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Clinical and Patient-Reported Outcomes of Medial Stabilized Versus Non–Medial Stabilized Prostheses in Total Knee Arthroplasty: A Systematic Review and Meta-Analysis

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ABSTRACT

Background: The aim of this systematic review and meta-analysis was to compare the clinical and patient-reported outcome measures (PROMs) of medial stabilized total knee arthroplasty (TKA) with non–medial stabilized TKAs.

Methods: A systematic search of multiple databases was conducted in October 2019. A meta-analysis was conducted for the Knee Society Score (KSS), Knee Society Functional Score (KFS), range of motion (ROM), Oxford Knee Score (OKS), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), and Forgotten Joint Score (FJS).

Results: A total of 857 articles yielded 21 studies eligible for inclusion with 13 studies used for quantitative analysis. The meta-analysis revealed that the medial stabilized group had a mean FJS that was 13.8 points higher than that of the non–medial stabilized TKA (mean difference [MD]: 13.83, $P \leq .0001$, 95% confidence interval [CI]: 8.90-18.76, $I^2 = 0\%$) which was less than the minimal clinically important difference of 14. The medial stabilized group also demonstrated a statistically significant difference in the postoperative ROM (MD = 2.52, $P = .05$, 95% CI: −0.03 to 5.07, $I^2 = 85\%$) and OKS when compared with the non–medial stabilized group (MD = 1.25, $P = .02$, 95% CI: 0.17-2.33, $I^2 = 27\%$), but these were not clinically significant. There was no statistically or clinically significant difference in the KSS, KFS, and WOMAC scores.

Conclusion: Medial stabilized knee prostheses demonstrated no clinically significant differences for the ROM, OKS, WOMAC, KSS, and KFS. The FJS demonstrated the greatest MD and warrants further investigation. Future research is required using patient-reported outcome measures with a lower ceiling effect such as the FJS.

Total knee arthroplasty (TKA) is an effective treatment option for end-stage osteoarthritis [1–3]. There is a rapidly increasing demand for this procedure, with an expected 3.48 million TKA procedures to be performed annually by 2030 in the United States alone [4]. Knee osteoarthritis contributes more than $27 billion annually in health-care expenditures in the United States [5]. Since the introduction of the TKAs in the 1950s, implant designs have improved significantly in the modern era, resulting in increased joint survivorship, stability, patient satisfaction, and overall knee function [6–8]. Although TKAs have been shown to reduce pain and improve activities of daily living, 19% of patients are still not satisfied after TKA [6]. An ideal TKA should mimic native knee

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kinematics to facilitate joint stability and optimize the range of motion (ROM), ensuring high functional abilities in all activities of daily living [8,9]. Natural knee kinematics exhibit differential posterior translation of the femoral condyles during flexion resulting in a net internal rotation centered around the medial femoral condyle. However, several studies have demonstrated that changes in kinematics after TKA resulted in paradoxical anterior translation of the femur [9,10]. It is theorized that these differences between natural and post-TKA kinematics are a major contributor to the rates of dissatisfaction reported after TKA [11]. In an attempt to more consistently mimic normal knee kinematics, the medial stabilized (MS) prosthesis was designed [12]. These prostheses have a highly conforming medial compartment limiting anteroposterior translation with a less conforming lateral compartment articulation allowing for an unrestricted posterolateral rollback of the lateral femoral condyle. However, it remains unclear whether the use of the MS prosthesis translates into improved outcomes for patients [13].

Previous studies have compared the clinical and patient-reported outcomes of MS prosthesis and non-MS designs with conflicting results. A prior systematic review and meta-analysis was conducted in 2017 and was unable to reach a clear conclusion on the clinical performance of the MS prosthesis because of a small number of studies [14]. In addition, patient-reported outcome measures (PROMs) such as the Forgotten Joint Score (FJS) were not able to be quantitatively analyzed in this prior review [14]. Furthermore, there have been several high-quality original articles recently published, which warrants an updated synthesis of the literature. Therefore, the aim of this current review is to quantitatively compare the clinical and patient-reported outcomes between MS and non-MS TKAs to provide recommendations for clinical practice and future research directions.

Methods

A systematic meta-analysis was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines. This review was registered with the International Prospective Register of Systematic Reviews database (CRD42019131327) in June 2019.

Articles were included if studies (1) reported the ROM or validated PROMs in both MS and non-MS groups; (2) included true MS designed prosthesis that were commercially available and not prostheses showing MS as determined by kinematics; and (3) included non-MS groups consisting of any other prosthesis designs. Studies were excluded if they (1) were not available in English; (2) were conducted on cadavers; and (3) included revision TKAs.

The databases PubMed, Scopus, Embase, Medline, CINAHL, and Cochrane were searched on October 2, 2019. There were no restrictions on the date of publication, with all articles that were published before this search date included. The search term used in PubMed was as follows with alterations made as per each database's requirements: *"knee replacement" OR "knee replacements" OR "knee arthroplasty" OR "knee arthroplasties" OR "TKA" OR "total knee" OR "knee prostheses" OR "knee prosthesis") AND ("medial pivot" OR "medial stabilized" OR "medial stabilised" OR "medially stabilised" OR "medially stabilized" OR "ball-and-socket" OR "ball and socket" OR "medial conforming" OR "medially conforming" OR "medial rotation" OR "medial congruent" OR "medial rotation" OR "MRK" OR "SAIPH" OR "GMK" OR "AMP"*.

