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Functional Outcomes of Different Bearing Surfaces for Total Hip Arthroplasty: A Systematic Review and Meta-Analysis

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Abstract

Background: Total hip arthroplasty (THA) has changed significantly since its inception, with various bearing surfaces affecting clinical outcomes. This systematic review aimed to assess the functional results of various bearing surfaces in total hip arthroplasty using validated scoring systems.

Methods: This systematic review was carried out in accordance with PRISMA guidelines, and the protocol was registered in PROSPERO under CRD42025634591. Studies were included based on predefined criteria for population, intervention type, and reported clinical outcomes. Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), Harris Hip Score (HHS), and SF-12 were analyzed closely.

Results: 18 clinical trials with a mean follow-up of 100.69 months were included. MoM implants showed superior HHS, WOMAC, and SF-12 scores compared to CoC, CoP, and MoP ($P<0.001$), suggesting better quality of life and improved functional outcomes. CoM showed slightly better WOMAC scores over MoM, but the difference was not statistically significant. The most common reason for revision was dislocation (36 cases), while osteolysis was the most common complication (43 cases).

Conclusion: MoM implants demonstrated better quality of life and functional outcomes, but their use has declined due to safety concerns. Other implants may reduce complications related to metal ion release. These findings help surgeons choose THA implants by weighing benefits against long-term risks. Further research is necessary to refine implant selection criteria and long-term performance.

Keywords: Hip Prosthesis, Arthroplasty, Bearing Surface, Implant, metal-on-metal, ceramic-on-polyethylene, Treatment Outcomes

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Introduction

Since the very first usage of hip prosthesis by Wiles in 1938, total hip arthroplasty (THA) has become the most successful surgery of the 20th century (1, 2). This constructive surgery is now indicated for a wide range of pathologies. Compared with the past, patients undergoing THA are now more demanding. They always desire better outcomes from their surgery to such an extent that even some young patients may want to participate in recreational or sports activities after THA (3, 4). Looking at the numbers, the latest articles suggest a prevalence of 0.83% for THA in the United States population, and THA is carried out 1.5 million times in a year worldwide. The out-

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↑What is "already known" in this topic:
Metal-on-metal (MoM) bearing surfaces in total hip arthroplasty (THA) have previously shown favorable functional outcomes but have fallen out of favor due to complications such as metal ion release and adverse local tissue reactions (ARMD).

→What this article adds:
Despite demonstrating superior functional scores, this review confirms that the long-term risks associated with MoM implants outweigh their benefits. The findings reinforce current trends in avoiding MoM use and guide clinicians in selecting safer, effective alternatives.

standing numbers mentioned before come with common clinical complications, although the complication rates are low (5, 6).

Although numerous studies have compared different bearing surfaces in THA, there is no clear general agreement on which material yields the best long-term functional outcomes and patient satisfaction. Moreover, many previous studies have not simultaneously compared all five major types of articulations in a unified analysis. Various approaches, implants, and procedures have come up as a result of high demand and prevalence. One variation between different implants is their bearing surfaces. As implants are made of a cup and the head component, two bearing surfaces are present. The combination of these surfaces determines different traits and clinical outcomes for each type. Some of the commonly used bearing surfaces are ceramic-on-ceramic (CoC), ceramic-on-polyethylene (CoP), ceramic-on-metal (CoM), metal-on-polyethylene (MoP), and metal-on-metal (MoM) (2). Several factors can cause THA to fail and dictate a revision surgery, such as friction and particle debris freed from the surfaces into the joint space, which can cause aseptic loosening (7, 8). The freed debris can also mandate biological reactions. These inflammatory reactions involve cytokines, macrophages, and lymphocytes based on the material of debris (9). MoP bearings are the conventional implant for the application. The Achilles of MoP is its aseptic loosening due to wear particles. To confront this, newer materials and bearings have been developed (10). MoM bearings are associated with a low risk of osteolysis; however, adverse local soft tissue reactions remain a concern.

Additionally, they may lead to elevated metal ion concentrations in the blood (9, 11-13). In comparison with conventional implants, CoC decreases the risks of revision surgery, radiolucent line, osteolysis, aseptic loosening, and dislocation (14). Compared to MoM bearings, CoC bearings exhibit a lower incidence of osteolysis and infrequent local tissue adverse reactions. The downside is that CoC implants are associated with a higher occurrence of bearing-related noise collated with MoP and MoM (9, 12, 14). CoM was designed to overcome the squeaking sound and risk of component fracture attributed to CoC and to overcome the high wear rate and metal ion release of MoM implants (15). Another ceramic-entailing implant, CoP, has better results in terms of squeaking sound and total implant fracture, in comparison with CoC (16).

This review aims to shed light on the clinical outcomes of different implants and bearings. Alongside the massive research that has investigated the structure or failure factors of each implant surface type, this study can bring out information about the final clinical outcomes of THA implant bearing surfaces and help surgeons complete their decision-making process with no blind spots left. This systematic review is designed to answer the following question: Among patients undergoing primary total hip arthroplasty (P), how do different bearing surfaces (I), in the absence of a direct comparator (C), affect functional and patient-reported outcomes and complication rates (O).

Methods

The study employed systematic review methods as outlined in the Cochrane Handbook (17). We conducted this study in accordance with PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (18), and the study protocol was registered at PROSPERO (International Prospective Register of Systematic Reviews) under the code of CRD42025634591. This study was free from IRB (institutional review board) approval as no individual data was directly obtained.

Search strategy

The independent researchers searched five online databases: PubMed, Scopus, Web of Science, Google scholar and ScienceDirect using the following keywords: *(*surface material*)* AND (("Hip prosthesis"[Mesh]) OR ("Arthroplasty, Replacement, Hip"[Mesh]) OR ("Femoral Head Prosthesis"[Mesh]) OR ("Hip Arthroplasty"[Mesh]) OR ("Total hip replace*"[Title/Abstract]) OR ("Total hip arthroplas*"[Title/Abstract]) OR ("Hip arthroplas*"[Title/Abstract]) OR ("Hip replace*"[Title/Abstract])) AND *(*outcome*)* AND ((“ceramic-on-ceramic”) OR (“metal-on-metal”) OR (“metal-on-polyethylene”) OR (“ceramic-on-polyethylene”)) from April 5, 1985, to January 10, 2025 with no filters applied. No time or language restrictions were applied. The extent of this study follows the PICO templates (P = patients undergoing total hip arthroplasty, I = total hip arthroplasty, C = No comparator required, O = functional outcomes, patient-reported outcomes, revision, and complications). Grey literature sources (ClinicalTrials.gov and WHO ICTRP) returned 691 records in total, none of which matched the predefined inclusion criteria. Although Google Scholar and ScienceDirect were included in the initial search strategy, they did not yield any unique or eligible records based on the predefined inclusion criteria; thus, their results were not reported separately in the PRISMA flow diagram.

