

# **Influence of Prosthetic Design on Squeaking After Ceramic-on-Ceramic Total Hip Arthroplasty**

## **Abstract**

Squeaky ceramic-on-ceramic (COC) total hips have received much recent publicity, and implant design may be implicated. We reviewed 270 consecutive COC total hip arthroplasties in 233 patients comparing four implant combinations representing four manufacturers. A cohort (n=45) of Stryker Trident acetabular cups paired with Stryker Accolade femoral stems showed a dramatically higher incidence of “**problem squeaking**”—defined as always audible to others and occurring at least once per week—with a 35.6% incidence of squeaking and 11.1% incidence of problem squeaking. The three non-Stryker designs (n=225) revealed 3.6% squeaking ( $p<0.0001$ ) and 0.44% problem squeaking ( $p=0.006$ ). The Stryker system has a unique design and metallurgy. Our results suggest that, although the genesis of squeaking in COC total hips is multifactorial, prosthetic design plays a key role.

**Keywords:** hip arthroplasty, ceramic, squeak, noise

## **Introduction**

Total hip arthroplasty (THA) has proven a reliable treatment option for disabling hip conditions for many years. A major limitation to longevity of hip arthroplasty has been wear of the articular bearing surfaces. In general, lower wear rates lessen the need for revision hip arthroplasties, thus benefitting patient health and society by containing costs.

A number of bearing options have been developed over the years, with some disagreement regarding which articulation is optimal for a given patient [1-4]. Metal-on-metal, metal-on-polyethylene, ceramic-on-ceramic, and ceramic-on-polyethylene articulations each holds

potential advantages and disadvantages. The orthopedic implant industry is constantly striving to improve technology and implant quality in an effort to prolong longevity. One promising option has been development of the ceramic-on-ceramic (COC) articulation, which was used as early as the 1970s in its first-generation form [5-8].

An uncommon occurrence following total hip arthroplasty has been development of noises with hip motion. Most notably, squeaking can occur with hard-on-hard bearings. Although squeaking is not usually accompanied by pain or other symptoms, it can have significant psychological and social consequences when severe. The genesis of squeaking is probably multifactorial. Recent studies have looked at potential causes for squeaking including patient-specific factors such as height, weight, age, and activity level, and technical and mechanical factors including component malpositioning at the time of surgery, microseparation, edge loading, stripe wear, inadequate lubrication, particulate metal debris, and differences in femoral offset, neck length, neck design, and head size. Implant design is also suspected as a possible contributor to squeaking [9-17].

Prior to 2003, squeaking after COC total hip arthroplasty had not been reported as a major issue. However, after FDA approval of two implant designs in 2003, an unusually high incidence of intense squeaking, audible to bystanders, became apparent in several patients. This cross-sectional study was undertaken to determine whether squeaking is related to a particular implant combination or design. We also sought to elucidate any other relevant patient or implant factors related to squeaking.

## **Materials and Methods**

From November 1999 through February 2006, 306 COC total hip arthroplasties were performed in 267 patients by the primary author. All patients had a minimum of two years follow up with

the mean follow-up duration 51.9 months (range, 24-111). Thirty-four patients with 36 total hip arthroplasties were lost to follow up, leaving 233 patients with 270 total hip arthroplasties for study.

## **Implants**

Four COC implant combinations of 2 distinct designs were used. One design utilized a rectangular cross-sectioned, tapered, Zweymuller-type stem made of a standard alpha-beta titanium alloy and 12/14 Morse taper with an acetabular component having a ceramic insert which seated flush to the titanium shell (Figure 1a). Three implant combinations utilized this design:

1) Encore Medical Keramos acetabular cup (DJO Surgical, 9800 Metric Blvd., Austin, TX 78758) with SL-Plus femoral stem (Smith & Nephew Orthopaedics, 1450 Brooks Road, Memphis, TN 38116); (138 hips, 51%)

2) Plus Orthopedics Intraplant MPF cup (Smith & Nephew Orthopedics AG, Erlenstrasse 4a, CH-6343 Rotkreuz, Switzerland) and SL-Plus stem (58 hips, 21%)