Eligibility of studies was determined in two main stages with an initial abstract screen independently performed by two authors (R.T. and J.S.). A full-text screen was then conducted of the short-listed articles by the same authors. A third author (K.D.) was consulted if there were disagreements on eligibility criteria. Studies were included in the meta-analysis if they reported a mean and standard deviation for the outcomes of interest. Authors of articles that reported a median and range were contacted to request a mean and standard deviation value. If no additional information was received, these articles were not included in the meta-analysis but were included in the review for qualitative discussion in the Results section.

Data Extraction

Data extraction was performed independently by two authors (J.S. and R.T.) in accordance to the Cochrane guidelines. A summary of the extracted data is shown in Tables 1 and 2. Relevant data extracted included publication information (study design, country and year); study methodology (recruitment method, randomization, single site or multisite, number, and training of surgeons); and surgery type (bilateral or unilateral knee arthroplasty). Prosthesis type (MS, cruciate retaining, or sacrificing), participant recruitment, outcome data, and supplementary information (funding and conflicts of interest) were also extracted.

Quality Assessment

Quality assessment and risk of bias were performed independently by two authors (J.S. and R.T.). Cohort studies were analyzed using the Newcastle Ottawa scale [33], with a score of 8 or 9 considered high quality, 5-7 medium quality, and <5 low quality. Randomized studies were assessed using the Cochrane Risk of Bias tool.

Statistical Analyses

Owing to the heterogeneity between studies, a random-effect model was chosen for the meta-analysis. The mean difference (MD) was utilized as the summary measure for this analysis, with a *P* value and 95% confidence interval (CI) also reported. Only articles that reported a mean and standard deviation for each outcome of interest were able to be included in the meta-analysis. One article reported the Oxford Knee Score (OKS) using the older scoring system (60 to 12), which was transformed into the newer scoring system (0 to 48) by subtracting the score from 60 [34]. A minimum of three articles reporting data for a specific outcome was required for a meta-analysis to be performed. Heterogeneity between studies was assessed using I^2 values, with 25% considered low heterogeneity, 50% moderate heterogeneity, and 75% high heterogeneity. Publication bias was analyzed by examining funnel plots of the data created using Review Manager Software, version 5. The level of statistical significance was determined at 5%. Clinical significance was evaluated using minimal clinically important difference (MCID) values calculated in external studies. Preoperative PROMs were compared for each of the outcome measures to ensure that there was no initial bias present. Statistically significant differences in baseline PROMs were found for one study [18] for Knee Society Score (KSS) favoring the non-MS group, two studies [15,18] for the Knee Society Functional Score (KFS), which both favored the non-MS group, one study [20] for the ROM, which favored the MS group, and one study for WOMAC [15], which favored the MS group. There were no preoperative differences in the OKS for the two groups, and the FJS is not able to be performed as a baseline score.

Table 1
Overview of Studies Included in the Meta-Analysis.

Study (y)	Study Country	Study Design	Sample Size (n)		Participant Characteristics			Baseline Differences	Prosthesis		MS, Cruciate Retaining, or Sacrificing	Follow-Up Duration (y)	Outcome Measures	Summary of Results
			MS	NMS	Age	Sex (% Female)	BMI (Mean ± SD)		Medial Stabilized	Non–Medial Stabilized				
Hossain et al [13] (2011)	UK	RCT	40	40	MS - 72.5 ± 9.7 NMS - 68.9 ± 12.1	MS- 71% NMS - 18.2%	MS - 28.9 ± 6.2 NMS - 29.5 ± 8.1	Higher proportion of females in the MS group ($P = .03$); no statistically significant difference in preoperative PROMs and ROM	Medial Rotation ™ MRK MatOrtho	Posterior stabilized Press-Fit Condylar Sigma™ DePuy	CS	1-2	KSS, KFS, ROM, WOMAC, OKS, SF-36, TKFQ	MS group had a superior ROM and TKFQ compared with the NMS group
Bae et al [15] (2016)	Korea	Retrospective cohort	150	150	MS - 66.7 ± 7.1 NMS - 66.7 ± 6.5	MS - 96.8% NMS - 98.6%	MS - 26.4 ± 3.2 NMS - 25.9 ± 4.4	No statistically significant differences in participant characteristics, preoperative KFS ($P < .05$) and WOMAC ($P < .05$) lower in MS group	Advance® Medial-Pivot MicroPort	Posterior stabilized Press-Fit Condylar Sigma™ DePuy	CS	5.2 (mean)	KSS, WOMAC, Kujala, Feller, Flexion, ROM	No statistically significant difference in outcomes between the MS and NMS groups
Papagiannis et al [16] (2016)	Greece	Prospective cohort	24	22	MS - 70.25 ± 1.96 NMS - 72.92 ± 1.46	NR	NR	NR	Advance® Medial-Pivot MicroPort	Rotating platform posterior stabilized type	NR	2-3	KSS, ROM, KFS	No statistically significant difference in outcomes between the MS and NMS groups
Choi et al [17] (2017)	Korea	Retrospective cohort	49	52	MS - 66.7 ± 6.8 NMS - 67.5 ± 7.5	MS - 88% NMS - 89%	MS - 27.6 ± 2.1 NMS - 27.5 ± 4.8	No statistically significant differences	Advance® Medial-Pivot MicroPort	Rotating-platform mobile-bearing Advanced coated system ACS® Implantcast	NR	5	KSS, ROM, WOMAC, patient satisfaction	Higher patient satisfaction in the MS group ($P = .031$) but all other outcomes showed no significant differences
Nakamura et al [18] (2018)	Japan	Retrospective cohort	45	45	MS - 74.3 ± 10.3 NMS - 74.1 ± 8.1	MS - 84.4% NMS - 84.4%	MS - 25.6 ± 3.7 NMS - 25.8 ± 3.1	Medial stabilized group had a lower weight ($P = .015$), lower KSS ($P = .035$) and KFS ($P = .013$)	FINE® Knee Teijin Nakashima Medical	Cruciate-retaining Hi-Tech Knee II cementless Teijin Nakashima Medical	CR	2	KSS, ROM	MS group had a significantly higher KSS ($P < .001$), ROM, reduced surgical time, and lower estimated total blood loss ($P = .001$)
Nishitani et al [19] (2018)	Japan	RCT	33	32	MS - 73.8 ± 6.0 NMS - 74.4 ± 6.6	MS - 69.7% NMS - 78.1%	MS - 27.7 ± 4.5 NMS - 26.9 ± 4.9	No statistically significant differences	Bi-Surface TKA - Medial pivot insert	Bi-Surface TKA - Symmetric dish tibial insert	NR	2	KSS, 2011 KSS, KFS, ROM	No statistically significant difference in outcomes between MS and NMS
Samy [20] (2018)	Canada	Retrospective cohort	57	60	MS - 64.4 ± 10.5 NMS - 66.7 ± 8.6	MS - 61.8% NMS - 61.4%	MS - 29.7 ± 5.2 NMS - 31.3 ± 8.2	No statistically significant differences in participant characteristics; the MS group had a higher preoperative ROM (120.3 vs 112.8, $P = .02$)	Evolution® Medial Pivot	Posterior stabilized Persona® Zimmer Biomet	NR	1	ROM, FJS-12	MS group had a higher FJS ($P = .007$)
Indelli et al [11] (2019)	USA	Retrospective cohort	50	50	MS - 67.3[a] NMS - 67.6[a]	MS - 7% NMS - 8%	MS - 34.6 NMS - 34.4	No statistically significant differences	Persona® The Personalized Knee Medially congruent (MC)	Posterior stabilized Persona® Zimmer Biomet	CS	2 (minimum)	OKS, KSS, ROM	No statistically significant difference in PROMs, the NMS group had a higher ROM than the MS group
Edelstein et al [21] (2019)	USA	RCT	25	25	MS- 67 ± 8 NMS - 64 ± 7	MS - 72% NMS - 60%	MS - 32.8 ± 5.8 NMS - 34.2 ± 5.8	No statistically significant differences	Medial stabilized GMK® Sphere Prosthesis	Posterior stabilized GMK® prosthesis Medacta	CS	2	OKS, VR12, IKDC, KSS, KFS, FJS, ROM, PROMIS	No statistically significant difference in outcomes between the MS and NMS groups

