The Squeaking Hip: A Cause for Concern-Disagrees

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Ceramic-on-ceramic total hip arthroplasty (THA) prostheses have been used for more than 30 years since first being introduced in 1970 by Boutin.[1,2] This articulation has demonstrated the lowest wear rate among various articulations materials.[3] Proponents of ceramic-on-ceramic THA report extremely low wear rates, which may provide a solution to osteolysis.[4,5]

Clinically, the long-term results of ceramic THAs have been promising, in part as the result of the improvements in the manufacturing processes of the ceramic material as well as the design of the partner components.[6-8] Despite the excellent clinical results, the occurrence of squeaking in ceramic-on-ceramic THA recently has been discussed as a potential worrisome problem.[9,10] This article reviews the incidence, proposed etiologies, and clinical significance of this phenomenon.

Incidence

The phenomenon of audible squeaking following THA has been reported in the 1950s with the Judet acrylic hemiarthroplasty[11] and more recently, in metal-on-metal resurfacing hip replacements.[12] Walter et al[13] reported on their experience of implanting 2397 primary and 319 revision ceramic THAs and observed an incidence of squeaking of only 0.48% (13 of 2716. Furthermore, only 1 (0.037%) of these THAs has required revision for squeaking. A similar low incidence of squeaking of 0.5% (8 of 1600) has been noted by J. P. Garino in a letter (September 2006).

Two recent clinical analyses have reported a substantially higher incidence of squeaking in ceramic-on-ceramic THA.[9,10] Hozack et al[9] observed squeaking in 30 of 1056 ceramic-on-ceramic THA for an incidence of 2.7%, and Jarrett et al[10] reported an incidence of 7% (10 of 159).

Interestingly, the same implant (Trident; Stryker Orthopaedics, Mahwah, NJ) was used in both reports. The Trident implant uses a modular ceramic liner within a titanium encasement that has an extended rim designed to prevent metal-on-ceramic impingment; this design concept typically is not incorporated in most historical ceramic-on-ceramic THA designs (Figure 1).

Figure 1: Photograph of the Trident modular ceramic acetabular component with an elevated titanium rim.

Etiology

The exact etiology of squeaking in ceramic-on-ceramic THA remains elusive and is likely multifactorial. Proposed causes of squeaking include:

- Femoral head microseparation and subluxation from the acetabular component, often associated with impingement and secondary stripe wear,
- Edge loading as a result of acetabular component malposition,
- Entrapment of third-body wear debris within the ceramic articulation from femoral neck-socket impingement on extended metal rims present on some ceramic acetabular components,[14]
- Disruption of fluid film lubrication regimes,
- Mismatched ceramic bearings, and
- Ceramic material type.

Stripe wear is the term used to describe the long, narrow, and crescent-shaped area of damage occasionally seen in retrievals of ceramic femoral heads and liners.[15] This distinct shape is believed to be the result of liner contact between the head and the edge of the liner (edge loading). This phenomenon has been reported in first- and second-generation alumina bearings and has been associated with vertical acetabular component abduction

inclination angles, young patients, and revision surgery.[16]

Nevelos et al[17] proposed stripe wear results from microseparation of the femoral head from the acetabular component during the swing phase of normal walking with subsequent edge loading during heel strike. This is supported by in vivo video fluoroscopic analyses of patients implanted with numerous different designs of THA that have demonstrated femoral head sliding (microseparation) from the acetabular component during gait and an abduction-adduction maneuver.[18-20]

Microseparation and subluxation can result in intragranular fracture or pullout of the ceramic material, with the potential production of large debris microparticulate up to 3 µm in size[21] that can serve as grinding media within the articulation. This subsequently may interrupt the normal fluid film lubrication regime typically seen with ceramic THA, allowing squeaking to occur. If this occurs, additional third-body debris may be created, further contributing to the presence of squeaking.

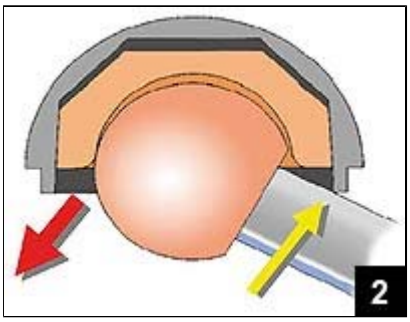

Figure 2: Diagram demonstrating femoral neck impingement on an elevated metal rim resulting in microseparation of the femoral head from the acetabular component.

We hypothesize the risk of stripe wear and intragranular ceramic material loss is increased in any condition that results in femoral neck-acetabular component rim impingement such as component design or malposition. Design factors known to increase the incidence of impingement alone or in combination include reduced femoral head size,[22] increased anteroposterior femoral neck width,[23] and acetabular component rim geometry.[24]

Acetabular component designs with an elevated titanium rim can result in decreased range of motion until impingement occurs, likely producing microseparation of the femoral head, increased stresses on the opposite side of the liner (contrecoup lesion), and eventual stripe wear (Figure 2). This impingement also could generate third-body titanium debris from the neck and rim, resulting in metallosis, painful synovitis, and notching of the femoral neck and acetabular rim, potentially contributing to the presence of squeaking (Figure 3).[14]

The hypothesis of impingement and edge loading as an etiology of squeaking after ceramic-on-ceramic THA is supported by retrieval analyses.[9,25] Hozack et al[9] evaluated six ceramic acetabular liners from Trident implants in patients with squeaking. They observed 100% exhibited evidence of edge loading and stripe wear, and 83.3% (five of six) demonstrated signs of femoral neck-acetabular component rim impingement.