3) Wright Medical Lineage cup and Wright Medical Profemur Z stem (Wright Medical Technology, Inc., 5677 Airline Road, Arlington, TN 38002); (29 hips, 11%)

The second design utilized an oval cross-sectioned, tapered, titanium stem made of a proprietary TMZF beta titanium alloy and V40 Morse taper with a ceramic acetabular insert encased in a titanium shell which extended past the ceramic insert (Figure 1b). One implant combination utilized this design:

4) Stryker Trident PSL cup and Stryker Accolade stem (Stryker Orthopaedics, 325 Corporate Drive, Mahwah, New Jersey 07430); (45 hips, 17%)

## **Questionnaire**

Two hundred thirty-three patients with a total of 270 hips were contacted by telephone or interviewed in person to complete a survey regarding any noises emanating from their hip prosthesis. Patients were questioned regarding their occupation (sedentary, standing-walking, mild laborer, heavy laborer), activity level (UCLA Score), pain score (Harris Hip Pain Score), location of pain, stiffness, and presence of any squeaks or other noises. Once the noise was clarified, the participants were questioned about other details, such as timing of onset after surgery, intensity, frequency, and affect on daily activities.

### **Grading of Squeak (Table 1)**

A scale for grading the frequency of the squeak was created with a Grade I being less than weekly, Grade II occurring 1-4 times per week, Grade III being >4 times per week but not daily, and Grade IV occurring daily.

A grading scale was also created for the audible intensity of the squeak with a Grade A being perceptible only to the patient, Grade B occasionally audible to others, Grade C always audible to others, and Grade D loud enough to create a social problem for the patient, typically from embarrassment or fear of attracting attention. We defined “**problem squeaking**” as any squeak with an intensity that is always audible to others (Grade C or D) and a frequency of at least once per week (Grade II and above).

### **Statistical Analysis**

Chi-squared analysis was used to determine categorical variables and the Student-t test to determine continuous variables associated with squeaking. Thirteen independent variables were then further analyzed using a multiple logistic regression analysis to determine statistical significance. The logistic regression analysis was performed using Epi Info 6 software developed by the Centers for Disease Control. Independent variables analyzed were:

A) *Demographic Variables* – gender, age, height, weight, Body Mass Index (BMI), laterality, activity level (UCLA Score), and diagnosis.

B) *Implant Variables*- implant manufacturer, acetabular cup size, femoral head size, femoral head length, and femoral component offset.

After all squeaking hips were identified, radiographic analysis of acetabular component position was performed by matching each hip with problem squeaking in 1:1 fashion against controls without problem squeaking based on implant manufacturer, gender, age, diagnosis, BMI, follow-up duration, activity level, acetabular cup size, and femoral head size. Cup implant position was then assessed based on inclination and anteversion. Implant position was determined by a direct measure of radiographic inclination, followed by calculation of anteversion as first described by Ackland [18-20]. This data was then analyzed using Student's t-test.

## **Results**

Two hundred and thirty-three patients (270 hips) with COC total hip arthroplasties were interviewed. The severity of squeaking hips is outlined in Table 1 based on frequency (Grades I-IV), audible intensity (Grades A-D), and manufacturer. Twenty-four hips (8.8%) reported squeaking of any frequency or intensity. The mean onset to squeaking was 19.6 months (range, 1-72 months). Six hips (2.2%) hips were identified as having “problem squeaking.” The mean onset to problem squeaking was 22.3 months, (range, 8-72 months).

Of the thirteen independent variables assessed for problem squeaking, three variables showed a statistically significant correlation with problem squeaking (Table 2). Five of the six problem squeakers were from the cohort of 45 Stryker Trident cup/Accolade stem combination hips. This resulted in an 11.1% incidence of problem squeaking within this group vs. a 0.44% incidence of

problem squeaking for all other implant combinations combined (odds ratio, 34.5; 95% confidence interval, 2.83 - 421;  $p=0.006$ ). The other problem squeaker was a Plus Intraplant cup mated with an SL-Plus stem, an incidence of 1.7% (1 of 58 hips) within this implant group.

