Ceramic-on-Ceramic Versus Ceramic-on-Polyethylene Bearing Surfaces in Total Hip Arthroplasty

DONGCAI HU, MD; XIAO YANG, MM; YANG TAN, MD; MOHAMMED ALAIDAROS, MM; LIAOBIN CHEN, MD, PhD

The choice between ceramic-on-ceramic (COC) and ceramic-on-polyethylene (COP) in primary total hip arthroplasty (THA) remains controversial. The purpose of this study was to evaluate the reliability and durability of COC vs COP bearing surfaces in THA. Based on published randomized, controlled trials (RCTs) identified in PubMed, Embase, and the Cochrane Central Register of Controlled Trials, the authors performed a meta-analysis comparing the clinical and radiographic outcomes of COC with those of COP. Two investigators independently selected the studies and extracted the data. The methodological quality of each RCT was assessed using the Physiotherapy Evidence Database (PEDro) scale. Relative risks and 95% confidence intervals from each trial were pooled using random-effects or fixed-effects models depending on the heterogeneity of the included studies. Nine RCTs involving 1575 patients (1747 hips) met the predetermined inclusion criteria. Eight of 9 included RCTs had high methodological quality. The heterogeneity was not significant, and all the results were pooled using a fixed-effects model. The results demonstrated that COC significantly increased the risks of squeaking and total implant fracture compared with COP. No significant differences with respect to revision, osteolysis and radiolucent lines, loosening, dislocation, and deep infection were observed between the COC and COP bearing surfaces. This meta-analysis resulted in no sufficient evidence to identify any clinical or radiographic advantage of COC vs COP bearing surfaces in the short- to mid-term follow-up period. Long-term follow-up is required for further evaluation. [Orthopedics. 2015; 38(4):e331-e338.]

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Total hip arthroplasty (THA) has become a common treatment for end-stage hip joint diseases. With advancing implant designs and surgical techniques used in THA, bearing surface wear and the resultant wear-induced osteolysis have become the major limitations for long-term prosthesis survivorship, especially in young, active patients.\(^1,2\) The conventional metal-on-polyethylene (MOP) bearing surfaces generate particulate debris over time, potentially leading to osteolysis and implant failure.\(^1,3\)

Alternative bearing surfaces for THA have been developed in an attempt to reduce wear and improve implant longevity. Ceramic bearing surfaces are now available. It has been reported that ceramic-on-polyethylene (COP) significantly reduced the polyethylene wear rate compared with MOP, but polyethylene wear and the resulting debris cannot be ignored.\(^4,5\) Replacing the polyethylene liner with ceramic seems to be an ideal option, especially in young, active patients. Ceramic-on-ceramic (COC) bearing surfaces were developed to reduce wear debris. They have the mechanical advantages of wear debris reduction and reduction of subsequent debris-induced osteolysis. Despite a lower wear rate, concerns exist regarding the cost and adverse events, such as ceramic fractures and audible squeaking.\(^6,8\) Some randomized, controlled trials (RCTs) have been conducted comparing COC and COP THAs to determine the optimal bearing surface, but different studies reached different conclusions. The choice of the optimal bearing surface for THA remains controversial.\(^2,5,6,9-14\)

The goal of the current study was to evaluate the reliability and durability of COC vs COP bearing surfaces for THA.

**MATERIALS AND METHODS**

**Search Strategy**

The authors searched online databases, including PubMed, Embase, and the Cochrane Central Register of Controlled Trials, and the last search of the databases occurred on October 19, 2013. Search terms used were ceramic and polyethylene and total hip arthroplasty and random*.

**Eligibility Criteria**

Articles that met the following criteria were included in the study: (1) patients underwent primary THA; (2) study compared COC and COP bearing surfaces; (3) studies reported clinical or radiographic outcomes of THA (at least 1 desirable outcome); (4) studies were prospective RCTs; and (5) full text was published in English.

