**	**Reported outcomes**	**Summary of the outcomes**
Samy et el 2017	Retrospective	Canada	1 year	MP-76 patients PS-88 patients	EVOLUTION Medial-Pivot (MicroPort, Arlington, TN)	NR	Zimmer Persona Posterior Stabilized (Zimmer,Warsaw, IN)	ROM, FJS-12, survivorship	FJS-12 score was significantly better in MP group. No difference in ROM and survivorship
Papagiannis et el 2016	Prospective	Greece	2-3 years	MP-24 patients PS-22 patients	Fixed-bearing Medial Pivot implant (Arlington, TN, Wright Medical, AdvanceTM)	NR	Mobile bearing Rotating Platform Posterior Stabilized TKA	ROM, KSS, KFS, kinematic profile	No significant difference between the two groups
Lin et el 2020	Retrospective	China	20 months (average)	MP-103 patients PS-271 patients	the Advance (Microport, Arlington, TN, USA)	NR	the NexGen (Zimmer, Warsaw, IN, USA) and the Scorpio NRG (Stryker, Mahwah, NJ, USA)	ROM, Patient satisfaction, NRS	No significant difference between the two groups
Kulshrestha et el 2020	RCT	India	2 years	MP-40 patients PS-40 patients	ADVANCE, Wright Medical Technology, Arlington, TN, USA	PCL was sacrificed if flexion balance couldn't be achieved or if the flexion gap was too tight.	NexGen Legacy, Zimmer, Warsaw, IN, USA	ROM, new KSS, FJS, DOPS, EQ-5D	ROM, objective KSS were significantly better in PS group. DOPS (Time up and go and self-paced walk) were significantly better in MP group. No difference in the other outcomes
Lee et el 2020	RCT	China	1 year	46 patients (patients received MP implant in one knee and PS in the other knee)	MP implant	NR	PS implant	ROM, FJS, KSS, KFS, WOMAC, Patient preference, patient satisfaction, Pain Score	No significant difference in all outcomes between the two groups
Hossain et el 2011	RCT	UK	1 year, 2 years	MP-40 patients PS-40 patients	Medial Rotation KneeTM (MRK; Finsbury Orthopaedics, Leatherhead, Surrey, UK)	PCL sacrificed	Fixed-bearing Press Fit Condylar SigmaTM PS (PFC; DePuy, Warsaw, IN)	ROM, KSS, KFS, WOMAC, OKS, SF-36, TKFQ, Radiology	ROM, WOMAC subscale of pain, physical component of SF-36, TKFQ was significantly better in MP group. There was no significant difference in the other outcomes
Gray et el 2020	RCT	Australia	6 months	MP-26 patients PS-23 patients	MS (GMK sphere) (Medacta International, Switzerland)	PCL sacrificed	PS (GMK primary posterior-stabilized) (Medacta International, Switzerland)	kinematics (6-degree-of-freedom, femoral condylar motion)	knee kinematics observed for MP resemble those of the healthy joint more closely than PS
Gill et el 2019	RCT	Pakistan	2 years	MP-35 patients PS-35 patients	ADVANCE Medial-Pivot System (MicroPort Orthopedics)	PCL sacrificed	Zimmer or Johnson & Johnson Posterior Stabilizing	ROM, KSS, FJS-12	ROM, FJS-12 were significantly better in MP group. No significant difference in KSS

