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Comparison between ceramic-on-polyethylene versus metal-on-polyethylene prostheses in Total Hip Arthroplasties: a systematic review and meta-analysis

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The Guidelines Project, an initiative of the Brazilian Medical Association, aims to combine information from the medical field to standardize how to conduct, and to assist in the reasoning and decision-making of doctors. The information provided by this project must be critically evaluated by the physician responsible for the conduct that will be adopted, depending on the conditions and the clinical condition of each patient.

INTRODUCTION

Total hip arthroplasty (THA) is considered one of the most successful orthopedic interventions worldwide. The technological evolution of this technique began at the end of the 19th century, when studies began to evaluate the tolerance of the human body to foreign bodies.

Since then, the hunt for improvement and better long-term results has continued with the search for new surfaces, greater material biocompatibility, and less aggressive surgical techniques[1].

There are several models of prostheses available for this procedure, which differ from each other in various ways, ranging from the fixation method used (cemented or not) to the type of material that composes them, the most widely used being metallic, ceramic, or plastic (polyethylene) components.

These differences directly affect the survival period and replacement of each prosthesis and are considered contributing factors to prosthesis wear, osteolysis around it, and its aseptic loosening.

In view of the above, we performed a systematic review with meta-analysis in order to compare the hip prosthesis with a femoral head and acetabulum composed of ceramic and polyethylene, respectively, with the prosthesis composed of metal and polyethylene. The reviews, wear rates, and clinical outcomes were considered.

METHODS

The methodology will address the following information: the clinical question, structured question (PICO), eligibility criteria of the studies, sources of information consulted, search strategies used, critical evaluation method (risk of bias), follow-up greater than 24 months, quality of evidence, data to be extracted, measures to be used to express the results, and the method of analysis.

Clinical question

For THA, is the use of ceramic-on-polyethylene prostheses more efficient than metal-on-polyethylene prostheses?

Structured question

P (population): Adult patients undergoing THA
I (intervention): Ceramic-on-polyethylene prostheses
C (comparison): Metal-on-polyethylene
O (“*outcome*”): Reviews, wear rates, and clinical outcomes.

Eligibility criteria

- PICO components
- Randomized clinical trials (RCTs)
- No time restriction
- Languages English, Spanish, and Portuguese
- Full text or abstract with necessary data
- Outcomes expressed in absolute number of events or mean/median with variation

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Exclusion criteria

- Observational and noncomparative studies
- In vitro and/or animal studies
- Case series or case reports
- Narrative or systematic reviews

Sources of information consulted and search strategies

Medline via PubMed, manual search

(Arthroplasty, replacement, Hip OR Hip Prosthesis OR Hip Prostheses) AND (Metal OR Metals OR Ceramic OR ceramics OR Polyethylene OR Polyethylenes OR Polythene OR LDPE OR HDPE OR Polymers OR Polypropylenes) AND random*

Risk of bias and quality of evidence

For RCTs, the following risks of bias will be evaluated: focal question, randomization, blinded allocation, double blinding, evaluator blinding, losses, analysis by intention to treat (ITT), definition of outcomes, and sample size calculation.

Data extracted

Author, year of publication, study design, characteristics and number of patients, intervention, comparison, and outcomes (reviews, wear rate, and clinical outcomes)

Outcome measures

For categorical variables, we use absolute numbers, percentage, absolute risk, risk reduction or increase, number needed to treat (NNT) or harm (NNH), AND 95% confidence interval (95%CI). For continuous variables, means or difference between means with standard deviation are utilized.

Expression of the results

If there is the possibility of aggregating the results of the included studies regarding one or more common outcomes, a meta-analysis will be performed using the RevMan version 5.3 software (Cochrane)[2].

To calculate the mean and standard deviation, when not presented in the work, the VassarStats software is used: Website for Statistical Computation[3].

Analysis of the quality of evidence

The quality of the evidence is assessed using the GRADEpro software[4].

RESULTS

The results presented include diagram of study retrieval (Figure 1) and selection, risk of bias (Table 1), results by outcome, quality of evidence (grade, Table 2), and evidence synthesis.

