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Incidence and Factors Associated with Squeaking in Alumina-on-Alumina THA

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Abstract
Background The alumina-on-alumina bearing surface, which has a high wear resistance and a good biocompatibility, is widely used in THA but recently has been associated with squeaking. While various authors have reported factors associated with squeaking, they remain poorly understood.
Questions/purposes To contribute to the debate on squeaking we therefore asked the following questions: (1) What is the incidence of squeaking in alumina-on-alumina THA? (2) What factors are associated with squeaking in alumina bearings in our practice?
Methods We retrospectively reviewed 168 patients (173 hips) who had primary alumina-on-alumina THAs. The mean age of the patients was 53 years (range, 18 to 81 years). Minimum followup was 5.6 years (average, 7.3 years; range, 5.6–9.4 years). All patients were evaluated clinically and radiographically with attention to periprosthetic osteolysis, squeaking, and ceramic fracture. When the patient reported squeaking, we determined the onset, reproducibility, and activities associated with the squeaking. We recorded patient (gender, age, height, weight, and body mass index) and surgical factors (abduction angle of cup, size and length of ceramic head component, and diameter of cup in the implant).
Results Eight of the 168 patients (5%) had squeaking hips. Squeaking was more common in males and in those with large ceramic heads. There were no complications or revisions in the squeaking group. One ceramic liner fracture was associated with trochanteric nonunion.
Conclusions When recommending alumina-on-alumina bearing surfaces to patients they should be clearly informed of the possibility of squeaking. Patients with risk factors for squeaking should be followed at regular intervals.
Level of Evidence Level IV, therapeutic study. See the Guidelines for Authors for a complete description of levels of evidence.

Each author certifies that he or she has no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.
Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.
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Introduction

Periprosthetic osteolysis in total hip arthroplasty (THA) owing to wear debris is the major threat to the long-term survival of THA [3, 22]. Metal-on-polyethylene bearing surfaces have been the mainstays of THA, but wear debris from polyethylene may cause periprosthetic osteolysis and eventually component loosening may occur. To minimize wear debris, alternative bearing surfaces with improved tribologic properties have been developed and, among them, alumina-on-alumina bearing surfaces, which have been used since the 1970s [19, 20]. Alumina-on-alumina bearings reportedly decrease inflammation, osteolysis, and loosening related to polyethylene wear debris [7]. However, early-generation alumina-on-alumina bearings had relatively low mechanical strength of the ceramic material [33] with associated with ceramic fracture [9, 18, 27], accelerated ceramic wear [32], and acetabular component loosening [29]. The long-term survivorship for early-generation alumina-on-alumina bearings ranged from 45% to 68.3% at 18 years [16, 19].

Many improvements have been made in the manufacture and design of ceramic implants since then [4]. The newer generation of ceramics have been associated with a fracture rate of less than 0.004% and wear rate in vitro less than 0.001 mm per year. In addition, the short term and intermediate term studies show high levels of function [5, 12, 23, 25]. Despite these improvements, the potential for ceramic fracture still remains as one of the major concerns. More recent studies have reported ceramic fracture rates range from 0.5% to 3.2% [10, 18, 27, 37, 40]. Moreover, before 2005, the squeaking of ceramic bearings was largely ignored and interpreted as only a minor complication [39]. However, recently many authors [1, 10, 11, 17, 24, 26, 31, 34, 36, 38, 39] have reported squeaking with an incidence ranging from 0.3% to 20.9% [2, 24, 26, 30, 38]. One study [36] suggests malpositioning is a factor, while another [39] showed squeaking hips were more common in taller, heavier, and younger patients and yet another [31] reported a difference in height between patients with squeaking and nonsqueaking hips.

To contribute to the debate on squeaking we therefore asked the following two questions: (1) What is the incidence of squeaking in alumina-on-alumina THA? (2) What demographic and implant-related factors are associated with squeaking in ceramic bearings in our practice?

