Ceramic-on-Ceramic Total Hip Arthroplasty

Incidence of Instability and Noise

David Schroder MD, Lindsey Bornstein BA,
Mathias P. G. Bostrom MD, Bryan J. Nestor MD,
Douglas E. Padgett MD, Geoffrey H. Westrich MD

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Abstract

Background Alternative bearing materials in THA have been developed to reduce the incidence of osteolysis. Alumina-on-alumina bearings exhibit extremely low wear rates in vitro, but concerns exist regarding component impingement with the potential for dislocation and the occurrence of noise.

Questions/purposes We determined generation of squeaking and the relationship between squeaking and component position.

Methods We prospectively entered 436 alumina-on-alumina, cementless, primary THAs in 364 patients into our institutional database. All procedures were performed with the same surgical technique and the same implant. We obtained Harris Hip scores and a noise questionnaire and assessed radiographic component position and loosening. We determined the difference in abduction angle between squeakers and nonsqueakers. Minimum followup was 2 years (average, 3.5 years; range, 2.0–6.2 years).

Results The mean Harris hip score increased from 51.9 preoperatively to 94.4 at latest followup. Six hips underwent reoperation: four hips (1.1%) for dislocation and two (0.53%) for periprosthetic fracture after trauma. The incidence of noise of any type was 11%, with the most common type of noise being clicking or snapping. Squeaking was reported by 1.9% of patients, with no patient being revised for this phenomenon. We found no association between component position and squeaking.

Conclusions At average 3 years followup, 98% of ceramic-on-ceramic THAs did not require a revision, with 1.1% of hips having been revised for dislocation. Fewer than 2% of patients reported hearing an audible squeak, with no association found between component position and squeaking.

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

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D. Schroder, L. Bornstein
Department of Orthopaedic Surgery, Hospital for Special Surgery, New York, NY, USA

M. P. G. Bostrom, B. J. Nestor, D. E. Padgett,
G. H. Westrich (✉)
Department of Orthopaedic Surgery, Hospital for Special Surgery, Weill Cornell Medical College, 535 East 70th Street, New York, NY 10021, USA
e-mail: westrichg@hss.edu

Introduction

Wear- and particle-driven osteolysis remain a major long-term failure mode of total joint arthroplasty [13]. Strategies to reduce wear have focused on improvements of the bearing surface, including the use of enhanced polyethylene and the introduction of alternative bearings such as metal-on-metal and ceramics. In vitro testing has confirmed ceramic-on-ceramic bearings have the lowest wear rates of all tested couples [26] and would seem best suited to the high-activity patient in whom long-term wear is a concern.

The use of ceramic bearings in THA was introduced in the 1970s [20]. The initial studies reported instances of bearing chipping and fractures [10, 20, 24]. Improvements in ceramic manufacturing, namely hot isostatic pressing,

resulted in decreased grain size and yielded a noticeable decrease in the rate of material fracture and chipping [24].

Early to intermediate clinical followup studies of 1–5 years with these newer ceramic bearings have reported low revision rates and few reports of wear, periprosthetic bone loss, or lysis [14, 15, 18, 19, 31]. Reported dislocation rates with ceramic bearings have been low (ie, 1.1% to 3%) [4, 7]. Some authors have reported problems unique to these hard-on-hard bearings, such as clicking and squeaking, as well as instances of chipping, despite these new manufacturing techniques for ceramics [14, 16, 19, 23, 28, 30]. However, few reports exist investigating the presence of squeaking during specific daily activities and how this may relate to patient satisfaction.

We determined the incidence of noise, specifically squeaking, how and when squeaking most affected patients, and the relationship between squeaking and component position of ceramic-on-ceramic THAs; we also sought to confirm previous reports of function, and revision, osteolysis, and dislocation rates.

Patients and Methods

We reviewed the records of all 364 patients who underwent 436 primary ceramic-on-ceramic THA with a metal backed socket between January 2003 and December 2006. The only exclusion criterion was having less than 2 years of followup. During this time we performed a total of 1,865 primary THAs in 1,640 patients. The indications for the use of this implant were younger and/or more active patients. Relative contraindications for the use of this implant were elderly low-demand patients. Of the 364 patients, four died, one of whom had bilateral THAs, leaving 360 patients and 431 THAs available for review. Clinical followup was available for 317 patients (88%) with 375 THAs. There were 117 women and 200 men. The diagnosis at time of primary THA was osteoarthritis in 298 hips (80%), avascular necrosis in 46 (12%), posttraumatic osteoarthritis in 16 (4%), developmental dysplasia in 13 (4%), and rheumatoid arthritis in 2 (0.53%). The average age of patients at the time of surgery was 54 years (range, 21–80 years). Minimum followup was 2 years (average, 3.5 years; range, 2.0–6.2 years). The remaining 43 patients with 56 THAs were lost to followup. Attempts were made to contact these patients over the phone and through the mail. However, they either did not return our calls or their phone numbers and/or addresses were no longer valid. No patients were recalled specifically for this study; all data was obtained from medical records and radiographs. This study was approved by our institutional review board.

