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Causes of Failure of Ceramic-on-Ceramic and Metal-on-Metal Hip Arthroplasties

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Abstract

Background Few large series of hard bearing surfaces have reported on reasons for early failure. A number of unique mechanisms of failure, including fracture, squeaking, and adverse tissue reactions, have been reported with these hard bearing surfaces. However, the incidence varies among the published studies.

Questions/purposes To confirm the incidences, we identified the etiologies of early failures of hard-on-hard bearing surfaces for ceramic-on-ceramic and metal-on-metal THAs.

Methods We retrospectively reviewed records of 2907 THAs with hard-on-hard bearing surfaces implanted between 1996 and 2009; 1697 (58%) had ceramic-on-ceramic and 1210 (42%) had metal-on-metal bearing surfaces. We recorded bearing-related complications and compared them to nonspecific reasons for revision THA. The minimum followup of the ceramic-on-ceramic and

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metal-on-metal cohorts was 6 months (mean, 48 months; range, 6–97 months) and 24 months (mean, 60 months; range, 24–178 months), respectively.

Results The overall revision rate for ceramic-on-ceramic THA was 2.2% (38 of 1697), with aseptic loosening accounting for 55% of revisions (femur or acetabulum). The bearing accounted for 13% of the revisions in the ceramic-on-ceramic THA cohort. The overall metal-on-metal revision rate was 5.4% (65 of 1210), 17 involving adverse tissue reactions related to the metal-on-metal bearing surface (17 of 1210, 1.4% of cases; 17 of 65, 26% of revisions).

Conclusions Twenty-six percent of the revisions from metal-on-metal and 13% of ceramic-on ceramic were bearing related. The overall short- to medium-term revision rate was 2.2% and 5.4% for ceramic-on-ceramic and metal-on-metal, respectively. The most common etiology of failure was loosening of the femoral or acetabular components.

Level of Evidence Level IV, therapeutic study. See the Guidelines for Authors for a complete description of level of evidence.

Introduction

Hard-on-hard bearings (metal-on-metal [MOM] and ceramic-on-ceramic [COC]) have been increasingly utilized in the past decade in an attempt to improve the long-term results of THA [1]. One presumed advantage is lower wear rate and debris generation from the articulating surface. Wear rates of MOM and COC hip prostheses reportedly have two to three times less volumetric wear than metal-on-polyethylene (MOP) when tested in laboratory settings [5]. MOM articulations allow for larger head-neck ratios than current options for MOP, which allows for a larger ROM before impingement and stability [31]. Recent studies demonstrated larger-diameter metal heads decreased dislocation rates to as low as 0.05% and were able to better approximate anatomic femoral heads in primary arthroplasty [21], while other studies found a higher rate of revision for dislocation, up to 0.8% in hard-on-hard THA, particularly with the use of smaller head sizes [26].

Both hard-on-hard bearing options were developed and used before the short- to medium-term results of highly crosslinked polyethylene were reported. The wear rate of highly crosslinked polyethylene is 23%–95% lower than conventional polyethylene [3, 4, 13], even for thinner liners, allowing for use of larger femoral heads, neutralizing the purported advantages of the hard bearings to a degree. However, these data emerged over time, as hard bearings became available in the marketplace and grew rapidly, peaking to about 40% use during THA by 2006 [1].

Since then, concerns with use of hard-on-hard bearing surfaces in THA have steadily increased [2] due to unique complications reported with varying frequency. For ceramics, the major unique complications are fracture and noise generation (squeaking). For metals, the major concerns are adverse tissue reactions of various descriptions and, to a lesser degree, failure of ingrowth or early loosening of components. Various authors reported the frequency of fracture of contemporary devices between 0.004% and 0.19% [27, 30, 31] and squeaking between 1% and 21% [3, 16, 28]. The incidence of major tissue reactions is unknown currently, but some believe it to be around 1% or less [2] and that of early loosening to be between 1% and 6% [11]. However, the incidence of these complications leading to revision arthroplasty is not well established by prior literature.

We therefore determined (1) the rates of revision for current COC and MOM THA and (2) the reasons for revision compared to published reports.

