Comparative postoperative prognosis of ceramic-on-ceramic and ceramic-on-polyethylene for total hip arthroplasty: an updated systematic review and meta-analysis (#93216)

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Comparative postoperative prognosis of ceramic-on-ceramic and ceramic-on-polyethylene for total hip arthroplasty: an updated systematic review and meta-analysis

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Objective. To compare the clinical outcomes between ceramic-on-ceramic (CoC) and ceramic-on-polyethylene (CoP) bearing surfaces in patients undergoing total hip arthroplasty (THA) through a pooled analysis and evidence update.

Methods. We performed a systematic literature search using PubMed, Embase, Cochrane Library and Web of Science up to March 2023 for studies that compared the bearing surfaces of CoC and CoP in patients undergoing THA. The primary outcomes were the incidence of common postoperative complications and the rate of postoperative revision. The secondary outcome was the Harris Hip Score.

Results. A total of 10 eligible studies involving 1946 patients (1192 CoC-THA *versus* 906 CoP-THA) were included in the evidence synthesis. Pooled analysis showed no significant difference in the rates of common postoperative complications (dislocation, deep vein thrombosis, infection, wear debris or osteolysis) and of revision. After eliminating heterogeneity, the postoperative Harris Hip Score was higher in the COC group than in the COP group. However, the strength of evidence was moderate for Harris Hip Score.

Conclusion. CoC articulations are more commonly used in younger, healthier, and more active patients. While the performance of conventional polyethylene is indeed inferior to highly cross-linked polyethylene, there is currently a lack of sufficient research comparing the outcomes between highly cross-linked polyethylene and CoC bearing surfaces. This area should be a focal point for future research, and it is hoped that more relevant articles will emerge. Given the limited number of studies included, the heterogeneity and potential bias of those included in the analysis, orthopaedic surgeons should select a THA material based on their experience and patient-specific factors, and large multicentre clinical trials with > 15 years of follow-up are needed to provide more evidence on the optimal bearing surface for initial THA.

Trial registration PROSPERO registration number: CRD42023400537

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Key words: Ceramic-on-Ceramic; Ceramic-on-Polyethylene; Total Hip Arthroplasty; Complications; Revision; Harris Hip Score

Introduction

After non-operative treatments have failed, total hip arthroplasty (THA) is often a recommended option for most young patients with osteoarthritis or other degenerative diseases of the hip. In fact, it is projected that there will be 635,000 THAs performed in the United States over the next decade[1]. Although the survival rate of patients undergoing THA has significantly improved in many countries, such as China and the United Kingdom, many young patients need revision surgery due to wear, aseptic loosening, and other problems [2, 3]. Are these reasons for revision related to the type of prosthesis? The choice of implant combination in THA has long been controversial, it is still unclear which of these articulations is superior in the long or very long term.

At present, ceramic-on-ceramic (CoC) and ceramic-on-polyethylene (CoP) bearings are the most commonly used in clinical work during THA [4], but which should be used in a given clinical situation is unclear. Research studies have shown that CoC bearings for THA can lower the risk of wear debris , aseptic loosening, and lead to high 10-year survival rates in patients under 60 years old[5, 6]. On the other hand, CoP bearings has been found to reduce the risk of postoperative periprosthetic joint infection[7], while using ceramic-on-highly-crosslinked-polyethylene (HXLPE) resulted in less wear debris and no increased risk of postoperative complications[8].

Dong *et al*. [9] were the first to evaluate CoC and CoP bearings for THA. In addition, two meta-analyses compared postoperative complication and revision rates between the CoC-THA and CoP-THA groups, but neither evaluated the postoperative prognosis or the optimum bearing surface for THA [10, 11]. Two novel studies on this matter were published in 2021 and 2022 [12, 13]. This meta-analysis compared the results of the two bearing surfaces after THA, objectively (complications and revision) and subjectively (Harris Hip Score). We also reviewed the latest evidence, to provide guidance in the preoperative selection of CoC bearings or CoP bearings.

Methods

Protocol and registration

This systematic review and meta-analysis followed a preprint registered in the International Prospective Register of Systematic Reviews (PROSPERO; CRD42023400537) and was designed and conducted according to the guidelines in the Cochrane Handbook.

Search strategy and data sources

We conducted a meta-analysis of all studies that compared COC and COP for THA, identified by searching PubMed, Embase, Cochrane Library, and Web of Science up to March 2023. References were managed using Endnote X9 software (Clarivate Analytics). In addition, relevant reviews and the references of selected articles were examined for potentially relevant trials.

Eligibility criteria

The inclusion criteria were as follows: (1) prospective randomised studies; (2) retrospective randomised studies (3) randomised controlled trials (RCTs) (3) studies of patients undergoing THA; (3) studies comparing COC-THA and COP-THA; (4) studies reporting complications or revisions or Harris Hip Score; (5) studies in which the mean age of the patients was > 40 years; (6) studies published in the English language.

The following studies were excluded: (1) non-human studies; (2) non-original studies (letters, reviews, editorials); (3) studies using a cross-over design; (4) studies with no control group; (5) studies after secondary surgery; (6) interim follow-up of the same study; and (7) studies without available data.

Study selection and data extraction

After removing duplicates, each article was screened independently by two reviewers who were blind to the journal, author, institution at which the study was performed and the date of publication, to identify potentially eligible studies and relevant clinical trials. One reviewer (TYW) was responsible for extracting the data, and another (YPJ) checked the data for accuracy against the source material. The final eligibility of the retrieved full-text articles for inclusion was assessed independently by two reviewers. Differences of opinion were resolved by discussion, and if no agreement was reached, the third reviewer (TL) made the final decision.

Quality assessment

The quality of included studies was evaluated using the Cochrane risk of bias assessment tool. The standards implemented by the Oxford Centre for Evidence-based Medicine were applied to assess the level of evidence. Two investigators independently evaluated the quality and level of evidence for eligible studies. An arbiter was consulted to reconcile any disagreements.

Statistical analysis

Statistical analysis was performed with Review Manager 5.4 (Cochrane Collaboration, Oxford, UK) and Stata 12.0 (StataCorp LP, College Station, Texas) software. The weighted mean difference (WMD) and 95% CI were calculated for the continuous outcome (Harris Hip Score). The medians and interquartile ranges of continuous data were converted to means and standard deviations. The results of binary variables (dislocation, fracture, deep vein thrombosis, infection, wear debris or osteolysis and revision) are expressed as odds ratios (OR) with 95% confidence intervals (CI). For meta-analyses, the Cochrane Q p-value and I^2 statistic were applied to assess heterogeneity. A $p < 0.05$ or $I^2 > 50\%$ indicated significant heterogeneity; in such cases, a random-effects model was used to estimate the combined WMD or OR. Otherwise, a fixed-effects model was used. We performed one-way sensitivity analyses to evaluate the effects of included studies on the combined results for outcomes with significant heterogeneity. A value of $p < 0.05$ was considered indicative of statistical significance.