**Study Identification**

Two trained investigators (D.H., X.Y.) independently identified studies using the Physiotherapy Evidence Database (PEDro) scale,\(^15,16\) a widely used checklist that includes 11 criteria. Each item was scored “yes” or “no,” with a maximum score of 10 because the first item was not scored. Any trial with a score of 6 or more was considered high quality. Any conflicts were resolved by discussion with a third investigator (Y.T.).

**Data Extraction**

Two investigators (D.H., X.Y.) independently extracted the data. Any conflicts were resolved by discussion with a third investigator (Y.T.). The information retrieved from each study included the following items: demographic information and numbers of patients and hips allocated, revisions, cases of osteolysis and radiolucent lines, aseptic loosenings, intra- and postoperative implant fractures, cases of squeaking, dislocations, deep infections, and heterotopic ossifications. The authors planned to extract data on postoperative hip function outcomes between the COC and COP bearing surfaces, but the studies used different indexes or scales to assess these outcomes.
Therefore, the authors did not extract data regarding postoperative hip function outcomes.

**Statistical Analysis**

RevMan version 5.1 statistical software (The Nordic Cochrane Centre, The Cochrane Collaboration, Oxford, United Kingdom) was used for data analysis. For each study, relative risk (RR) and 95% confidence interval (CI) were calculated for dichotomous outcomes. The results of the RCTs were pooled using the Mantel-Haenszel fixed-effects model. A $P$ level less than .05 was considered significant. Heterogeneity between comparable studies was tested with the chi-square test and the $I^2$ test. A $P$ value greater than .1 and an $I^2$ value less than 50% were considered as no statistical heterogeneity.

**RESULTS**

**Literature Search**

Using the authors’ search strategy, 83 articles were identified: 44 from PubMed, 36 from Embase, and 3 from the Cochrane database (Figure 1). Of all the study titles and abstracts, 18 studies proved to be potentially eligible, so the full-text articles were reviewed. Eight of the 18 studies were excluded due to a lack of necessary data. One study was excluded because it did not coincide with the initial trial plan and lacked COP group data.17 Nine RCTs involving 1575 patients with 1747 hips met the inclusion criteria.

**Study Characteristics**

Characteristics of the 9 studies are presented in Table 1. Follow-up time of all included studies ranged from 1 to 10 years (short- to mid-term follow-up), and 4 studies had follow-up times of more than 5 years.3,10,11,12 Four studies were sponsored by companies (Smith & Nephew, Stryker, DePuy, and Biomet). In 4 studies, patients were limited to those younger than 61 years.6,9,11
Study Quality
The methodological quality of the included RCTs was assessed using the PEDro scale. The results showed that 8 RCTs had high methodological quality and 1 trial had low quality. All studies used the randomized method. Four studies used concealed allocation (Table 2).

Revision
All 9 studies provided detailed information regarding revisions. Figure 2 shows the results of the pooled statistical analyses. No significant difference was found in the THA revision rates of the COC and COP groups (2.7% vs 2.8%, respectively; RR=0.95; 95% CI, 0.54-1.68; P=.85; homogeneity, P=.56).

Loosening
The results of 6 studies (1099 hips) revealed no significant difference in the loosening rate between the COC and COP bearing surfaces (1.8% vs 1.0%, respectively; RR=1.55; 95% CI, 0.59-4.07; P=.38; homogeneity, P=.76) (Figure 4).

Osteolysis and Radiolucent Lines
A pooled analysis of 7 studies (1155 hips) revealed no significant difference in the incidence of osteolysis and radiolucent lines in the COC and COP groups (0.3% vs 1.2%, respectively; RR=0.43; 95% CI, 0.11-1.68; P=.22; homogeneity, P=.80) (Figure 3).

Squeaking
Five studies (1033 hips) provided detailed information regarding squeaking. A pooled analysis of these studies revealed that COC bearing surfaces significantly increased the risk of squeaking compared with COP bearing surfaces (1.9% vs 0%, respectively; RR=8.07; 95% CI, 1.46-44.49; P=.02; homogeneity, P=.96) (Figure 5).