The second variable correlating with problem squeaking was pre-operative diagnosis of rheumatoid arthritis. Three of 6 problem squeakers (50%) were rheumatoids versus 10 of 264 (3.8%) non squeakers (odds ratio, 20,601; 95% confidence interval, 353.1 – 1,202,043;  $p<0.0001$ ). The third variable correlating with problem squeaking was a short (minus) neck length. Four of 6 problem squeakers (67%) had short necks compared to 36 of 264 (14%) non-squeakers (odds ratio, 11.55; 95% confidence interval, 0.99 – 135;  $p=0.05$ ). Independent variables which did not correlate with problem squeaking included gender, age, height, weight, BMI, laterality, activity level, acetabular component size, femoral head size, and femoral offset.

Measurements of acetabular inclination and anteversion were performed from follow-up radiographs and compared between the matched groups. Mean cup inclination was  $45.7\pm 3.8$  degrees (range, 40-50) in problem squeakers vs  $45.7\pm 4.9$  degrees (range, 39-50) in hips without problem squeaking ( $p=1.00$ ). Mean anteversion was  $14.7\pm 6.6$  degrees (range, 6-24) in problem squeakers vs  $13.8\pm 1.9$  degrees (range, 11-16) in hips without problem squeaking ( $p=0.77$ ).

Although a total of 11 patients underwent revision of one or both arthroplasty components, no patient had undergone revision because of squeaking at the time of publication.

## **Discussion**

Ceramic-on-ceramic (COC) articulation in total hip arthroplasty provides the most durable wear rate among available bearing surface options and may increase the longevity of the arthroplasty [4,21]. This potential advantage is becoming increasingly important as the average

age of patients undergoing hip arthroplasty continues to decline and average life expectancy continues to increase.

Although various noises have been described with all types of bearing surfaces, squeaking has only been described with hard-on-hard bearings [22]. However, prior to 2003, squeaking COC articulations were only reported in cases of head/cup size mismatch or with use of zirconia against alumina counterfaces [23]. Since FDA approval of the Stryker Orthopaedics and Wright Medical COC articulations in the United States in 2003, squeaking following total hip arthroplasty has garnered significant attention from the orthopedic community and the media [22, 24-26].

Many hypotheses have been proposed to explain possible causes and mechanisms for squeaking. Factors related to the implant, surgical technique, and patient-specific issues have all come under scrutiny. Previously reports have described microseparation, edge loading, and stripe wear, component malposition and impingement of the femoral neck, metal or granular debris, and bearing composition mismatch (e.g. alumina insert and zirconium head) [10,11,13,24,27]. Chevillotte and co-authors recently suggested that disruption of the lubrication film resulting from particulate metal debris is the most likely contributing factor to squeaking in COC total hip arthroplasties [17].

Numerous reports confirm that many patients experience sounds (squeaks, clicks, pops, or grinds) following hip arthroplasty. In our study, patients with 24 of 270 COC hips reported an audible squeak. Six of these hips had what we defined as a “problem squeak,” with an intensity always audible to others and a frequency of at least once per week. It is likely that others may develop squeaking with time, as the mean time to onset of problem squeaking was 22.3 months while the minimum follow-up period for this study was only 24 months.

We believe that a painless, infrequent sound of any kind is likely of little significance, but that if it becomes persistent, frequent, intense, or painful, it may be the harbinger of more serious problems. In addition to the social embarrassment and psychological effects it may create, such a problem squeak may signify damage to the ceramic bearing surfaces that could lead to early wear or even catastrophic implant failure [28]. Whether earlier surgical intervention in patients with audible but otherwise asymptomatic squeaking is indicated has yet to be determined. One might consider diagnostic arthroscopy in those patients where a significant mechanical abnormality is suspected [29].

