HIP

The role of patient factors and implant position in squeaking of ceramic-on-ceramic total hip replacements


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We investigated factors that were thought to be associated with an increased incidence of squeaking of ceramic-on-ceramic total hip replacements. Between June 1997 and December 2008 the three senior authors implanted 2406 primary total hip replacements with a ceramic-on-ceramic bearing surface. The mean follow-up was 10.6 years. The diagnosis was primary osteoarthritis in each case, and no patient had undergone previous surgery to the hip. We identified 74 squeaking hips (73 patients) giving an incidence of 3.1% at a mean follow-up of 9.5 years (4.1 to 13.3).

Taller, heavier and younger patients were significantly more likely to have hips that squeaked. Squeaking hips had a significantly higher range of post-operative internal rotation (p = 0.001) and external rotation (p = 0.003) compared with silent hips. Patients with squeaking hips had significantly higher activity levels (p = 0.009). A squeaking hip was not associated with a significant difference in patient satisfaction (p = 0.24) or Harris hip score (p = 0.34). Four implant position factors enabled good prediction of squeaking. These were high acetabular component inclination, high femoral offset, lateralisation of the hip centre and either high or low acetabular component anteversion.

This is the largest study to date to examine patient factors and implant position factors that predispose to squeaking of a ceramic-on-ceramic hip. The results suggest that factors which increase the mechanical forces across the hip joint and factors which increase the risk of neck-to-rim impingement, and therefore edge-loading, are those that predispose to squeaking.

Squeaking of a total hip replacement (THR) was first reported with the Judet acrylic hemiarthroplasty. It may occur after the failure of a polyethylene-bearing surface when movement occurs between a metal head and the acetabular metal shell or ceramic head and the acetabular shell. Currently, squeaking is primarily a problem of hard-on-hard bearings, and has been increasingly reported as a complication of modern ceramic-on-ceramic bearings. The incidence of squeaking ranges from < 1% to 20.9%. Squeaking hips have been shown in an earlier study undertaken by our unit to be associated with younger, heavier and taller patients. These factors may be associated with increased mechanical demands. Squeaking was also shown, in the same study, to be associated with either excessive or insufficient anteversion of the acetabular component. However, it may also occur in ceramic bearings with ideal placement of the acetabular component and in the absence of neck to rim impingement. In rare cases, the squeak is not tolerated by the patient and has prompted a revision. We further investigated factors associated with an increased risk of squeaking. Identification of these factors may help to identify the cause of the squeaking ceramic-on-ceramic hip.

Patients and Methods

We identified all squeaking hips occurring after ceramic-on-ceramic THRs which were carried out in our unit. All patients were asked at follow-up: "Has your hip ever made a squeaking noise?" If a patient was unable to attend the clinic they were asked the same question by telephone. If possible the squeak was elicited in the clinic. If not the patient was questioned closely to differentiate between squeaking and other noises around the hip.

Patient demographics and clinical information were collected prospectively at pre-operative assessment and one year post-operatively. We investigated the patient factors which were thought to play a role in increased mechanical demands; age at surgery, height and weight, as well as factors which might impact on the risk.
of edge loading: range of hip movement and body mass index (BMI). We compared outcomes between squeaking hips and silent hips using the Harris hip score (HHS), and patient satisfaction measured on a visual analogue scale (VAS) from one (least satisfied) to ten (most satisfied). We also used a control group of all primary ceramic-on-ceramic THRs undertaken at our hospital.

Standard anteroposterior (AP) standing radiographs of the pelvis taken pre-operatively and at least six months post-operatively were digitised and examined independently at the Orthopaedic Biomedical Imaging Institute, University of Chicago, using Hip Analysis Suite software (University of Chicago, Chicago, Illinois). The following variables were recorded: acetabular component anteversion, inclination, and medialisation (position of the centre of rotation pre- and post-operatively, relative to the teardrop), femoral offset and the joint reaction force direction and magnitude (calculated with reference to the patient's weight). Our control group of patients all had ceramic-on-ceramic primary THRs where the pre-operative diagnosis was primary osteoarthritis (OA). Patients who had undergone previous hip surgery were excluded from both groups. The control group were matched to the squeaking hip group for age at surgery (within two years), gender, bearing surface, femoral head size, and acetabular and femoral component type. All control patients had undergone their surgery at least two years earlier to allow time for any squeaking to develop. We have previously identified that squeaking develops at a mean of 14 months following surgery. Power analysis for binary logistic regression with β = 0.8 and α = 0.05 suggested that a control patient to squeaking hip patient ratio of 4:1 was appropriate and this ratio was obtained. An identical radiological analysis was performed on the control patients. Assessors were blinded to the controls and squeaking hip patients.