Esposito et el 2020	Retrospective	Italy	12-18 months	MP-20 patients PS-20 patients	Medacta GMK® Sphere Medially Stabilized Knee	PCL sacrificed	Posterior Stabilized Zimmer Persona®	kinematics, kinetics and electromyography	Gait analysis showed that PS group kinematic, kinetic and EMG parameters were closer to the healthy group and, in turn, to physiological gait than MP group parameters.
Edelstein et al 2019	RCT	USA	1 year, 2 years	MP-25 patients PS-25 patients	GMK Sphere Prosthesis, Medacta, Castel San Pietro Switzerland	PCL sacrificed	GMK Posterior-Stabilized Prosthesis	ROM, KSS, KFS, FJS, OKS, VR-12, PROMIS, IKDC, satisfaction, Timed GUAG, Sagittal stability using a KT-1000 arthrometer	MP group had significant better sagittal stability more than PS at 30 degrees (midflextion). No significant difference between the two groups.
Dowsey et el 2020	RCT	Australia	1 year	MP-29 patients PS-26 patients	GMK Sphere (Medacta International SA, Castel San Pietro, Switzerland)	NR	GMK Knee System posterior stabilized (Medacta International SA, Castel San Pietro, Switzerland)	KSS, KFS, OKS, WOMAC, VR-12, TUG, 6MWT, adverse events	No significant difference between the two group
Benjamin et el 2018	RCT	UK	1 year	MP-10 patients PS-10 patients	MCBS (SAIPH Knee system, MatOrtho, Leatherhead, United Kingdom)	PCL sacrificed	single radius fixed-bearing (Press Fit Triathlon knee system, Stryker, Kalamazoo, Michigan)	KSS, OKS, gait parameters (cadence, walking speed, stride length and stance time, peak stride, mid support and push-off forces)	There was no statistically significant difference between the two groups
Bae et el 2016	Retrospective	Korea	5.2 years (average)	MP-124 patients (150 knees) PS-138 patients (150 knees)	ADVANCE MP prosthesis (Wright Medical, Arlington, TN)	PCL sacrificed only in 75 knees	PFC Sigma (Johnson & Johnson Professional Inc, Raynham, MA)	ROM, KSS, WOMAC, Kujala, Feller, complication, survivorship, radiology	No significant difference between the two groups
Anderson et el 2002	Retrospective	USA	19 months (average)	MP-20 patients PS-20 patients	Advance medial pivot (Wright Medical Technology, Arlington, TN)	PCL sacrificed	posterior-stabilized Axiom PSK (Wright Medical Technology, Arlington, TN)	Patellofemoral Complications (Knee pain, crepitant sensation, patellar clunk), ROM, Radiology	Complications were significantly lower in MP group than PS group. Patellar tilt was significantly greater in MP group than PS group. No significant difference in other outcomes between the two groups
Minoda et el 2003	Prospective	Japan	1 year	17 patients (22 knees) MP-11 knees PS-11 knees	Advance Medial-Pivot Knee, Wright Medical Technology, Arlington, TN	NR	5 received posterior-stabilized (I-BII, Zimmer, Warsaw, IN) and six received Scorpio PS, Stryker Osteonics Howmedica, Rutherford, NJ),	Polyethylene wear particles, KSS, KFS, UCLA Activity Level, HSS, Quantitative Activity	The number of wear particles was significantly lower in MP group than PS group. Postoperative KSS, KFS, HSS were significantly higher in PS group, No significant difference in Quantitative Activity and UCLA Activity Level
Indelli et el 2018	Retrospective	USA	2 years (minimum)	MP-50 patients PS-50 patients	Persona (Zimmer, USA) Medially Congruent (MC)	PCL sacrificed	Persona (Zimmer,Biomet, USA) Posterior-Stabilized (PS)	ROM, OKS, KSS, complication, radiology	ROM was significantly higher in MP group than PS group. No significant difference between the two groups in the other outcomes.
Wautier et el 2016	Prospective	Belgium	1 year (minimum)	MP-10 patients PS-20 patients	Sphere (Medacta, Castel San Pietro, Switzerland)	NR	Vanguard posterostabilized (PS) (Biomet, Warsaw, USA) and Persona PS (Zimmer, Warsaw, USA)	KSS, KOOS, FJS-12, proprioception, AP translation using a KT-1000 arthrometer, radiology	no significant difference in between the two groups.

Zhang et el 2020	Prospective	china	1 month	MP-98 patients PS-109 patients	Wright Advance medial pivot prosthesis	NR	Zimmer NexGen prosthesis (NexGen LPS Flex, Zimmer, Warsaw)	ROM, VAS, Inflammation biomarkers (leukocyte, ESR, and CRP), HB	CRP and ESR significantly higher and HB was significantly lower in PS group than MP group. No significant difference between the two groups in ROM and VAS.
Yuan et el 2019	RCT	China	5 years	MP-49 patients PS-51 patients	Advance Medial - Pivot Knee System, Wright Medical	PCL sacrificed	PS prosthesis (NexGen LPS-Flex, Zimmer, Warsaw, IN)	HSS, WOMAC, complications, radiology, CRP, and erythrocyte sedimentation rate	no significant difference between the two groups
Shi et el 2020	Retrospective	china	6 years	MP-290 patients PS-237 patients	MP (Advance Medial-Pivot Knee System, Wright Medical Group)	NR	PS prosthesis (NexGen LPS-Flex, Zimmer, Warsaw, IN)	ROM, KSS, WOMAC, FJS, complications, survival rate	no significant difference between the two groups
Shakespeare et el 2006	Prospective	UK	1 year	MP-248 patient (261 knees) PS-267 patients (288 knees)	Medial Pivot (Wright Medical, Arlington TN)	NR	913 posterior stabilized implant (Wright Medical, Arlington TN).	ROM	No significant difference between the two groups
Schütz et el 2019	Retrospective	Switzerland	1 year (minimum)	MP-10 patients PS-10 patients	GMK Sphere	NR	GMK Primary PS	kinematics (A.P translation, rotation)	the smallest range of medial compartment A–P translation, the largest range of lateral compartment A–P translation, and the largest range of tibial internal/ external rotation were found in the MP group
Pritchett et el 2012	RCT	USA	6.3 years (average)	MP-239 patients PS-192 patients (patients received two implants one in each knee)	MP prosthesis (Wright Medical Technology [WMT], Arlington, TN)	PCL sacrificed	posterior-substituting (PS) prosthesis (Biomet; DePuy; Stryker; WMT; and Zimmer)	Noise-related symptoms	Noise-related symptoms was significantly lower in MP group
Pritchett et el 2011	RCT	USA	6.4 years (average)	MP-239 patients PS-152 patients patients received two implants one in each knee	MP prosthesis (Wright Medical Technology [WMT], Arlington, TN)	PCL sacrificed	posterior-substituting (PS) prosthesis (Biomet; DePuy; Stryker; WMT; and Zimmer)	Patients preference, ROM, pain score, KSS, KFS, alignment, stability	Patient preference significantly higher in MP group than PS group. no significant difference in all other outcomes between the two groups
Hosseininasab et el 2019	Retrospective	Switzerland	1 year (minimum)	MP-10 patients PS-10 patients	GMK Sphere	NR	GMK Primary posterior stabilized	the collateral elongation patterns	No significant difference between the two groups
Batra et el 2020	RCT	India	4 years	53 patients (patients received MP implant in one knee and PS in the other knee)	ADVANCE® Medial Pivot, Micro Port Orthopedics, Arlington, TN, USA	PCL sacrificed	Genesis II, Smith and Nephew, Memphis, USA	KSS satisfaction score, KSS expectation score, OKS, ROM, flexion deformity, radiology, kinematics (Patellar tendon angle)	KSS satisfaction and KSS expectation scores were significantly higher in MP group than PS group. Kinematics of MP group was significantly better than those of PS TKAs
Vanduren et el 2007	Retrospective	UK	1 year (minimum)	MP-13 patients PS-12 patients	AMP, Wright Medical Technology, Memphis, USA	NR	Scorpio PS	kinematic (Tibial–femoral contact points, PTA), ROM	In PS group, The PTA was lower than normal in extension and higher than normal in flexion. In MP group, The PTA was similar to normal from extension to mid flexion and then higher than normal beyond to high flexion. The PS design fails to fully restrain paradoxical anterior movement. The MP knee does not show significant anterior movement