Walter et al[25] analyzed retrieved components of four different designs from 10 THA patients with squeaking. They found 100% of the components exhibited edge-loading wear, 90% had an extended metal rim, and 60% demonstrated evidence of neck-rim impingement.

In addition to microseparation and edge loading, Walter et al[13] have suggested acetabular component malposition may contribute to the incidence of squeaking after ceramic THA. They evaluated acetabular component position using computed tomography scans in 17 ceramic-on-ceramic THA patients who exhibited squeaking and compared them with a matched control group of THA patients without squeaking.

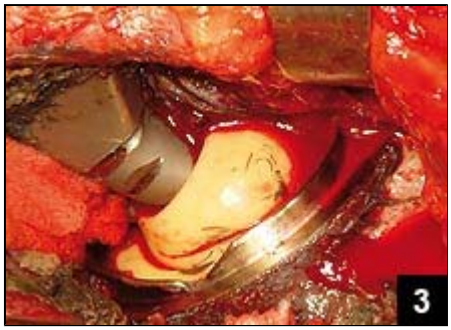

Figure 3: Intraoperative photograph demonstrating femoral neck impingement on an elevated metal rim resulting in notching of both the femoral neck and the acetabular metal rim.

Acetabular component position within the recommended range of 45±10° of abduction inclination and 25±10° of anteversion[26] was present in 94% of the control group versus only 35% of the ceramic THAs that demonstrated squeaking. Hips that squeaked with walking had acetabular components that were more anteverted (mean: 40°) than hips that squeaked with deep bending (mean: 18°, P=.020), suggesting impingement may play a role in this phenomenon.

Walter et al[13] also noted squeaking ceramic-on-ceramic THA patients were younger (mean age: 56 years, P<.01), taller (mean height: 179 cm, P<.0003), and heavier (mean weight: 90 kg, P<.001) than those without the presence of squeaking. However, other authors did not believe acetabular component malposition played a role in their reports of squeaking following ceramic-on-ceramic THA.[9,10]

Morlock et al[27] reported a case of squeaking in a mismatched couple in which a zirconia ceramic head was coupled with an alumina ceramic acetabular component. Their analysis of the retrieval revealed the head exhibited heavy local damage in the articulation zone. Although the alumina ceramic socket showed minor wear signs, there were large deviations from an ideal sphere. They stated the damage might have been caused by an unsatisfactory fit between the femoral head and socket, resulting in high stress concentrations and increased wear of the zirconium head.

To avoid such problems, components of different manufacturers should not be mixed and matched unless explicitly stated. Similar results of accelerated wear with this wear couple (zirconia on alumina) has been reported by Stewart et al[28] in a hip simulator analysis incorporating severe microseparation.

It remains to be proven whether the ceramic material type plays a role in the incidence of squeaking. Currently, the two most commonly used ceramic materials are hot isostatically pressed (HIPed) alumina ceramic (Biolox Forte; CeramTec AG, Plochingen, Germany) and the newer alumina matrix composite (AMC) ceramic (Biolox Delta; CeramTec), which consists of 75% alumina, 24% zirconia, and 1% mixed oxides. The alumina matrix provides the hardness of the composite, while the presence of the zirconia and mixed oxides improve the fracture toughness by preventing crack propagation.[29]

Stewart et al[30] performed a hip simulator analysis with these two ceramic material articulation couples. They found that in the presence of severe microseparation (200-500 µm), wear of AMC heads on HIPed alumina inserts was significantly less than the wear of HIPed alumina heads on HIPed alumina liners throughout the 5-million-cycle test duration.

In addition, they also found severe microseparation of AMC femoral heads on HIPed alumina liners produced wear stripes 4 to 5 mm wide and 17 to 53 µm deep. In contrast, severe separation of AMC heads on AMC liners produced wear stripes that were much shallower (1.5-16 µm). This may be related to the reduced grain size of the AMC ceramic material (<0.8 µm) compared with the grain size of the HIPed alumina material (1-5 µm).

We hypothesized the reduced wear depth observed with the AMC on AMC ceramic articulation may result in less disruption of the fluid film lubrication regime and a lesser risk of squeaking when this material is used. This hypothesis is supported by a survey of patients implanted with ceramic THA as part of a multicenter FDA investigation using Biolox Delta ceramic femoral heads and liners in which the senior author (D.A.D.) has participated. To date, 232 ceramic THAs have been performed, and no squeaking has been reported.

Clinical Significance

While certainly an annoyance to patients, the long-term clinical sequelae of squeaking ceramic THAs is not known. In the majority of reports, the squeaking of ceramic THAs does not result in pain and has rarely required reoperation.[9,10,13] In the review by Walter et al,[25] only 4 (0.15%) of the 2716 ceramic THA reviewed were scheduled for or had required revision THA for squeaking.

Finally, anecdotal reports of spontaneous resolution of squeaking have been observed. Although we are unsure of the etiology of spontaneous resolution of squeaking, we wonder if some small amount of self-polishing of worn, roughened ceramic surfaces may occur that allows for some improvement in fluid film lubrication.

Summary

Total hip arthroplasty with ceramic-on-ceramic bearing surfaces has demonstrated low wear with excellent clinical outcomes.[2,3,7] More recently, concerns have surfaced because of the presence of audible squeaking in some ceramic-on-ceramic THA patients. The incidence of this phenomenon has been low and has infrequently required reoperation.

The exact etiology of squeaking remains unclear but is likely related to variations in surgical technique, patient selection, and implant design, particularly those designs that result in premature femoral neck-acetabular component rim impingement such as the presence of modular ceramic liner designs that are placed within a titanium encasement which has an extended rim. Hopefully, with continued improvements in design, materials, and component positioning, squeaking following ceramic-on-ceramic THA can be minimized.

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