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Table 1 (*continued*)

Study (y)	Study Country	Study Design	Sample Size (n)		Participant Characteristics			Baseline Differences	Prosthesis		MS, Cruciate Retaining, or Sacrificing	Follow-Up Duration (y)	Outcome Measures	Summary of Results
			MS	NMS	Age	Sex (% Female)	BMI (Mean ± SD)		Medial Stabilized	Non−Medial Stabilized				
French et al[22] (2019)	Australia	Prospective cohort	53	50	MS - 69.5 ± 6.9 NMS - 66.1 ± 7.9	MS - 65.2% NMS - 50%	MS - 32.9 ± 9.1 NMS - 32.6 ± 5.4	Participants in the medial stabilized group were older ($P = .031$), no statistically significant differences in preoperative PROMs	Medial stabilized SAIPH® Knee System MatOrtho	Cruciate-Retaining Knee Vanguard®	NR	1	KOOS, KOOS-12, KOOS-Short form, KOOS-JR, WOMAC, OKS, EQ-5D-5L, and UCLA, FJS, VAS-satisfaction, ROM	MS group had a higher FJS (P - .05), KOOS-12 QoL subscale, all other PROMs showed no statistically significant differences
Gill et al [23] (2019)	Pakistan	RCT	35	35	MS - 68.9 ± 2.7 NMS - 68.6 ± 2.1	MS - 62.9% NMS - 68.6%	NR	NR	Advance® Medial-Pivot MicroPort	Posterior-stabilizing TKA Prosthesis Zimmer or Johnson & Johnson	CS	2	KSS, FJS-12, ROM	MS group had a higher FJS ($P < .001$) and ROM compared with the NMS group
Yuan et al [24] (2019)	China	RCT	49	51	MS - 69.43 ± 5.97 NMS - 69.63 ± 5.72	MS - 54% NMS - 55%	MS - 27.81 ± 5.17 NMS - 27.59 ± 4.86	No statistically significant differences	Advance® Medial-Pivot MicroPort	Posterior stabilized NexGen LPS-Flex Zimmer prosthesis	CS	5 (Mean)	HSS, WOMAC	No statistically significant difference in outcomes between the MS and NMS groups
Jones et al [25] (2019)	Australia	Prospective cohort	30	30	MS - 69.6 ± 8.8 NMS - 69.5 ± 8.5	MS - 53% NMS - 53%	MS - 30.5 ± 4 NMS - 31.7 ± 4.1	No statistically significant differences in participant characteristics; no preoperative PROMs	Medial stabilized SAIPH Knee MatOrtho	Cruciate-retaining Vanguard Cruciate-retaining NexGen Condylar stabilized Triathlon	CS	1	FJS, KOOS, WOMAC, OKS, VAS	MS group had a higher FJS ($P = .01$), KOOS ($P = .04$), OKS ($P = .02$), and a lower WOMAC ($P = .02$)