Patients and Methods

We retrospectively reviewed 2869 patients who had 3346 THAs with hard-on-hard bearing surfaces implanted between January 1996 and March 2009; 1757 (53%) were COC components and 1589 (47%) were MOM components (Table 1). During that time, we treated 13,073 patients, between two institutions, with THA using all implants. The indications for the use of a hard-on-hard bearing surface were (1) patients with end-stage arthritis, (2) active patients, (3) patients younger than 60 years, and (4) patients at high risk for instability (MOM cohort). The contraindications for surgery were patients with (1) infection, (2) severe bone loss, (3) compromised soft tissue envelope, (4) neurovascular deficiency, and (5) preexisting conditions prohibiting induction of anesthesia. The average age of the patients in the COC cohort was 50 years (range, 15–80 years), with 1017 patients (60%) being men. The mean height and weight of this cohort were 1.7 m (range, 1.2–2.2 m) and 100 kg (range, 37.2–214.5 kg), respectively. The average age of the patients in the MOM cohort was 58 years (range, 19–89 years), with 628 (52%) patients being men. The mean height and weight in this cohort were 1.7 m (range, 1.2–1.9 m) and 92.5 kg (range, 45.5–205 kg), respectively. No patients were recalled specifically for this study; all data were obtained from medical records and radiographs. We had prior Institutional Review Board permission.

For the COC cohort, we used one of six different acetabular shell types between 2002 and 2009, with the two most common types being Trident® PSL® (806 of 1757 patients, 45%) and Trident® Hemispherical® (692

Table 1. Summary of results of COC and MOM THA

Demographic variable	COC	Revised	Nonrevised	p value	MOM	Revised	Nonrevised	p value
Total number of THAs	1757				1589			
MOM Group 1					351	12	339	< 0.001
MOM Group 2					750	41	709	< 0.001
MOM Group 3					488	12	476	0.166
Number of THAs with followup	1697 (98%)				1210 (76%)			
Male	1017	23	994	0.939	628	17	611	
Female	680	15	665		582	48	534	< 0.001
Age (years)	50	45	50	0.001	58	56	58	0.206
Height (m)	1.7	1.7	1.7	0.773	1.7	1.7	1.7	0.009
Weight (kg)	100	97.5	85.6	0.027	92.5	89.9	92.7	0.355
BMI (kg/m^2)	35	31.8	28.4	0.016	31.4	31.9	31.3	0.575

COM = ceramic-on-ceramic; MOM = metal-on-metal.

of 1757, 39%) (Stryker Orthopaedics, Mahwah, NJ, USA). Between 2002 and 2009, we used 10 types of femoral stems, with the most common being Accolade® (1338 of 1757 patients, 76%) (Stryker Orthopaedics). Femoral head sizes ranged from 28 to 36 mm. Minimum followup was 6 months (mean, 50.4 months; range, 6–96 months) in the COC cohort, with 1697 records (97%) available. Six different surgeons performed the procedures, each utilizing a modified Hardinge approach [10] while the patient was in a supine position. Patients in the COC cohort returned for followup visits at 6 weeks, 6 months, and 1 year. Afterwards, we followed up with patients at either 1- or 2-year intervals to assess for component failure. At each postoperative visit, the surgeons evaluated patients and obtained radiographs. Sixty patients from the COC cohort were lost to followup at an average of 65 days (range, 0–179 days).

Between 1996 and 2006, the surgeons at one center performed 1589 MOM primary THAs, of which a minimum 2-year followup (mean, 60.2 months; range, 24–178 months) was available for 1210 (76%). The surgeons utilized three systems of acetabular construct: a modular titanium shell with a CoCr insert and a 28- or 32-mm inner diameter (351 patients, 22%), a CoCr monoblock shell of increasing thickness mated with a 38-mm CoCr head (750, 47%), and a solid "resurfacing style" CoCr monoblock thin (3-mm) shell with anatomic heads of increasing diameter (40–60 mm) (488, 31%). Four surgeons performed the procedures, all utilizing a modified direct lateral approach (modified Hardinge) with the patient in the lateral decubitus position. Patients were followed at 6 weeks and then seen yearly thereafter. At each postoperative visit, the surgeons evaluated patients and obtained radiographs. Three hundred seventy-nine patients from the MOM cohort were lost to followup at an average of 234 days (range, 3–690 days). From the medical records, we determined whether the patient had a revision and those lost to followup.

We used a two-tailed unpaired t-test to assess differences in continuous variables (age, height, weight, BMI) and a two-tailed Fisher exact test to determine differences in sex proportions between revised and unrevised hips. We used a univariate regression analysis for the MOM design type data. We analyzed all data using SPSS® (SPSS Inc, Chicago, IL, USA).