Bianchi et el 2021	Retrospective	Italy	2 years (average)	MP-16 patients PS-16 patients	Evolution Medial Pivot; Microport, Shangai, CHN	NR	Persona-PS; Zimmer, Warsaw, IN, USA	FJS, ROM, Gait analysis	FJS was significantly higher in MP group. No significant difference in the other outcomes between the two groups
Wang et el 2021	Retrospective	China	1.6 years (average)	MP-126 patients PS-126 patients	Advance® Medial-Pivot, Wright	NR	NexGen LPS-Flex, Zimmer, Warsaw, IN	KSS, KFS, WOMAC, Kujala score, ROM, complications, radiology	ROM and complications were significantly higher in PS group. Kujala score was significantly better in MP group. Patellar tilt at the 90 degrees position was significantly smaller in MP group than PS group. No significant difference in the other outcomes between the two groups.
Beach et el 2019	Retrospective	Australia	1 year (minimum)	MP-18 patients (26 knees) PS-18 patients (26 knees)	Medial Pivot (Advance/ Evolution; Microport Orthopaedics, TN, USA	NR	PS (Legion; Smith&Nephew, UK)	kinematics (rotation and extension), EMG (muscle activity)	No significant difference in between the two groups at the kinematics. At muscle activity MP showed significantly greater knee extensor activation during the step-ascent than the PS group

were retrospective cohort studies. A summary of the characteristics of included studies is provided (Table 2).

Our review included 3837 knees (1855 in MP group, 1982 in PS group). The subjects in the MP group had an average age of 68.7 years (± 3.7 years), of which 884 out of 1855 patients (61.54 %) were female, with an average body mass index of 29.68 kg/m^2 (± 2.8). The PS cohort had a similar patient distribution with an average age of 68.5 years (range: (± 3.3 years), of which 1025/1982 (58.88%) were female, with an average body mass index of 29.24 kg/m2 (±6.58). A summary of the patient demographics of included studies is provided (Table 1).

Our meta-analysis comparatively assessed the ROM, KSS (total and functional), and WOMAC scores at one year, two years and midterm (5-8 years) follow up. We also assessed FJS and OKS at one and two years follow-up *(41)*.

Overall, six studies assessing 1142 knees reported on postoperative ROM after one year. 546 of these were of MP design while 596 were of PS design. The MP group reported an insignificantly higher ROM. The heterogeneity analysis demonstrated major statistical evidence for variation within the study (I^2 = 86 %). The cumulative MD was significant at 3.43 (95% CI, -0.53-7.39; P<0.09) (Fig 4).

Nine studies including 1067 knees reported on postoperative ROM after two years. In this group there were 450 MP and 617 PS TKAs. Once again, the MP cohort reported insignificantly superior ROM compared to the PS group. The heterogeneity analysis demonstrated major statistical evidence for variation within the study (I^2 = 92 %). The cumulative MD was significant at 1.92 (95% CI, -1.18-5.03; P < 0.22) (Fig 4).

Three studies reported on ROM at midterm follow-up with a total of 933 knees assessed. Out of these, 493 were MP knees and 440 were PS knees. Heterogeneity analysis demonstrated moderate evidence for variation within the study (I^2 = 66%). Data analysed by the random-effects model suggested no significant difference for the midterm ROM between the two cohorts. The cumulative MD was significant at 0.90 (95% CI, 3.37-5.17; P < 0.96) (Fig 4).

Table 3. — Newcastle-Ottawa Scale (NOS) for assessing the quality of Cohort studies

Study	Selection				Comparability	Exposure			Total
	Representativeness of the Exposed Cohort	Selection of the Non-Exposed Cohort	Ascertainment of Exposure	Demonstration That Outcome of Interest Was Not Present at Start of Study	Comparability of Cohorts on the Basis of the Design or Analysis	Assessment of Outcome	Was Follow-Up Long Enough for Outcomes to Occur	Adequacy of Follow Up of Cohorts	Total number of stars
Samy et al. 2017	*	*	*	*	*	*	*	0	7
Lin et al. 2020	0	*	*	*	*	*	*	0	6
Bae et al. 2016	*	*	*	*	**	*	*	*	9
Anderson et al. 2002	*	*	*	*	*	*	*	*	8
Indelli et al. 2018	0	*	*	*	**	*	*	*	8
Beach et al. 2019	*	*	*	*	**	*	*	*	9
Shi et al. 2020	*	*	*	*	**	*	*	0	8
Schütz et al. 2019	*	*	*	*	**	*	*	*	9
Hosseininasab et al. 2019	*	*	*	*	**	*	*	0	8
Vanduren et al. 2007	*	*	*	*	**	*	*	0	8
Papagiannis et al. 2016	*	*	*	*	*	*	*	0	7
Esposito et al. 2020	*	*	*	*	**	*	*	*	9
Minoda et al. 2003	*	*	*	*	**	*	*	*	9
Zhang et al. 2020	*	*	*	*	*	*	0	*	7
Shakespeare et al. 2006	*	*	*	*	*	*	*	0	7
Wautier et al. 2016	*	*	*	*	**	*	*	*	9
Wang et al. 2021	*	*	*	*	**	*	*	*	9
Bianchi et al. 2021	*	*	*	*	**	*	*	*	9