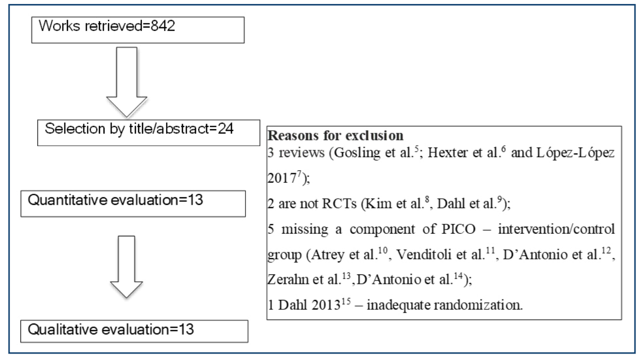

Figure 1. Flowchart of the selected works (CONSORT).

In total, 842 studies were retrieved (Medline via PubMed). After applying the eligibility criteria, 24 studies were selected, of which 13 studies were included for full-text evaluation (Figure 1).

Characteristics of the included studies

Bjorgul et al.[16]

A total of 399 hips were selected, of which 376 patients aged below 73 years with hip osteoarthritis (OA) undergoing THA. All prostheses had a femoral head of 28 mm; those composed of ceramic-on-polyethylene were compared with others with metal-on-polyethylene according to the Harris Hip Score (HHS) outcomes and the number of surgical reviews; the follow-up time was 84 months.

Ise et al.[17]

Participants included 77 patients aged over 60 years with hip OA undergoing THA. The ceramic-on-polyethylene prosthesis (with three different types of ceramic in the femoral head) was compared with the metal-on-polyethylene prosthesis, all with a 22.225-mm head. The follow-up time was 36 months, and the outcome linear wear rate per mm/year was analyzed through radiographic examinations.

Jassim et al.[18]

A total of 401 patients aged over 18 years with hip OA were analyzed. For the THA, prostheses with a 32-mm femoral head, composed of ceramic-on-polyethylene or metal-on-polyethylene, were used. Patients were followed up for 60 months, and the outcome analyzed was linear wear rate in mm/year.

Jonsson et al.[19]

Participants included 120 patients aged 59–80 years with hip OA who underwent THA. The size of the femoral head was 28 mm, and a comparison was made between the prostheses made of ceramic-on-polyethylene and prostheses made of metal-on-polyethylene. HHS outcomes were analyzed along with linear wear rate in mm/year through radiographic examinations. The follow-up time was 60 months.

Table 1. Risk of bias and quality of evidence.

Author/Year	Randomization	Blinded allocation	Double blind	Evaluator blinding	Losses	Prognostic characteristics	Outcomes	ITT	Sample calculation	Early interruption
Bjorgul, et al.[16]	Green	Green	Red	Red	Red	Green	Green	Red	Red	Green
Ise, et al.[17]	Green	Yellow	Red	Yellow	Red	Green	Green	Red	Red	Yellow
Jassim, et al.[18]	Green	Green	Red	Green	Green	Green	Green	Red	Green	Green
Jonsson, et al.[19]	Green	Green	Red	Green	Red	Green	Red	Red	Red	Green
Kadar, et al.[20]	Green	Green	Red	Green	Red	Green	Red	Red	Green	Green
Kawate, et al.[21]	Green	Yellow	Red	Yellow	Yellow	Yellow	Green	Red	Red	Green
Kim[22]	Green	Green	Yellow	Green	Green	Green	Green	Green	Red	Green
Kraay, et al.[23]	Green	Green	Red	Green	Green	Green	Green	Green	Green	Green
Morison, et al.[24]	Green	Green	Red	Green	Green	Green	Green	Green	Green	Green
Nakahara, et al.[25]	Yellow	Yellow	Yellow	Red	Green	Green	Green	Yellow	Green	Green
Zaoui, et al.[26]	Green	Green	Yellow	Green	Green	Green	Green	Yellow	Green	Green
Bergvinsson, et al.[27]	Green	Green	Red	Green	Green	Green	Green	Red	Green	Green
Kayani, et al.[28]	Green	Green	Red	Green	Red	Green	Green	Red	Green	Green

ITT: Intention to treat.