Results

Study selection and characteristics

Figure 1 outlines study selection and reasons for exclusion. A total of 3640 relevant articles in PubMed (n = 888), Embase (n = 1272), Cochrane Library (n = 99), and Web of Science (n = 1381) were identified. After removing repeated studies, and reading titles and abstracts, 10 full-text articles involving 1946 patients and 2098 THA surgeries were included in the pooled analysis. Of these articles, seven were prospective randomised studies [13-19], two were retrospective randomised studies [12, 20] and one was an RCT [21]. All studies were in English and were published between 2005 and 2022. The mean follow-up period was 2–15 years. HXLPE liners were used in two of the studies [17, 20], and conventional polyethylene liners in the others [12-16, 18, 19, 21]. All the articles presented baseline age, sex, and body mass index values. The characteristics of the studies are listed in **Table 1**. We did not assess publication bias because < 10 studies were included in the required observation measures.

Demographic characteristics

There was no significant difference between the two groups in terms of gender (female/total, OR: 0.90; 95% CI: 0.74, 1.09; $p = 0.27$), BMI (WMD: 0.04; 95% CI: -1.20, 1.29; $p = 0.94$). However, the two groups were significantly different in baseline age (WMD: -4.07; 95% CI: -5.93, -2.20; $p < 0.0001$) (**Table 2**). The mean age of patients in the CoP-THA group was 4 years older than in the CoC-THA group.

Risk of bias

Overall, the risk of bias was low across the trials. All trials used allocation concealment, followed a blinded design, and no selective reporting occurred. One trial [16] did not describe the sources of the exposed and non-exposed groups, and the exposed group in one trial [21] was not representative, all of whom were volunteers. The rate of loss to follow-up was > 10% in five trials [14-16, 19, 20], and loss to follow-up was not clearly described in one trial [13]. The study groups of four trials [13, 14, 16, 17] were significantly different in age from the control group and were not comparable in age, so other biases may have been introduced. **Figures 2 and 3** summarise the risks of bias of the included studies.

Primary outcome: Rates of common postoperative complications and revision surgery

Dislocation rate

Postoperative dislocations were reported in 7 of the 10 studies, involving 1742 patients (1086 CoC-THA *versus* 807 CoP-THA) [14, 16-21]. There was no significant difference between the two groups (OR: 0.85; 95% CI: 0.51, 1.42; $p = 0.54$), and no significant heterogeneity ($I^2 = 0\%$, $p = 0.77$) (**Figure 4A**).

Deep vein thrombosis rate

Three studies with 579 patients (468 CoC-THA *vs.* 432 CoP-THA) were included in the analysis of the postoperative deep vein thrombosis rate [14, 16, 19]. Evidence synthesis revealed a similar deep vein thrombosis rate in the two groups (OR: 1.22; 95% CI: 0.44, 3.43; $p = 0.70$) without significant heterogeneity ($I^2 = 0\%$, $p = 0.83$) (**Figure 4B**).

Infection rate

Five of the ten studies provided the number of infection events after THA, one of which reported periprosthetic joint infection [13], two reported superficial infection and deep infection [14, 17] and two studies did not clearly describe the site of infection [15, 19]. A total of 606 patients were analysed (374 CoC-THA *vs.* 315 CoP-THA). The rate of infection was similar in the two groups (OR: 1.28; 95% CI: 0.52, 3.17; $p = 0.59$), and no significant heterogeneity ($I^2 = 0\%$, $p = 0.80$) was detected (**Figure 4C**).

Wear debris or osteolysis rate

Three articles reported generation of much wear debris and subsequently osteolysis during postoperative follow-up, involving 455 patients (268 CoC-THA *vs.* 232 CoP-THA) [12, 14, 15]. The wear debris or osteolysis rates were non-significantly lower in the CoC-THA group compared to the CoP-THA group, but do approach significance with a p value of 0.06 (OR: 0.41; 95% CI: 0.16, 1.05; $p = 0.06$). No significant heterogeneity ($I^2 = 0\%$, $p = 0.85$) was detected (**Figure 4A**). What I need to note here is that convention poly, rather than crosslinked poly, was used in the three papers we included for the the section on wear debris.

Revision surgery

Seven of the ten studies reported information on the revision surgery [13-16, 19-21]. Revision surgery was performed in 949 patients (1026 hips) in the CoC-THA group and 723 patients (760 hips) in the CoP-THA group. The mean follow-up duration was 2.0–15 years. Common causes included hip instability, loose components, wear and osteolysis, infection, recurrent or multiple dislocation and implant or periprosthetic fracture, all of which were common postoperative complications. A small number of patients experienced stem subsidence, implant tilt, and persisting pain of unknown cause after surgery, so revision surgery was performed. The revision surgery rate in the CoC-THA group was non-significantly lower (RR: 0.77; 95% CI: 0.45, 1.32; p = 0.35). No significant heterogeneity (I^2 = 38%, p = 0.14) was observed (**Figure 5**).

Secondary outcome: postoperative Harris Hip Score

Because few of the included studies evaluated hip function after surgery, there was insufficient information to compare hip function among implant combinations. The Harris Hip Score was used in six studies. Because one study did not differentiate between CoC-THA and CoP-THA scores [14], and another did not clearly describe the standard deviation or range of scores [17], only four sets of data were analysed, involving 420 patients (239 CoC-THA *vs.* 186 CoP-THA) [13, 15, 19, 20]. The mean follow-up duration was 8.1–15 years. The Harris Hip Score improved significantly in both groups compared to that preoperatively (**Table 2**), it was non-significantly higher in the CoC-THA group (WMD: 2.50; 95% CI: -1.26, 6.26; p = 0.19). However, statistically significant heterogeneity was observed (I^2 = 55%, p = 0.08) (**Figure 6**).

Because of the > 50% heterogeneity in postoperative Harris Hip Score, we conducted one-way sensitivity analyses to evaluate the influence of each individual study on the combined WMD by removing the studies one-by-one. Exclusion of Epinette *et al*. [20] eliminated the heterogeneity of the Harris Hip Score (I^2 = 0%, p = 0.78) (**Figure 7**) and the postoperative Harris Hip Score was significantly higher in the CoC-THA group than in the CoP-THA group (WMD: 5.17; 95% CI: 1.38, 8.96; p = 0.007) (**Figure 8**), suggesting that this study accounted for most of the heterogeneity.

Discussion

In this meta-analysis based on 7 prospective randomised studies, 2 retrospective randomised studies and 1 RCT (1946 patients; 1192 CoC-THA *vs.* 906 CoP-THA), we found no evidence of a significant difference between CoC-THA and CoP-THA in objective indicators (incidence of common postoperative complications and the rate of postoperative revision) and a subjective indicator (Harris Hip Score) of the postoperative prognosis. This is likely to be because both bearing couples achieved good clinical results in the long-term follow-up.