Patients and Methods

From March 2000 to February 2004, we performed 259 THAs of various sorts in 227 patients. The alumina-on-alumina bearing THAs were performed in patients younger than 65 years old or in patients regardless of age who wanted THA using alumina-on-alumina bearings. During the study period, 168 patients (192 hips) received cementless THA using alumina-on-alumina bearing surfaces. The mean age of the patients was 53 years (range, 18 to 81 years). Among the 168 patients, 17 patients (17 hips, 8.8%) were lost to followup because they were not seen at a clinical followup from 3 years to 5 years postoperatively and could not be reached. Two deaths occurred in 2 years and 3 years after surgery, respectively, and were unrelated to THA. Therefore, 149 patients (173 hips) had at least 5 years of followup. The study group included 53 men and 96 women. The most common reason for THA was rheumatoid arthritis (Table 1). The minimum followup was 5.6 years (average, 7.3 years; range, 5.6–9.4 years).

Table 1. Indications for THA

Diagnosis	Number of hips
Rheumatoid arthritis of the hips	75
Osteoarthritis of the hips	44
Osteonecrosis of the femoral head	40
Ankylosing spondylitis	8
Miscellaneous conditions	6

We used two acetabular components: 64 Secur-Fit® hemispherical acetabular PSL cups (Stryker Ireland Ltd, Limerick, Ireland)) and 109 ABG II® cups (Stryker Ireland). The femoral components were 173 ABG II® femoral stems. The acetabular and femoral components were cementless. The ceramic insert was Biolox® Forte ceramic insert (Stryker Ireland) with a metal-backed socket. We used the ceramic V40™ femoral head (Stryker Ireland) composed of two head diameters (28 mm, 32 mm) and three modular component lengths (short [−4 mm], medium [0 mm], long [+4 mm]). The 28-mm-diameter head was used in 135 hips and the 32-mm-diameter head in 38 hips. A short-neck modular femoral head component was used in seven hips, a medium-neck modular femoral head component in 131 hips, and a long-neck modular femoral head component in 35 hips.

Surgery was performed by a single surgeon (IYC) through a lateral approach with a trochanteric osteotomy in all hips. To reattach the greater trochanter, the stainless steel wires were inserted crosswise through the femur and then inserted through holes in the greater trochanter. The tightening of wires and tying of square knots with Kirschner wire bows were performed twice. The rigidity of greater trochanter fixation was confirmed by moving the greater trochanter with the towel clip.

For postoperative rehabilitation, patients were instructed in quadriceps setting exercises immediately after surgery, and active range of motion exercise of hips and knees was encouraged as soon as possible. Patients were allowed to walk using two crutches after 3 days with partial weight bearing and full weight bearing was allowed 6 weeks postoperatively.

The clinical and radiographic evaluations were performed at 6 weeks, at 3 months, at 5 months, 1 year, and annually thereafter. Two of us (YSK, KTH) who did not take part in the surgery independently evaluated the patients clinically and radiographically. The Harris hip score [21] was checked preoperatively, 6 weeks postoperatively, and at latest followups. Thigh pain and inguinal pain were also evaluated. We retrospectively reviewed medical records and radiographs for the information.

If they were too limited, we tried to get more information from outpatients by periodic followup and telephone contact.

Two of us (YSK, KTH) evaluated separately all hip AP and crosstable lateral radiographs taken postoperatively and at the latest followup. The abduction angle of the cup was measured by the angle formed by the horizontal line drawn through the teardrops and the plane of opening of the cup [8]. The stable fixation of the femoral component was defined as the absence of the reactive line adjacent to the porous-surfaced portion of the implant and the presence of spot welds of endosteal new bone contacting the porous surfaces according to the method of Engh et al. [15]. For evaluation of fixation of the acetabular component, fixation was considered stable if there was no radiolucent line surrounding three zones as described by DeLee and Charnley [14] and no positional change of acetabular component according to the method of Latimer and Lachiewicz [28]. Periprosthetic cystic or scalloped lesions with a diameter of more than 2 mm that were not present on the immediate postoperative radiograph were defined as periprosthetic osteolysis.