Intra- and Postoperative Implant Fracture
A pooled analysis of 4 studies (1234 hips) revealed no significant difference in intraoperative implant fracture rate between the COC and COP groups (0.89% vs 0%, respectively; RR=3.25; 95% CI, 0.69-15.28; P=.14; homogeneity, P=.76) (Figure 6). A pooled analysis of 6 studies (1533 hips) revealed no significant difference in postoperative implant fracture rate between the COC and COP groups (0.85% vs 0%, respectively; RR=3.54; 95% CI, 0.77-16.33; P=.11; homogeneity, P=.98) (Figure 7). The total incidence of intra- and postoperative implant fractures in the COC group was statistically significantly higher (P=.02) than that of the COP group (Figure 8), indicating that COC increased the total implant fracture rate.

Dislocation
A forest plot of all 9 studies (1747 hips) indicated no significant difference in THA dislocation rates between the COC and COP groups (3.1% vs 4.0%, respectively; RR=0.77; 95% CI, 0.47-1.25; P=.29; homogeneity, P=.98) (Figure 9).

Other Complications
A pooled analysis of 6 studies revealed no significant difference in deep infection

Table 2
PEDro Scores of Included Studies

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<th>PEDro Criteriaa</th>
<th>Study</th>
<th>1</th>
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</table>

Abbreviations: N, no; PEDro, Physiotherapy Evidence Database; Y, yes.

aPEDro criteria: (1) eligibility criteria; (2) random allocation; (3) concealed allocation; (4) baseline comparability; (5) participant blinding; (6) therapist blinding; (7) assessor blinding; (8) >85% follow-up; (9) intention-to-treat analysis; (10) between-groups statistical comparison for at least 1 key outcome; (11) point estimates and variability measures for at least 1 key outcome.
rates between the COC and COP groups. A pooled analysis of the studies revealed no difference in the risk of deep infection, deep venous thrombosis, pulmonary embolus, heterotopic ossification, trochanteric bursitis, or leg-length discrepancy between the COC and COP groups (Table 3).

Potential publication biases were evaluated using funnel plots. The shapes of the funnel plots showed relative symmetry, and there was no obvious evidence of publication bias.

**Discussion**

Debate is ongoing regarding the optimal bearing surfaces for THA, especially in young patients. Young patients are expected to place higher demands on THAs because they are more active and have a longer life expectancy. Because of lower wear and osteolysis rates, ceramic bearing surfaces are increasingly used for THA, especially in young, active patients. Ceramic could be used as a hard-on-soft articulation with a polyethylene liner or as a hard-on-hard articulation with a ceramic liner. To the authors’ knowledge, this is the first published systematic review and meta-analysis of RCTs comparing THAs with COC and COP bearing surfaces. This meta-analysis included 9 RCTs, and the results showed that except for a lower squeaking rate for COP THA, there were similar results in the rates of revision, osteolysis and radiolucent lines, loosening, dislocations, intra- and postoperative implant fractures, deep infection, deep venous thrombosis, and pulmonary embolus between the COC and COP THA groups.

A major long-term complication of THA is aseptic loosening, which accounts for more than half of all revisions. Although the etiology of aseptic loosening is not clear, there is a general acceptance that aseptic osteolysis and subsequent implant failure occur because of a chronic inflammatory response to implant-derived wear particles. A postoperative radiographic analysis demonstrated that the mean linear wear rate in a COC THA was statistically lower than that in a COP THA. Lombardi et al reported decreased rates of wear, osteolysis, and aseptic loosening with COC bearing surfaces. In the current meta-analysis, no significant differences...
were found regarding the rates of osteolysis, loosening, and revision between the 2 types of bearing surfaces in the short- and mid-term follow-up.