Results

Of 1697 patients with COC THAs, 38 (2.2%) had revision THA (Table 1). The mean age of these 38 patients was 45 years, which was younger ($p = 0.001$) than the rest of the cohort at a mean of 50 years. There was no difference ($p = 0.939$) between the percent of men (23 of 38, 61%) and women (15 of 38, 39%) in the COC revision group. The average weight (97.5 kg) ($p = 0.027$) and BMI (31.8 kg/m^2) ($p = 0.016$) were higher in the revision group. The most common reason for revision was aseptic loosening (Table 2). The stem was loose in 10 patients, the cup in eight, and both in three, with an overall failure of fixation rate of 1.2% or 55% of the revisions (21 of 38). Five cases (0.2% overall; 13% of revisions) were perceived to be related to the bearing surface or design of the components (squeaking, four; fracture, one), and 10 cases were revised for impingement and/or subluxation potentially attributable to surgeon-related positioning of the components (impingement, subluxation; 0.6% overall, 26% of revisions). Average time to revision was 25.7 months.

Sixty-five of the 1210 MOM THAs (5.4%) underwent revision (Table 1), of which 17 were due to adverse tissue reactions related to the MOM implant (17 of 1210, 1.4% of cases overall; 17 of 65, 26% of revisions) (Table 3). The

Table 2. Reported survival rates and complications of ceramic-on-ceramic THA

Study	Number of hips	Followup (months)*	Survival (%)	Level of evidence	Reported complications
Lombardi et al. [20]	65	73 (26–108)	95	II	Aseptic loosening (1); fracture (1); infection (1)
Hamilton et al. [9]	177	31 (21–49)	98	I	Aseptic Loosening (2); dislocation (2); fracture (1); infection (3)
Petsatodis et al. [25]	85	252	84	IV	Aseptic loosening of cup (6); aseptic loosening of stem (1)
Lee et al. [18]	88	130 (120–142)	97	IV	Fracture (2); noise/squeak (13); impingement/fretting (6); periprosthetic fracture (1); dislocation (1)
Lewis et al. [19]	56	100 (58–121)	97	I	Dislocation (1); pain unknown (1)
Capello et al. [3]	380	96	96	I	Fracture (2); squeak (3); psoas tendinitis (1); infection (3); periprosthetic fracture (1); aseptic loosening (1)
Iwakiri et al. [12]	82	80 (60–100)	91	IV	Fracture (3); dissociation (1); infection (2); dislocation (1); fretting/impingement (1)
Current study	1697	50 (6–96)	98	IV	Infection (1); aseptic loosening of cup (8); aseptic loosening of femur (10); aseptic loosening of both cup and femur (3); squeaking (4); fracture (1); liner (impingement, subluxation, wear) (11)

* Values are expressed as mean, with range in parentheses.

Table 3. Reported survival rates and complications of metal-on-metal THA

Study	Number of hips	Followup (months)*	Survival (%)	Level of evidence	Reported complications
Dastane et al. [6]	112	66 (26–140)	99	III	Aseptic loosening (1); dislocation (2); impingement (2); dissociation (1); periprosthetic fracture (1)
Jacobs et al. [15]	95	40 (36–68)	99	I	Dislocation (1); aseptic loosening (1)
Neumann et al. [24]	100	126 (120–143)	94	IV	Aseptic loosening (4); periprosthetic fracture (1); mechanical failure (1)
Korovessis et al. [17]	217	77 (6–112)	93	IV	Aseptic loosening (10); infection (3); dislocation (1)
Milosev et al. [23]	640	85 (28–126)	93	IV	Infection (6); aseptic loosening (25); dislocation (1); fracture (1); dissociation (1)
Dorr et al. [7]	70	60 (48–84)	98	IV	Aseptic loosening (1); dislocation (2); infection (1)
Current study	1215	60 (24–178)	95	IV	Infection (10); aseptic loosening (32); metallosis/hypersensitivity (17); dislocation (1); cup well fixed (5)

* Values are expressed as mean, with range in parentheses.

most common cause of revision was aseptic loosening, which occurred in 32 cases (32 of 1210, 2.6% overall; 32 of 64, 50% of revisions). The incidence of revision was higher in women ($p < 0.001$) and for the second type of component (38-mm inner diameter, solid, CoCr shell) ($p < 0.001$) (Table 1). In addition, the revision procedures were associated with substantial tissue damage, a compromised clinical result after revision, and a higher than expected revision rate.

Discussion

During the past decade, various studies have reported outcomes and survival of alternative bearing surfaces in THA [6, 7, 9, 12, 14, 15, 19, 20, 23–25]. Complications associated with the use of hard-on-hard bearings include squeaking, fracture, liner disassociation, metallosis, and hypersensitivity reactions occurring in some patients [14]. However, the incidence of these complications leading to revision arthroplasty is not well established by prior literature. We therefore determined (1) the rates of revision for current COC and MOM THA and (2) the reasons for revision compared to published reports.