Although there was no significant difference in dislocation rate between the CoC-THA and CoP-THA groups, dislocation was associated with liners and femoral heads of different sizes [22], which were not controlled for in all the included studies. The authors suggested that the reason for the slightly lower dislocation rate in the CoC-THA group than in the CoP-THA group maybe the use of a larger femoral head in the CoC-THA group than the CoP-THA group. This is consistent with THA biomechanics regarding increased jump distance with a larger head. Besides, a 10° or 20° lip liner on a standard polyethylene liner as well as a smaller head size may alter this outcome [16, 18].

Deep vein thrombosis has not been reported to be related to the implanted inlay. Although a meta-analysis revealed no evidence that material selection affects the risk of infection [23], clinical studies in Australia and New Zealand showed that the risk of infection after CoC-THA was significantly reduced compared with CoP-THA [24, 25]. This may be related to the reduction of bacterial biofilm formation caused by the chemical and physical properties of ceramic materials [26]. However, it is important to note that before conducting clinical trials, factors such as BMI and comorbidities that have a strong influence on infection rate should be taken into account, which can affect the final results of clinical trials

The wear rate of traditional polyethylene is higher than that of ceramic, and friction can produce particles that lead to osteolysis [27, 28]. Unsurprisingly, the wear or osteolysis rate was non-significantly higher in the CoP-THA group. It is possible that some wear debris or osteolysis data were not recorded because patients died or were lost to follow-up for other reasons. Furthermore, only three studies reported wear debris or osteolysis, and this limited series did not show statistical significance.

In many published series and joint arthroplasty registries, wear debris-induced osteolysis is the most common cause of postoperative revision surgery [29]. In this meta-analysis, the revision rate was non-significantly higher in the CoP-THA group than in the CoC-THA group, just as rate of wear or osteolysis was slightly higher in the COP group than in the COC group. Young patients tend to pay more attention to revision surgery rates, because they have long life expectancies. However, the studies included in this meta-analysis involved patients > 40 years old. It is possible that some patients who need revision surgery do not have it because they are too old. There was no significant difference in the rate of common postoperative complications (dislocation, deep vein thrombosis, infection, wear debris or osteolysis) or in postoperative revision between the two groups, consistent with two previous meta-analyses [10, 11]. However, in addition to the bearing surface, other factors—such as the diameter of the femoral head [4], the position of the acetabular cup [30], and the manufacturer of the prosthesis [31]—can influence these rates.

The postoperative Harris Hip Score was non-significantly higher in the CoC-THA group than in the CoP-THA group, and there was high heterogeneity among the studies. After excluding the main sources of heterogeneity, the postoperative Harris Hip Score was significantly higher in the CoC-THA group than in the CoP-THA group (WMD: 5.17; 95% CI: 1.38, 8.96; p = 0.007). This contradicts a previous meta-analysis, which showed no difference in Harris Hip Score between the two groups [32]. The specific reasons for the discrepancy need further exploration. However, in the study by Lopez-Lopez et al.[32], both the COC and COP groups used small heads and non-bone cement implants. Moreover, their focus was on comparing the Harris Hip Score of conventional metal-polyethylene (non-highly cross-linked), small-headed, cemented implants versus new materials implants. Therefore, I believe that our study, which specifically compares the postoperative Harris Hip Score of COC and COP bearings, is more targeted. Besides, the Harris Hip Score may be too subjective and further clinical trials of longer follow-up are needed. There are too few clinical studies available to support our findings. In this meta-analysis, the preoperative and postoperative Harris Hip Score increased significantly in the CoC-THA group, compared to the CoP-THA group, in all the included studies. Patients may subjectively perceive less pain and better joint function after CoC-THA.

Strengths and limilations

To the best of our knowledge, previous studies on the selection of bearing surfaces for THA are all from the perspective of doctors, focusing on the outcome of the operation. However, this current report is the first to focus on postoperative outcomes from the patient's perspective and to provide an important reference for patients in preoperative selection of bearing surfaces for THA.

Although we used the Cochrane collaborative-recommended GRADE system to evaluate the results, this study has several limitations. First, the clinical trials in the references we included did not take into account factors such as BMI, comorbidities, and they tended to use COC bearings in younger patients, so these variables were not controlled well. Second, we analysed a small number of trials, precluding the generation of funnel plots to assess publication bias. The inclusion of studies with small sample sizes may lead to smaller study effects, leading to large standard deviations (SDs). Third, there were insufficient data to perform a subgroup analysis according to type of prosthesis, which may have introduced bias. Finally, since only two of the cited literatures used crosslinked poly, there was insufficient data. We could not distinguish conventional poly from crosslinked poly. However, it is worth noting that in the analysis of wear debris, the use of highly cross-linked polyethylene liners was not included in the study, so the accuracy of the data is guaranteed.

Conclusion

Pooled analyses demonstrated that CoC and CoP had comparable postoperative prognoses after initial THA. The overall and subtype analyses showed similar rates of dislocation, deep vein thrombosis, and infection. Although the results may not be statistically significant, CoC had better wear resistance, a lower osteolysis rate, and a slightly lower revision rate. After eliminating heterogeneity, the CoC bearing surface had a higher Harris Hip Score, and the prognosis was improved by CoC-THA. The findings could be pertinent to young patients such as those with hip disease due to avascular necrosis or dysplasia. However, the small number of studies included, and the presence of heterogeneity hamper the generalisation of our findings. Therefore, orthopaedic surgeons should select a THA material based on their experience and patient-specific factors, and large multicentre clinical trials with > 15 years of follow-up are needed. Compared to conventional

PE, HXLPE has been considered an ideal substitute as it significantly reduces wear debris and does not increase the risk of postoperative complications. However, there is still a lack of sufficient research on the comparative effectiveness of HXLPE and CoC bearing surfaces. This area should remain a primary focus for future research, with the hope that more orthopedic surgeons will take notice of this aspect and that more relevant articles will be published in the future.

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Table 1. Baseline characteristics of include studies.

Authors	Study period	Region	Study design	Follow-up (y)	patients (hips, n)	
					CoC	CoP
Amanatullah[14]	1999-2001	USA	Prospective	5	166 (196)	146 (161)
Atrey[15]	1997-1999	Canada	Prospective	15	29 (29)	28 (29)
BAL[16]	1998-2001	USA	Prospective	2	238 (250)	241 (250)
Beaupre[21]	1998-2003	Canada	RCT	10	48 (48)	44 (44)

Epinette[20]	1997-2002	France	Retrospective	10	412 (447)	216 (228)
Feng[17]	2009-2012	China	Prospective	7	71 (93)	62 (77)
Giuseppe[12]	2005-2008	Italy	Retrospective	15	43 (43)	43 (43)
Lewis[18]	1997-1999	Canada	Prospective	8	NA (30)	NA (26)
Ochs[19]	1997-1999	Germany	Prospective	8.1	22 (22)	21 (21)
van Loon[13]	2003-2004	Netherlands	Prospective	10	34 (34)	27 (27)