To determine the causes of squeaking, patients were asked: "After surgery, have you ever heard or felt any noise when moving?" If a patient said "yes", he/she was asked: "Can you reproduce the noise?" or "Can you describe the noise?" Noises were defined as either "squeak", "click", "grind", or "pop" [24]. When the patient reported squeaking, we asked further questions regarding onset, reproducibility, and activities associated with the squeaking. We additionally sought to find related factors, including gender, age, height, weight, and body mass index (BMI) among patient factors and abduction angle of the cup, size and length of the ceramic head component, diameter of cup, and head-cup diameter ratio among implant and surgical factors.

We used an independent-sample Student's t test to compare age, height, weight, BMI, abduction angle of cup, diameter of cup, and head-cup diameter ratio between patients without and with squeaking. Differences in gender, diameter of head, and neck length of head were compared using chi square test.

Results

Incidence of noise from the hip was observed in 19 of 173 hips (11%) (Table 2). Specifically, eight hips (5%) squeaked and 11 hips (6%) clicked. There were no cases of grind and pop. The squeaking began between 8 and 17 months postoperatively among patients with squeaking hips. One patient could reproduce the squeak in the clinical setting and squeaking occurred in stair climbing. Others complained squeaking occurred incidentally when they walked. However, no patient complained of pain during the squeak.

Table 2. Comparison between the nonsqueaking and squeaking groups

Parameter	Nonsqueaking	Squeaking	P value
Number of hips	165	8	
Gender			0.015
Male	50	6	
Female	115	2	
Age (years)*	52.8	46	0.232
Height (cm)*	162.8	161.4	0.951
Weight (kg)*	60.2	60.9	0.943
Body mass index (kg/m^2)*	22.8	22.9	0.956
Abduction angle of cup (°)*	48.3	50.5	0.360
Cup size (mm)*	52.7	52.4	0.835
Size of ceramic head component			0.002
28 mm	133	2	
32 mm	32	6	
Head-cup diameter ratio*	0.550	0.552	0.937
Neck length of ceramic head component			
Short	7	0	0.690
Medium	124	7	
Long	34	1	

* Values are expressed as means.

Gender was associated with squeaking (Table 2). Squeaking was higher ($p = 0.015$) in the hips of male patients (six males and two females in the squeaking group and 50 males and 115 females in the nonsqueaking group). Age, height, weight, and BMI were not associated with squeaking. Among the implant factors, only head size was related to squeaking. Squeaking was more frequent ($p = 0.002$) in hips with a 32-mm ceramic head than in those with 28-mm ceramic heads (Table 2). We found no differences in abduction angle of the acetabular component, length of ceramic head, or head-cup diameter ratio between patients with squeaking and those without.

The mean Harris hip score improved from 47 points (range, 22–75 points) preoperatively to 94 points (range, 77–98 points) at the time of the latest followup. There was thigh pain in nine hips and inguinal pain in eight hips, none of which were associated with squeaking. All of the patients experiencing pain took NSAIDs for 8 weeks and their pain was relieved. Radiographically, there was no evidence of osteolysis and loosening in the acetabular and femoral components. No subsidence of the femoral stem was observed.