Our study shows a strong correlation between implant design and incidence of squeaking. Five of 6 hips with problem squeaking had a Stryker Trident PSL acetabular cup mated with a Stryker Accolade femoral stem. The Trident ceramic insert is encased in a titanium sleeve with a raised rim, which increases the material strength of the ceramic by 50 percent and protects the insert from rim fractures when there is neck impingement or during insertion [30]. However, this elevated rim also reduces range of motion leading to earlier femoral neck impingement during range-of-motion (Figure 2). Barrack has shown that this design leads to metal-metal impingement and decreases the motion arc by 10-15 degrees [12]. Neck-rim impingement generates particulate metal debris which can disrupt the fluid film lubrication and lead to squeaking [17]. Additionally, neck-rim impingement can lead to lever out, edge loading, and stripe wear which may lead to further damage to the ceramic counterfaces. Several authors have implicated this elevated rim in the genesis of squeaking [9,12,15,17,23,24].

The Stryker Accolade femoral stem utilizes a unique metallurgy. The proprietary TMZF beta titanium alloy (Ti-12Mo-6Zr-2Fe) offers 25 percent greater flexibility than the more common alpha-beta titanium alloy (Ti-6Al-4V) and reportedly yields a modulus of elasticity which more

closely resembles that of bone [31]. Additionally, Stryker literature states that TMZF maintains a 20% higher tensile strength than the Ti-6Al-4V alloy. Murphy has suggested that oxides from this unique alloy may cause adhesion, abrasion, or lubrication disruption leading to squeaking [32].

The Accolade stem also has a proprietary V40 Morse taper rather than the more common 12/14 taper utilized by the other 3 femoral implants. The Stryker V40 taper is 11% smaller than their more common C-taper and has been implicated as a factor related to squeaking by at least one author [14].

The acetabular components of the non-squeaking hips are designed with a ceramic liner which seats flush with the acetabular shell. The femoral stems are composed of more traditional alpha-beta titanium alloys (Wright Medical Profemur Z, Ti-6Al-4V and SL-Plus, Ti-6Al-7Nb) and standard 12/14 Morse tapers. Thus, significant differences exist between the designs and metallurgies of the squeaking and non-squeaking implants.

We hypothesize that the much higher incidence of squeaking with the unique Stryker design combination is caused by the unique acetabular design combined with the unique femoral metallurgy and/or neck/trunnion design. Capello and co-authors reported a 0.8% incidence of squeaking at 8 years when the Stryker Trident acetabular component was mated with their Omnifit stem [8]. Murphy and others have suggested the Trident cup only squeaks when mated with the Accolade stem but not with the Omnifit stem [9,15,16,22,32]. Our results corroborate these findings.

Short head lengths have previously been reported to predispose to squeaking COC articulations [23,33]. Our study corroborates this finding. A short head length may lead to earlier neck impingement due to the tapered geometry of the prosthetic femoral neck, effectively

increasing the diameter of the area which contacts the edge of the acetabular ceramic [34]. Short necks may also lead to soft tissue laxity that can lead to microseparation and stripe wear [35,36].

A very intriguing correlation in our study was the relationship of rheumatoid arthritis to problem squeaking. Intuitively, one might expect the reduced activity level and increased volume of inflammatory joint fluid to play a protective role in development of squeaking. Is it possible that abnormal viscosity and makeup of inflammatory synovial fluid disrupts the lubrication film leading to squeaking? Could contractures or altered gait seen in many rheumatoids with multiple joint involvement lead to impingement, abnormal joint forces, and squeaking? These questions are yet to be answered.

Further explanation of our findings and those of earlier studies seeking to explain the genesis of squeaking may enable a reduction in its overall incidence. Although some have associated **all** COC bearing surface combinations with squeaking, it is becoming clear that only certain designs will squeak. It is therefore critical that all COC designs are not incriminated in the genesis of squeaking. Why this Stryker specific COC implant combination leads to such a high incidence of problem squeaking is not yet entirely clear. The authors conclude that squeaking can be minimized by avoiding use of the Stryker Trident cup with the Accolade stem, avoiding the use of short neck lengths, and possibly avoiding COC bearing surfaces in rheumatoid patients.

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