Author	**Mean age (SD)**		**Material design**	**Female (%)**		**BMI (SD)**	
	CoC	**CoP**		**CoC**	**CoP**	**CoC**	**CoP**
Amanatullah[14]	50.4 (12.8)	54.7 (12.9)	A-on-A VS. A-on-PE	36.1	42.5	29.6 (12.4)	29.6 (12.4)
Atrey[15]	50.4 (12.8)	54.7 (12.9)	A-on-A VS. A-on-PE	41.4	46.4	26.7(6.6)	28.2(5.2)
BAL[16]	54.97 (14.7)	60.93 (12.8)	A-on-A VS. A-on-PE	47.1	55.2	NA	NA
Beaupre[21]	51.3 (6.9)	53.6 (6.5)	A-on-A VS. A-on-PE	45.8	45.4	NA	NA
Epinette[20]	68.04 (9.7)	68.66 (10.0)	A-on-A VS. A-on-HXLPE	73.3	69.4	27.4 (4.5)	28.14 (4.93)
Feng[17]	51.21 (9.6)	58.77 (9.3)	A-on-A VS. A-on-HXLPE	56.3	53.2	25.12(1.98)	23.27(1.98)
Giuseppe[12]	63.4 (6.5)	67.8 (11.0)	A-on-A VS. A-on-PE	46.5	51.2	27 (3.1)	25.9 (3.3)
Lewis[18]	41.5 (8.9)	42.8 (6.9)	A-on-A VS. A-on-PE	NA	NA	26.7 (6.6)	28.2 (5.2)
Ochs[19]	64.4 (7.8)	69.2 (7.2)	A-on-A VS. A-on-PE	31.8	33.3	NA	NA
van Loon[13]	55.7 (8.5)	64.2 (5.3)	A-on-A VS. A-on-PE	64.7	77.8	26.9 (4.1)	27.6 (4.1)

A-on-A: Alumina-on-Alumina; A-on-PE: Alumina-on-Polyethylene; A-on-HXLPE: Alumina-on-Highly-Crosslinked-Polyethylene; NA: not available; BMI: body mass index.

Table 2. Preoperative and postoperative Harris hip score.

Author	Patients (hips, n)		Mean Harris hip score (SD)			
			CoC-THA		CoP-THA	
	CoC-THA	CoP-THA	Preoperative	Postoperative	Preoperative	Postoperative
Atrey[15]	29 (29)	28 (29)	50.3 (13.7)	48.8 (19.9)	94.6 (5.5)	88.7 (10.5)
Epinette[20]	412 (447)	216 (228)	40.12 (10.6)	44 (9.5)	98.53 (2.96)	98.29 (3.91)
Feng[17]	71 (93)	62 (77)	47.9 (NA)	40.4 (NA)	89.6 (NA)	86.7 (NA)
Ochs[19]	22 (22)	21 (21)	NA	NA	91 (21.6)	89 (12.1)
van Loon[13]	34 (34)	27 (27)	47.5 (13.4)	50.2 (13.3)	91.4 (17.0)	87.3 (18.5)

NA: NA: not available.

Figure 1

Figure 1. Flowchart of the systematic search and selection process.

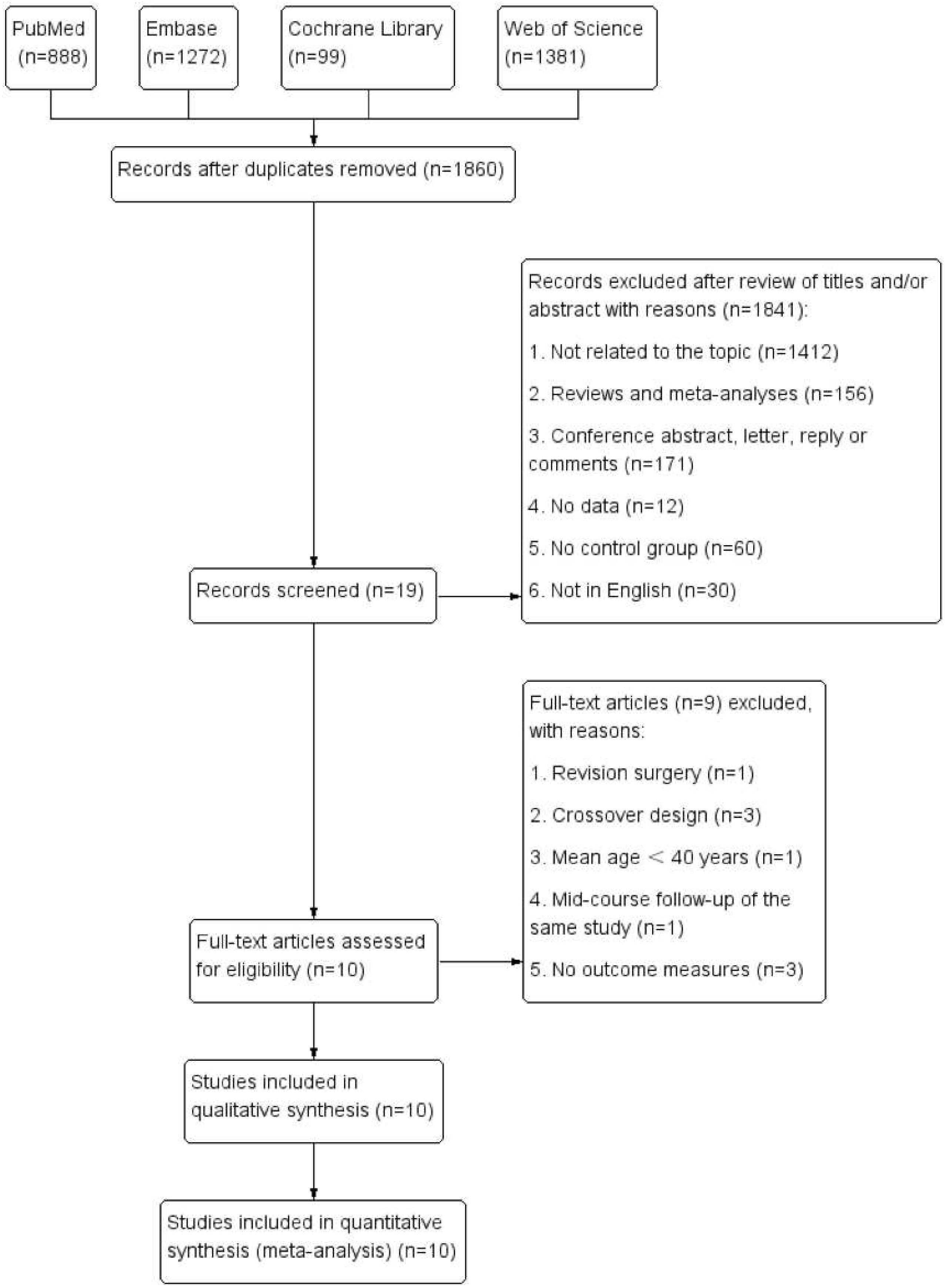

PubMed (n=888)
Embase (n=1272)
Cochrane Library (n=99)
Web of Science (n=1381)
Records after duplicates removed (n=1860)
Records excluded after review of titles and/or abstract with reasons (n=1841):
1. Not related to the topic (n=1412)
2. Reviews and meta-analyses (n=156)
3. Conference abstract, letter, reply or comments (n=171)
4. No data (n=12)
5. No control group (n=60)
6. Not in English (n=30)
Records screened (n=19)
Full-text articles (n=9) excluded, with reasons:
1. Revision surgery (n=1)
2. Crossover design (n=3)
3. Mean age < 40 years (n=1)
4. Mid-course follow-up of the same study (n=1)
5. No outcome measures (n=3)
Full-text articles assessed for eligibility (n=10)
Studies included in qualitative synthesis (n=10)
Studies included in quantitative synthesis (meta-analysis) (n=10)

Figure 2

Figure 2. Quality assessment of risk of bias summary in included studies.