Seven studies reported on KSS at 1 year follow-up encompassing 349 knees. 178 reported on PS protheses and 171 on MP prostheses. PS knees were found to have an insignificantly higher KSS at one year compared with MP knees. The heterogeneity analysis demonstrated moderate statistical evidence for variation within the study (I^2 = 65 %). The cumulative MD was significant at -0.43 (95% CI, -4.05- 3.19: P<0.82) (Fig**.** 5).

Five studies including a total of 521 knees reported on postoperative KSS after two years. Out of that number, 261 were MP TKAs and 260 were PS TKAs. The PS group reported a superior KSS to the MP group. The heterogeneity analysis demonstrated high statistical evidence for variation within the study (I^2 = 91 %). The cumulative MD was found to be significant at -1.74 (95% CI, 1.45-4.94; P < 0.29) (Fig. 5).

Two studies reported on KSS at midterm follow-up with a total of 827 knees. This included 387 MP prostheses and 440 PS prostheses. Heterogeneity analysis demonstrated high statistical evidence for variation within the study (I^2 = 95%). Data pooled by random-effects model suggested a significantly higher KSS for the PS knee. The cumulative MD was significant at -0.90 (95% CI, 2.73-4.52; P < 0.001) (Fig 5).

Five studies including 349 knees (148 PS; 151 MP) reported on KSS functional score after one year. PS knees demonstrated an insignificantly higher KSS functional score at one year follow-up. The heterogeneity analysis demonstrated moderate statistical evidence for variation within the study (I^2 = 58 %). The cumulative MD was insignificant at 1.78 (95% CI, 4.04-7.60: P=0.55) (Fig. 6).

Four studies encompassing 451 knees (225 PS; 226 MP) reported on KSS functional score after two years. They reported a marginally higher non-significant functional KSS with the MP cohort versus the PS cohort. Heterogeneity analysis demonstrated low statistical evidence for variation within the study (I^2 = 42 %). The cumulative MD was insignificant at 0.42 (95% CI, -1.90 -2.75; P =0.72) (Fig 6).

Two studies reported on functional KSS at midterm follow-up encompassing a total of 827