Squeaking is a recognized complication of THA with COC bearing surfaces, but squeaking is not unique to ceramic bearings. Squeaking has also been reported with metal-on-metal THA. Squeaking could be intolerable enough for some patients to seek revision THA. The reported incidence of squeaking after COC THA varies between 0.3% and 20.9%. The squeaking rate in the current study was 1.9%, which is consistent with the reported rate in the literature. In the current meta-analysis, squeaking was found to occur in only the COC group. There were no cases of squeaking in the COP group. This difference was significant. The etiology of squeaking in COC THA is unclear, but it is thought to be multifactorial, involving the patient, surgical technique, and implant factors. Possible mechanisms include microseparation associated with impingement, stripe wear, edge loading, and cup malposition. Squeaking can be avoided to some degree, especially that caused by surgical technique errors. It can be prevented through medialization of the acetabular cup and avoidance of the use of shortened femoral necks, which may result in neck impingement.

Although the current meta-analysis showed no statistically significant difference in intra- and postoperative implant fracture rates between the COC and COP groups, all of the reported intra- and postoperative implant fractures occurred in the COC group. The total incidence of intra- and postoperative implant fractures in the COC group was higher than that in the COP group. Ceramic is a brittle material. Ceramic liner fractures typically occur during the process of inserting the ceramic liner into the metal acetabular cup due to improperly seated liners or cup deformation, which could result from tapping the edge of the cup in an attempt to adjust its position, especially when impacting the cup into hard bone. The insertion of a ceramic liner requires great attention and precision. Because the COC is a type of hard-on-hard bearing surface and the COP is a type of hard-on-soft bearing surface, postoperative implant fractures are theoretically more likely to occur in COC THAs. The nonsignificant difference may be due to the low incidence of postoperative implant fractures. A ceramic liner fracture is generally a subtle and underestimated event and is not directly related to trauma. The occurrence of ceramic fracture is reported to occur in between 0.013% and 3.7% of patients who have undergone a COC THA. The current authors’ results showed an occurrence of 0.85%, which coincides with results in the literature. Despite the improvement in materials manufacturing, ceramic brittleness remains a major concern. Other causes of postoperative implant fracture include impingement during extremes of range of motion or sudden high-impact loading.
It is possible that dislocations are related to the head size rather than to the bearing surfaces used. Studies have shown that large-diameter femoral heads have a lower dislocation rate. In the current meta-analysis, 69% of patients in the COC group received a larger femoral head than did patients in the COP group. However, the meta-analysis revealed no significant difference in dislocation rates between the groups.

The authors included RCTs with high quality, but the meta-analysis has several limitations. First, the follow-up period of the 9 included RCTs ranged from 1 to 10 years, and all of the follow-up periods were less than 10 years. This time period is far below the implant life expectancy and too short to form a conclusive decision regarding the implant longevity of these 2 types of bearing surfaces, especially in young, active patients. A retrospective study reported that a minimal wear rate and limited osteolysis could be expected up to 20 years postoperatively in cases of COC THA. Further follow-up is required for long-term (more than 10 years) observation. Second, the meta-analysis extracted adverse outcomes only and lacked postoperative hip function outcomes. This analysis is insufficient for evaluating the clinical performance of these 2 types of bearing surfaces. Third, the meta-analysis was limited to articles published in English. This may result in potential publication and language bias. Fourth, different ceramic or polyethylene materials were used in the different studies. These may be confounding factors in this meta-analysis.

**CONCLUSION**

This meta-analysis of RCTs suggests that COC bearing surfaces significantly increase the risks of squeaking and total implant fracture compared with COP bearing surfaces in THA. Similar results were found in the incidences of revision, osteolysis and radiolucent lines, loosening, dislocation, and deep infection between the COC and COP THA groups in the short- to mid-term follow-up period. Long-term follow-up is required for further evaluation.

**REFERENCES**


**Table 3**

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*Abbreviations: COC, ceramic-on-ceramic; COP, ceramic-on-polyethylene; DVT, deep venous thrombosis.*
135.