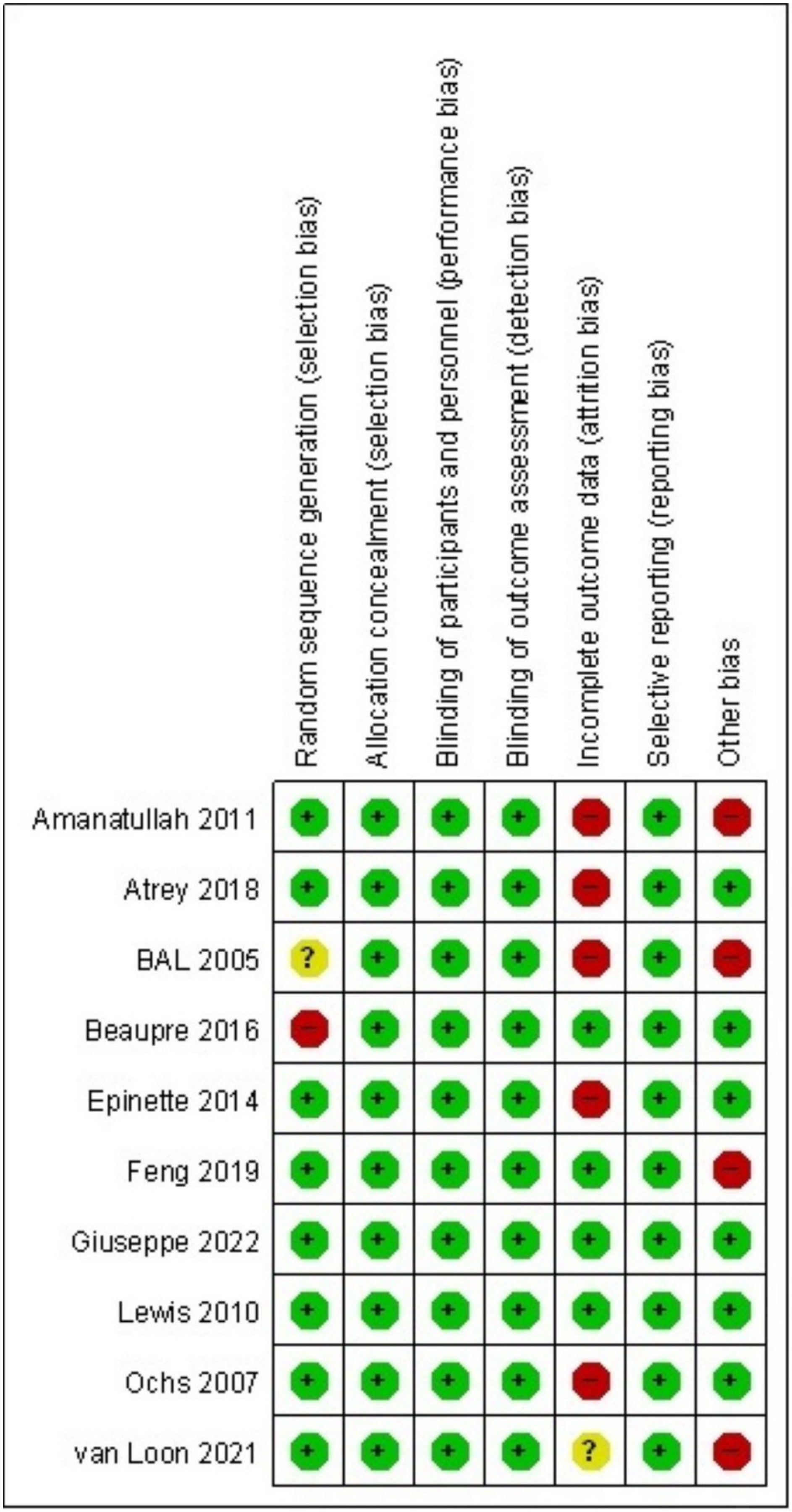

Random sequence generation (selection bias)
Allocation concealment (selection bias)
Blinding of participants and personnel (performance bias)
Blinding of outcome assessment (detection bias)
Incomplete outcome data (attrition bias)
Selective reporting (reporting bias)
Other bias
Amanatullah 2011
Atrey 2018
BAL 2005
Beaupre 2016
Epinette 2014
Feng 2019
Giuseppe 2022
Lewis 2010
Ochs 2007
van Loon 2021

Figure 3

Figure 3. Risk of bias graph.