All procedures were performed with the same surgical technique via a posterior approach with the patients in the

lateral decubitus position. The acetabulum was reamed to the size of the acetabular component that was selected, since the actual components are slightly larger to achieve a press fit. Femoral preparation involved axially reaming and then broaching until the proper press fit was achieved. Components for all cases were the Trident® PSL® (Stryker Orthopaedics, Mahwah, NJ) or hemispherical cementless cup and the SecurFit® stem, a hydroxyapatite-enhanced uncemented stem (Stryker Orthopaedics, Mahwah, NJ). The ceramic components used in this study were alumina (Ceramtec AG, Plochingen, Germany). After the final reduction, posterior short external rotators and posterior capsular repair were performed in all cases. Femoral component head sizes were 28 mm in 41 cases (11%), 32 mm in 254 cases (68%), and 36 mm in 80 cases (21%).

The postoperative physical therapy protocol was standardized. Patients were mobilized on the day of surgery if the surgery was performed in the morning; if the surgery was performed in the afternoon, patients were mobilized the following day. Patients were instructed on ROM and strengthening exercises and all therapy was supervised. Patients were weight bearing as tolerated, starting with a walker and then moving to a cane when able to (typically postoperative day 1) and were able to achieve stair climbing before hospital discharge. Physical therapy was performed for about 30 minutes, two times a day.

All patients consented to enter our implant registry and data were prospectively collected and entered in the registry. Patients were seen preoperatively, 6 weeks postoperatively, and then yearly thereafter. At each office visit (both preoperatively and postoperatively), AP pelvic and frogleg lateral hip radiographs were performed. At each of these visits, patients also completed a packet of surveys, which included both the Harris Hip Survey [12] and a self-reported noise questionnaire (Appendix 1). In addition to these questionnaires, information on patient demographics, primary diagnosis, revision, and dislocation was entered into the registry. The noise questionnaire was added to the packet of surveys given to each patient after some patients had already returned for followup. Therefore, the noise questionnaire was completed by 306 of 360 patients (85%).

One of us (DS), who was not a treating surgeon, evaluated the AP pelvic and frogleg lateral hip radiographs for signs of osteolysis, component position, and loosening. Osteolysis was assessed at the acetabulum according to the classification of DeLee and Charnley [8] and at the femoral component as described by Gruen et al. [11]. Component position was assessed by measuring cup abduction angle on the PACS digital x-ray system using the methods described by Visser and Konings [27]. Using digital software to measure hip implant radiographs within PACS reportedly has intraobserver and interobserver Kappa values of

0.9–0.97 and 0.74–0.83, respectively [17]. Bony ingrowth was described according to criteria of Engh et al. [9].

Statistical analysis was performed using SAS Version 9.1 (SAS Institute Inc., Cary, NC). A Wilcoxon rank sum test was used to determine differences in abduction angle between squeakers and nonsqueakers. Patients who did not complete the noise questionnaire were eliminated from this comparison. Raw percentages were calculated to determine the incidence of noise, squeaking, revision rate and dislocation rate. Patients who did not complete the questionnaire were not included in any incidence calculation based on data collected using that questionnaire.

Results

The self-reported incidence of noise of any type was 11% (41 of 362). The majority of patients reported that they rarely heard this noise (Table 1). Patients reported clicking as the most common type of noise (Table 2). Some patients experienced the noise during more than one type of activity (Table 3). The incidence of patient-reported audible

Table 1. Frequency of noise

Frequency of noise	Incidence
Rarely (n = 23)	56.1%
Occasionally (n = 12)	29.3%
Frequently (n = 6)	14.6%
Always (n = 0)	0%

Table 2. Type of noise

Type of noise	Incidence
Squeak (n = 9)	31.0%
Click (n = 19)	46.3%
Snap (n = 2)	4.9%
Grind (n = 4)	9.8%
Pop (n = 2)	4.9%
Other (n = 5)	12.2%

