■ HIP

Excellent results of large-diameter ceramic-on-ceramic bearings in total hip arthroplasty

IS SQUEAKING RELATED TO HEAD SIZE?

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Aims

This study reports the mid-term results of total hip arthroplasty (THA) performed using a monoblock acetabular component with a large-diameter head (LDH) ceramic-on-ceramic (CoC) bearing.

Patients and Methods

Of the 276 hips (246 patients) included in this study, 264 (96%) were reviewed at a mean of 67 months (48 to 79) postoperatively. Procedures were performed with a mini posterior approach. Clinical and radiological outcomes were recorded at regular intervals. A noise assessment questionnaire was completed at last follow-up.

Results

There were four re-operations (1%) including one early revision for insufficient primary fixation (0.4%). No hip dislocation was reported. The mean University of California, Los Angeles (UCLA) activity score, 12-Item Short-Form Health Survey (SF-12) Mental Component Summary (MCS) score, SF-12 Physical Component Summary (PCS) score, Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) score, and Forgotten Joint Score (FJS) were 6.6 (2 to 10), 52.8 (25.5 to 65.7), 53.0 (27.2 to 66.5), 7.7 (0 to 63), and 88.5 (23 to 100), respectively. No signs of loosening or osteolysis were observed on radiological review. The incidence of squeaking was 23% (n = 51/225). Squeaking was significantly associated with larger head diameter ($p < 0.001$), younger age ($p < 0.001$), higher SF-12 PCS ($p < 0.001$), and UCLA scores ($p < 0.001$). Squeaking did not affect patient satisfaction, with 100% of the squeaking hips satisfied with the surgery.

Conclusion

LDH CoC THAs have demonstrated excellent functional outcomes at medium-term follow-up, with very low revision rate and no dislocations. The high incidence of squeaking did not affect patient satisfaction or function. LDH CoC with a monoblock acetabular component has the potential to provide long term implant survivorship with unrestricted activity, while avoiding implant impingement, liner fracture at insertion, and hip instability.

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Ceramic-on-ceramic (CoC) bearings were developed for total hip arthroplasty (THA) because of their excellent tribological properties, with low surface roughness, high hardness, scratch resistance, and high wettability.[1] Other bearing systems have well-documented problems. Conventional polyethylene is associated with osteolysis due to wear debris.[2] Metal-on-metal (MoM) bearings are associated with adverse reactions to metal debris, including elevated metal ions and pseudotumours.[3] The first CoC bearing was introduced in France in the 1970s.[4] Mid- to long-term results of CoC bearings showed very favourable results with limited osteolysis and great implant survivorship.[5] However, failures linked to component fracture or impingement were reported.[6,7] Improvements in ceramic material have decreased the fracture risk to 0.1% in clinical studies.[8]

More recently, larger diameter head (LDH) CoC bearings were introduced to provide increased range of movement (ROM) and stability, without the associated problems seen in MoM bearings. These benefits should allow the patient to convalesce immediately following THA without

Fig. 1a

Fig. 1b

a) Preoperative and b) postoperative anteroposterior radiographs of a 40-year-old fireman, who had bilateral Legg–Calvé–Perthes disease. His pastimes included kayaking, cycling, and rock climbing. Bilateral ceramic-on-ceramic large-diameter head total hip arthroplasties were performed in one stage. No range of movement restrictions were imposed. He resumed his work and leisure activities without restriction after four months. At five years' follow-up, he is very satisfied with his clinical results. He has heard squeaking noises in his left hip on a few occasions but describes it as "not bothersome". He considers his right hip as a natural or forgotten hip and the left one as an artificial hip without limitations.