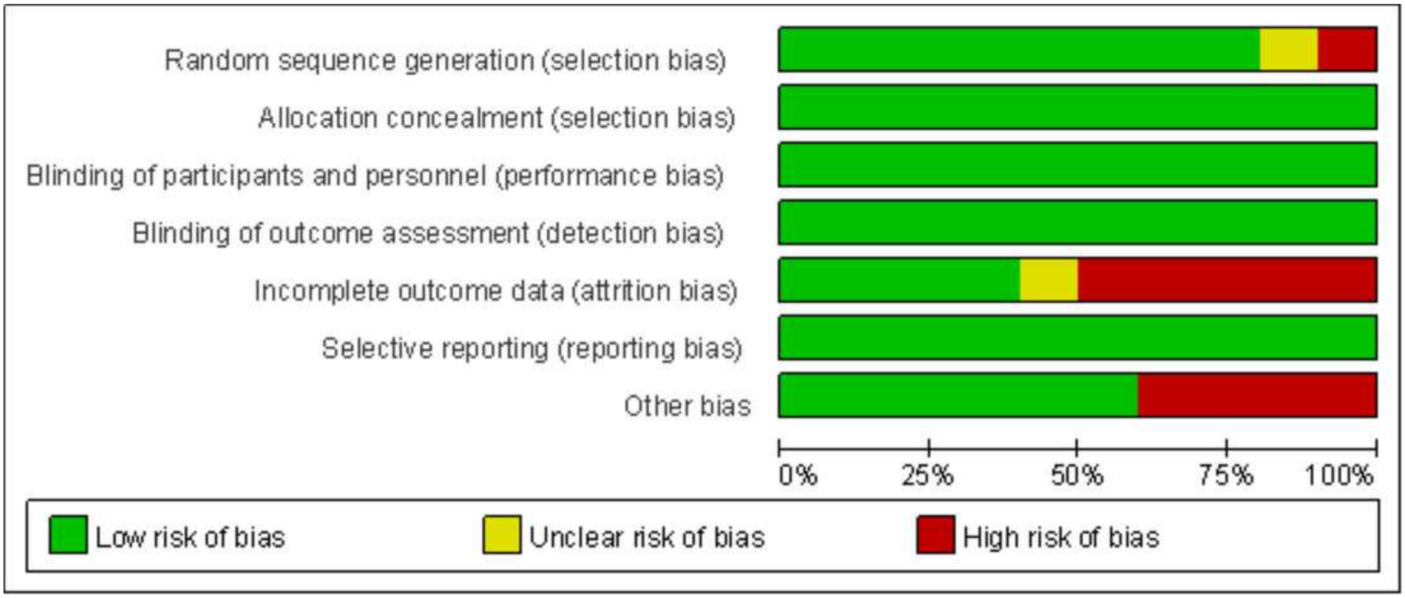
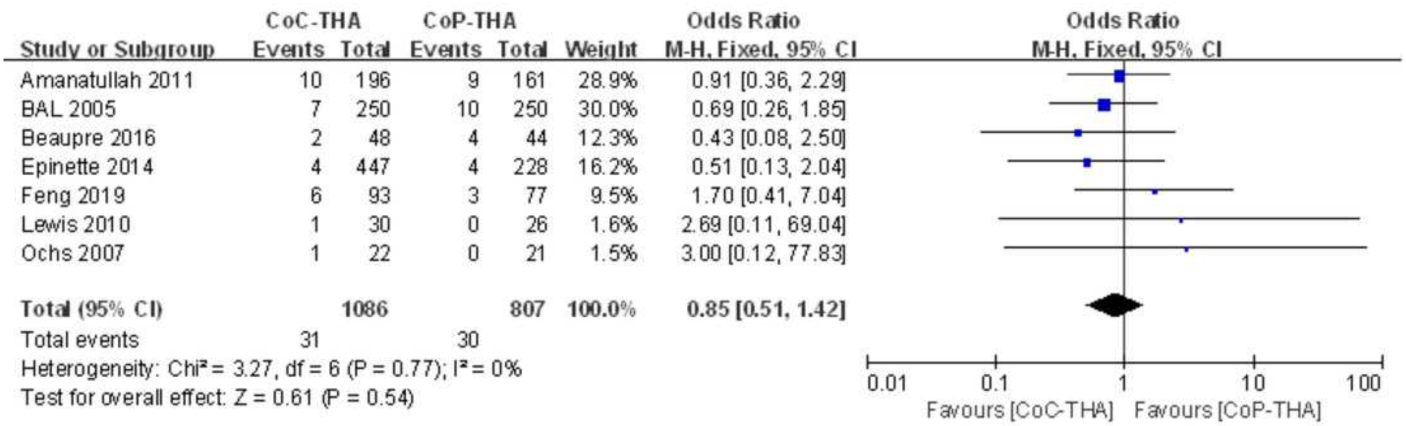


Figure 4

Figure 4. Forest plots of postoperative complication outcomes: (A) dislocation rate



Study or Subgroup	CoC-THA Events	CoC-THA Total	CoP-THA Events	CoP-THA Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Amanatullah 2011	10	196	9	161	28.9%	0.91 [0.36, 2.29]
BAL 2005	7	250	10	250	30.0%	0.69 [0.26, 1.85]
Beaupre 2016	2	48	4	44	12.3%	0.43 [0.08, 2.50]
Epinette 2014	4	447	4	228	16.2%	0.51 [0.13, 2.04]
Feng 2019	6	93	3	77	9.5%	1.70 [0.41, 7.04]
Lewis 2010	1	30	0	26	1.6%	2.69 [0.11, 69.04]
Ochs 2007	1	22	0	21	1.5%	3.00 [0.12, 77.83]
Total (95% CI)		**1086**		**807**	**100.0%**	**0.85 [0.51, 1.42]**
Total events	31		30			

Heterogeneity: Chi² = 3.27, df = 6 (P = 0.77); I² = 0%

Test for overall effect: Z = 0.61 (P = 0.54)

Figure 5

Figure 4. Forest plots of postoperative complication outcomes: (B) deep venous thrombosis rate

Study or Subgroup	CoC-THA Events	CoC-THA Total	CoP-THA Events	CoP-THA Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Amanatullah 2011	3	196	2	161	32.9%	1.24 [0.20, 7.49]
BAL 2005	4	250	4	250	59.9%	1.00 [0.25, 4.04]
Ochs 2007	1	22	0	21	7.3%	3.00 [0.12, 77.83]
Total (95% CI)		**468**		**432**	**100.0%**	**1.22 [0.44, 3.43]**
Total events	8		6			

Heterogeneity: Chi² = 0.37, df = 2 (P = 0.83); I² = 0%
Test for overall effect: Z = 0.38 (P = 0.70)

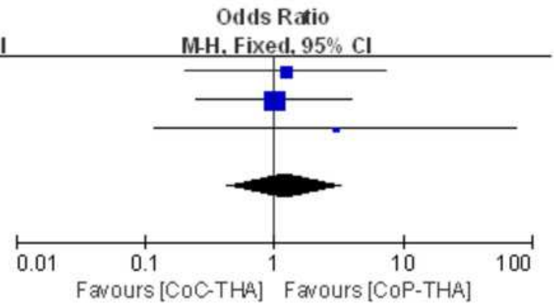


Figure 6

Figure 4. Forest plots of postoperative complication outcomes: (C) infection rate

	CoC-THA		CoP-THA			Odds Ratio
Study or Subgroup	Events	Total	Events	Total	Weight	M-H, Fixed, 95% CI
Amanatullah 2011	7	196	5	161	63.0%	1.16 [0.36, 3.71]
Atrey 2018	1	29	0	29	5.6%	3.11 [0.12, 79.43]
Feng 2019	0	93	1	77	19.4%	0.27 [0.01, 6.79]
Ochs 2007	1	22	0	21	5.7%	3.00 [0.12, 77.83]
van Loon 2021	1	34	0	27	6.3%	2.46 [0.10, 62.89]
Total (95% CI)		**374**		**315**	**100.0%**	**1.28 [0.52, 3.17]**
Total events	10		6			

Heterogeneity: $Chi^2 = 1.62$, df = 4 (P = 0.80); $I^2 = 0\%$
Test for overall effect: Z = 0.54 (P = 0.59)

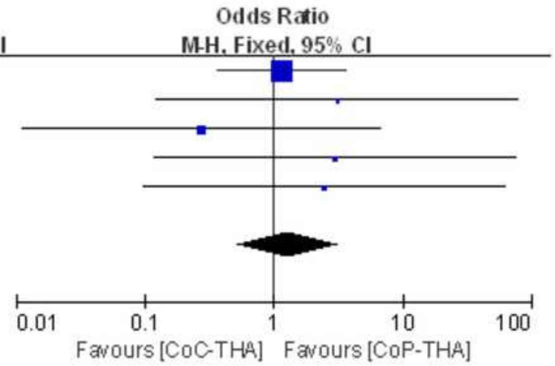


Figure 7

Figure 4. Forest plots of postoperative complication outcomes: (D) wear debris or osteolysis rate.