Absence of bias | Absence of information | Presence of bias

Table 2. Grade table for evaluating the level of evidence.

Certainty assessment							№ of patients		Effect		Certainty	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Intervention (%)	Comparison (%)	Relative (95%CI)	Absolute (95%CI)		
1. Linear wear (mm/y) XLPE												
9	Randomized trials	Serious[a,b]	Not serious	Not serious	Not serious	None	448	443	–	MD 0 (0.01 minor to 0)	⊕⊕⊕◯ moderate	
2. Linear wear (mm/y) UHMWPE												
4	Randomized trials	Serious[a,b]	Not serious	Not serious	Not serious	None	67	71	–	MD 0 (0.04 minor to 0.05 higher)	⊕⊕⊕◯ moderate	
3. Surgical reviews												
7	Randomized trials	Serious[a,b]	Not serious	Not serious	Serious[c]	None	2/400 (0.5)	5/400 (1.3)	Not estimable	10 more for 1.000 (from 10 less to 20 more)	⊕⊕◯◯ low	
4. Head size												
11	Randomized Trials	Very serious[a,b,d]	Very serious[e]	Very serious[e]	Serious[c]	None	518	536	–	SMD 0.75 higher (0.52 lowest to 2.03 highest)	⊕◯◯◯ very low	
5. Harris hip score (HHS)												
5	Randomized trials	Very serious[a,b,d]	Not serious	Not serious	Serious[c]	None	147	155	–	MD 5.02 smaller (7.3 minor to 2.73 minor)	⊕◯◯◯ very low	

CI: confidence interval; SMD: standardized mean difference. [a]Absence of analysis by intention of treatment; [b]Absence of blinding; [c]Long confidence interval; [d]Absence of sample calculation; [e]High heterogeneity.

Kadar et al.[20]

In total, 77 patients aged 59–80 years with hip OA who underwent THA were selected; the ceramic-on-polyethylene hip prosthesis (with three different types of ceramic in the femoral head) was compared with the metal-on-polyethylene hip prosthesis, using femoral heads of 22,225 and 28 mm. The linear wear rate in mm/year was evaluated by radiographs. The follow-up time was 24 months.

Kawate et al.[21]

This was a comparative study evaluating 60 patients, including 62 hips with OA undergoing THA. The following outcomes were compared: clinical (HHS), linear wear in mm/year, and volumetric wear rate in mm^3 between individuals with a ceramic-on-polyethylene hip prosthesis and others with a metal-on-polyethylene hip prosthesis, all using a 26-mm femoral head. The follow-up time was 60 months.

Kim[22]

This study comprised 52 patients aged up to 50 years, including 104 hips with OA. Participants underwent THA using either ceramic-on-polyethylene or metal-on-polyethylene prosthesis with a 28-mm femoral head. HHS outcomes, reviews performed, and linear and volumetric wear rates were evaluated. Follow-up time ranged from 60 to 96 months.

Kraay et al.[23]

This was a clinical trial with 60 participants aged between 50 and 75 years and 104 hips with hip OA undergoing THA. The prostheses used had a femoral head of 28 mm and were made of ceramic-on-polyethylene or metal-on-polyethylene. The outcomes investigated were the number of reviews and the linear wear rate; clinical analysis was performed using the HHS tool. The follow-up time was 51 months.

Morison et al.[24]

In total, 80 patients were selected, ranging in age from 18 to 65 years, with 91 hips with OA, submitted to a ceramic-on-polyethylene hip prosthesis, compared with a metal-on-polyethylene hip prosthesis, using a 28-mm femoral head. The following outcomes were evaluated: HHS, reviews, and linear wear rate in mm/year by radiographs. The follow-up time was 60 months.