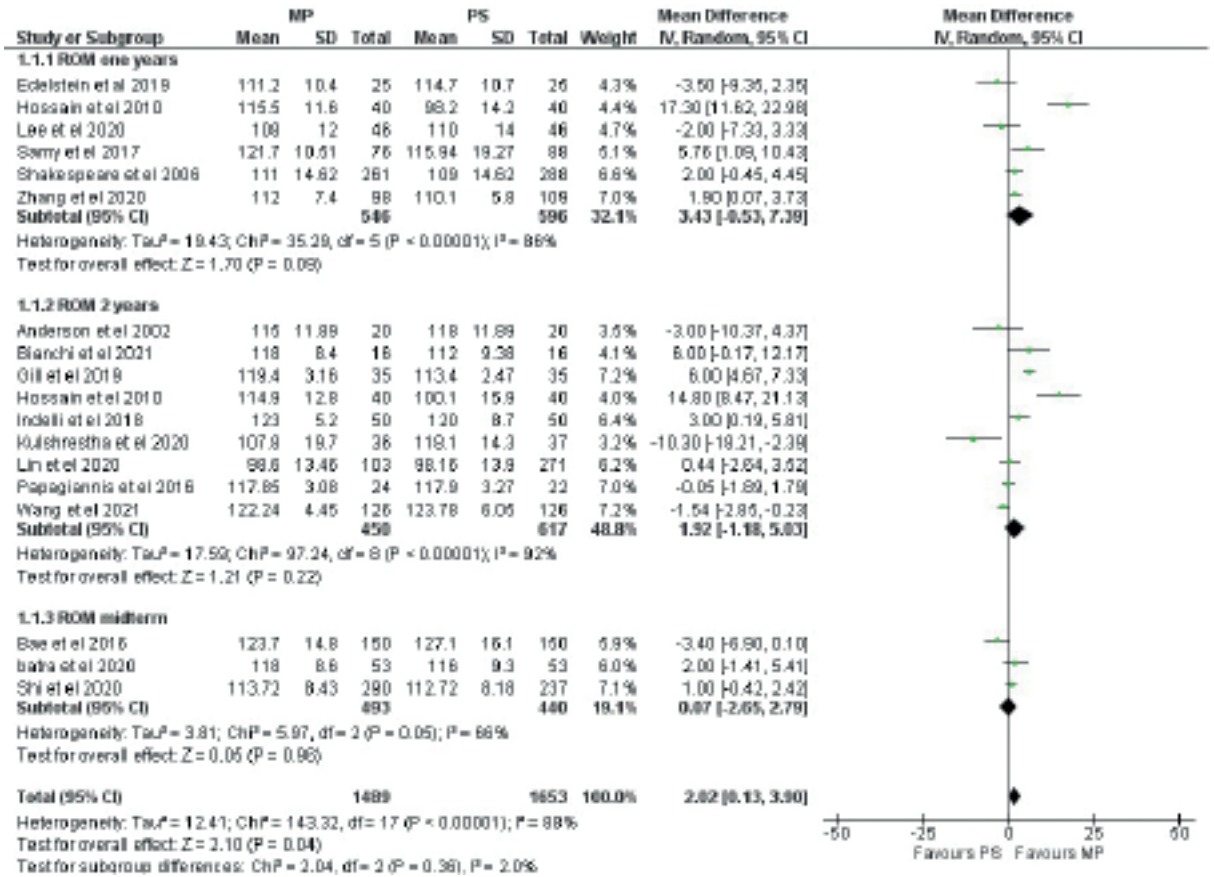

Figure 4. — Forest plot of comparison of ROM after one year, two years and midterm follow up.

knees (387 PS; 440 MP). Heterogeneity analysis demonstrated moderate statistical evidence for variation within the study (I^2 = 75%). Data pooled by random-effects model reported a non significant difference in favour of the PS cohort. The cumulative MD was insignificant at -0.15 (95% CI, 2.30-2.60; P = 0.66) (Fig. 6).

Overall, four studies including 289 knees (151 PS; 138 MP) reported on FJS after one year. They reported a non significantly better FJS score for the MP cohort at one year. The heterogeneity analysis demonstrated moderate statistical evidence for variation within the study (I^2 = 68 %). The cumulative MD was insignificant at 3.77 (95% CI, -7.72-15.25; P= 0.52) (Fig. 7).

Three studies totalling 175 knees (88 PS; 87 MP) reported on postoperative FJS at two years post-op. They reported a significantly superior FJS with the MP cohort versus the PS cohort. The heterogeneity analysis demonstrated high statistical evidence for variation within the study (I^2 = 86 %). The cumulative MD was insignificant at 8.94 (95% CI, -2.82-20.71; P <0.06) (Fig. 7).

Three studies including 227 knees (112 PS; 115 MP) recorded WOMAC score after one year. They reported an improved but nonsignificant WOMAC score for the MP group at one year follow-up. The heterogeneity analysis demonstrated moderate statistical evidence for variation within the study (I^2 = 56 %). The cumulative MD was insignificant at 1.88 (95% CI, 4.52-8.29: P=0.56) (Fig. 8).

Two studies totalling 332 knees (166 PS; 166 MP) reported on WOMAC score after two years. The MP cohort recorded an insignificantly higher functional KSS compared with the PS group. The heterogeneity analysis demonstrated moderate

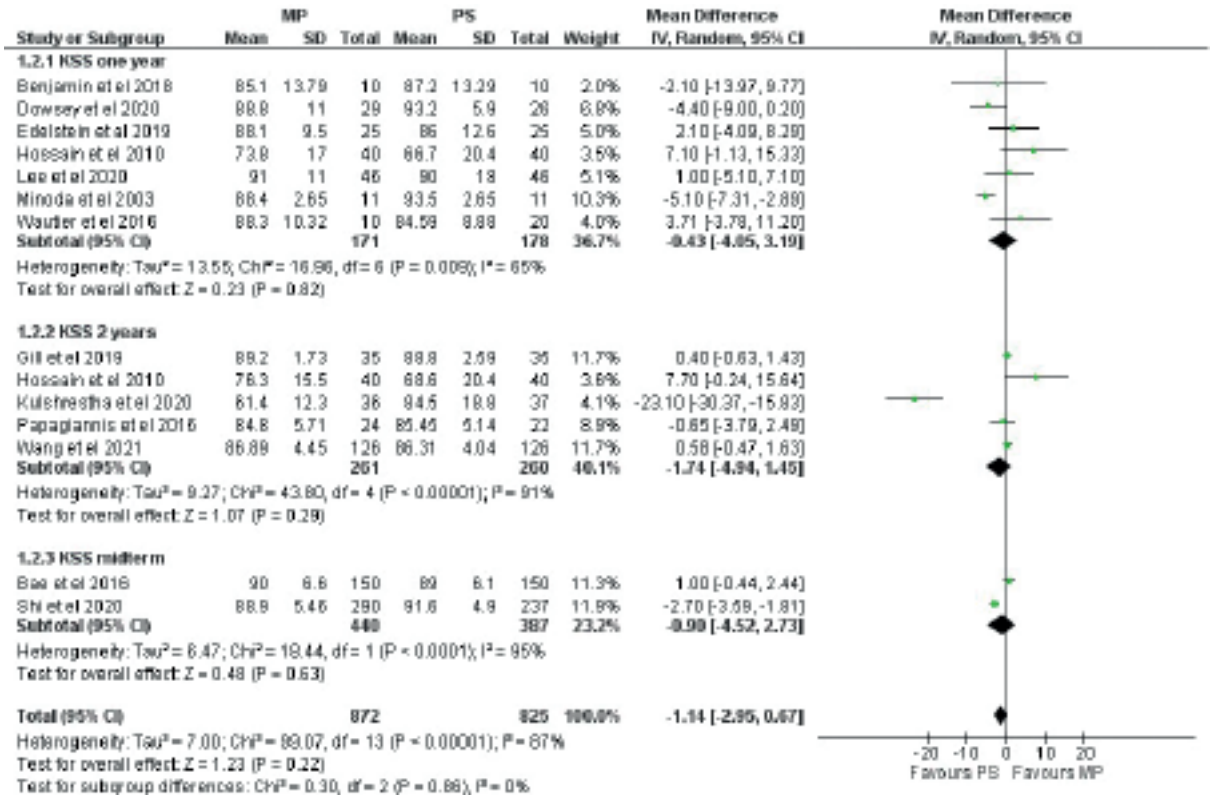

Figure 5. — Forest plot of comparison of KSS between MP and PS knee after one year, two years and midterm follow up.

statistical evidence for variation within the study (I^2 = 59 %). The cumulative MD was insignificant at 1.18 (95% CI, -7.40-5.04; P =0.71) (Fig. 8).