ROM, range of motion; FJS, Forgotten Joint Score; OKS, Oxford Knee Score; KSS, Knee Society Score; KFS, Knee Society Functional Score; KOOS, Knee Injury and Osteoarthritis Outcome Score; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index; SF-36, Short-Form 36; TKFQ, Total Knee Function Questionnaire; VR12, Veterans RAND 12-item Health Survey; IKDC, International Knee Documentation Committee; KOOS, The Knee Injury and Osteoarthritis Outcome Score; KOOS-JR, The Knee Injury and Osteoarthritis Outcome Score-Joint Replacement; EG-5D-5L, EuroQuality of life - 5 Dimension; UCLA, University of California at Los Angeles Activity Scale; VAS, Visual Analogue Scale; HSS, Hospital for Special Surgery Scoring; MS, medial stabilized; NMS, non−medial stabilized; PROMs, patient-reported outcome measures; RCT, randomized control trial; MRK, medial rotation knee; CS. cruciate sacrificing; CR, cruciate retaining; NR, not reported; TKA, total knee arthroplasty.

[a] Medians used but no IQR reported.

Table 2
Overview of Studies Included in Qualitative Synthesis.

Study (y)	Study Country	Study Design	Sample Size (n)		Participant Characteristics			Baseline Differences	Prosthesis		MS Posterior. Cruciate Retaining (CR). or Sacrificing (CS)	Follow-Up Duration (Years)	Outcome Measures	Summary of Results
			MS	NMS	Age	Sex (% Female)	BMI (Mean ± SD)		Medial Stabilized	Non–Medial Stabilized				
Schmidt et al [10] (2003)	USA	Prospective cohort	5	10	MS - 68[a] NMS - 65[a]	NR	NR	NR	Advance® Medial-Pivot MicroPort	Posterior cruciate retaining - Sigma® and Advance®	NR	2.17 (Mean)	KSS, Fluoroscopic gait analysis	No statistically significant difference in outcomes between the MS and NMS groups
Shakespeare et al [26] (2006)	UK	Prospective cohort	261	288	MS - 76[a] NMS - 78[a]	MS - 49% NMS - 52%	NR	No statistically significant differences	Advance® Medial-Pivot MicroPort	Posterior stabilized 913	NR	1	ROM	No statistically significant difference in outcomes between the MS and NMS groups
Kim et al [27] (2009)	Korea	RCT (participants received 1 prosthesis in each knee)	92	92	Overall - 69.5 ± 7.92	Overall - 92.4%	Overall - 27.8 ± 3.15	No statistically significant differences	Advance® Medial-Pivot MicroPort	Mobile Bearing Press-Fit Condylar Sigma™ DePuy	CR	2-3	KSS, HSS, Pain score, ROM, Knee preference	MS group had inferior outcomes (KSS, ROM, patient preference) to NMS group and higher rates of complication
Pritchett [28] (2011)	USA	RCT (participants received 1 prosthesis in each knee)	440	440	Overall - 68	Overall - 70%	NR	NR	Advance® Medial-Pivot MicroPort	1. ACL-PCL retaining BioPro 2. PCL retaining prosthesis Biomet 3. Posterior-substituting Biomet 4. Mobile Bearing prosthesis P.F.C Sigma	CS	6.8 (Mean)	KSS, KFS, patient preference, ROM	MS group had a higher patient preference than the NMS groups
Ishida et al [29] (2014)	Japan	RCT	20	20	MS - 71 (60-81) NMS - 72 (63-79)	MS - 95% NMS - 95%	MS - 27.2 (21.4-36.2) NMS - 26.0 (21.8-34.5)	No statistically significant differences	Advance® Medial-Pivot MicroPort	Advance® Double High insert	CS	5	KSS, KSFS, ROM, UCLA activity score	No statistically significant difference in outcomes between the MS and NMS groups
Kim et al [30] (2017)	Korea	RCT (participants received 1 prosthesis in each knee)	195[a]	195[a]	Overall - 65.6 ± 6.9	Overall - 71.4%	Overall - 29.8 ± 3.1	No statistically significant difference	Advance® Medial-Pivot MicroPort	Cruciate-retaining mobile-bearing Press-fit condylar P.F.C Sigma prosthesis	CR	12.1 (Mean)	KSS, KFS, WOMAC, UCLA activity score, ROM, satisfaction, complications	MS group had significantly lower KSS, WOMAC, ROM, satisfaction and higher complication rates
Wautier and Thienpont [31] (2017)	Belgium	Prospective Cohort	10	30	MS - 72 ± 11 NMS - 70 ± 9	MS - 40% NMS - 40%	MS - 33 ± 5 NMS - 26 ± 4.5	MS group had a statistically significant higher BMI ($P < .05$), no preoperative PROMs recorded	GMK® Sphere Medacta	Posterior stabilized Persona® TKA[b]	NR	1 (Minimum)	FJS, KSS, KOOS (symptom, pain, ADL, sport, QOL), stability, proprioceptive testing	No statistically significant difference in outcomes between the MS and NMS groups
Benjamin et al [32] (2018)	UK	RCT	10	10	MS - 62.4 (54-71) NMS - 64.8 (58-73)	MS - 40% NMS - 30%	NR	NR	Medial stabilized SAIPH ®Knee MatOrtho	Press-Fit Triathlon® Knee Stryker	CS	1 (Minimum)	KSS, OKS	No statistically significant difference in outcomes (KSS and OKS) between the MS and NMS groups

ROM, range of motion; FJS, Forgotten Joint Score; OKS, Oxford Knee Score; KSS, Knee Society Score; KFS, Knee Society Functional Score; KOOS, Knee Injury and Osteoarthritis Outcome Score; HSS, Hospital for Special Surgery Scoring; UCLA, University of California at Los Angeles Activity Scale; MS, medial stabilized; NMS, non–medial stabilized; PROMs, patient-reported outcome measures; RCT, randomized controlled trial; TKA, total knee arthroplasty.
Age—Reported as the mean ± SD or median (IQR).
[a] No SD reported.
[b] Wautier–Persona group used as comparison.