Nakahara et al.[25]

In total, 94 patients were compared, with a mean age of 58.5 years, with 102 hips with OA, submitted to a ceramic-on-polyethylene hip prosthesis, compared with a metal-on-polyethylene hip prosthesis, using a 26-mm femoral head, and the outcomes were evaluated: reviews and linear wear rate in mm/year by radiographs. Follow-up time was 72 months.

Zaoui et al.[26]

In this study, 100 patients aged over 75 years with hip OA were included, submitted to a ceramic-on-polyethylene hip prosthesis, compared with a metal-on-polyethylene hip prosthesis, using a 22.25-mm femoral head. The outcome evaluated include linear wear rate in mm/year by radiographs. The follow-up time was 48 months.

Bergvinsson et al.[27]

A total of 50 patients with a mean age of 60 years and a mean body mass index (BMI) of 27 with primary hip OA were randomized, comparing ceramic-on-polyethylene hip prosthesis versus metal-on-polyethylene, using a 32-mm head. The outcomes evaluated were linear wear in mm/year, reviews, and hip disability and osteoarthritis outcome score. The follow-up time was 60 months.

Kayani et al.[28]

This was a multicenter study including 401 patients aged over 18 years with degenerative/erosive disease due to hip OA, avascular necrosis, or rheumatoid arthritis undergoing THA. Prostheses with a 32-mm head, composed of metal-on-polyethylene versus ceramic-on-polyethylene, were compared. The outcomes of surgical review, linear wear in mm/year, and clinical outcome by the Western Ontario and McMaster Univ rsities Arthritis index were analyzed. The follow-up time was 120 months.

Analysis of results by outcome

In the evaluation of linear wear (mm/year) between cross-linked ceramic polyethylene (XLPE) and metal XLPE, nine studies were included, with 448 patients in the ceramic XLPE group (intervention) and 443 patients in the metal XLPE group (control). Only one test had a lower wear result favorable to ceramic polyethylene[3].

Ceramic XLPE reduces annual wear measured in mm/year compared to metal XLPE. However, this reduction is less than five thousandths of mm/year (Figure 2). The quality of available evidence is moderate (Table 2).

In the evaluation of linear wear (mm/year) between ultra-high-molecular weight ceramic polyethylene (UHMWPE) and metal UHMWPE, three studies were included, with 67 patients in the ceramic UHMWPE group and 71 patients in the metal UHMWPE group.

There is no difference in wear measured in mm/year when comparing ceramic UHMWPE and metal UHMWPE prostheses (Figure 3). The quality of available evidence is moderate (Table 2).

In the evaluation of surgical reviews of THA between ceramic XLPE and metal XLPE, seven studies were included, with 400 patients in the ceramic XLPE group and 400 patients in the metal XLPE group.

In surgical reviews of THA with a follow-up of more than 60 months, when comparing the use of ceramic XLPE and metal XLPE hip prostheses, there is no difference in the number of procedures (Figure 4). The available evidence is of low quality (Table 2).

In the evaluation of the femoral head subgroup with a size ranging from 22 to 32 mm between ceramic XLPE and metal XLPE, in the linear wear outcome nine studies were included, with 518 patients in the ceramic XLPE group and 536 patients in the metal XLPE group.

Evaluating the subgroup of femoral stem heads with different measures 22, 26, 28, and 32 mm) in hip arthroplasty, there is no evidence of difference between ceramic XLPE and metal XLPE (Figure 5). The quality of available evidence is very low (Table 2).

Harris Hip Score

In the clinical evaluation of the HHS, there is a maximum score of 100 points, assessing pain, function, deformity, and range of motion, with pain and function having a greater weight. Five studies were included, with 147 patients in the ceramic XLPE group and 155 patients in the metal XLPE group.

In hip arthroplasty clinical reviews evaluated by the HHS, there is a difference in score favoring metal XLPE, when compared to ceramic XLPE (Figure 6). The available evidence is of very low quality (Table 2).