Eligibility criteria and study selection

Studies with the following criteria were included: (1) both prospective and retrospective clinical trials; (2) patients undergoing primary THA; (3) studies that scrutinized outcomes of primary THA. On the other hand, the exclusion criteria were: (1) any studies other than clinical trials; (2) studies that included only revision cases; (3) studies that did not report the desired outcomes. The studies without reporting before and after scores of the outcome were excluded from the analysis using a complete case analysis approach.

After retrieving initial results and eliminating duplicates, three independent reviewers (BF, ASh, IG) began to screen studies using the inclusion criteria pertaining to the title and abstract of the articles. Any disputes were resolved by the fourth reviewer (S.A.). Afterward, these reviewers managed a secondary screening of the full texts, with any following conflicts being coordinated.

Data extraction

Data, including patients’ demographics, clinical find-

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ings (such as arthroplasty surface type, revision, reason for revision, etc.), and functional outcomes such as (WOMAC, HHS, VAS pre and post operation) were extracted using an Excel spreadsheet by three independent reviewers (ASh, BF, IG). At last, the extracted data was cleaned, and all the disagreements were resolved by a single reviewer (ShA).

Quality assessment

To evaluate the risk of bias and the relevance of included studies, the Risk of Bias 2 (RoB 2) tool developed by the Cochrane Collaboration was used to evaluate bias through five domains and provide an overall risk of bias assessment. Each domain was scored 'high risk of bias', 'some concerns', or 'low risk of bias' accordingly.

Statistical analysis

The generalized linear mixed model (GLMM) approach was used for multiple treatments comparison meta-analysis as a kind of meta-regression (19). Accordingly, the treatment group was considered as a factor variable, change in HHS, SF-12, and WOMAC scores (after minus before) was considered as the outcome variable, the sample size was considered as a variable for frequency weights, and the study label was regarded as a random intercept for multilevel mixed-effects modeling. Intraclass correlation coefficient (ICC) was used as a post-estimation of the mixed model to investigate the heterogeneity of the studies. -mixed- command was used in Stata 17 software (Stata Corp. LLC, TX, US). The effect size was reported as an unstandardized beta coefficient with a 95% confidence interval (CI). Publication bias was not investigated as it was not possible to draw a funnel plot due to different treatments. Sensitivity analysis was not applicable.

Results

Study selection

Our search in five different databases and trial registries retrieved 11,605 results. Of this number, 4,278 results were duplicated and removed. Finally, 7327 results were screened for title and abstract. Out of these, 7309 were excluded, and finally, 18 studies were selected for data extraction and analysis. All the details of the screening process are shown in Figure 1.