Results

Study Selection

After removal of duplicates, there were 857 articles identified for screening (Fig. 1). An initial abstract and title screen was performed, which left 107 articles for full-text analysis. One additional article was also identified through a 'cited by' search in Scopus. There were 21 studies that were assessed as eligible for inclusion in this systematic review. Only 13 of these articles [11,13,15–25] provided sufficient detail to be included in the meta-analysis, with the remaining eight articles [10,26–32] included for qualitative synthesis.

Study Characteristics

Ten of the studies included were randomized control studies [13,19,21,23,24,27–30,32], six were prospective cohort studies [10,16,22,25,26,31], and five were retrospective studies [11,15,17,18,20]. Two studies [17,21] involved patients who had undergone bilateral TKA with an MS prosthesis in one knee and a non-MS joint in the other. Further participant and study details are summarized in Tables 1 and 2.

Risk of Bias and Quality Assessment

Quality assessment of the cohort studies revealed that seven studies [11,15,17,18,22,25,31] were rated as high quality and four [10,16,20,26] were determined to be of medium quality (Supplementary 1). Risk of bias of the ten randomized controlled trials [13,19,21,23,24,27–30,32] for each of the domains can also be seen in Supplementary 2.

Quantitative Synthesis

The combined meta-analysis (Fig. 2) highlights the overall MDs between the MS and non-MS groups for the ROM, FJS, OKS, KSS, and KFS. Figure 3 shows the quantitative analysis for the WOMAC outcome. Accordingly, there was an MD in the ROM of 2.52 degrees in favor of the MS group (MD: 2.52 $P = .05$, 95% CI: −0.03 to 5.07), but there was high heterogeneity ($I^2 = 85\%$; Figure 2). There was also a statistically significant increased mean FJS of 13.83 for the MS group (MD: 13.83, $P \leq .0001$, 95% CI: 8.90-18.76, $I^2 = 0\%$) when compared with the non-MS group. This is less than the MCID value for the FJS of 14 [35]. There was a small increase in the OKS of 1.25 favoring the MS group (MD: 1.25, $P = .02$, 95% CI: 0.17-2.33, $I^2 = 27\%$), but this was also less than the MCID value of five [36]. The analysis revealed no significant differences between the MS and non-MS groups for the KSS (MD: 1.13, $P = .2$, 95% CI: −0.59 to 2.84, $I^2 = 66\%$) and KFS (MD = −0.95, $P = .17$, 95% CI: −2.30 to 0.39, $I^2 = 0\%$). Furthermore, no significant differences were identified between the MS and non-MS groups (MD: −1.80, $P = .21$, 95% CI: −4.61 to 1.02, $I^2 = 68\%$) for the WOMAC outcome with an MD of 1.8 favoring the non-MS group (Fig. 3). Based on visual inspection of the funnel plots for all outcome measures, there was no observable asymmetry, although this was difficult for measures such as the FJS, OKS, and WOMAC, which had a smaller number of studies.

Qualitative Synthesis

Many other PROMs could not be quantitatively synthesized because of an insufficient number of studies reporting them. These included the Knee Injury and Osteoarthritis Outcome Score (KOOS), which was reported in three studies [22,25,27]. Jones et al. [25] demonstrated that the MS group overall had a higher statistically significant KOOS than the non-MS group (84.0 vs 69.3, $P = .01$). Another study concluded that the MS group had a similar overall KOOS to the non-MS group (84.6 vs 82.2, $P = .420$); however, there was a significant difference in the quality of life subscale favoring the MS prosthesis (82.8 vs 74.4, $P = .043$) [22]. The final article reporting on the KOOS demonstrated that there was no statistically significant difference between the two groups [31]. Other PROMs included the Hospital for Special Knee Surgery Scoring, which demonstrated conflicting results for the two studies reporting this outcome [24,27]. The University of California at Los Angeles (UCLA) activity scores also highlighted that there were no significant differences between the MS and non-MS groups [22,29,30]. Similarly, for the articles reporting Visual Analogue Scale-Satisfaction (VAS) scores, there were no statistically significant differences in the two groups [22,25]. Another study investigated patient preferences for varying types of prostheses and found that patients preferred an MS design when compared with a posterior-stabilized, posterior cruciate-retaining, or mobile-bearing prosthesis [28].

A limited number of studies reported on outcomes including the FJS, KSS, OKS, and WOMAC but were unable to be included in the meta-analysis because of insufficient outcome reporting. These studies are described in Table 2, with the results of each article summarized. Most of these articles demonstrated no significant differences between the MS and non-MS groups for each of these outcomes. However, there was one article [17] that demonstrated a statistically significant difference favoring the non-MS group for the ROM, KSS, and WOMAC. In addition, there was one article that demonstrated a significant increase in the KSS for the MS group [31].