Fig. 2a

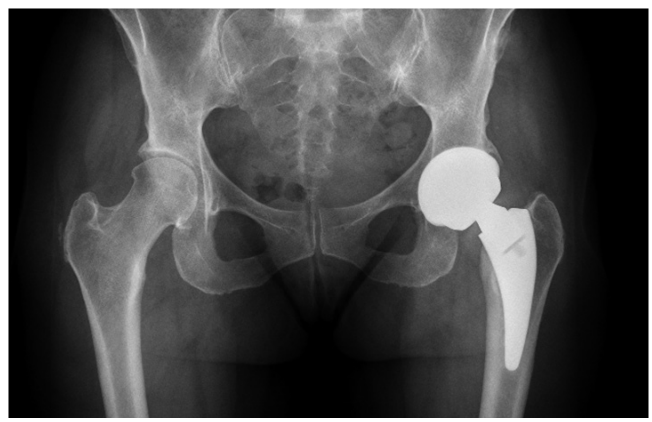

Fig. 2b

a) Preoperative and b) one-year postoperative anteroposterior radiographs of a 55-year-old female yoga teacher with osteoarthritis and a small build. She wishes to resume teaching yoga and does not want to be restricted by her hip. A 50 mm acetabular component (last reamer 49 mm) was implanted, allowing a 40 mm diameter femoral head.

the need to restrict the ROM, should facilitate bilateral THA, should provide early return to leisure activities or vocation (Fig. 1), and may prevent stem to liner impingement (Fig. 2). These LDH CoC THAs require thin ceramic liners. Therefore, to minimize the risk of liner fracture due to incorrect assembly of a modular acetabular component,[9] CoC LDH are now offered as a monoblock implant. It is manufactured pre-assembled and then implanted as a monoblock component.

One specific problem of hard-on-hard bearings is noise generation. McDonnell et al[10] reported a squeaking incidence of 21% in 208 hips with the LDH CoC DeltaMotion System (DePuy Synthes, Warsaw, Indiana). With the same implant, Goldhofer et al[11] reported an incidence of squeaking of 17% at five years' follow-up. There were, however, no significant differences regarding patient satisfaction or clinical outcomes between the patients with squeaking and silent hips.

Since 2011, our group has performed more than 2500 LDH CoC THAs using the Maxera hip system (Zimmer Biomet, Warsaw, Indiana, Fig. 3). The aim of this study is to report the mid-term clinical and radiological results of our first 276 hip arthroplasties, with a minimum of four years of follow-up.

Patients and Methods

Between August 2011 and March 2013, 276 primary THAs were performed on 246 patients using the Maxera Cup and ceramic LDH (Zimmer Biomet). The patient demographics are summarized in Table I. All patients ≤ 75 years with life expectancy above 15 years were considered candidates for this implant. Based on preoperative radiographs and intraoperative assessment, patients were excluded if the surgeon deemed the acetabular bone stock was inadequate to rely solely on press-fit primary fixation.

Fig. 3

Photograph of the Maxera acetabular component and Delta ceramic femoral head.

All procedures were performed by four arthroplasty surgeons at two institutions (AR, ML, VM, and PAV). Ethical approval was obtained from the hospital ethics committee, and all patients gave informed consent. The surgery was performed using a mini-posterior approach. The femoral implants included: 215 CLS Spotorno (78%) (Zimmer Biomet); 53 Profemur Preserve stem (19%) (MicroPort Orthopaedics Inc., Arlington, Tennessee); seven Wagner Cone (3%) (Zimmer Biomet); and one MS-30 Cemented Stem (0.4%) (Zimmer Biomet).

Functional outcomes. Outcome data were collected prospectively. Patients had regular follow-up appointments with radiographs at six weeks, 12 months, and then annually. At last follow-up, functional assessments were performed using the University of California at Los Angeles (UCLA) activity score,[12] the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) score,[13] and the Physical Component Summary (PCS) and Mental Component Summary (MCS) scores of the 12-Item Short Form Health Survey (SF-12).[14] The Forgotten Joint score (FJS),[15] THA perception, and patient satisfaction were also assessed.

Noise assessment. A specific assessment of squeaking and other noises was performed at last follow-up. The incidence, type, frequency, intensity, time interval, and activities which triggered the production of noise from the prosthetic hip after surgery were assessed through categorical, ordinal, and open-ended questions.