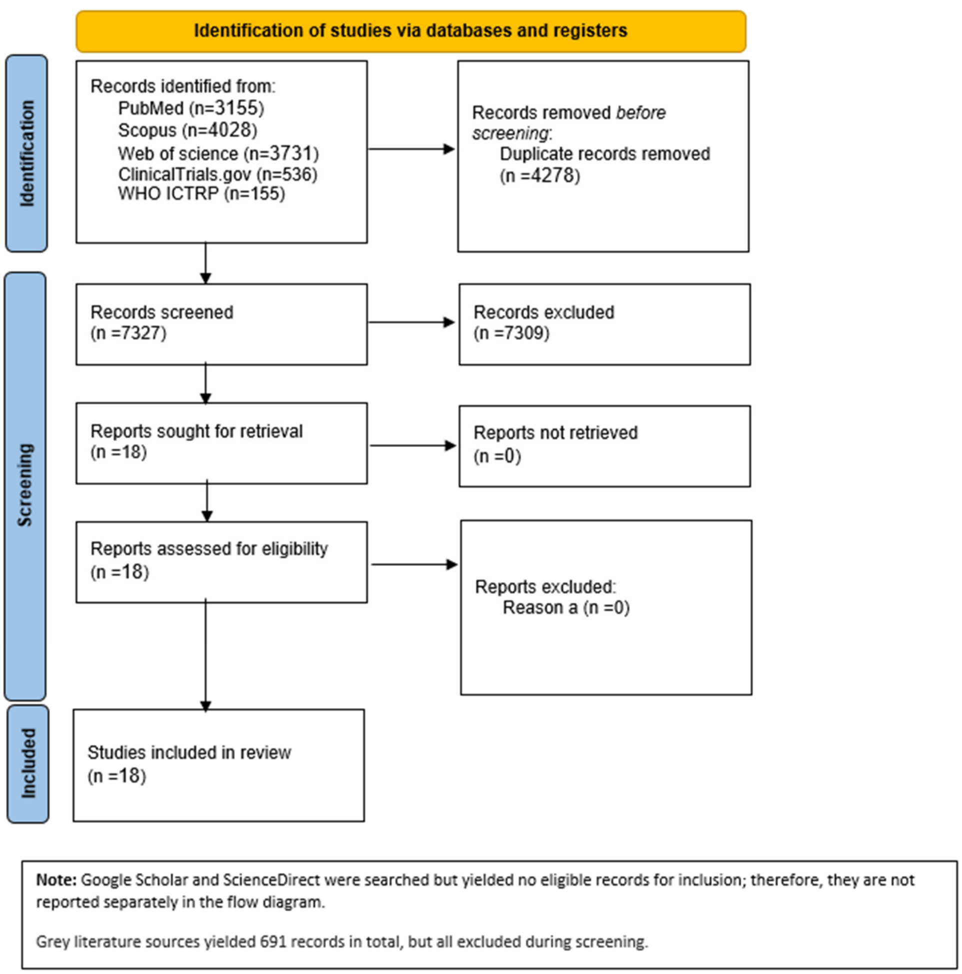

Figure 1. PRISMA flow chart of the study

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Study characteristics

Our 18 included articles were all clinical trials. The mean age of the studies' populations (two studies did not report mean age) was 58.21 years. We found 100.69 months of follow-up among studies on average (Table 1). Four studies compared CoP and CoC, and three of them compared MoP and MoM. MoM vs MoM, CoM vs MoM, and MoP vs CoC were each compared in 2 studies. CoC vs CoC, MoP vs CoM, and MoM vs MoP vs CoP were each investigated in one study. MoP and CoC were each studied in comparison with another modality of treatment in two separate studies (Table 2A and Table 2B). Considering the arthroplasty technique, 10 studies used the uncemented method; three studies used the cemented method, one study used both, and four studies did not report whether they applied the cemented or uncemented method. Overall, four studies did not report any details about revision surgery among their patients, but all the other studies had at least one case of revision. Dislocation was the most common cause of revision, with 36 cases. Osteolysis was the most common complication, with 43 cases. Six studies did not present data about complications.

Of the 18 studies we included, six studies had a low risk of bias, eight had a moderate risk of bias, and one had a high risk of bias. The randomization process domain contained the largest proportion of studies assessed as having a moderate risk of bias. Bias due to Missing Outcome Data was the only domain with a study reporting a high risk. Further details of the risk of bias assessment are manifested in Figure 2.

Reported outcomes

The results of multilevel mixed effects models are shown (Table 3). Accordingly, MoM was considered as a reference treatment for comparisons. Hence, the other groups of treatment showed a significantly lower HHS and SF-12 (P<0.001) (Table 4). Heterogeneity was observed for all three outcomes (ICC >50%) (Table 3).

The mean preoperative HHS was 48.00 (range 39.00 – 58.30), and the mean postoperative HHS was 91.30 (range 81.90 – 96.00). MoM implants were better than CoC, Cop, and MoP implants in increasing HHS (P<0.001).

The mean WOMAC score was 58.70 (range 39.50 –

Table 1. Demographic data of the patients included in RCTs

author	Subgroup number	Sample size (M:F)	Mean age (SD)	Mean Follow-up (SD)	Year	Country
Ando (20)	1	85(19:66)	65.4(8.6)	24	2015	Japan
Ando (20)	2	75(19:56)	66.2(9)	24	2015	Japan
Atrey (21)	1	32(NM)	NM	120(NM)	2017	Canada
Atrey (21)	2	36(NM)	NM	120(NM)	2017	Canada
Atrey (21)	3	34(NM)	NM	120(NM)	2017	Canada
Atrey (22)	1	28(NM)	42.8(6.9)	198(29.4)	2017	Canada
Atrey (22)	2	29(NM)	41.5(8.9)	201.6(24)	2017	Canada
Beaupre (23)	1	48(26:22)	51.3(6.9)	NM	2016	Canada
Beaupre (23)	2	44(24:22)	53.6(6.5)	NM	2016	Canada
Bjorgul (24)	١	123(39:84)	63.3(8)	55.2(NM)	2013	Norway
Bjorgul (24)	٢	127(39:88)	62.8 (12.1)	55.2(NM)	2013	Norway
Bjorgul (24)	٣	124(51:73)	63.9(10.8)	55.2(NM)	2013	Norway
Borgwardt (25)	١	76(35:41)	66.4(11.2)	120(NM)	2016	Denmark
Borgwardt (25)	٢	72(30:42)	68.2(10.9)	120(NM)	2016	Denmark
Borgwardt (25)	٣	75(26:49)	69.8(10.2)	120(NM)	2016	Denmark
Borgwardt (25)	٤	76(19:57)	69.1(10.6)	120(NM)	2016	Denmark
D'Antonio (26)	1	100(65:35)	53(11.4)	60.7(25.6)	2005	USA
D'Antonio (26)	2	100(63:37)	54(10.7)	59.6(36.7)	2005	USA
D'Antonio (26)	3	100(61:39)	55(10.4)	58.6(32.7)	2005	USA
Higgins (27)	1	110(69:41)	65.2(NM)	104.4(6.4)	2019	Finland
Higgins (27)	2	101(64:37)	65.2(NM)	104.4(6.8)	2019	Finland
Higuchi (28)*	1	85(21:64)	55.2(NM)	108(27)	2016	Japan
Higuchi (28)*	2	147(31:116)	54.2(NM)	87.6(27)	2016	Japan
Jacobs (29)	1	95(46:49)	53.3(18-75)	46.8(7.8)	2004	USA
Jacobs (29)	2	76(51:25)	55.7(31-75)	42(7.8)	2004	USA
Kim (30)	1	133(84.49)	53(7)	205(9)	2020	Korea
Kim (30)	2	133(84:49)	53(7)	205(9)	2020	Korea
Kostretzis (31)	1	24(14:10)	50(7.1)	168(7.8)	2021	Canada
Kostretzis (31)	2	24(15:9)	50(7.8)	168(7.8)	2021	Canada
Lombardi (32)	1	64(35:29)	57(10.7)	73(20.5)	2010	USA
Lombardi (32)	2	45(24:21)	60(11.0)	72(16.7)	2010	USA
MacDonald (33)	1	22(NM)	NM	38.4(5.1)	2003	Canada
MacDonald (33)	2	18(NM)	NM	38.4(5.1)	2003	Canada
Nikolaou (34)	1	36(18:18)	52.6(11.0)	60(NM)	2012	Canada
Nikolaou (34)	2	34(17:17)	52(11.2)	60(NM)	2012	Canada
Schouten (35)	1	36(18:18)	62(8.2)	60(NM)	2017	New Zealand
Schouten (35)	2	31(21:10)	64(8.0)	60(NM)	2017	New Zealand
Vendittoli (36)	1	69(38:31)	56.8(10.7)	252(16.8)	2021	Canada
Vendittoli (36)	2	71(30:41)	54.9(12.5)	252(16.8)	2021	Canada
Zijlstra (37)	1	NM(NM)	79(NM)	120(NM)	2010	Netherland
Zijlstra (37)	2	NM(NM)	79(NM)	120(NM)	2010	Netherland

Each row in the table shows a group (control/intervention) in the study, NM= not mentioned, all studies are prospective randomized controlled trials, *observational study.