	CERA XLPE			METAL XLPE				Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Fixed, 95% CI
Bergvinsson 2020	0.26	0.22	25	0.23	0.13	25	0.0%	0.03 [−0.07, 0.13]
Ise (B) 2009	0.059	0.027	23	0.068	0.039	20	1.2%	−0.01 [−0.03, 0.01]
Ise 2009	0.067	0.044	25	0.068	0.039	20	0.8%	−0.00 [−0.03, 0.02]
Jassim 2015	0.023	0.01	121	0.028	0.01	123	78.2%	−0.01 [−0.01, −0.00]
Jonsson 2015	0.01	0.01	18	0.02	3	22	0.0%	−0.01 [−1.26, 1.24]
Kawate 2009	0	0.03	32	0.01	0.03	30	2.2%	−0.01 [−0.02, 0.00]
Kayani 2022	0.022	0.05	135	0.031	0.07	133	2.3%	−0.01 [−0.02, 0.01]
Morison 2014	0.061	0.038	22	0.076	0.045	23	0.8%	−0.01 [−0.04, 0.01]
Nakahara 2014	0.03	0.014	47	0.029	0.015	47	14.3%	0.00 [−0.00, 0.01]
Total (95% CI)			**448**			**443**	**100.0%**	**−0.00 [−0.01, −0.00]**

Heterogeneity: $Chi^2 = 5.85$, $df = 8$ ($P = 0.66$); $I^2 = 0\%$
Test for overall effect: $Z = 3.91$ ($P < 0.0001$)

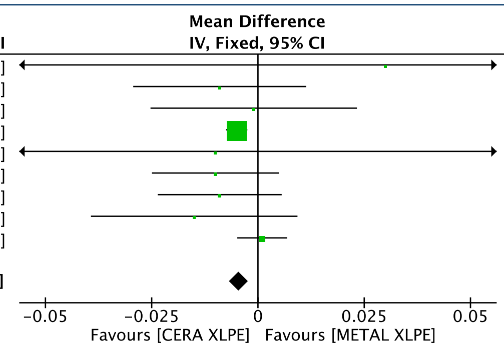

Figure 2. Forest plot of the ceramic XLPE vs. metal XLPE comparison analyzing wear outcome in mm/year.

	CERA UHMWPE			METAL UHMWPE				Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Fixed, 95% CI
Bergvinsson 2020	0	0	0	0	0	0		Not estimable
Jonsson 2015	0.2	0.09	21	0.18	0.1	25	57.4%	0.02 [−0.03, 0.07]
Morison 2014	0.24	0.11	21	0.24	0.14	21	29.9%	0.00 [−0.08, 0.08]
Zaoui 2015	0.078	0.21	25	0.14	0.21	25	12.8%	−0.06 [−0.18, 0.05]
Total (95% CI)			**67**			**71**	**100.0%**	**0.00 [−0.04, 0.05]**

Heterogeneity: $Chi^2 = 1.57$, $df = 2$ ($P = 0.46$); $I^2 = 0\%$
Test for overall effect: $Z = 0.17$ ($P = 0.87$)

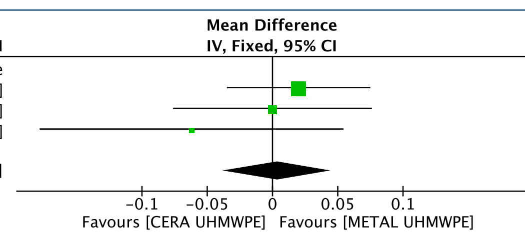

Figure 3. Forest plot of the ceramic UHMWPE vs. metal UHMWPE comparison analyzing wear outcome mm/year.