Radiological outcomes. Anteroposterior and cross-table lateral radiographs were performed preoperatively, postoperatively, and at last follow-up. Acetabular inclination was measured on the anteroposterior radiograph and anteversion measured on the cross-table lateral radiograph, by one arthroplasty fellow, using the technique described by Pulos et al.[16] The occurrence of osteolysis or radiolucent lines was noted using the DeLee

Table I. Patient demographics

Criteria	
Hips, n	276
Mean age at surgery, yrs (SD; range)	53.8 (10.3; 16 to 73)
Gender, n (%)	
Female	150 (*61.0*)
Male	96 (*39.0*)
Mean height, cm (SD; range)	168 (9.5; 145 to 198)
Mean weight, kg (SD; range)	77.1 (16.5; 45.5 to 136.1)
Mean body mass index, kg/m^2 (SD; range)	27.2 (4.9; 16.2 to 41.7)
Diagnosis, n (%)	
Primary osteoarthritis	222 (*80.4*)
Structural hip disorder	21 (*7.6*)
Avascular necrosis	16 (*5.8*)
Legg–Calvé–Perthes disease	7 (*2.5*)
Inflammatory arthritis	6 (*2.2*)
Post traumatic arthritis	4 (*1.4*)
Lost to follow-up, n (%)	9 (*3.3*)
Deceased, n (%)	3 (*1.1*)
Mean time to follow-up, mths (SD; range)	66.5 (6.9; 48.0 to 78.5)

and Charnley classification[17] for the acetabular components and the Gruen classification[18] for stems. Acetabular component migration was evaluated by comparing the implant alignment on sequential radiographs. The contact patch to rim distance (CPRD) was calculated using the method described by Amstutz et al.[19]

Statistical analysis. Data are presented with means (with standard deviations (SD) and ranges) for continuous variables and frequencies for categorical variables. Statistical analysis was performed using SPSS version 24 (IBM Corp., Armonk, New York). For comparison between squeaking and non-squeaking hips, Student's *t*-test (two-tailed), Mann-Whitney test, and chi-squared analyses were used for continuous data with normal distribution, continuous data with non-normal distribution, and categorical data, respectively. Stepwise multivariate analyses were also conducted to determine the best squeaking predictors. The significance level was set to a p-value < 0.05.

Results

Of the 276 hips included in this study, 264 were reviewed clinically at a mean of 67 months (48 to 79) postoperatively, a total of nine (3%) were lost to follow-up and three (1%) were deceased from medical conditions which were unrelated to the surgery. There were four re-operations (1.4 %) including one revision (0.4%) performed for early (less than four weeks) acetabular component migration secondary to insufficient primary fixation (revised to a 2 mm larger Maxera Cup at six weeks). The patient had an excellent recovery after revision procedure and her last follow-up data at five years are included in the current report. Of the three other re-operations, one was for a suspicion of acute prosthetic joint infection, one for a sciatic neuropathy which required a femoral-shortening osteotomy, and one for a traumatic periprosthetic femoral fracture at 50 months post-operatively. No hip dislocation was reported. Intraoperatively, there were five (2%) undisplaced acetabular rim fractures, with a stable component left *in situ* requiring no specific treatment

Table II. Comparison of functional and radiological outcomes

Criteria	All hips (n = 225)	Squeaking hips (n = 51)	Non-squeaking hips (n = 174)	p-value
Mean UCLA activity score (SD; range)	6.6 (1.9, 2 to 10)	7.6 (1.8)	6.4 (1.9)	< 0.001*†
Mean SF-12 score (SD; range)				
Mental Component Summary	52.8 (8.1, 25.5 to 65.7)	52.5 (8.4)	52.9 (8.0)	0.760*
Physical Component Summary	53.0 (7.2, 27.2 to 66.5)	56.1 (5.1)	52.1 (7.5)	< 0.001*†
Mean WOMAC score (SD; range)	7.7 (14.8, 0 to 63)	5.7 (9.2)	7.9 (11.1)	0.277‡
Mean Forgotten Joint Score (SD; range)	88.5 (14.8, 23 to 100)	89.1 (13.9)	88.2 (15.0)	0.962‡
Satisfaction (n, %)				0.490§
Strongly satisfied	208 (*92.4*)	46 (*90.2*)	162 (*93.1*)	
Satisfied	15 (*6.7*)	5 (*9.8*)	10 (*5.7*)	
Neutral	2 (*0.9*)	0 (*0*)	2 (*1.1*)	
Dissatisfied	0 (*0*)	0 (*0*)	0 (*0*)	
Strongly dissatisfied	0 (*0*)	0 (*0*)	0 (*0*)	
Perception (n, %)				0.067§
Natural hip	127 (*50.2*)	22 (*43.1*)	92 (*52.9*)	
Artificial hip without limitation	61 (*24.1*)	10 (*19.6*)	45 (*25.9*)	
Artificial hip with minimal limitations	63 (*24.9*)	19 (*37.3*)	35 (*20.1*)	
Artificial hip with important limitations	2 (*0.8*)	0 (*0*)	2 (*1.1*)	
Non-functional hip	0 (*0*)	0 (*0*)	0 (*0*)	
Mean acetabular component abduction, ° (SD; range)	45.3 (5.8, 31.1 to 57.7)	44.3 (6.3)	45.6 (5.6)	0.165*
Mean acetabular component anteversion, ° (SD; range)	28.6 (8.3, 3.8 to 45.4)	27.1 (7.7)	29.1 (8.0)	0.128*
Mean CPRD, mm (SD; range)	9.1 (3.2, 2.0 to 19.4)	9.9 (3.2)	8.8 (2.9)	0.016*