Two studies reported on midterm WOMAC scores encompassing a total of 827 knees (387 PS; 440 MP). Heterogeneity analysis demonstrated no statistical evidence for variation within the study (I^2 = 0%). Data pooled by random-effects model reported a significant higher score in favour of the MP cohort. The cumulative MD was insignificant at 1.77 (95% CI, -2.70-0.85; P = 0.0002) (Fig. 8).

Overall, five studies including 308 knees (151 PS; 157 MP) reported on OKS after one year. They reported an insignificantly higher OKS for the PS cohort at one year follow-up. Heterogeneity analysis demonstrated low statistical evidence for variation within the study (I^2 = 16 %). The cumulative MD was insignificant at -0.43 (95% CI, - 2.01- 1.16; P= 0.60) (Fig. 9).

Four studies involving 336 knees (168 PS; 168 MP) recorded OKS at two years follow-up. They reported an insignificantly higher OKS within the MP cohort. The heterogeneity analysis demonstrated low statistical evidence for variation within the study (I^2 = 30 %). The cumulative MD was insignificant at -0.41 (95% CI, -0,22-1,05; P =0.20) (Fig. 9).

DISCUSSION

The most important finding in this review was that the post-operative ROM was insignificantly higher in the MP cohort compared with the PS cohort. The MP design is a combination of a congruent medial compartment and a less congruent lateral compartment. It is still somewhat controversial as to whether this design achieves normal physiological knee kinematics. The MP knee showed improved kinematics in vivo which might explain the better KSS at short and midterm follow up *(30)*. However, after examining multiple different implant designs, some authors have claimed that around 50% of patients achieve medial pivoting gait and

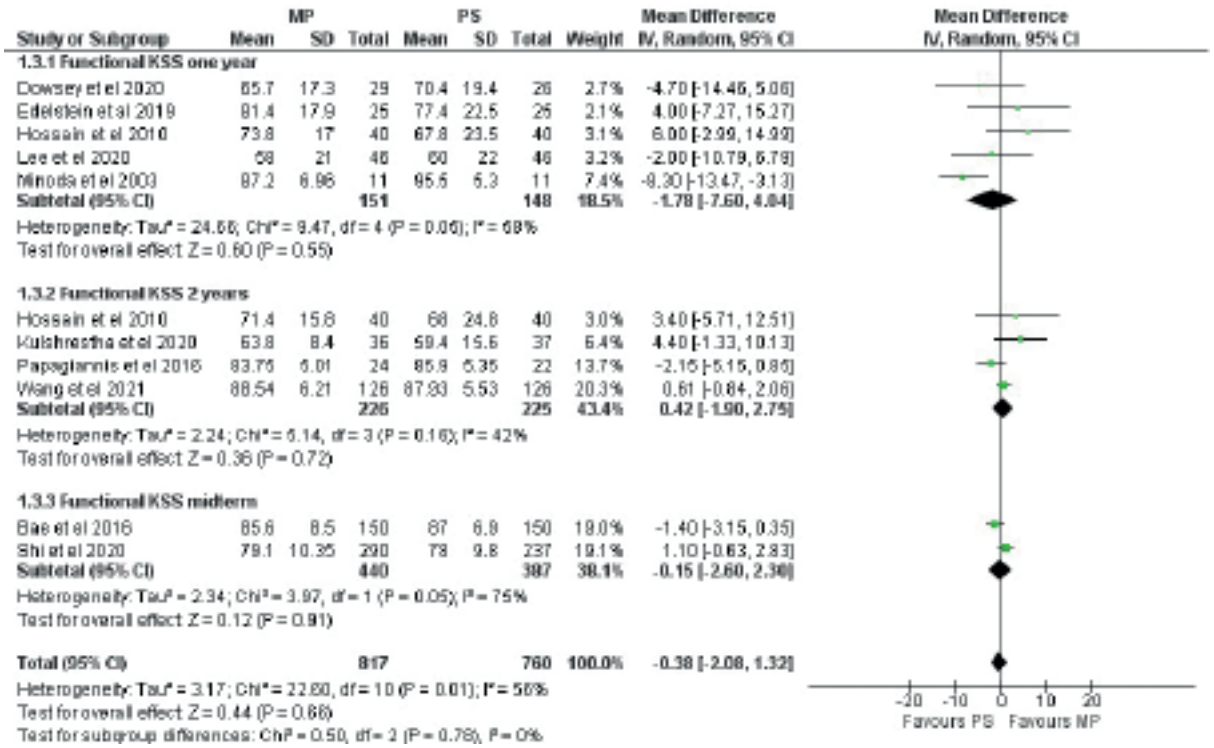

Figure 6. — Forest plot of comparison of functional KSS between MP and PS knee after one year, two years and midterm follow up.