	CERA XLPE		METAL XLPE			Risk Difference
Study or Subgroup	Events	Total	Events	Total	Weight	M-H, Fixed, 95% CI
Bergvinsson 2020	0	25	0	25	6.3%	0.00 [−0.07, 0.07]
Bjorgul 2013	1	111	3	115	28.2%	−0.02 [−0.05, 0.02]
Kadar 2011	0	30	0	30	7.5%	0.00 [−0.06, 0.06]
Kawate 2009	0	31	0	29	7.5%	0.00 [−0.06, 0.06]
Kayani 2022	0	135	0	133	33.5%	0.00 [−0.01, 0.01]
Morison 2014	1	21	2	21	5.3%	−0.05 [−0.20, 0.11]
Nakahara 2014	0	47	0	47	11.8%	0.00 [−0.04, 0.04]
Total (95% CI)		**400**		**400**	**100.0%**	**−0.01 [−0.02, 0.01]**
Total events	2		5			

Heterogeneity: $Chi^2 = 1.82$, $df = 6$ ($P = 0.94$); $I^2 = 0\%$
Test for overall effect: $Z = 0.86$ ($P = 0.39$)

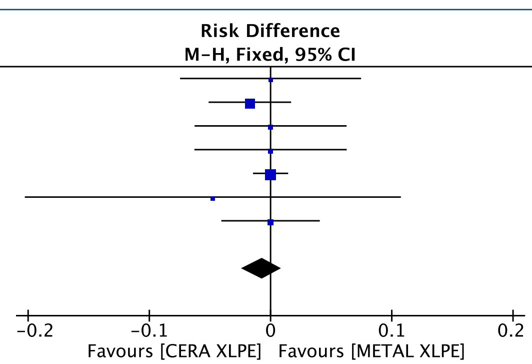

Figure 4. Forest plot of the ceramic XLPE vs. metal XLPE comparison analyzing the outcome reviews.