This study had several limitations. First, our study population was from two joint arthroplasty centers and did not represent the general population, as hard-on-hard bearings are more likely to be used in younger patients who need THA. The surgeons most likely selected patients with high levels of activity to receive hard-on-hard bearings, the current indication for the use of these bearing surfaces. Thus, we could not match these patients for age and activity level with a cohort receiving other bearing surface to conduct a comparative analysis. Second, a variety of devices were utilized, including different femoral stems and acetabular components, as well as different varieties of COC and MOM bearing surfaces. Hence, the failure of THA in this cohort was due to a multitude of reasons, most of which related to prosthetic devices, and not all failures occurred because of the bearing surface. Third, many surgeons contributed patients, with the potential that each surgeon performed the procedure differently. We had no standard protocol for performing the THA and the use of hard-on-hard bearing surfaces. Fourth, despite having a digital database that minimizes errors in place at both institutions, the retrospective character of our study in which recollection of data may be inaccurate. Some of the patients in one or both institutions may have sought evaluation and treatment for possible complications elsewhere. Fifth, while the overall cohort was relatively large, the subcohorts were too small to perform a multivariable analysis to determine differences in the groups while controlling for potentially confounding variables.

A review of recent COC outcomes demonstrated survival rates of 84%–98% [9, 25] (Table 2). Our data support these findings with a survival rate of 98%. The etiologies for revision varied depending on the study and length of followup. In our analysis, the most common reason for revision THA was not bearing related, which was consistent with the previous studies reporting outcomes of COC THA. A review of recent literature reporting outcome of MOM THA demonstrated an overall survival rate between 93% and 99% [6, 23] (Table 3). The failure rate of MOM THA in our cohort (5%) was similar to these previous reports. The majority of the studies reported aseptic loosening as the most common cause of revision for the MOM THA, again consistent with the outcomes of our study [17, 23].

We found only 13% of failures of COC THA were potentially attributable to bearing surface, and the majority of failures in this cohort were acetabular or femoral component related. We found squeaking and fracture were the most common bearing surface-related complications. The etiology of impingement was not clear in all cases but believed to have occurred as a result of excessive anteversion of the acetabular component in patients with elevated ceramic acetabular liner. Impingement may be an important contributor to wear of any bearing surface if components are malpositioned and several recent articles have specifically discussed accelerated wear with the use of COC bearing surfaces [8, 29]. Hence, failure to recognize malpositioning of acetabular components could have accelerated failure for all bearings, despite improved wear rates of hard-on-hard compared to metal on polyethylene. The results from the MOM cohort demonstrated the use of the hard bearing surfaces attributed to 26% of revisions. The use of MOP could have helped to avoid adverse tissue reactions requiring revision surgery. Studies have reported failures with specific MOM designs, and surgeons should consider these before implantation and widespread use [22]. Despite the revisions attributed to hard-on-hard bearings, the data highlight the initial workup of a failed hard-on-hard bearing should mirror that of MOP. Infection, aseptic loosening, component malposition, and recurrent dislocation all are potential reasons for failure of THA and should be investigated before attributing the failure to the bearing surface alone.

Despite the complications due to the use of hard-on-hard bearing surfaces, the overall short-term revision rates in our study were 2.2% for COC and 5.4% for MOM. These rates were consistent with other studies documenting similar success with the use of alternative bearings [18, 31]. Our study retrospectively reviewed a combined 2869 patients who underwent hard-on-hard THA. We had 439 patients between both cohorts lost to followup.

We reviewed the complications and revisions associated with the use of hard-on-hard bearings, and despite documented, successful, short-term outcomes, we believe the data do not warrant the widespread use of alternative bearings and replacement of traditional MOP. Because of these results and other ongoing concerns, improvements in hard-on-hard bearing technology continues, and surgeons should reserve current implementation for as-yet-undefined patient populations in need of THA. Despite improvements in alternative bearing choices for THA, early failures due to impingement and wear can still result from technical error and malpositioning. Metal-on-highly crosslinked polyethylene has demonstrated encouraging results in short- to medium-term studies, although the long-term implications of free radicals using this bearing surface are still unknown. Which bearing surface demonstrates superior long-term outcomes has yet to be resolved, and thus more long-term studies are needed to formulate a decision. Surgeons should counsel possible candidates for alternative bearings on the potential complications associated with their use, including but not limited to squeaking, implant failure, and soft tissue reaction. Based on our findings, we believe surgeons should be guarded when considering the use of current MOM technology in female patients. It is our opinion that, as with many new advancements in technology, one should temper early aggressive enthusiasm and widespread implementation with review of long-term studies and scrutiny of complications that may arise with its use.

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