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Table 2A. Study characteristics of the included articles

Author	Arthroplasty surface type	Cemented/ uncemented	Reason for arthroplasty	Type of material
Ando (20)	MoM	Uncemented	OA (82.5%), ON (13.9%), PD (1.1%), TOA (1.1%), SCF (1.1%) n = 86	Magnum (CoCrMo)
	MoM	Uncemented	OA (92.3%), ON (7.6%) n = 78	Conventional (CoCrMo) inserts within modular Ti alloy
Atrey (21)	MoP	Uncemented	OA (59.3%), AVN (15.6%), DDH (6.2%), PTA (3.1%), RA (3.1%), Other (12.5%) n = 32	CoCr femoral head with an XLPE
	MoP	Uncemented	OA (63.8%), AVN (16.6%), DDH (5.5%), RA (2.7%), Other (11.1%) n = 36	CoCr femoral head with an UHMWPE
	CoC	Uncemented	OA (73.5%), AVN (8.8%), DDH (2.9%), PTA (2.9%), RA (2.9%), Other (8.8%) n = 34	CoC bearing
Atrey (22)	CoP	NM	OA (34.4%), AVN (10.3%), SUFE (3.4%), DDH (27.5%), TA (17.2%), PD (6.8%) n = 29	NM
	CoC	NM	OA (51.7%), AVN (10.3%), SUFE (3.4%), DDH (17.2%), TA (13.7%), IA (3.4%) n = 29	NM
Beaupre (23)	CoC	Uncemented	NM	HA-coated shell and Alumina Bearing Couple ceramic insert and CCt head
	CoP	Cemented	NM	A Crossfire® insert and a CCt head
Bjorgul (24)	MoM	Cemented	NM	WPAC with a 28 mm diameter Metasul insert
	MoP	Cemented	NM	WPAC with Protasul CoCrMo alloy
	CoP	Cemented	NM	WPAC with ceramic (Sulox Alumina)
Borgwardt (25)	CoP (ZoP (zirconia on polyethylene))	Cemented	NM	Tetragonal zirconia, Liner of polyethylene-coated TAV
	MoM	Cemented	NM	CoCrMo
	MoP	Cemented	NM	Tetragonal zirconia, Liner of polyethylene coated TAV and of hemispherical outer shape (Asian Hip System)
	CoC (AoA)	Cemented	NM	Cup insert composed of alumina ceramic paired with poly-ethylene backing, within a porous coated shell made of wrought TAV alloy
D'Antonio (26)	CoC	NM	OA (84%), PTA (1%), AVN (12%), DV (2%), SUFE (1%) n = 100	Porous-coated shell
	CoC	NM	OA (79%), PTA (4%), AVN (17%), DV (1%) n = 100	Arc-deposited hydroxyapatite
	MoP	NM	OA (77%), PTA (6%), AVN (16%), FFF (1%) n = 100	Co on P
Higgins (27)	CoM	Uncemented	NM	CoCr
	MoM	Uncemented	NM	Co
Higuchi (28)	CoC	Uncemented	OA (77.6%), AVN (21.1%), PTA (1.1%) n = 85	Without MBTS
	CoC	Uncemented	OA (82.9%), AVN (16.3%), PTA (0.6%) n = 147	MBTS

98.00) preoperatively and 53.44 (range 11.00 – 94.00) postoperatively. Again, MoM implants were better than CoC, CoP, and MoP implants in increasing WOMAC score ($P<0.001$). CoM implants showed better results in comparison with MoM implants; however, the observed difference did not reach statistical significance ($P=0.304$).

The mean score of SF-12 was 30.91 (range 28.50 – 32.80) and 43.9 (range 5.50 – 53.50) preoperatively and

Table 2A. Continued

Author	Arthroplasty surface type	Cemented/ uncemented	Reason for arthroplasty	Type of material
Jacobs (29)	MoM	Uncemented	OA (61.0%), PTA (8.4%), AVN (20.0%), DDH (6.3%), Ninf D (4.2%) n = 95	NM
	MoP	Uncemented	OA (71.0%), PTA (3.9%), AVN (21.0%) DDH (3.9%) n = 76	P (moderately cross-linked GUR 1050)
Kim (30)	CoC	Uncemented	NM	Al
	CoP	Uncemented	NM	A, XLPE
Kostretzis (31)	MoM	Uncemented	OA (79%), PA (4%), DDH (9%), ON (4%), RA (4%) n = 24	Durom acetabular cup (hip resurfacing)
	MoM	Uncemented	OA (80%), PA (4%), DDH (4%), ON (8%), PSA (4%) n = 24	Durom acetabular cup (Large diameter head)
Lombardi (32)	CoC	NM	OA (86%), AVN (9%), LCP (2%), PTA (2%), SCFE (1%) n = 64	Modular femoral heads of alumina matrix composite (Biolox1 delta) articulating on pure alumina ceramic liners (65 - trial group) – for both groups each cup was Porous Plasma Sprayed (PPS1) titanium shells - femoral head size (28-mm and 32-mm)
	ZoP	NM	OA (84%), AVN (9%), DDH (7%) n = 44	Zirconia ceramic modular heads articulating on highly crosslinked polyethylene liners (45 - control group)
MacDonald (33)	MoM	NM	NM	NM
	MoP	NM	NM	NM
Nikolaou (34)	MoP	Uncemented	OA (64%), AVN (17%), DDH (5%), RA (3%), Other (11%) n = 36	28 mm diameter CoCr head with UHMWPE liner (36 hips - CoP)
	CoC	Uncemented	OA (73%) AVN (9%) DDH (3%) PTA (3%) RA (3%) Other (9%) n = 34	28 mm diameter C head and C acetabular liner (34 - CoC)
Schouten (35)	CoM	Uncemented	NM	Corail AMT cementless, collarless femoral stems - Pinnacle acetabular shells - Ultramet Co-Cr-Mo alloy liners - either femoral head made of Z toughened AC or Co-Cr-Mo - head size was 36 mm in all but two patients (28 mm)
	MoM	Uncemented	NM	Corail AMT cementless, collarless femoral stems - Pinnacle acetabular shells - Ultramet Co-Cr-Mo alloy liners - either femoral head made of Z toughened AC or Co-Cr-Mo - head size was 36 mm in all but two patients (28 mm)
Vendittoli (36)	MoP	Uncemented & Cemented	NM	P with a 28 mm stainless steel femoral head for MoP-cemented femoral implant with Ti alloy and uncemented acetabular implant made of Ti
	CoC	Uncemented & Cemented	NM	A with A femoral head of 32 mm in CoC- cemented femoral implant with Ti alloy and an uncemented acetabular implant made of Ti
Zijlstra (37)	MoP	Cemented	NM	NM
	MoM	Cemented	NM	NM