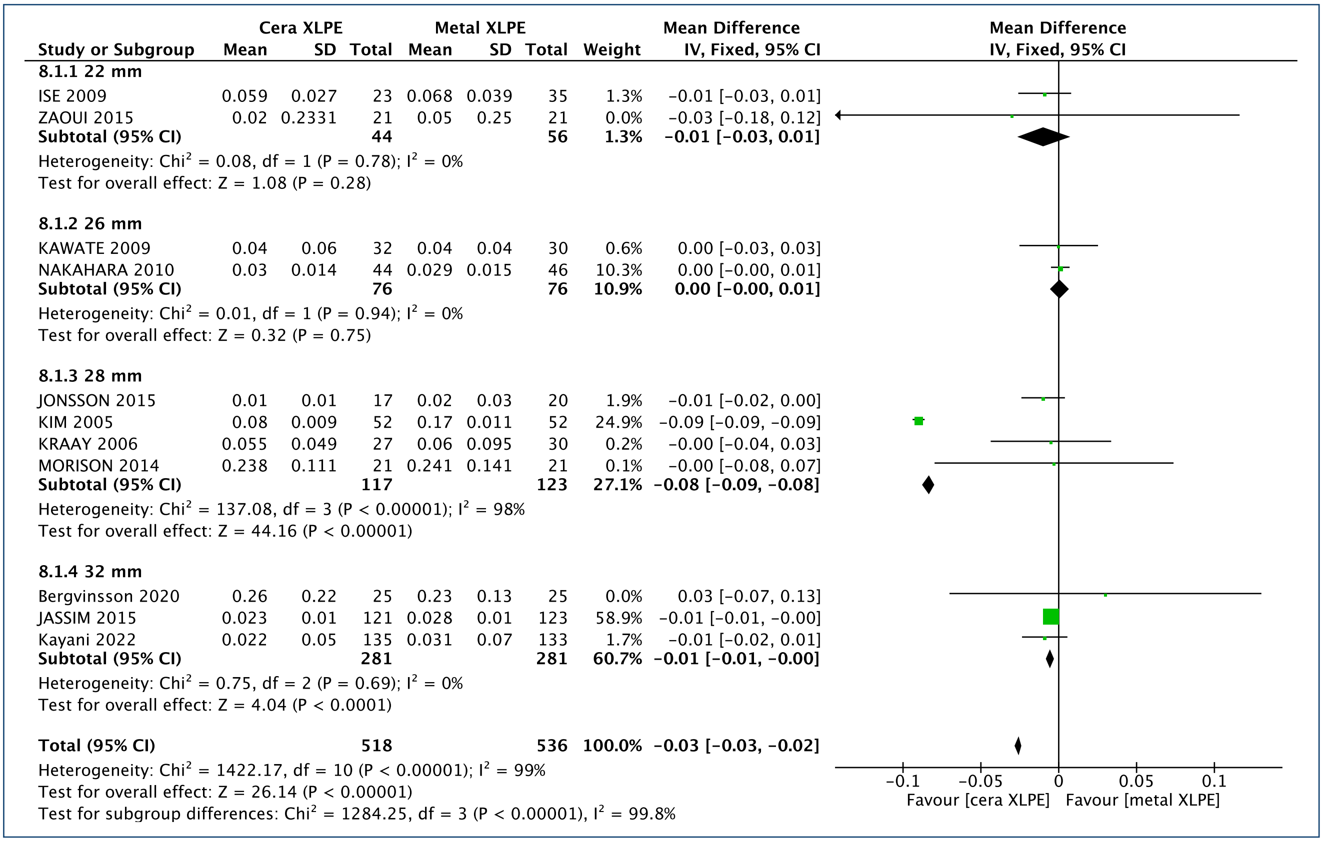

Figure 5. Forest plot of the ceramic XLPE vs. metal XLPE comparison analyzing a subgroup of femoral head size in the linear wear outcome.

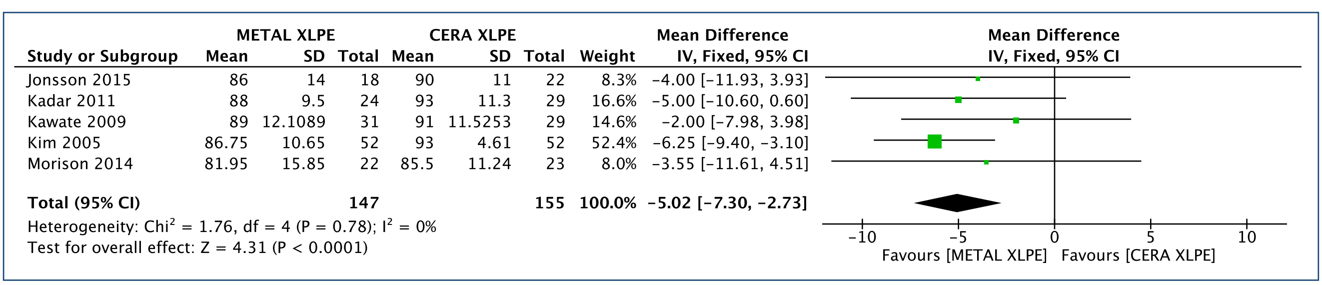

Figure 6. Forest plot of the ceramic XLPE vs. metal XLPE comparison analyzing hip arthroplasty clinical reviews evaluated by the HHS.

DISCUSSION

THA is an orthopedic procedure that has become increasingly common in Brazil, mainly due to the increase in life expectancy and the expansion in the performance of this surgery in younger and more active patients. In view of this, the search for data on durability has become increasingly frequent due to the emergence of new materials.

The main reason for THA failure is wear of the bearing surface and the resulting osteolysis induced by this wear, which can cause loosening and implant failure. Therefore, modern materials with better wear characteristics such as metal, ceramic, and high cross-linked polyethylene are now being used in THAs around the world.

Dumbleton et al.[29] reported that the incidence of osteolysis increases with a higher linear wear rate. *The literature suggests that osteolysis is infrequent when the wear rate is less than 0.1 mm/year and almost absent when the wear rate is less than 0.05 mm/year*[29]. Jassim et al.[18] found that the linear wear difference was 0.005 mm/year, while Kaiany et al.[28] found it to be 0.009 mm/year, favorable to ceramic XLPE components.

Similarly, the structural analysis performed in the literature also shows the absence of evidence of benefit of the ceramic XLPE prosthesis over the reference prosthesis (metal XLPE) for the surgical review rate and HHS outcomes. Although there is a proven statistical difference in the radiological evaluation of wear, this is not demonstrated in numbers on the clinical reality of the patients analyzed, as in the follow-up period of 24–84 months, there was no difference found in the evaluation of the surgical reviews or in the postoperative clinical framework that this greater wear could provide.