*Two-tailed Student's *t*-test

†Statistically significant

‡Mann–Whitney U test

§Chi-squared test for satisfaction and perception was performed after recategorization due to low frequencies in some groups

and without sequelae. There were five (2%) proximal femur calcar cracks, treated with cerclage wiring. No ceramic implant fracture was reported.

Functional outcomes. Functional outcomes are summarized in Table II. The mean UCLA activity scale, SF-12 MCS and PCS scores, WOMAC score, and FJS were respectively 6.6, 52.8, 53.0, 7.7, and 88.5. In all, 223 patients (99%) were satisfied with their THA and 188 prosthetic hips (74%) were perceived as natural or having no limitations.

Radiological outcomes. The mean acetabular abduction angle was 45.3° (31.1° to 57.7°) and anteversion was 28.6° (3.8° to 45.4°). All patients showed satisfactory bony ingrowth of the acetabular component, with no evidence of acetabular component migration or osteolysis. There was no osteolysis or subsidence around the femoral component. Only one hip had cortical hypertrophy in Gruen zone 4 and 5. There was one hip with heterotopic ossification (Brooker grade 2).[20] The CPRD was calculated and presented in Table II.

Noise generation. Prior to completion of a specific questionnaire on noise perception, squeaking noise was spontaneously reported in routine clinical assessments for only 11 hips (4%). At final follow-up, of the 225 hips in patients who completed the noise assessment questionnaire, noise was reported for 67 hips (30%). A total of 51 hips (23%) reported a squeaking noise and 17 (8%) reported a clicking noise. Of the squeaking hips, 42 (82%) described the noise as "non-disturbing", nine (18%) as "disturbing but bearable", and none as "unbearable." Squeaking noises were heard either rarely with certain movements, every week, or every day for 39 (77%), nine (18%), and three (6%) of the squeaking hips, respectively. The squeaking began in the first two years for 17 (17/46, 37%) of the squeaking hips, in the third or fourth year for 11 (11/46, 24%), and after more than four years for 18 (18/46, 39%); five patients (5/51, 10%) could not recall when the squeaking started. Squeaking had stopped for 12% of these hips at time of last follow-up. Frequently reported activities that caused squeaking were weight-bearing hip flexion (37 hips, 73%), e.g. putting on shoes, rising from a low sitting position such as a toilet seat or climbing a ladder, or standing hip rotation after prolonged weight-bearing (ten hips, 20%), e.g. pivoting on one leg after standing in line for a while. Patients were unable to identify specific activities or movements responsible for squeaking events in five (5/51, 10%) cases.

Characteristics of squeaking hips relative to non-squeaking hips are detailed in Tables II and III. Squeaking was reported more often in younger patients ($p < 0.001$), patients with higher SF-12 PCS ($p < 0.001$) or UCLA scores ($p < 0.001$), and patients with larger CPRD ($p = 0.016$). Greater femoral head size was associated with increased squeaking (Table III, Student's *t*-test (two-tailed): $p < 0.001$). More males reported squeaking (33% *vs* 16%, chi-squared test; $p = 0.002$). However, as seen in Table IV, there were no males in the 32/36 mm group and only 8% in the 40 mm group. At the other end, there are only three women (6.5%) with a 48 mm bearing diameter. In this sample, gender is associated with bearing diameter in such a way that precludes separation of the effects of each. We performed stepwise multivariate analyses including bearing diameter or gender and found that the best predictors were UCLA score, age, gender, or