Discussion

The aim of this systematic review and meta-analysis was to synthesize and compare the PROMs and clinical outcomes of the MS and the non-MS prostheses. This review demonstrated that patients undergoing a TKA with an MS knee prosthesis reported a mean FJS of 13.83 higher than the non-MS prosthesis (MD: 13.83, $P < .0001$) although this is less than the MCID value for FJS of 14 [35]. The OKS also demonstrated a statistically significant increase in the MS group (MD: 1.25, $P = .02$) that was less than the minimal clinical difference score of 5 [36]. In addition, participants who underwent an MS TKA showed a marginally superior ROM (MD: 2.52, $P = .05$), although the 95% CIs crossed the null value of 0 (95% CI: −0.03 to 5.07) and there was high heterogeneity between studies ($I^2 = 85\%$). Furthermore, although there is no MCID value for the ROM within the literature, a difference of 2.52 degrees between the two groups is unlikely to be clinically significant. The other PROMs such as the KSS, KFS, and WOMAC showed no statistically significant differences between the MS and non-MS prostheses.

Although the mean FJS calculated in this study of 13.83 is less than the MCID of 14, there were only 5 studies able to be included in the meta-analysis and the 95% CIs (8.90 to 18.76) contained the MCID. Therefore, further primary studies evaluating the FJS between MS and non-MS prostheses are required to determine the true difference. The lack of differences between the two groups for many of the PROMs may be attributed to the limitations of the scoring systems themselves. While many of the PROMS are useful, their ability to distinguish differences between positive outcomes and excellent outcomes are difficult because of the "ceiling effect" of these tools [37]. However, the FJS has been consistently demonstrated to have a lower ceiling effect, suggesting it may have superior discriminatory abilities than other PROMs and allows for detection of even small improvements between patients [38]. The importance of the FJS lies in the necessity for knees to be free of pain, move with an acceptable ROM, and provide stability in both flexion and extension for patients to simply "forget" their artificial

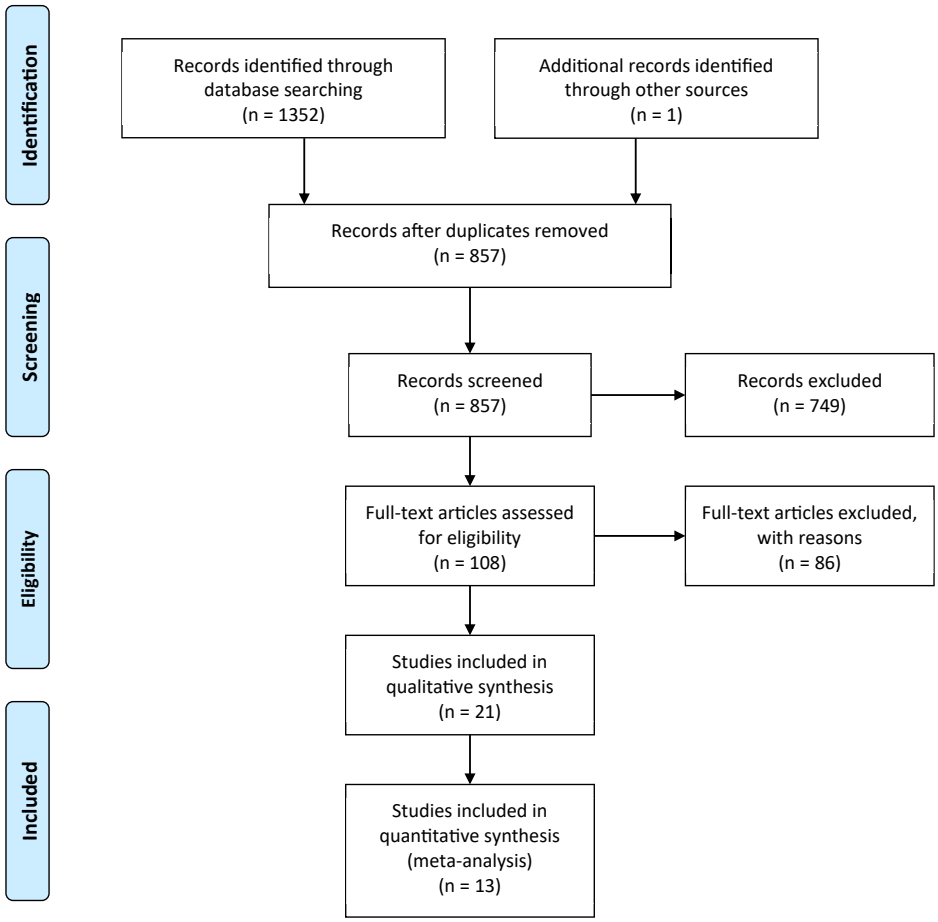

Fig. 1. PRISMA flow diagram. PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analysis guidelines.

joint [39]. This highlights that the parameters evaluated using the FJS may be better suited to detect postoperative functionality [37,40,41] and that "forgetting the joint" may be the ultimate goal of arthroplasty [27]. The findings of this review are also similar to the results by French et al [22] who demonstrated a statistically significant increase in the FJS in the MS groups but similar scores for all other PROMs. This suggests that the MS prosthesis may further benefit patients, with the ceiling effect of the majority of PROMs limiting the ability to discriminate differences between prosthesis designs. Considering that the FJS was not utilized as an outcome measure by several studies, there may have been a difference in the PROMs that was not detected in other studies because of the limited, inherent nature of the older scoring systems. All future studies comparing MS and non-MS knee prostheses should utilize the FJS as an outcome measure to detect any discernible differences between the groups.