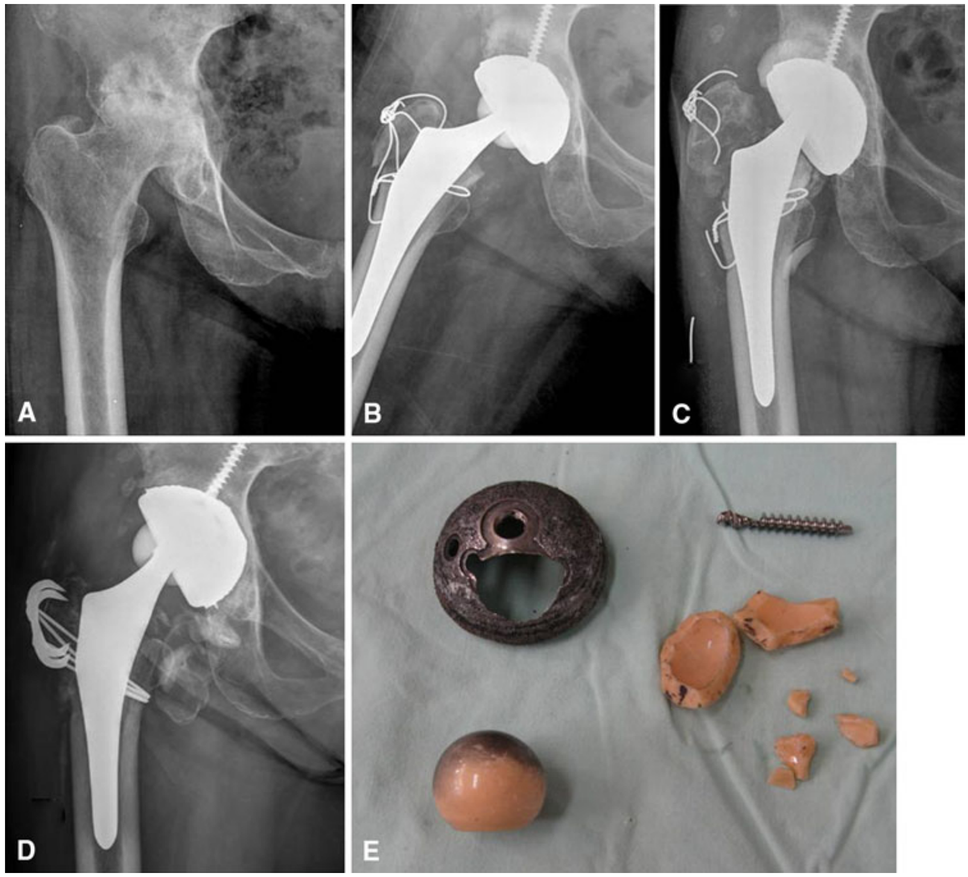

Fig. 1A–E Images illustrate the case of a 56-year-old woman who underwent THA using alumina-on-alumina bearing surfaces. (**A**) A preoperative radiograph shows rheumatoid arthritis of the right hip. (**B**) An immediately postoperative radiograph shows good position of the implant. (**C**) A radiograph taken 5 years postoperatively shows nonunion of the greater trochanter and multiple fragments of the ceramic insert. (**D**) A radiograph shows the hip after revision THA. (**E**) A photograph shows the fractured alumina insert.

There were no complications in the squeaking group and no revision was performed owing to squeaking. Specifically, there was one ceramic liner fracture at 5-year followup. The 56-year-old patient with rheumatoid arthritis had undergone a primary ceramic-on-ceramic THA with 32-mm-diameter and medium-length ceramic head. Three months after surgery, greater trochanteric nonunion was observed, but no treatment was given because the nonunion gap was less than 2 cm and there was no pain and limping when walking. Five years after surgery, she noticed a grinding sensation in her hip with instability and discomfort. The radiograph was checked and a fracture of the ceramic insert was found. Revision THA was then performed (Fig. 1). There was one case of dislocation. The patient fell 3 months after surgery and dislocation occurred. There was one case of intraoperative periprosthetic fracture treated with open reduction and internal fixation, and subsequently the fracture healed. There was one acute infection treated with intravenous first-generation cephalosporin for 6 weeks. During 6-year followup, there was no recurrence of infection. Trochanteric nonunion occurred in four hips. The migration of the greater trochanter was less than 2 cm and no impairment of walking abilities was observed.

Discussion

The alumina-on-alumina THA has been used since the 1970s and reportedly has low wear rate and low incidence of osteolysis [4, 10, 12, 13, 20, 23, 25]. It is currently used in young and active adults and the intermediate-term studies report excellent results [4, 6, 12, 40]. However, during the last 5 years, a squeaking issue has been documented, but the causes of squeaking are not understood [24, 35, 38, 39]. Patients receiving alumina-on-alumina THA at our institute began to complain of squeaking. This prompted us to observe the type of noise and the incidence of squeaking in order to determine its associated factors.