Between June 1997 and December 2008 the three senior authors (WLW, BAZ, WKW) implanted 2406 primary THRs with ceramic-on-ceramic bearings. The diagnosis was primary OA in each case, and no previous surgery had been undertaken on any hip. Most of the ceramic bearings were manufactured in third generation alumina ceramic (Biolox Forte; Ceramtec, Plochingen, Germany). A total of 92 alumina ceramic bearings (Dermarquest, Vincennes, France), and 60 alumina matrix composite bearings (Biolox Delta, Ceramtec) were also implanted. The largest femoral head size possible was used for a given acetabular component size. A posterolateral approach with repair of the posterior structures was used in each case.

Statistical analysis. The Kolmogorov-Smirnov test was used to test for normality of data. When comparing pre- and post-operative variables with normally distributed data we calculated the means and SD and the t-test was used to determine significant differences in the means. For non-parametric variables the Mann-Whitney U test was used to determine significant differences in the medians. Where a power analysis was performed we have assumed two tails and 80% power (1-β = 0.8, α = 0.05). Statistical significance was set at a p-value < 0.05.

We assumed that the role of implant position in squeaking was likely to be multifactorial. We therefore designed our statistical analysis to identify which of the implant position factors are useful in predicting whether or not a hip will squeak. This analysis is presented visually using a Receiver Operating Characteristic (ROC) curve. This curve is a graphical plot of the sensitivity vs 1-specificity and represents the ability of the implant factors to predict squeaking. A test with perfect discrimination has a ROC curve that passes through the upper left corner (100% sensitivity, 100% specificity). Therefore the closer this curve is to the upper left corner, the higher the area under the curve (Az) and the greater the predictive value of the test. The performance of the logistic regression is reflected by the Az value, with an area of 1 representing a perfect test and an area of 0.5 representing a test which has a predictive value equivalent to flipping a coin. Areas under the curve are classified as follows: 0.9 to 1, excellent; 0.8 to 0.9, good; 0.7 to 0.8, fair; 0.6 to 0.7, poor. First a t-test was performed for each of the implant variables described above, comparing squeaking hips with controls. Variables with a p-value of ≤ 0.1 were included for analysis in the logistic regression model and contributed to the ROC curve.

Results
There were 74 hips (73 patients, 3.1% incidence) that squeaked. The mean time from operation to when the squeaking was first noticed was 40 months (1 to 96). In all, four patients (5%) described squeaking with every step, 23 (32%) every day, and 46 (63%) less than once per day. In 56 patients (77%) the main activity that elicited a squeak was bending, in 12 (16%) it was walking, three (4%) climbing stairs and two (3%) on sports activities. At a mean follow-up of 9.5 years (4.1 to 13.3) 11 hips (15%) were found to have stopped squeaking. Taller and heavier patients were significantly more likely to have hips that squeaked. The mean height of the patients with hips that squeaked was 172 cm (SD 8.9) compared with a mean of 169 cm (SD 9.4) for silent hips (p = 0.003). The mean weight of patients with hips that squeaked was 80.2 kg (SD 14.4), compared with a mean of 76.4 kg (SD 15.3) for silent hips (p = 0.04). Obesity, however, was not associated with squeaking. There was no significant difference in BMI between patients with squeaking and silent hips. The mean BMI in squeaking hips was 26.8 kg/m² (SD 4.6) and in silent hips 26.6 kg/m² (SD 4.4, p = 0.53).

Younger patients were significantly more likely to have hips that squeaked. The mean age of patients with a squeaking hip was 60 years (SD 11.1) and with a silent hip was 65 years old (SD 9.8, p < 0.001).

Table I compares the range of movement (ROM) between squeaking and silent hips.
There was a significant negative correlation between age and external rotation of the hip (Spearman’s correlation coefficient = -0.182, p = 0.047). Similarly, there were significant negative correlations between height and hip flexion (Spearman’s = -0.244, p = 0.007), and adduction (Spearman’s = -0.190, p = 0.046); and between weight and hip flexion (Spearman’s = -0.239, p = 0.08) and adduction (Spearman’s = -0.183, p = 0.044). Therefore, in order to reduce the confounding effect of age, height and weight when investigating the role of ROM in squeaking, we performed a matched control analysis. A power study indicated that three control hips were needed for each squeaking hip. Control hips were matched for age (within two years), height (within 10 cm) and weight (within 5 kg).