Table III. Comparison of characteristics for squeaking hips

Characteristics	Squeaking hips (n = 51)	Non-squeaking hips (n = 174)	p-value*
Mean age, yrs (SD)	49.3 (9.9)	55.5 (9.8)	< 0.001*†
Gender, n (%)‡			0.002†§
Female	22 (*15.9*; *43.1*)	116 (*84.1*; *66.7*)	
Male	29 (*33.3*; *56.9*)	58 (*66.7*; *33.3*)	
Mean weight, kg (SD)	79.8 (16.4)	76.5 (16.6)	0.217*
Mean body mass index, kg/m^2 (SD)	26.8 (4.0)	27.2 (5.2)	0.587*
Mean bearing diameter, mm (SD)	44.1 (3.4)	42.1 (3.6)	< 0.001*†
Bearing diameter, n (%)¶			0.001†§
32 mm or 36 mm	1 (*6.7*; *2.0*)	14 (*93.3*; *8.0*)	
40 mm	17 (*17.3*; *33.3*)	81 (*82.7*; *46.6*)	
44 mm	13 (*19.7*; *25.5*)	53 (*80.3*; *30.5*)	
48 mm	20 (*43.5*; *39.2*)	26 (*56.5*; *14.9*)	

*Two-tailed Student's *t*-test

†Statistically significant

‡Shown as % with this hip classification (i.e. squeaking hips *vs* non-squeaking hips) as a proportion of all hips; % with this gender as a proportion of all hips

§Chi-squared test

¶Shown as % with this hip classification (i.e. squeaking hips *vs* non-squeaking hips) as a proportion of all hips; % with this bearing diameter as a proportion of all hips

Table IV. Cross-tabulation of gender *versus* bearing diameter

Bearing diameter	Gender, n (%)		Total
	Female	Male	
32 mm or 36 mm	15 (*10.9*)	0 (*0*)	15 (*10.9*)
40 mm	90 (*65.2*)	8 (*9.2*)	98 (*43.6*)
44 mm	30 (*21.7*)	36 (*41.4*)	66 (*29.3*)
48 mm	3 (*2.2*)	43 (*49.4*)	46 (*20.4*)

bearing diameter (p = 0.001, p = 0.002, p = 0.01 and p = 0.01, respectively). No significant statistical associations were found between other factors such as acetabular component abduction angle (p = 0.165), component anteversion (p = 0.128), femoral stem type (p = 0.129), WOMAC score (p = 0.277), SF-12 MCS (p = 0.760), FJS (p = 0.962), or the operating surgeon (p = 0.633).

Despite the squeaking sound, 22 of the squeaking hips (43%) were perceived as "natural" compared with 92 for the non-squeaking hips (53%). Overall, the patients' perception of their hip was not statistically different in the silent *versus* the squeaking hips (chi-squared test; p = 0.079). All patients who reported squeaking (n = 51, 100%) stated that they were satisfied with their hip arthroplasty.

Discussion

To the authors' knowledge, this is the first study reporting the outcomes of the Maxera monoblock ceramic acetabular component with a large diameter ceramic femoral head. At a mean of 67 months, this bearing performs well with only one revision in 276 hips (0.4 %). There were no dislocations and excellent functional outcomes were observed. The incidence of squeaking is 23%, but no patients reported being significantly troubled by the noise.

Disadvantages of traditional CoC bearings are material brittleness with potential fracture, noise generation by the bearing, and femoral neck problems related to impingement on the ceramic liner.[1,21] Femoral head diameter may also be limited by the liner thickness required for a modular acetabular component. To increase the bearing diameter ratio (i.e. a larger head in smaller acetabular component), the ceramic liner and metallic shell combination needs to be thinner. To optimize its taper connection in the titanium shell and minimize the risk of liner fracture due to incorrect surgical assembly, CoC LDH acetabular systems are offered as a monoblock construct that is pre-assembled. We have not encountered implant fractures with this implant design. This acetabular component design does not allow supplementary screw fixation and thus requires adequate primary press fit fixation. In this series, there was one acetabular revision within the first postoperative week for early loosening (Fig. 4). Great attention should be paid to acetabular bone preparation, component size selection, and implant impaction technique.