Table 3. Activities during which patients experienced noise

Activity	Incidence
Walking (n = 11)	26.8%
Exercising/sports (n = 8)	19.5%
Bending down (n = 5)	12.2%
Stairs (n = 5)	12.2%
Squatting (n = 4)	9.8%
Sex (n = 4)	9.8%

squeaking was 1.9% (seven of 362). Audible squeaking was defined as a squeak that the patient said other people could hear. Of those audible squeakers, three patients heard the squeak rarely (43%), two heard it occasionally (29%), and two heard it frequently (29%). Patients most commonly experienced the squeak while squatting (N = 2, 28.6%), walking (N = 2, 29%), or bending (N = 2, 29%). Patients also experienced the squeak while sitting (N = 1, 14%), moving one's leg (N = 1, 14%), and going up and down stairs (N = 1, 14%). No patients reported the squeaking substantially affected their quality of life, which was defined as a score greater than or equal to 6 on a 10 point scale (mean = 2, range, 1–5). No patient reported that the noise was associated with pain. Of the seven hips with reported audible squeaking, no patient had a revision for squeaking.

The average abduction angle of the entire cohort was 46.0° (± 6.2). No difference (p = 0.0743) was found between the abduction angle of patients with squeaking (median 52, mean 50.1, standard deviation 10.3) and those without (median 46.3, mean 46.0, standard deviation 6.0).

The mean Harris hip score for the entire cohort increased from 51.9 preoperatively to 94.4 at last followup. Overall, six of 375 (1.6%) hips underwent revision. The time to revision averaged 1 year and 5 months after primary THA. Reasons for revision included instability in four and posttraumatic periprosthetic fracture in two. Another patient experienced thigh pain with a positive bone scan showing increased uptake at the tip of the stem (stress concentration) for which a strut allograft was placed. There were no infections. All surviving implants had radiographic evidence of stable bony ingrowth. No Trident® acetabular component had any evidence of loosening, and no SecureFit® stem had any evidence of loosening. No osteolysis was noted on any hip at either the cup or stem. No hip sustained a fracture of the alumina components at followup evaluation.

Revision for instability in our case series occurred in only four cases (1.1%). An additional patient experienced subjective instability and was treated nonoperatively with physical therapy directed at hip strengthening. With one of the hips revised for instability, the patient did not even realize the dislocation had occurred and this was thought to be a neuropathic joint.

Discussion

The long term issue with total hip arthroplasty is related to wear. Strategies aimed to reduce wear and lysis are currently focused on improving the bearing surface. Clinical investigation into the use of alternative bearings such as cross linked polyethylenes, metal on metal bearings, and

ceramic-on-ceramic are therefore timely and appropriate. The purpose of our study was to evaluate the incidence of squeaking in a large series of ceramic-on-ceramic total hip replacements at short term followup and the relationship between squeaking and component position. Noise, specifically squeaking, has emerged as a concern for both patients and clinicians, and although not unique to ceramic bearings, the incidence of squeaking following ceramic-on-ceramic THA may be more prevalent than in other implant systems, potentially affecting patient quality of life [3]. We also reviewed rates of revision and instability following ceramic-on-ceramic THA.

There are several limitations of this study. First, our assessment of the incidence of noise was based on self-reported patient data, and patients may have different thresholds for what they consider an audible noise or specifically a squeak. Also, it has been noted that some patients may not notice implant noise until specifically prompted or asked by a healthcare professional. Second, our incidence of instability and noise, specifically squeaking, was low and therefore we could not establish relationships between patient factors, surgical factors, and implant specific factors. Third, our center is a large joint replacement center and the findings may not be generalizable to the general community.

At an average followup of 3.5 years, 98% of hips were functioning well. We found an overall incidence of any patient reported noise of 11% with squeaking reported in 1.9% of hips. Noise after total hip arthroplasty is not unique to ceramic bearings, but the occurrence of noise, especially squeaking, has become a particularly important issue with ceramic bearings [23, 28, 30]. The reported incidence of squeaking ranges from 1% to 21% [14, 16, 23, 30] (Table 4). Therefore, the low incidence of squeaking observed in our study across multiple surgeons compares favorably with literature. Additionally, a majority of audible squeakers experienced squeaking rarely or occasionally, and squeaking was mostly limited to during squatting, walking, and bending. No patient reported that the squeak was associated with pain, and no patient reported that the squeaking substantially affected their quality of life. Although squeaking remains a concern following ceramic-on-ceramic THA, squeaking had little

effect on postoperative patient function and satisfaction in our cohort at short term followup.

The etiology of squeaking is still unclear. Walter et al. [30] suggest a series of events resulting from edge loading of components, especially when components are malpositioned. These authors suggest that the friction created by fluid film lubrication breakdown with edge loading results in some form of resonance at parts of the total hip construct, specifically the metal portions (stem and shell), with frequencies in the audible range [30]. Others have suggested metal transfer and deposition onto the femoral head may be responsible for this phenomenon [5]. While component malposition has been suggested as a cause [29], others have noted squeaking in well-positioned components [14, 23]. We were unable to demonstrate any difference between the median abduction angle of patients with squeaking (52°) and those without (46.3°); however, there was a trend towards significance and only a small cohort of patients reported a squeak ($n = 7$). Therefore, our study does not support improper component position as a cause of implant squeaking.