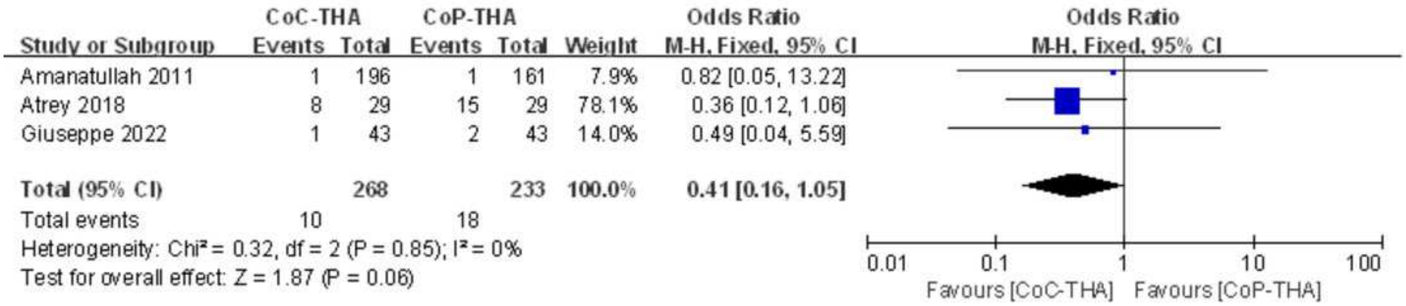


Figure 8

Figure 5. Forest plots of revision surgery outcomes.

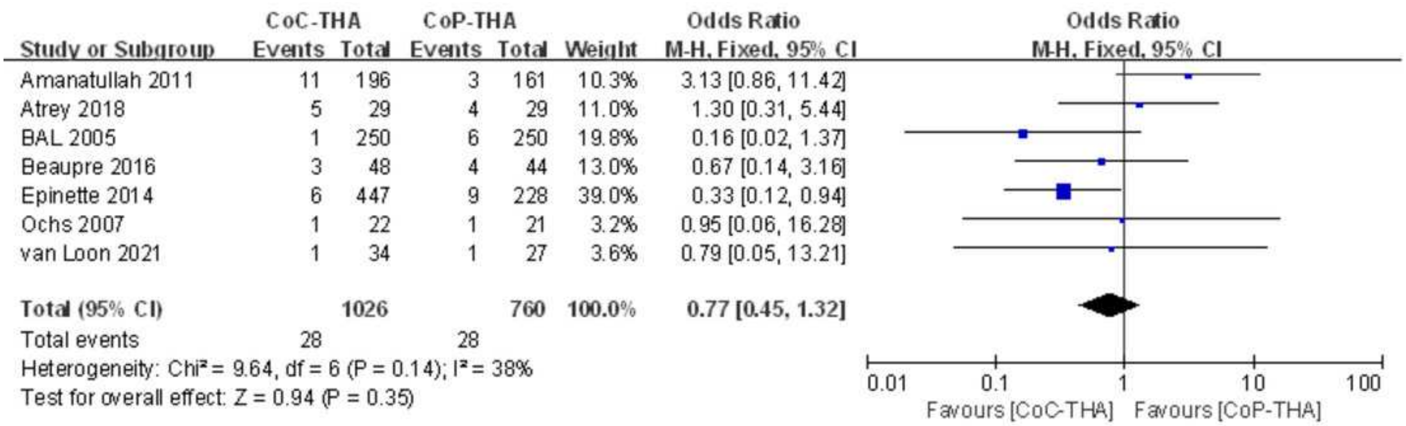


Figure 9

Figure 6. Forest plots of postoperative Harris hip score.

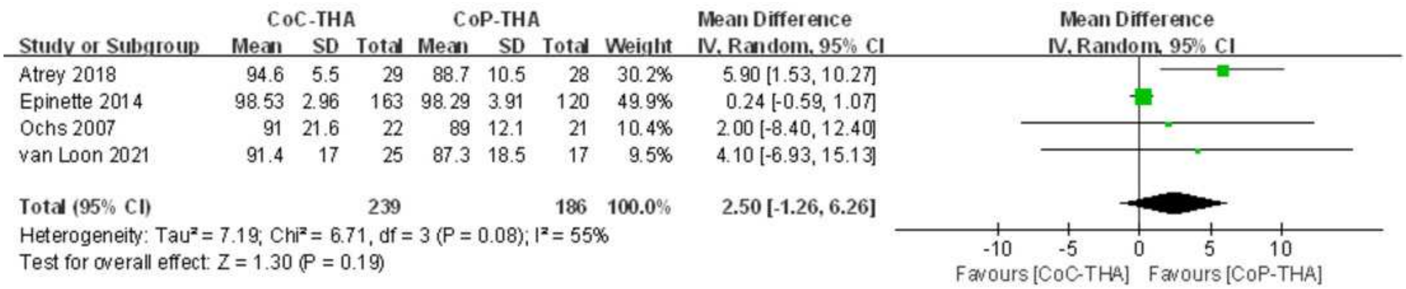


Figure 10

Figure 7. Sensitivity analysis of postoperative Harris hip score.