There was only one study [30] that consistently demonstrated inferior outcomes for the MS group, and this was excluded from the meta-analysis because of an insufficient reporting of outcomes. The authors [30] compared bilateral knees with one MS prosthesis and one non-MS prosthesis randomized in each knee of the same patient. The authors reported inferior results in the ROM, KSS, WOMAC, and patient satisfaction for the MS group at statistical significance. However, this study also had a statistically significant increase in complication rates, including postoperative infection and recurrent joint effusions in the MS group, which could have resulted in higher rates of dissatisfaction with this prosthesis. Given that this is the only study to report inferior outcomes for the MS group at statistical significance, it is likely that the negative outcomes can be explained by the higher complication rates. In addition, there were no other studies that reported higher complication rates for the MS group. Another bilateral TKA comparison study involving MS prostheses in one knee and non-MS prosthesis in the other knee demonstrated a statistically significant patient satisfaction rate in favor of the MS knee [28].

The main limitation with this systematic review and meta-analysis is the heterogeneity between studies. This was highlighted by the fact that the type of prosthesis compared varied between studies for both the MS and non-MS groups. This study compared all other primary designs (cruciate retaining, posterior stabilized, mobile bearing, etc.) with MS prostheses and did not compare with each prosthesis individually. As a result, it is challenging for a head-to-head comparison of a specific nonmedial prosthesis with an MS design. Another limitation was that we combined studies that used a within-participant study design (bilateral TKA studies) and those with a between-subject design (compared MS and non-MS prostheses in separate patients). Given the limited number of available studies, a combination of randomized controlled trials and observational studies was also used for the meta-analysis, which may have impacted on the overall quality of evidence. With the available data, it was not possible to calculate delta differences of the PROMs, and therefore, only an assessment of preoperative scores was able to be performed. However, this demonstrated only a very small number of articles that had baseline differences between the two groups, which is unlikely to have affected the results. In addition, not all studies

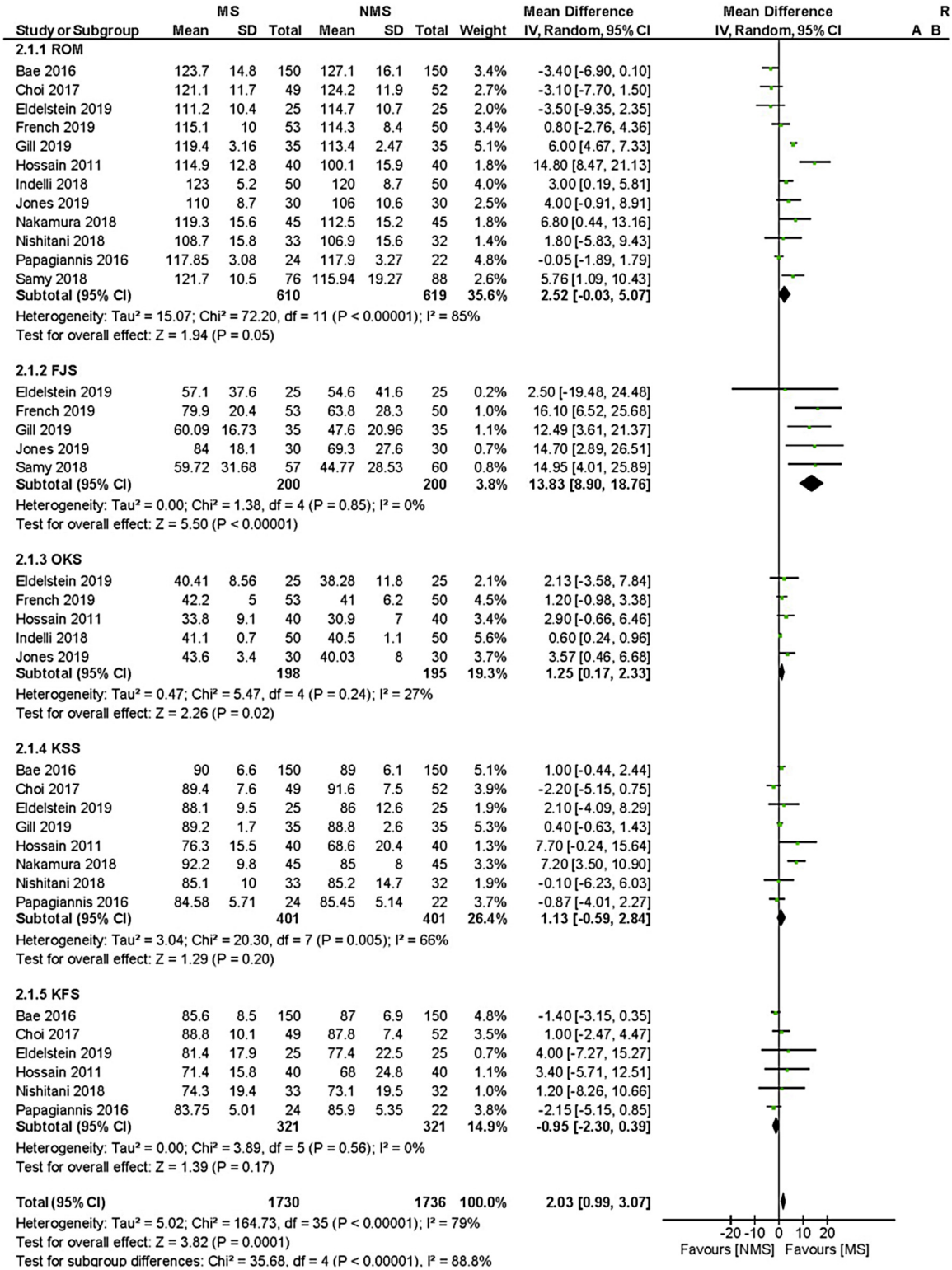

Fig. 2. Forest plots for the ROM, FJS, OKS, KSS, and KFS. ROM, range of motion; FJS, Forgotten Joint Score; OKS, Oxford Knee Score; KSS, Knee Society Score; KFS, Knee Society Functional Score; CI, confidence interval; MS, medial stabilized; NMS, non-medial stabilized.