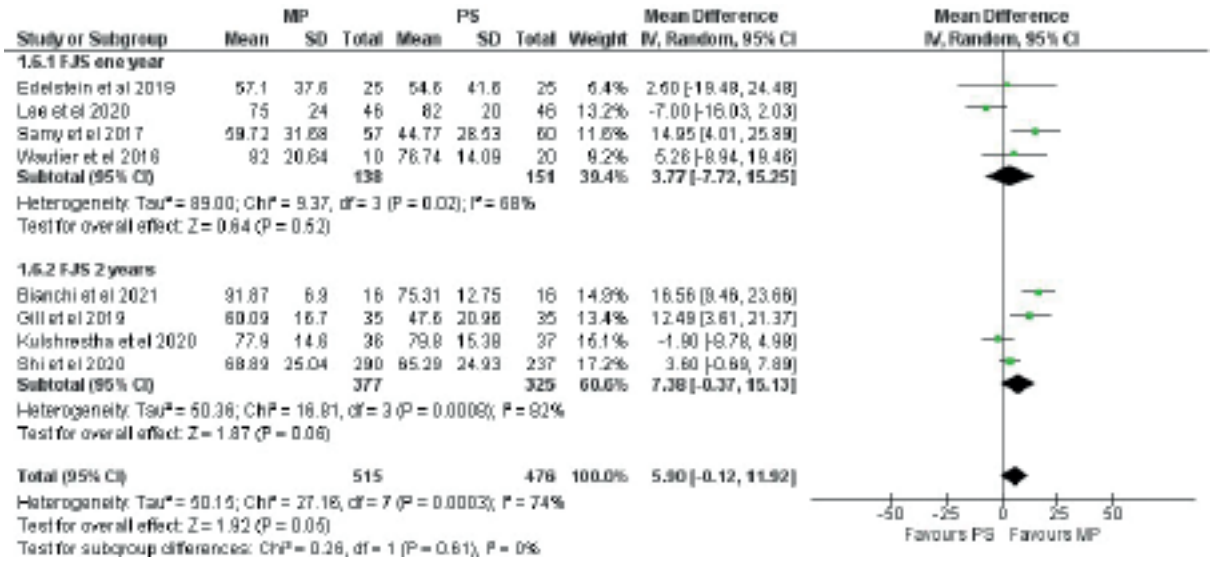

Figure 7. — Forest plot of comparison of FJS between the MP and the PS knee after one year and two years follow-up.

satisfactory knee flexion regardless of the knee prothesis they received, suggesting that knee motion doesn't absolutely correlate with the prothesis design *(42)*. Others authors couldn't report any significant kinematic or clinical advantage to the MP knee when compared to other implants at long term *(43,44)*. Previous studies that compared the MP and PS protheses were controversial. Some authors

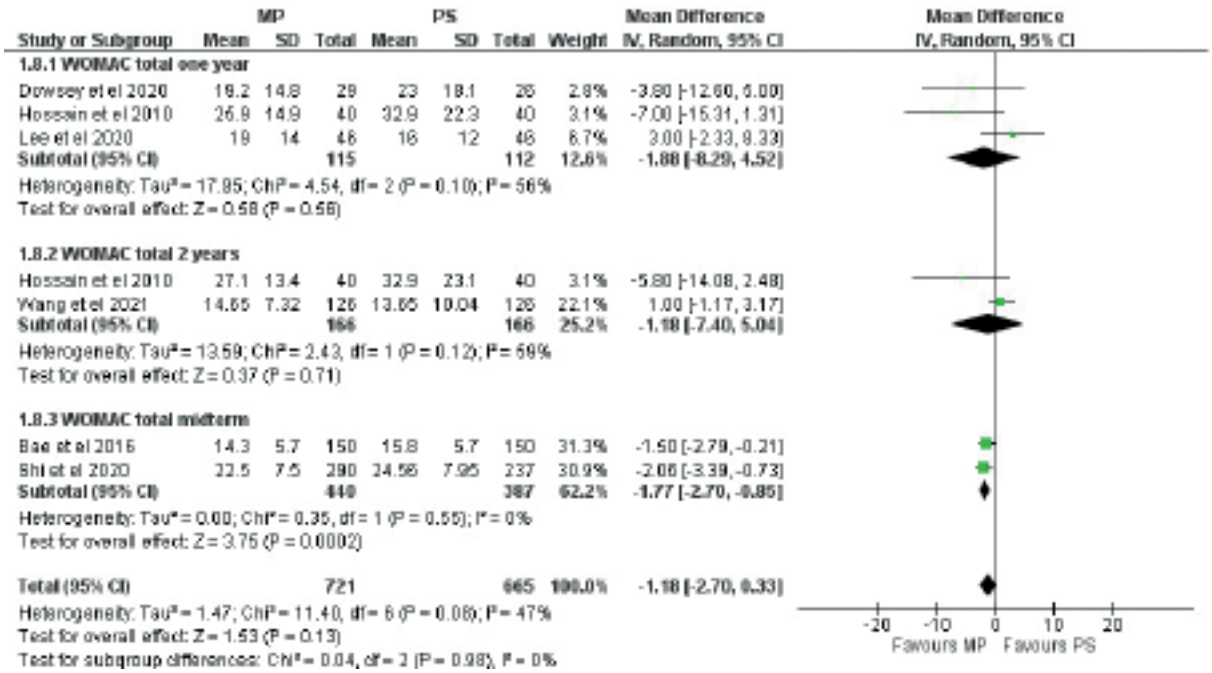

Figure 8. — Forest plot of comparison of WOMAC scores between the MP and the PS knee at one year, two years and midterm follow-up.