Table II compares the components of the ROM of the hip, between squeaking and silent matched control hips. The results are comparable to those in Table I and indicate that age, weight and height are not acting as confounding variables.

There was no significant difference in HHS between squeaking and silent hips. The median HHS in squeaking hips was 96 (51 to 100) and in silent hips was 95 (29 to 100) (p = 0.34, Mann-Whitney U test). However, the activity subgroup of the HHS was significantly higher in squeaking hips (median 14 (5 to 14)) when compared with silent hips (median 12 (2 to 14), p = 0.009 Mann-Whitney U test). There was no significant difference in patient satisfaction between those with squeaking and silent hips (p = 0.24).

No significant difference in HHS, HHS subgroups (including activity), or patient satisfaction was found in the control group.

There was no association between prosthetic femoral head size and squeaking (p = 0.837, chi-squared test) or between prosthesis type and squeaking, although the power of the study to demonstrate this was < 80%.

The variables for implant position in squeaking hips and controls were compared. Variables with p < 0.1 on t-test were included in the logistic regression and ROC curve analysis. These were: inclination of the acetabular component (greater inclination in squeaking hips), prosthetic femoral offset (greater offset in squeaking hips), and medialisation of the acetabular component (less medialisation in squeaking hips). In addition, we have previously shown that both high or low acetabular component anteversion is significantly associated with squeaking. A new variable was calculated as follows: (acetabular component anteversion minus mean acetabular component anteversion). This gives a measure of excessive or insufficient anteversion and is squared so that it is always a positive value. This new value has a p-value = 0.06 (t-test) when comparing squeaking hips and controls and so is included in the ROC analysis. Figure 1 shows the ROC analysis for the four variables with p < 0.1.

Using all four variables identified high acetabular component inclination, high femoral offset, low acetabular component medialisation and anteversion away from the mean, the area under the curve is 0.81. These four implant positioning factors enable us to predict accurately whether a hip will squeak or not.

**Discussion**

It is apparent both from the literature and from our results that no single factor accounts for squeaking in ceramic-on-ceramic THR. Patient factors shown by this study to be associated with squeaking were younger age, greater height and weight, and a greater range of internal and external rotation of the hip. These findings suggest that a combination of factors that predispose to impingement and edge loading (increased range of rotation) as well as factors that increase the mechanical forces across the joint (taller, heavier patients as well as younger patients with higher
activity scores) are likely to lead to squeaking. BMI was not significantly different between squeaking and silent hips, so obesity does not appear to be a risk factor.

This study identified four implant position factors that predicted squeaking. We previously identified high or low anteversion of the acetabular component as being associated with squeaking. 8 We suggest that the prosthesis is more likely to impinge and edge-load in these cases. The increased ROM found in hips that squeak is likely to contribute to the risk of edge-loading. Finite element analysis predicts increased wear in ceramic-on-ceramic bearings with increased inclination and high or low anteversion. 15 To date only reduced (but not increased) acetabular component anteversion has been shown in vivo to result in increased wear in ceramic-on-ceramic bearings. 16 High acetabular inclination has been shown to increase wear in metal-on-polyethylene bearings, and suboptimal acetabular inclination has been shown to result in increased penetration rates in ceramic-on-ceramic bearings in vivo. 17 A suggested mechanism explaining how these factors may lead to squeaking is that: under ideal conditions, hard-on-hard contact may lead to frictional energy dissipation. If this increase in friction is due to sliding, an increase in femoral offset should not result in increased forces across the hip joint. Height is positively correlated with femoral offset (Spearman rank correlation, 0.288, p = 0.048); it is possible, therefore, that height may be acting as a confounding factor.

In our practice squeaking has not been a major clinical problem. Any squeaking that does occur is usually benign and does not trouble the patient significantly. More troublesome squeaking is reported by other authors 22 this may be due to differences in surgical technique or implant selection. We continue to use ceramic-on-ceramic bearings with confidence, as we have not observed any association between squeaking and early failure of the bearing surface.

References