The limitations of our study are as follows. First, we followed the open question procedure in Mai et al. [31]; however, the criteria for accurately reporting a squeaking hip by the patients are unclear. We believed it preferable to the risk of underestimation or overestimation that can result from prompting. Standardization procedures would aid future research. We used open-ended questions and all patients who could reproduce a sound similar to squeaking were included in the squeaking group, which would reduce the number of neglected squeaking hips. Second, we had a small number of patients with squeaking. This limits the

Table 3. Incidence and factors of squeaking reported in the literature

Study	Number of hips	Incidence (%)	Factors
Lusty et al. [30] (2007)	301	0.3	
Walter et al. [38] (2007)	2716	0.6	Age, height, weight, position of cup
Capello et al. [10] (2008)	475	0.8	
Mai et al. [31] (2010)	336	10	Femoral neck geometry
Jarrett et al. [24] (2009)	149	10.7	
Keurentjes et al. [26] (2008)	43	20.9	Short neck length of femoral component
Choi et al. [current study]	173	5	Gender, head size

power of the study and increases the risk of a Type II error in presuming some factors are not associated with squeaking; that is, some of these factors might be associated with squeaking with greater numbers of patients. Third, we identified only one ceramic liner fracture precluding any generalization regarding the cause of that complication.

The incidence of squeaking in alumina-on-alumina THA in our study was 5% (eight of 173 hips). The reported prevalence of squeaking ranges from 0.3% to 20.9% (Table 3). Keurentjes et al. [26] observed a high rate of squeaking and stated that squeaking was likely to be a phenomenon indicative of potential complications that were possibly underreported, causing them to discontinue implanting this type of bearing. In contrast, Mai et al. [31], despite a high percentage of squeaking in their patients, concluded that most squeaking hips were pain-free and functioning well, and patients were generally satisfied with the outcome. They concluded that ceramic bearings are an acceptable treatment for young and active patients. In the case of our study, none of the squeakers reported pain or discomfort. As we were not able to find any clear evidence of complications in patients in squeaking group, following Mai et al. [31], we continue to use alumina-on-alumina THA. When this was explained, no patients objected to this procedure.

Our data suggest males are more likely to have a squeaking hip but we could not find a gender difference in the other studies reported previously. Walter et al. [39] demonstrated squeaking hips were more common in taller, heavier, and younger patients. Mai et al. [31] reported a difference in height between patients with squeaking and nonsqueaking hips. However, we did find differences in gender. We speculate the male predominance in squeaking could be the result of gender differences in physical activity since we assume men in the younger age group tend to be more physically active than women. The bearings in more active patients would increase mechanical demand and increase the possibility of squeaking [38].

Squeaking occurred more frequently in larger ceramic heads in our study. Mai et al. [31] reported no differences in head size in patients who squeaked and those who did not. We cannot be sure of the reasons for this discrepancy. However, larger heads could have increased ROM. Any increased ROM may lead to bony impingement at extreme ROM whereby the femur is levering against the pelvis, causing subluxation of the femoral head and edge loading, leading to stripe wear and squeak [31]. Larger heads also have a larger articulated surface which increases by the square of the head radius. Therefore, squeaking might be more likely if surface area is related to squeaking. We found no difference in abduction angle and size of cup between the squeaking and nonsqueaking groups, which supports the findings of Keurentjes et al. [26] and Restrepo et al. [36] who reported no difference in component orientation between squeaking and nonsqueaking groups.

In conclusion, we found that only male hips and large head size were more likely to be associated with squeaking. However, there was no evidence that squeaking led to complications. As a result, we continue to use an alumina-on-alumina bearing surface THA, taking care to explain the possibility of squeaking to patients. The possibility of squeaking should be clearly explained to patients who are undergoing THA using alumina-on-alumina bearing surfaces. The patient with related risk factors for squeaking should be followed up carefully at regular intervals.

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