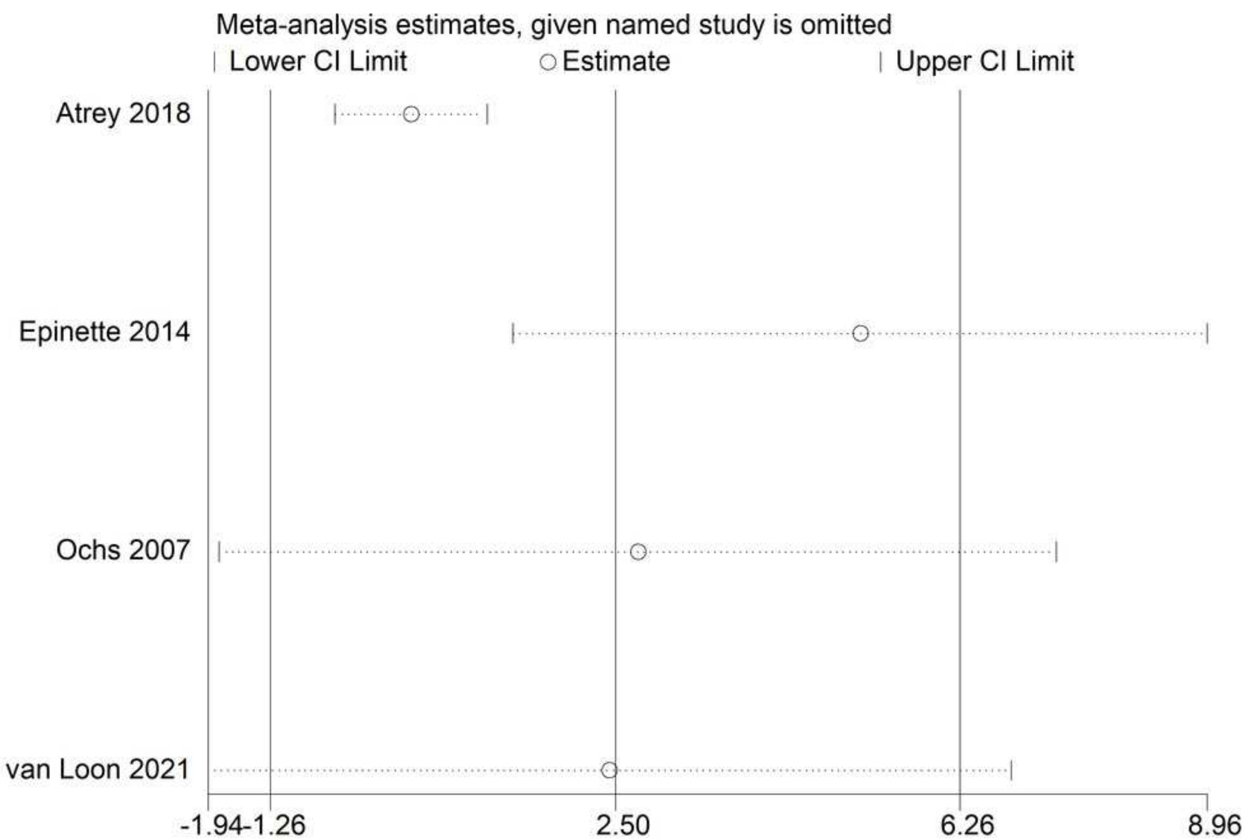


Figure 11

Figure 8. Forest plots of postoperative Harris hip score after excluding one study.

Study or Subgroup	CoC-THA Mean	CoC-THA SD	CoC-THA Total	CoP-THA Mean	CoP-THA SD	CoP-THA Total	Weight	Mean Difference IV, Random, 95% CI
Atrey 2018	94.6	5.5	29	88.7	10.5	28	75.0%	5.90 [1.53, 10.27]
Epinette 2014	0	0	0	0	0	0		Not estimable
Ochs 2007	91	21.6	22	89	12.1	21	13.3%	2.00 [-8.40, 12.40]
van Loon 2021	91.4	17	25	87.3	18.5	17	11.8%	4.10 [-6.93, 15.13]
Total (95% CI)			**76**			**66**	**100.0%**	**5.17 [1.38, 8.96]**

Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.50$, df = 2 (P = 0.78); $I^2 = 0\%$
Test for overall effect: Z = 2.68 (P = 0.007)

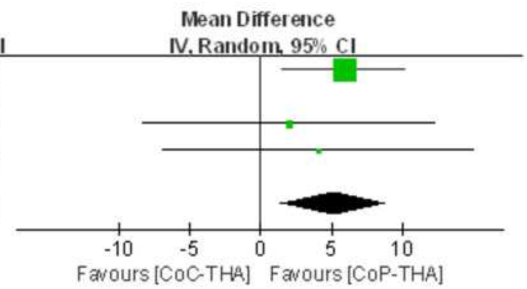


Table 1 (on next page)

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Beaupre[21]	1998-2003	Canada	RCT	10	48 (48)	44 (44)
Epinette[20]	1997-2002	France	Retrospective	10	412 (447)	216 (228)
Feng[17]	2009-2012	China	Prospective	7	71 (93)	62 (77)
Giuseppe[12]	2005-2008	Italy	Retrospective	15	43 (43)	43 (43)
Lewis[18]	1997-1999	Canada	Prospective	8	NA (30)	NA (26)
Ochs[19]	1997-1999	Germany	Prospective	8.1	22 (22)	21 (21)
van Loon[13]	2003-2004	Netherlands	Prospective	10	34 (34)	27 (27)

Author	Mean age (SD)		Material design	Female (%)		BMI (SD)	
	CoC	CoP		CoC	CoP	CoC	CoP
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Epinette[20]	68.04 (9.7)	68.66 (10.0)	A-on-A VS. A-on-HXLPE	73.3	69.4	27.4 (4.5)	28.14 (4.93)
Feng[17]	51.21 (9.6)	58.77 (9.3)	A-on-A VS. A-on-HXLPE	56.3	53.2	25.12(1.98)	23.27(1.98)
Giuseppe[12]	63.4 (6.5)	67.8 (11.0)	A-on-A VS. A-on-PE	46.5	51.2	27 (3.1)	25.9 (3.3)
Lewis[18]	41.5 (8.9)	42.8 (6.9)	A-on-A VS. A-on-PE	NA	NA	26.7 (6.6)	28.2 (5.2)
Ochs[19]	64.4 (7.8)	69.2 (7.2)	A-on-A VS. A-on-PE	31.8	33.3	NA	NA
van Loon[13]	55.7 (8.5)	64.2 (5.3)	A-on-A VS. A-on-PE	64.7	77.8	26.9 (4.1)	27.6 (4.1)

A-on-A: Alumina-on-Alumina; A-on-PE: Alumina-on-Polyethylene; A-on-HXLPE: Alumina-on-Highly-Crosslinked-Polyethylene; NA: not available; BMI: body mass index.

Table 2(on next page)

Table 2. Demographics characteristics of included studies.

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Outcomes	studies	No. of patients	WMD or OR	95% CI	p-value	Heterogeneity			
		CoC-THA/CoP-THA				Chi^2	df	p-value	I^2 (%)
Age (years)	[12-21]	1093/854	-4.07	[-5.93, -2.20]	<0.0001	33.56	9	0.0001	73
Gender (female)	[12-17, 19-21]	1063/828	0.90	[0.74, 1.09]	0.27	5.86	7	0.56	0
BMI (kg/m^2)	[12-15, 17, 18, 20]	785/548	0.04	[-1.20, 1.29]	0.94	30.07	6	<0.0001	80

BMI: body mass index; WMD: weighted mean difference; OR: odds ratio; CI: confidence interval.

Table 3(on next page)

Table 3. Preoperative and postoperative Harris hip score.

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Author	Patients (hips, n)		Mean Harris hip score (SD)			
			CoC-THA		CoP-THA	
	CoC-THA	CoP-THA	Preoperative	Postoperative	Preoperative	Postoperative
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Epinette[20]	412 (447)	216 (228)	40.12 (10.6)	44 (9.5)	98.53 (2.96)	98.29 (3.91)
Feng[17]	71 (93)	62 (77)	47.9 (NA)	40.4 (NA)	89.6 (NA)	86.7 (NA)
Ochs[19]	22 (22)	21 (21)	NA	NA	91 (21.6)	89 (12.1)
van Loon[13]	34 (34)	27 (27)	47.5 (13.4)	50.2 (13.3)	91.4 (17.0)	87.3 (18.5)

NA: NA: not available.