ZoP = zirconia on polyethylene / MoM = metal on metal / MoP = metal on polyethylene / CoP = ceramic on polyethylene / CoC = ceramic on ceramic / CoM = ceramic on metal / AoA = alumina on alumina; U = uncemented / C = cemented / U & C = uncemented and cemented; OA = osteoarthritis / ON = osteonecrosis / PD = perthes disease (LCP = Legg-Calve´-Perthes) / TOA = traumatic osteoarthritis / SCF = subcapital fracture / AVN = Avascular necrosis / DDH = development dysplasia of hip / PTA = Post-traumatic arthritis / PSA = Post-septic arthritis / RA = Rheumatoid arthritis / SUFE = Slipped upper femoral epiphysis / SCFE = slipped capital femoral epiphysis / TA = Traumatic arthropathy / IA = Inflammatory arthritis / DV = diastrophic variant / FFF = failed fracture fixation /Ninf D = Noninflammatory diagnoses / PA = Protrusio acetabuli; XLPE = highly cross-linked polyethylene / UHMWPE = ultra-high molecular weight polyethylene / CCt = Ceramic C-taper / WPAC = Weber polyethylene acetabular component / TAV = titanium-aluminium-vanadium / Co = cobalt / Cr = chromium / Mo = molibden / P = plyethylene / MBTS = metal-backed titanium sleeve / A = alumina / Z = zirconia / C = ceramic / Ti = titanium; Co = cobalt / Cr = Chromium; NM = not mentioned / NA = not applicable

postoperatively, respectively. MoM implants were better than CoC and MoP implants in increasing SF-12 scores (*P*<0.001). VAS scores were not reported in 16 studies. One study reported postoperative VAS scores only (VAS=7.7). One study reported preoperative and postoperative VAS scores as 3.95 and 0.75, respectively (Table 4).

Discussion

Total hip arthroplasty, also known as hip joint replacement surgery, is a reconstructive procedure designed to enhance the treatment of hip joint disorders that have not

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Table 2B. Revision outcomes and complications of the included articles

Author	Arthroplasty surface type	High metal ion level? Type of ion?	Revision (Yes / No)	Reason for revision	Time to revision (month mean)	Complication
Ando (20)	MoM	yes (Co and Cr)	NM	NM	NM	No
	MoM	yes (Co and Cr)	NM	NM	NM	Dislocation (1),
Atrey (21)	MoP	NM	Yes (1)	Periprosthetic fracture (1)	4	NM
	MoP	NM	Yes (1)	Infection (1)	18	Osteolysis
	CoC	NA	No	No	No	NM
Atrey (22)	CoP	NA	Yes (5)	Polyethylene wear (4), Osteolysis (1)	192	Osteolysis (12)
	CoC	NA	Yes (4)	Head fracture (1), Instability (1), Infection (1), Trunnionosis (1)	NM	Osteolysis (6)
Beaupre (23)	CoC	NA	Yes (3)	Injurious falls (3)	NM	No
	CoP	NA	Yes (5)	Dislocation (4), Recurrent instability (1)	NM	No
Bjorgul (24)	MoM	NM	Yes (8)	Infection (4), Loosening (4)	29.1	NM
	MoP	NM	Yes (3)	Infection (1), Dislocation (1), Pain (1)	22.8	NM
	CoP	NA	Yes (1)	Infection (1)	33.6	NM
Borgwardt (25)	CoP (ZoP (zirconia on polyethylene))	NA	Yes (10)	Dislocation (5), Loose stem in cement mantle (3), Loose acetabular shell (1), Loosening (1)	NM	Osteolysis*, Dislocation (12)
	MoM	NM	Yes (3)	Dislocation (1), Loose stem in cement mantle (1), Infection (1)	NM	Osteolysis*, Dislocation (1)
	MoP	NM	Yes (4)	Dislocation (1), Loose stem in cement mantle (3)	NM	Osteolysis*, Dislocation (4)
	CoC (AoA)	NA	Yes (19)	Dislocation (8), Loose stem in cement mantle (3), Loose acetabular shell (1), Cup insert loose or broken (6), RCF (1)	NM	Osteolysis*, Dislocation (16)
D'Antonio (26)	CoC	NA	Yes (2)	Femoral fracture (1), Loosening (1)	NM	NM
	CoC	NA	Yes (4)	Loosening (1). Sepsis (2), Dislocation (1)	NM	NM
	MoP	NM	Yes (8)	Leg-length discrepancy (1), Deep joint Infection (1), Osteolysis (1), Femoral fracture (1), Dislocation (4)	NM	NM
Higgins (27)	CoM	no	Yes (1)	ARMD (1)	NM	NM
	MoM	Yes (Co 3.8 mg/L Cr:1 mg/L after 5y)	Yes (11)	ARMD (7), Dislocation (2), Periprosthetic fracture (1), Leg-length discrepancy (1)	NM	NM
Higuchi (28)	CoC	NA	Yes (3)	Loosening (1), Ceramic liner fracture (1), Infection (1)	NM	Ceramic liner fracture (1), Squeaking (1)
	CoC	NA	Yes (1)	Osteolysis (1)	NM	Squeaking (1)
Jacobs (29)	MoM	NM	Yes (1)	Traumatic (1)	NM	Dislocation (1), Trochanteric bursitis (12), Wound problem (2)
	MoP	NM	Yes (19)	Dislocation (6), Infection (4), Patient request (1), leg-length discrepancy (2) ARMD (12), Loosening (4)	NM	Trochanteric bursitis (3)
Kim (30)	CoC	NA	NM	NM	NM	Squeaking (8), Acetabular fracture (3), Clicking sound (32)

responded well to traditional medical interventions. This surgical approach involves replacing the damaged hip joint with an artificial prosthesis, notably improving clinical outcomes and quality of life (38). A study by Smith et al. showed that despite the improved functional outcomes associated with hip resurfacing, THA offers greater implant survival (39). Choudhary et al. reported that THA is an effective treatment for post-traumatic hip arthritis, although factors such as patient characteristics, surgical methods, and implant choice influence the overall results (40). Our study evaluated the clinical outcomes of different implants and bearing surfaces in THA, revealing that the MoM-bearing surface provides better quality of life and functional outcomes, even though MoM is no longer an acceptable option due to high rates of adverse reactions (41). MoM-bearing surfaces have been widely used since the beginning of the 21st century, but nowadays, rates have decreased because of concerns about failure rates