Our results confirm that the dislocation risk is minimal, with no dislocation seen in the series. A number of trials have shown low dislocation rate with LDH (< 0.5%).[22,23] In the Australian Orthopaedic Association National Joint Replacement Registry, CoC bearings with a head size of 36 mm or greater have a lower revision rate than those with smaller head sizes. This is likely a result of a reduced dislocation rate.[24] At one year, the cumulative incidence of revision for dislocation is 2.0% for head sizes ≤ 28 mm, 0.4% for 32 mm, 0.3% for 36 mm to 38 mm, and 0.1% for ≥ 40 mm.[24]

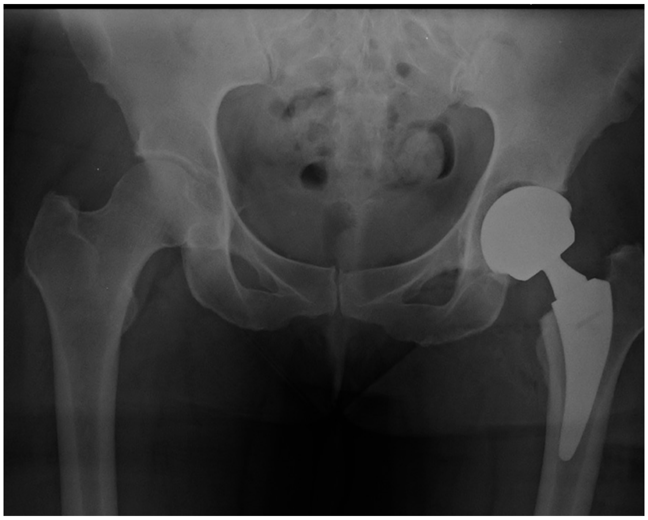

Fig. 4a

Fig. 4b

Postoperative radiographs of a 52 year-old female patient demonstrating a component that a) was not adequately impacted, b) leading to loss of position at one week postoperatively.

A purported advantage of CoC bearings in comparison with metal-on-polyethylene (MoP) is decreased wear, reduced polyethylene-debris-induced osteolysis, and improved long-term survivorship. Two randomized trials comparing a CoC bearing with a conventional cross-linked MoP bearing demonstrated much lower revision rates due to aseptic loosening in the CoC groups (1% *vs* 11%, p = 0.017; 11% *vs* 3%, p = 0.036).[5,25] However, in a randomized trial comparing highly cross-linked polyethylene with a CoC bearing, no significant differences were detected in the revision rate or functional outcomes, at a mean of 12 years' follow-up.[26] In our mid-term study, we did not see radiological signs of osteolysis or wear and no revisions were performed for aseptic loosening. Only one hip was revised, for failure of primary acetabular fixation.

The incidence of squeaking reported by our patients (23%) is comparable to other studies reporting on a similar monoblock ceramic acetabular component (DeltaMotion, Depuy).[10,11] The DeltaMotion implant was withdrawn from production in 2017, leaving the Maxera Cup (Zimmer Biomet) as the only monoblock ceramic acetabular component available. Overall, very few of our patients (9/264, 3%) reported that they were bothered by a squeaking noise. In fact, when patients were not specifically asked about squeaking, the self-reported squeaking rate was only 4%. Surprisingly, many patients reporting a squeaking noise still felt they had a natural hip (43%).

Bearing diameter was proportionally associated with squeaking, with rates of squeaking of 44% with 48 mm, 20% with 44 mm, 17% with 40 mm, and 7% for 36 mm (p < 0.001, Table III). This finding is similar to Goldhofer et al,[11] but differs from the findings of McDonnell et al,[10] who found a significantly higher incidence of squeaking with smaller femoral head sizes (p = 0.01). McDonnell et al[10] hypothesized that higher squeaking noise was the result of a decreased CPRD, the distance between the area of contact of the head on the bearing surface and the true rim of the liner.[27] In both the DeltaMotion and Maxera acetabular components, the coverage angle decreases from 169° with a 36 mm head to approximately 158° with a 40 mm or greater head, as a consequence of the lateralization of the centre of rotation (decreasing CPRD). A smaller CPRD would be associated with higher edge-loading and thus lead to stripe wear and squeaking.[28] In contrast, we found that the CPRD was significantly larger in the squeaking hips (10.0 *vs* 8.9; p = 0.016, Table II), since significantly more squeaking hips had larger heads (Table III). In larger bearings (> 40 mm), the coverage angle remains the same, but the CPRD increases. Other variables that affect the CPRD include the acetabular inclination and anteversion. We did not find an association between noise and acetabular inclination or anteversion, while McDonnell et al[10] found that squeaking hips had significantly decreased degrees of acetabular component inclination and anteversion. Pierrepont et al[29] investigated changes in the acetabular component anteversion between seating and standing in a matched group of squeaking and non-squeaking hips. They found the functional anteversion in the squeaking group in the flexed seated position was significantly lower than in the control group (mean 8°, -11° to 36° and mean 21°, -2° to 38°, respectively; p = 0.002). This was primarily due to increased anterior tilt of the pelvis in the seated position of the squeaking group.