Gosling et al.[5] and López-López et al.[7] showed results that are similar to those presented here.

The linear wear data analyzed in the RCTs of Jassim et al.[18], Jonsson et al.[19], Morrison et al.[24], and Zaoui et al.[26], comparing the acetabular components (XLPE vs. UHMWPE) on ceramic and metal surfaces did not demonstrate the superiority of ceramic to metal surfaces. However, when evaluating the wear within the same surface, whether ceramic or metal, we found a better performance of XLPE compared to UHMWPE.

The historical facts show that THA has increasingly prioritized the use of larger femoral heads, as they approximate the natural size of native femoral heads and provide the possibility of a lower rate of dislocations, to the detriment of the initial idea that smaller heads produce less wear.

Tsikandylakis et al.[30] concluded that the risk of surgical review due to dislocation is lower in femoral heads of 36 mm or more and volumetric wear together with frictional torque are greater in femoral heads greater than 32 mm. In addition, long-term survival is higher in femoral heads of 32 mm, especially when associated with the tribological pair of metal XLPE. In linear wear data in subgroups of femoral stem heads with different measures (22, 26, 28, and 32 mm) in hip arthroplasty, there is no evidence of difference between ceramic XLPE and metal XLPE.

The quality of evidence for the linear wear outcome is moderate (for both acetabular materials) due to the risk of severe bias (no blinding and no intention-to-treat analysis).

The outcome of surgical reviews is considered low due to the risk of bias (absence of blinding and analysis by intention to treat) and serious imprecision (long confidence interval).

In the HHS outcome, the evidence is of very low quality due to the risk of very severe bias (no blinding, intention-to-treat analysis, or sample size calculation) and severe imprecision (long confidence interval).

The quality of the femoral head outcome is also very low due to the risk of very severe bias (no blinding, no intention-to-treat analysis, and sample calculation), very severe inconsistency and indirect evidence (high heterogeneity), and high imprecision (long confidence interval).

SUMMARY OF THE EVIDENCE

Comparing ceramic and metal surfaces in THAs for OA, we identified a statistical difference in the outcome of linear wear in patients who used the XLPE acetabular component, in favor of the ceramic surface. This evidence is of moderate quality. However, the amplitude of this effect is very small, almost negligible.

In the evaluation of linear wear, changing the acetabular component to the UHMWPE, there is no difference between the analyzed surfaces. This evidence is of moderate quality.

For the outcome of surgical reviews, no statistical differences were found and the quality of evidence is low.

In the HHS outcome, there was a difference in favor of the metal XLPE prosthesis in relation to the ceramic XLPE prosthesis, but with very low quality of evidence.

There is no evidence that less radiological wear of the ceramic XLPE surface can result in fewer surgical reviews and a better postoperative clinical evaluation.

CONCLUSION

Considering the linear wear, reviews, and clinical outcomes (HHS), there is no evidence in this evaluation demonstrating that ceramic XLPE prostheses are more effective than metal XLPE prostheses in THAs. Therefore, the higher cost of ceramics is not justified.

AUTHORS' CONTRIBUTIONS

IAZS: Data curation, Formal Analysis, Writing – original draft, Writing – review & editing. **AA:** Data curation, Formal Analysis, Writing – original draft, Writing – review & editing. **AU:** Data curation, Formal Analysis, Writing – original draft, Writing – review & editing. **HK:** Data curation, Formal Analysis, Writing – original draft, Writing – review & editing. **GT:** Writing – review & editing. **MMN:** Data curation, Formal Analysis, Writing – original draft, Writing – review & editing. **MA:** Data curation, Formal Analysis, Writing – original draft, Writing – review & editing. **OST:** Data curation, Formal Analysis, Writing – original draft, Writing – review & editing. **PO:** Data curation, Formal Analysis, Writing – original draft, Writing – review & editing. **WMB:** Data curation, Formal Analysis, Writing – original draft, Writing – review & editing.

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