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Table 2B. Continued

Author	Arthroplasty surface type	High metal ion level? Type of ion?	Revision (Yes / No)	Reason for revision	Time to revision (month mean)	Complication
	CoP	NA	NM	NM	NM	NM
Kostretzis (31)	MoM	yes (Co (1.7 µg/L), Cr (1.4 µg/L))	Yes (2)	Loosening (2)	NM	No
	MoM	yes (Co (3.8 µg/L), Cr (1.9 µg/L))	Yes (5)	ARMD (4), Deep joint infection (1)	NM	Infection (1), ARMD (4)
Lombardi (32)	CoC	NA	Yes (3)	Migration (1), Traumatic fracture (1), Recurrent instability (1)	NM	NM
	ZoP	NA	Yes (3)	Instability (1) Dislocation (2)	NM	NM
MacDonald (33)	MoM	NM	NM	NM	NM	NM
	MoP	NM	NM	NM	NM	NM
Nikolaou (34)	MoP	NM	NM	NM	NM	NM
	CoC	NA	NM	NM	NM	Squeaking (3)
Schouten (35)	CoM	yes (Co (1.16 µg/l (0.41 to 14.67)), Cr (1.05 µg/l (0.16 to 12.58)))	Yes (2)	Infection (1) Loosening (1)	NM	NM
	MoM	yes (Co (2.93µg/l (0.35 to 30.29)), Cr (1.85 µg/l (0.36 to 17.00)))	Yes (1)	Pain (1)	NM	NM
Vendittoli (36)	MoP	NM	Yes (17)	Fracture (1), Loosening (16)	154.8	Dislocation (3)
	CoC	NA	Yes (7)	Traumatic (1), Loosening (1), Deep joint infection (5)	138.0	NM
Zijlstra (37)	MoP	yes (Co and Cr) / higher in MoM vs MoP	Yes (1)	Loosening (1)	NM	ALVAL (1) No pseudotumors
	MoM		Yes (3)	Loosening (3)		

ZoP = zirconia on polyethylene / MoM = metal on metal / MoP = metal on polyethylene / CoP = ceramic on polyethylene / CoC = ceramic on ceramic / CoM = ceramic on metal / AoA = alumina on alumina; ARMD = adverse reaction to metal debris / ALVAL = aseptic lymphocytic vasculitis-associated lesions / RCF = Removal of cement fragments; Co = cobalt / Cr = Chromium; NM = not mentioned / NA = not applicable
* Osteolysis was reported in the original study, but the number of cases was not specified.

and adverse reactions. ARMD is one of the main concerns with MoM-bearing surfaces (41). Another complication related to the MoM-bearing surface is metal ion release, which limits the use of this bearing surface (42).

A study by Söderman et al. demonstrated strong validity and reliability for HHS, WOMAC, and SF-12. Clinical outcomes of THA can be assessed by these key metrics (43). A maximum of 100 points for the HHS can be achieved, encompassing the following domains: function, pain, motion, and deformity. Function and pain, the two main factors, are assigned the most weight (47 and 44 points). The HHS under 70 points is regarded as a poor outcome (43). Since Bellamy et al. (1988) presented the WOMAC index, it has been tested and validated in various countries and languages (44, 45). WOMAC index is a self-reported, disease-specific health measure developed to evaluate patients with hip or knee osteoarthritis treated surgically or through nonsurgical methods (46). A lower score on the WOMAC index indicates better outcomes with less stiffness, pain, and better physical function (45). The SF-12 (Short Form-12) is a condensed form of the SF-36 health survey commonly used for the evaluation of health-related quality of life (47).

Among the orthopaedic interventions, THA is one of the most successful procedures performed today (48). For individuals experiencing hip pain due to different conditions, THA offers pain relief, functional restoration, and improved quality of life (49). Pain relief from osteoarthritis of the hip. This is especially true for patients who have not responded to nonoperative management options (50). Every THA includes two bearing surfaces (51). Surgeons now have different options when selecting the bearing surface for THA. The primary materials for acetabular liners are polyethylene, either in its conventional ultra-high molecular weight polyethylene (UHMWPE) form or cross-linked (XLPE), ceramics, or metal. Each one of these materials has its own advantages and drawbacks (52, 53).

The most widely selected pairing in THA is a ceramic femoral head with an acetabular liner of highly cross-linked polyethylene (54). Studies showed that highly cross-linked polyethylene has better wear performance than conventional high-density polyethylene (55, 56). Furthermore, a study by Hopper Jr et al. demonstrated better