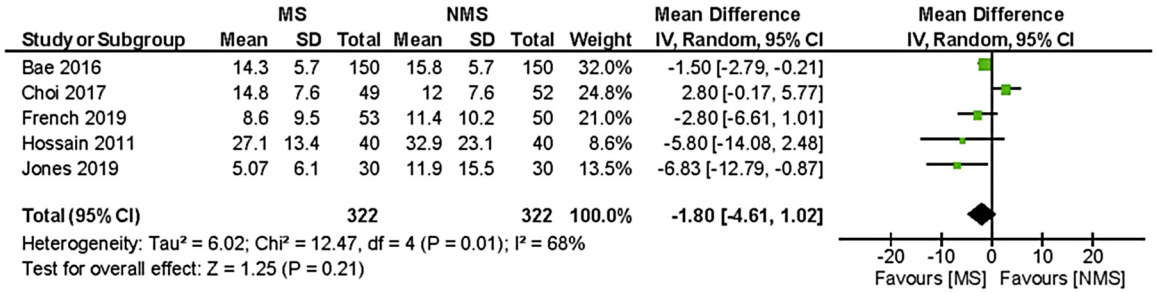

Fig. 3. Forest plot for the WOMAC. WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index; MS, medial stabilized; NMS, non-medial stabilized.

were able to be included in the meta-analysis as they did not report appropriate measures of central tendency and dispersion.

Conclusion

Overall, this meta-analysis demonstrated that there were no clinically significant differences between MS and non-MS prostheses for the ROM, OKS, WOMAC, KSS, and KFS. The FJS was statistically significant for the MS group and demonstrated the greatest difference in PROMs between the two groups. However, the FJS calculated in this study was marginally less than the MCID of 14, indicating this may not be clinically significant. Given that only a limited number of studies reported on the FJS and that the MCID was contained within the CIs, further research is required to determine whether there is any clinically relevant benefit to performing an MS TKA in regard to the FJS. Future studies should also consider using PROMs with a lower ceiling effect such as the FJS to ensure differences between prostheses are able to be appropriately discriminated.

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Appendix

Supplementary 1
Newcastle Ottawa Quality Assessment.

Author	Schmidt	Shakespeare	Bae	Papagiannis	Choi	Wautier and Thienpont	Nakamura	Samy	French	Indelli	Jones
Year Published	2003	2006	2016	2016	2017	2017	2018	2018	2019	2019	2019
Selection											
1. Representativeness of the exposed cohort Representative of the average patient to receive knee arthroplasty in the community	0	*	*	*	*	*	*	*	*	*	*
2. Selection of the nonexposed cohort Drawn from the same community as the exposed cohort?	*	*	*	*	*	*	*	*	*	*	*
3. Ascertainment of exposure (how was it recorded and who got each prosthesis?)	*	*	*	*	*	*	*	*	*	*	*
4. Demonstration that outcome of interest was not present at the start of the study	*	*	*	*	*	*	*	*	*	*	*
Comparability											
1. Comparability of the cohort on the basis of the design or analysis controlled for confounders Study cohorts are similar in regard to age and preoperative ROMs (one star for each)	**	*	**	0	**	*	*	*	*	**	*
Outcome											
1. Assessment of the outcome	*	*	*	*	*	*	*	*	*	*	*
2. Was the follow-up long enough for outcomes to occur (minimum of 1 y)	*	*	*	*	*	*	*	*	*	*	*
What was the median duration of follow-up (mo)?	Mean - 2 y 2 mo	12 mo	Mean - 5.2 y	2-3 y	5 y	Minimum 1 y	2 y	1 y	13 mo	2 y minimum	1 y
3. Adequacy of follow-up cohorts	0	0	*	0	*	*	*	0	*	*	*
Total (out of 9)	7	7	9	6	9	8	8	7	8	9	8

ROM, range of motion; KSS, Knee Society Score.
*,** Quality assessment of included observational studies using the Newcastle Ottawa Quality Assessment tool.

Supplementary 2
Cochrane Risk of Bias.

Author	Random Sequence Generation (Selection Bias)	Allocation Concealment (Selection Bias)	Blinding of Participants and Personnel (Performance Bias)	Blinding of Outcome Assessment (Detection Bias)	Incomplete Outcome Data (Attrition Bias)	Selective Reporting (Reporting Bias)	Other Bias
Benjamin et al 2018 [32]	+	+	+	+	−	+	
Edelstein et al 2019 [21]			+	+		+	
Gill et al 2019 [23]					+	+	
Hossain et al [13] 2011	+	+	+	+	+		
Ishida et al [29] 2014				+	+		
Kim et al [27] 2009		+					−
Kim et al [30] 2017		+		+	+	+	−
Nishitani et al [19] 2018	+		+	+	+	+	
Pritchett [28] 2011	+		+	+	−		
Yuan et al [24] 2019	+	+	+		+	+	

Risk of bias for included randomized control trials using the Cochrane Risk of Bias tool. Green represents low risk of bias, red represents a high risk of bias and an empty cell represents an unclear risk of bias.