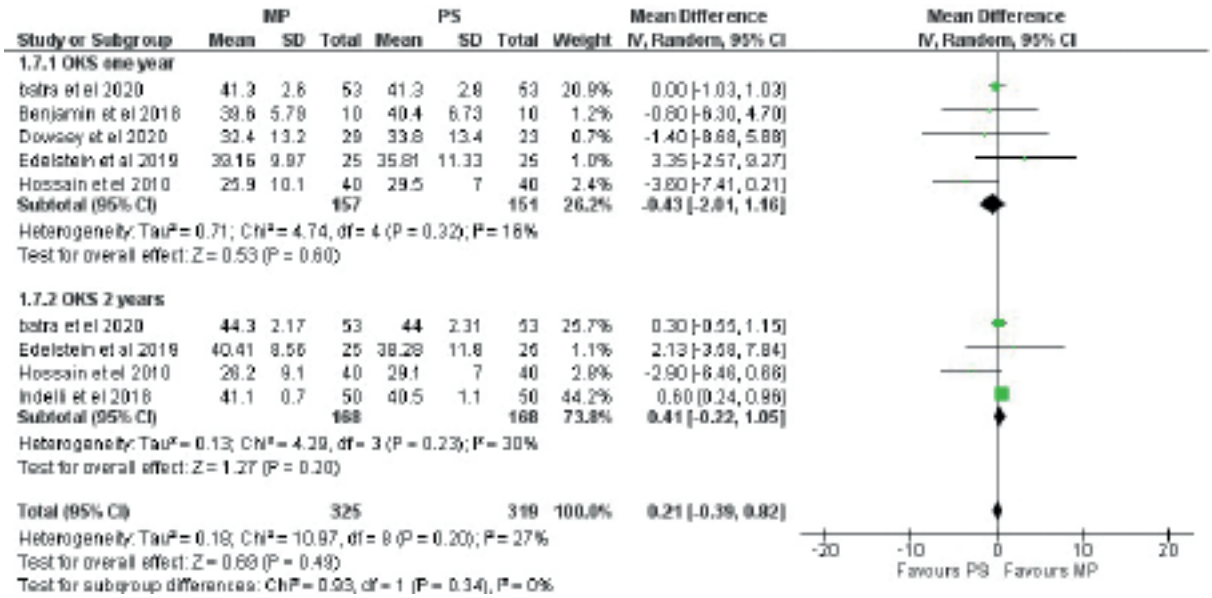

Figure 9. — Forest plot of comparison of OKS between the MP and the PS knee at one year and two years follow-up.

couldn't find any significant difference between the MP and PS knee in the context of patient satisfaction at one year follow-up *(23)*. However, other studies reported better FJS in the patients with the MP knee which did not correlate with our results in this review *(21,31)*. Dowsey et al. *(27)*, reported significatly superior pain, function, and quality of life outcomes among the MP cohort in their Randomised control

trial (RCT). In contrast, Kim et al.. *(45)* reported worse outcomes with the MP knee after two years follow. However, this study received serious criticism due to the infection rate associated with the MP cohort and the study's methodology in general *(46,47)*. Batra et al.. *(30)*, examined the kinematics of the MP and PS knee and demonstrated that the MP prothesis showed significantly better kinematics than the PS knee but reported no significant difference in the ROM between the two groups. Some researchers that assessed the kinematics of the prosthetic knees by using intraoperative sensors and CT guided navigation systems reported a higher satisfaction rate with the MP design *(48,49)*. The Australian Orthopaedic Association National Joint Replacement Registry (AOANJRR) reported encouraging outcomes for the MP TKA, with the same revision rate as the PS knee *(1)*. Edelstein et al.. *(26)*, reported mid flexion stability in the sagittal plane with the MP knee in comparison with a PS construct. Moreover, they reported improved patient function during standing in flexion activities in the MP cohort. To our knowledge, there is only one meta-analysis *(17)* that compared the pivot and the non-pivot knee designs. They analysed only the KSS and WOMAC score due to the limited number of studies included and they were unable to reach any significant conclusion in their review. To our knowledge this is the first study to use meta-analysis and systematic review to investigate the ROM and PROMs between the MP and PS knees.

One of the strengths of our study is the large number of patients included in our analysis (3837 knees). As well as this a significant portion or our included studies are modern, with nineteen published between 2018 and 2021. In terms of study limitations, the data used in this study was obtained from several studies reporting the ROM and PROMs between the MP and PS knees. The techniques and materials used in these studies were similar but not identical. Another limitation is the inclusion of eight retrospective studies in the meta-analysis. The observational patterns associated with retrospective cohort studies are more susceptible to bias in data collection, and are confronted by the incompetence to control for all the variables measured between the different cohorts included in each study. Another source of limitation was the lack of long-term follow-up. While the studies included reported scores for up to 8 years follow-up, there is a paucity of data beyond this. We would recommend more RCTs with a long term follow up period examining these two prosthetic designs.

CONCLUSION

In terms of ROM, KSS, OKS and FJS this meta-analysis suggests insignificant better short-term results for the MP knee compared with the PS prothesis. The MP implant also showed a significantly superior WOMAC score at short-term follow-up. An extended follow-up period is required to evaluate whether the MP knee is superior than the PS in the long-term.

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