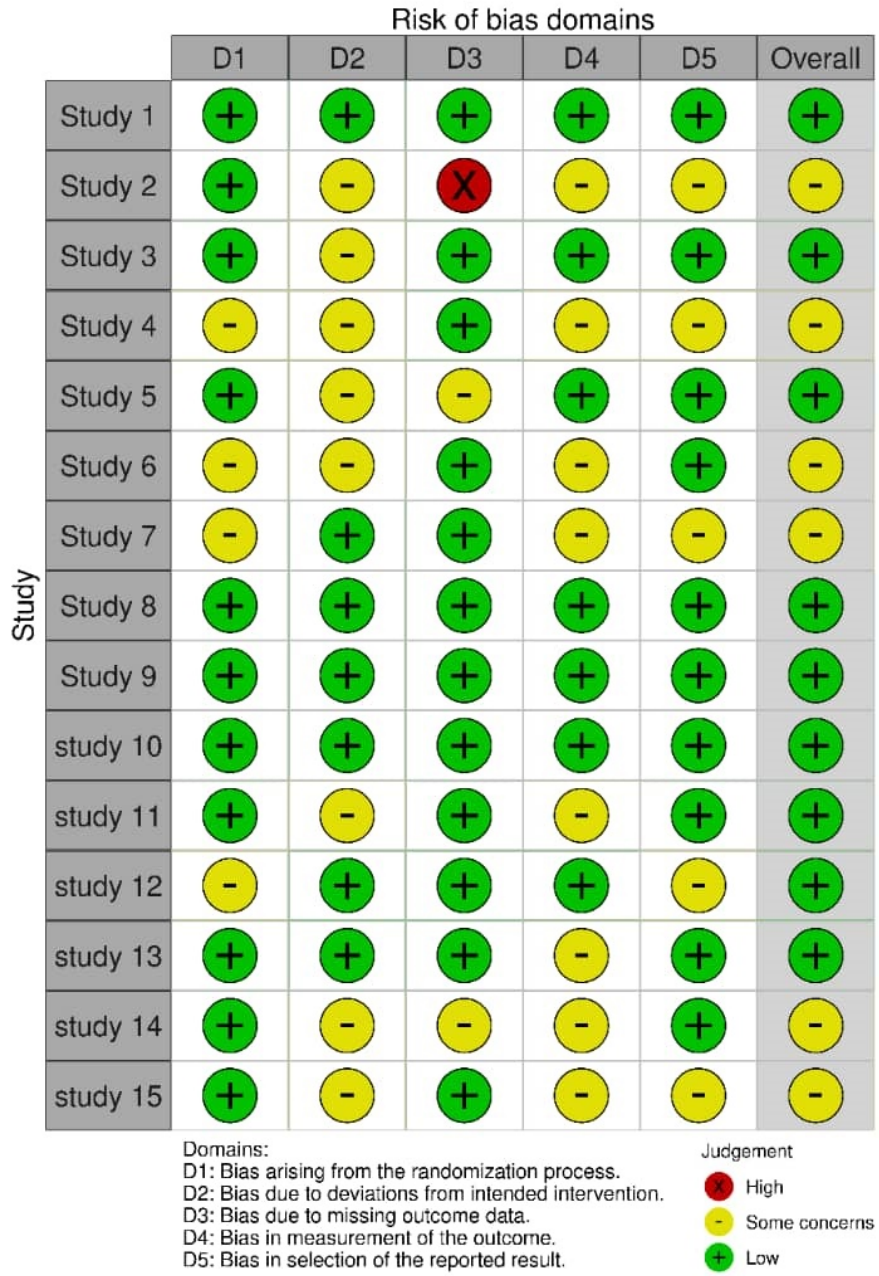

Figure 2. Risk of bias assesment

longevity of highly cross-linked polyethylene compared with conventional high-density polyethylene (57). Research by Molli et al. found that metal-on improved polyethylene bearings had a lower revision rate than MoM-bearings (58). Another key advantage of this type of bearing over the MoM bearings is that cobalt and chromium ion levels are significantly lower in MoP bearings (59). A study by Clarke et al. revealed that CoP-bearings offer an advantage of a 50% wear reduction compared to MoP-bearings (60). Meanwhile, a later study by Bergvinsson et al. reported that over the period of 5 years of follow-up, both ceramic and metal femoral heads showed similar polyethylene wear when used with modern highly cross-linked polyethylene (61).

Another bearing surface used in THA is CoC. Although these bearing surfaces have demonstrated reduced wear compared to standard MoP, some potential complications have restricted their widespread use (62, 63). CoC-bearing surfaces have shown rare occurrences of several breakages and smaller defects like chips and cracks, especially among patients with higher body mass index (BMI) and patients with smaller head sizes (64). Squeaking is another

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Table 2. Multilevel mixed effects model for multiple treatments comparison meta-analysis

Outcome	Treatment	Beta coefficient (95% CI)	*P* value	Variance (constant)	Variance (residual)	ICC
HHS	1	Reference		38.260	9.158	0.807
	3	-2.323 (-3.082, -1.563)	<0.001			
	4	-2.491 (-3.242, -1.739)	<0.001			
	5	-1.776 (-2.505, -1.047)	<0.001			
	Constant	45.030				
SF-12	1	Reference		356.851	0.013	0.999
	3	-36.384 (-36.470, -36.298)	<0.001			
	5	-40.000 (-40.070, -39.930)	<0.001			
	Constant	46.917				
WOMAC	1	Reference		1642.181	5.818	0.996
	2	43.905 (-39.829, 127.638)	0.304			
	3	-4.237 (-6.075, -2.398)	<0.001			
	4	-2.433 (-4.520, -0.347)	0.022			
	5	2.195 (0.693, 3.697)	0.004			
	Constant	-2.205				