In addition to the incidence of noise, we analyzed the rates of revision and instability following THA to confirm previous reports of implant performance at short term followup. There were six revisions in our patient cohort: four for instability and two for periprosthetic fracture. There were no cases revised for infection, bearing fracture or aseptic loosening of either the socket or stem. The revision rate of this series is consistent with that of prior reports. The original investigational device exemption study for the US Food Drug Administration reported survival at 5 years of 99% [7]. Case series with third-generation alumina components show excellent functioning at 7.5 years' followup with 96% survival when all causes of revision are considered [19]. A recent report of data collected as part of the Australian Orthopaedic Association Joint Replacement Registry revealed ceramic-on-ceramic THAs had the lowest cumulative rate of revision at 7 years (3%) compared to metal-on-metal (4%) and metal-on-polyethylene (3%) [25].

The dislocation rate for our cohort was 1.1% (4 of 375 hips). This incidence compares favorably to other published reports regarding dislocation after THA from both the Mayo Clinic as well as our own institution [2, 21] (Table 5). All patients were operated upon by four experienced surgeons using a standard posterolateral approach. The lower rates of instability may be related to two factors. During the time frame of this study, all patients had the posterior capsule and rotators reattached using the method described by Pellicci et al. [22]. In addition, the vast majority of patients (89%) had either a 32 or 36 millimeter diameter bearing surface. Either of these factors or a combination of the two may explain our low rate of

Table 4. Incidence of squeaking with ceramic bearings

Authors	Incidence
Jarrett et al. [14]	14/131 (10.7%)
Keurentjes et al. [16]	9/43 (20.9%)*
Restrepo et al. [23]	28/999 (2.7%)
Schroder et al. [current study]	7/362 (1.9%)

* Squeak defined as reproducible sound of squeaking, clicking or grating.

Table 5. Dislocation rates in primary total hip arthroplasty

Authors	Implant Type	Dislocation Rate
Berry et al. [2]	Variable	4.1% (868/21,047)
Capello et al. [4]	Ceramic	1.1% (18/1635)
D'Antonio et al. [6]	Polyethylene	4.2% (10/349)
	Ceramic	2.3% (7/165)
Padgett et al. [21]	Variable	4.8% (12/254)
Schroder et al. [current study]	Ceramic	1.1% (4/375)

instability. The observation of low rates of instability with ceramic on ceramic bearings is not new. D'Antonio et al. observed a higher instability rate with their metal-on-polyethylene cohort (4%, largely 28 millimeter head diameters) than with their ceramic group (3%, 32 millimeter) [6]. Capello et al. described a multicentered experience with a combined instability rate of 1.1%, although the posterolateral approach was not used at all centers [4]. While larger head diameter is implicit in the decreased rate of instability, what role the ceramic on ceramic bearing itself plays is not clear. It should be noted that instability occurred in five patients in this series and that four of the five were revised. Due to concerns regarding possible damage to the ceramic bearing surface

as a consequence of dislocation and reduction, our bias was to revise sooner than not. Retrieval analyses of ceramic bearings have demonstrated severe patterns of damage in cases revised for instability with extensive metal transfer and material loss of the ceramic component [1, 28]. Based upon this observation, we believe it is appropriate to consider revision for the unstable ceramic-on-ceramic total hip replacement.

Our data on the low incidence of implant noise and the negligible effect of squeaking on patient quality of life following ceramic-on-ceramic total hip arthroplasty supports the continued use of this implant system. Improvements in Harris Hip Score as well as the low rates of early revision and instability further confirm the safety and efficacy of this procedure in the younger patient in whom longer term use is a concern. Further studies are required to investigate possible causes of and ways to prevent squeaking, as no relationship between squeaking and component position was found. Whether the use of this newer bearing couple will result in the reduction of wear and osteolysis will need to be reported at longer term followup.

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Appendix 1: Total Hip Replacement Questionnaire

Does your hip replacement make a noise?

- a. Never b. Rarely c. Occasionally d. Frequently e. Always

How would you describe this noise?

- a. Squeak b. Click c. Snap d. Grind e. Pop f. Other_____

Can other people hear it?

- a. Yes b. No

Is this noise associated with pain?

- a. Yes b. No

With which activity do you experience this noise? (mark all that apply)

- a. Walking b. Stairs c. Sporting activities d. Other_____

How much does this noise affect your quality of life?

1 2 3 4 5 6 7 8 9 10

Never Occasionally Always

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