One possible explanation for the increased squeaking rate seen with larger bearings in our study is the increased friction-induced vibrations caused by a greater head diameter and the resultant loss of fluid film lubrication. This may occur when moving the hip after a period of inactivity or by particular loading conditions with increased range. In rotational dynamics, the frictional moment at the bearing interface is linearly related to the moment arm of the friction force vector, which is the radius of the bearing. Thus, as the bearing diameter increases, the frictional moment increases, and theoretically, more articular work is generated and converted to mechanical vibrations. By measuring frictional moments for large diameter bearings in a hip simulator, Bishop et al[30] showed that the frictional moments for a LDH CoC bearing increased by over five-fold in dry conditions (extreme loss of fluid film lubrication) relative to lubricated conditions. In dry conditions, the mean frictional moment of the 48 mm CoC bearings was almost twice that of the 32 mm bearings (24.2 Nm *vs* 12.3 Nm) and squeaking was loudest and independent of load for the larger CoC bearing. In our study, most patients reported noise with very specific movements and none after activities with repeated cycles such as walking or cycling. A larger head size, with a resultantly greatly increased sphere mass, would also reduce the natural resonant frequency of the stem-head construct and lead to a greater amplification of audible friction-induced vibrations.

Patient factors that have been found to be associated with squeaking include increased ligament laxity, increased hip ROM, and female gender.[10,11] In our study, more male patients reported squeaking (33% *vs* 16%; $p = 0.002$). However, gender was strongly associated with head size, such that we were unable to separate the effects of each (Table IV). Although we were unable to separate the effects of these two factors statistically, head size would offer the more scientifically plausible reasons for causation of squeaking as outlined above. We also found a higher rate of squeaking in younger ($p < 0.001$, Table III) and more active patients (higher UCLA and SF-12 PCS; $p < 0.001$, Table II). More active patients may put their hip through a higher ROM, increasing the risk of edge loading, which may result in squeaking.

This study has some limitations. Radiological measures were performed using plain images and, while this technique has demonstrated satisfactory reproducibility and validity,[31] CT scanning is preferable . Minor modifications were made to the SF-12 questionnaire without the approval of OptumInsight Life Sciences (QualityMetric, Johnston, Rhode Island), so the scores may not necessarily correlate with previous reported scores. Finally, the length of follow-up is reasonably short for a THA. This is, however, the first trial to report on the mid-term outcomes of the Maxera Cup system.

In conclusion, LDH CoC THAs have demonstrated excellent functional outcomes at medium term follow-up, with very low revision rates and no dislocations. The incidence of squeaking had no impact on patient satisfaction or function. Significant associations were found between squeaking and larger bearing diameters, increased activity level, and younger age. LDH CoC with a monoblock acetabular component has the potential to provide long-term implant survivorship with unrestricted activity, while avoiding implant impingement, liner fracture at insertion, and hip instability.

Take home message

- The Maxera large diameter head ceramic-on-ceramic bearing provided excellent functional outcomes and low revision rate (0.4%) at medium term follow-up.
-There were no dislocations or implant fractures.
-The incidence of squeaking was 23%, and associated with larger bearing diameter, younger age, and higher activity level, but no patients reported being troubled by the noise.
- Large diameter head ceramic-on-ceramic THA has the potential to provide long-term implant survivorship with unrestricted activity, while avoiding implant impingement, liner fracture at insertion, and hip instability.

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