Table 3. Reported VAS, HHS, and WOMAC scores across studies

Author	VAS pre op	VAS post op	HHS pre op	HHS post op	WOMAC pre op	WOMAC post op
Ando (20)	NM	NM	55.0	90.0	NM	NM
	NM	NM	55.0	90.0	NM	NM
Atrey (21)	NM	NM	49.1	91.1	59.0	12.0
	NM	NM	49.0	81.9	56.5	21.7
	NM	NM	45.6	86.3	59.5	12.7
Atrey (22)	NM	NM	48.8 ± 19.9	88.7 ± 10.5	NM	NM
	NM	NM	50.3 ± 13.7	94.6 ± 5.5	NM	NM
Beaupre (23)	NM	NM	NM	NM	47.1	83.3
	NM	NM	NM	NM	47.2	86.9
Bjorgul (24)	NM	NM	NM	91.1 ± 13.2	NM	NM
	NM	NM	NM	93.8 ± 8.8	NM	NM
	NM	NM	NM	93.6 ± 8.7	NM	NM
Borgwardt (25)	NM	NM	39.0	94.7	NM	NM
	NM	NM	47.5	97.7	NM	NM
	NM	NM	53.0	93.6	NM	NM
	NM	NM	47.9	90.3	NM	NM
D'Antonio (26)	NM	NM	NM	97.0	NM	NM
	NM	NM	NM	96.4	NM	NM
	NM	NM	NM	97.0	NM	NM
Higgins (27)	NM	NM	NM	94.0 ± 10.3	NM	pain 0.6 ± 1.6, stiffness 0.7 ± 1.2, ADL 3.5 ± 5.7
	NM	NM	NM	93.9 ± 9.7	NM	pain 0.7 ± 1.8, stiffness 0.7 ± 1.3, ADL 4.3 ± 7.6
Higuchi (28)	NM	NM	57.3 ± 8.9	89.1	NM	NM
	NM	NM	58.3 ± 1.5	89.1	NM	NM
Jacobs (29)	NM	NM	42.0	95.4	NM	NM
	NM	NM	43.0	96.1	NM	NM
Kim (30)	NM	7.8 ± 2.2	39.0	94.0	NM	NM
	NM	7.6 ± 2.4	41.0	93.0	NM	NM
Kostretzis (31)	NM	NM	NM	NM	NM	85.0
	NM	NM	NM	NM	NM	94.0
Lombardi (32)	NM	NM	51.0 (range, 6 – 68)	90.0 (range, 50–100)	NM	NM
	NM	NM	48.0 (range, 6-69)	92.0 (range, 49-100)	NM	/nm
MacDonald (33)	NM	NM	46.5	91.6	NM	NM
	NM	NM	46.6	92.0	NM	NM
Nikolaou (34)	NM	NM	47.1 (range, 22 - 63)	87.9 (range, 61 - 98)	Pain (47.57 (range, 15 to 75)), stiffness (38.60 (range, 12.50 to 75)), function (42.82 (range, 20.6 to 86.8))	Pain (91.65 (range, 35 to 100)), stiffness (87.04 (range, 37.5 to 100)), function (83.05 (range, 44.1 to 100))
	NM	NM	45.7 (range, 23 - 90)	91.0 (range, 61 - 100)	Pain (42.73 (range, 10 to 75)), stiffness (41.13 (range, 12.5 to 75)), function (40.86 (range, 5.9 to 75))	Pain (86.17 (range, 55 to 100)), stiffness (86.88 (range, 50 to 100)), function (range, 89.03 (35.3 to 100))
Schouten (35)	4.0	0.5	NM	NM	39.5	81.2
	3.9	1.0	NM	NM	43.0	82.1
Vendittoli (36)	NM	NM	NM	NM	67.3	19.4
	NM	NM	NM	NM	67.3	11.0
Zijlstra (37)	NM	NM	46.0	87.0	NM	NM
	NM	NM	48.0	90.0	NM	NM

NM = not mentioned

complication attributed to hard-on-hard bearing surfaces and more commonly occurs in CoC-bearings (65).

In this study, employing a precise analysis method, we demonstrated outstanding differences in SF-12. There was a significant improvement in SF-12 scores for MoM compared with CoC, and MoP, indicating significantly higher overall health-related quality of life (66). These findings are aligned with Hersnaes et al., who also found superior SF-12 outcomes for MoM, with improvements attributed to decreased implant wear and enhanced biomechanical stability (67).

In this work, MoM scored slightly higher in the HHS than other bearing surfaces. Despite the ceiling effects of the HHS, this small difference can also indicate slightly better hip function and less pain (43, 68). A study by Maldonado et al. showed that Ceiling effects tend to be more prevalent in younger, more physically active patients (69). In this study, WOMAC scores unveiled that MoM yielded better results than CoC, CoP, and MoP, but intriguingly, CoM showed better WOMAC scores than MoM. Although the latter difference was not statistically significant, CoM's better performance could be attributed to its lower risk of metal ion release and wear, which leads to fewer complications and less inflammation, as reported in studies including Saracco et al. and Yi et al. (70, 71). Additionally, recent research by Umar et al. indicates that MoM implants suggest better functional outcomes and good survival rates in younger patients (72). MoM implants are less brittle than ceramic components, which reduces the probability of implant failure due to fractures (73).

In the paper, MoM seems to be a good option for younger patients, individuals with active lifestyles seeking long-lasting hip arthroplasty options that provide enhanced durability and joint stability as they are associated with higher sf-12, WOMAC, and HHS scores, but due to high rates of adverse reactions, it is no longer an acceptable option (41, 74, 75). On the other hand, CoM implants may be a good choice for patients at high risk of adverse effects from metal ion release as they can decrease the likelihood of adverse reactions to metal debris, especially in THA (71, 76). Ultimately, this can contribute to alleviating pain, enhancing mobility, and improving overall quality of life over an extended period (72, 77). For patients concerned about the long-term health impacts of metal ion release, CoP and MoP implants may offer a more suitable alternative (78).

The study's approach was designed to uphold external and internal validity standards. To avoid the possibility of selection bias, Scopus, PubMed, and Web of Science were deeply analyzed for related studies. Our study had some limitations that need to be considered. The HHS, as mentioned above, has a maximum of 100 points, and a 2.5 difference in the HHS may seem less significant. The second is the ceiling effects of the Harris Hip Score, which means it does not adequately represent the extent of improvement or remaining concerns, particularly in younger and more active patients (69). Further research is required to evaluate whether these slight differences in the HHS are sufficient to make observable changes in the pain and function of patients. More studies should focus on whether CoM implants are more suitable for patients than MoM implants, based on their WOMAC scores.

Conclusion

This study highlighted the comparative clinical outcomes of different bearing surfaces in THA, particularly emphasizing the advantages of MoM implants regarding functional outcomes and quality of life as measured by HHS, WOMAC, and SF-12 scores. Despite the fact that MoM is no longer an option for THA due to high rates of adverse reactions, the data revealed that MoM implants outperformed CoC, CoP, and MoP implants in enhancing hip function and reducing pain, with statistically significant improvement across all measures ($P<0.001$). Considering all the metrics, MoM implants showed promising effects on improving functional outcomes and better quality of life.

Authors' Contributions

Amirhosein Sabaghian: Conceptualization, Methodology, Supervision, Investigation, Formal analysis Amirhosein Shahbazi: Conceptualization, Methodology, Investigation, Writing - Original Draft Bahram Fadaei Dowlat: Conceptualization, Validation, Investigation Iman Ghasemi: Conceptualization, Formal analysis, Software, Validation Yasin Ahmadi: Formal analysis, Resources Shayan Amiri: Conceptualization, Data Curation, Writing - Review & Editing, Supervision, Project administration, Funding acquisition.

Ethical Considerations

This systematic review and meta-analysis was performed in accordance with the Declaration of Helsinki. As it used only previously published data, no human or animal subjects were directly involved, and institutional review board approval or informed consent was not required. The protocol was registered in PROSPERO (CRD42025634591).

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Conflict of Interests

The authors declare that they have no competing interests.

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