Acta Scientific Orthopaedics (ISSN: 2581-8635)

Volume 5 Issue 11 November 2022

Case Report

A Cracking Tale of Ceramic Component Fracture Revision: A Case Report and Literature Review

Elliott A Ayling[1]*, Mohammed Amer[2,3] and Douglas Dunlop[2]

[1]*Department of Orthopaedics, University of Southampton, United Kingdom*

[2]*Department of Orthopaedics, University Hospital Southampton, United Kingdom*

[3]*Cairo University, Giza, Egypt*

***Corresponding Author:** Elliott A Ayling, Department of Orthopaedics, University of Southampton, United Kingdom.

DOI: 10.31080/ASOR.2022.05.0605

Received: August 29, 2022

Published: October 12, 2022

Abstract

Ceramic-on-ceramic (CoC) hip replacements present a significant issue upon fracture. Remnant ceramic particulates can become embedded in polyethylene, leading to wear of revision bearings causing significant metallosis.

This article uses a case report and literature review to explore the limited evidence guiding revisions of ceramic component fracture. The literature search used pre-defined search terms to explore the databases of PubMed, Ovid MEDLINE, The Cochrane Library and Web of Science.

The case report outlines a gentleman with significant metallosis following revision of a CoC fracture to a MoP. The remaining ceramic 'sand' can embed in polyethylene, resulting in wear of the opposing bearing surface. Good outcomes are reported for ceramic-on-polyethylene (CoP) and CoC revisions. Disastrous outcomes are seen with metal heads. This is consistent with our findings, where the serum cobalt and chromium soared and a metallosis soup developed.

Improperly revised ceramic components can present a significant risk to patients. Metallic replacement for ceramic fracture is inappropriate due to the potential for runaway abrasive wear. A ceramic ball should be a prerequisite of any such revision. This is poorly documented in the literature, with a need for greater awareness.

Keywords: Total Hip Arthroplasty; Revision; Ceramic Head Fracturea

Introduction

In total hip arthroplasty (THA), metal on polyethylene (MoP) articulations are the most popular [1]. However, the use of ceramic-on-ceramic (CoC) bearings has previously gained popularity (Figure 1) due to superior wear properties [2]. This makes CoC an appealing option for the younger patient.

However, the ceramics are liable to head fractures leading to a decline in their use. CoC is the second most common component pairing to result in implant fracture with an occurrence of 0.36 per 1000 prosthesis life years. Changing the liner component to polyethylene with ceramic head results in a reduction in fracture rate [1].

This presents a unique challenge to the surgeon due to ceramic debris causing third-body wear and the often-associated trunionosis. The relatively limited data of ceramic hip replacements compared to metal on polyethylene makes it difficult to definitively decide on the bearing choice in the revision procedure as well as whether a modular exchange vs a full component revision would yield better outcomes.

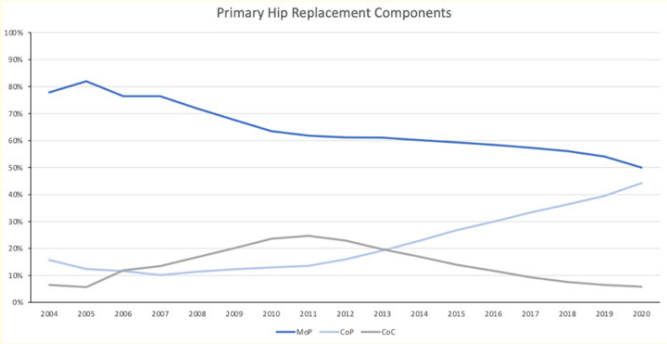

Figure 1: Changing prevalence of component selection in primary total hip arthroplasty [1].

Methods

For completeness of this case report, a literature search was undertaken to establish the understanding within the orthopaedic community surrounding CoC fracture revisions. The literature search was carried out between 1/20/2021 and 20/11/2021, online databases searched were PubMed, Ovid MEDLINE, The Cochrane Library and Web of Science. A full electronic search strategy based on the following PICOS criteria showing all keywords, alternate words and phrases and any search restrictions can be found in appendix 1. Salient findings in the papers investigated can also be found in appendix 1.

Criteria	Number of Papers	Excluded
(Total hip arthroplasty OR total hip replacement OR hip replacement surgery) AND (ceramic head fracture). 1990 to present. English language.	303	
AND (revision outcomes)	87	216
NOT (primary)	48	39
Exclusion of inappropriate studies and case reports	7	41
Added papers of interest known to researchers	2	-
Total	9	

Appendix 1

No date nor place of publication or journal restrictions were applied to the searches. Only English Language articles were considered, and exclusion of studies was performed in blind duplicate by investigators EA and MA. Disagreement was resolved via discussion.

Literature Review

Understandably there is limited evidence in the literature on revisions following a ceramic component fracture in total hip arthroplasty. The available data is gathered from level IV evidence.

A unifying statement across the evidence covered is that every attempt for a complete synovectomy and debridement should be made [3,4]. This will prevent the accumulation of debris in the joint which can wear down the components used in the revision.

There is no consensus in the literature for the optimal revision bearing surface. Good functional, radiological and survival outcomes have been reported for ceramic-on-polyethylene (CoP) and CoC articulations with the added risk of re-refracture especially with trunnion damage [5,6]. Conflicting results with cobalt-chromium heads against a polyethylene (PE) liner and disastrous outcomes with stainless steel heads and PE combination in terms of revision rates, osteolysis and metal ion levels [3,7]. A MoM articulation was even used by Park., *et al*. in his series. He reported good midterm follow up results with only 2 out of 22 cases revised (1 dislocation and 1 infection) [8].

Modular exchange versus full component revision is another contentious issue. Trebše., *et al.* changed all the cups in his case series and Allain., *et al*. reported better outcomes when the cup is exchanged [7,9]. Koo., *et al.* reported a lower complication rate when the stem was changed compared to stem retention [10]. Other authors adapted the policy of only changing the cup when the orientation is suboptimum and changing the stem with extensive trunnion damage [6,7].

Case

A 64-year-old gentleman was referred to our tertiary service with persistent pain following a revision hip replacement for ceramic head fracture. The patient had a primary uncemented hip

replacement (Furlong HAC stem) in 2016. The ceramic fractured during a scuffle in 2020. He described a crunching sensation when walking afterwards.

During the index revision performed outside our institution and despite three and a half hours of operating, trials of femoral stem removal including an extended trochanteric osteotomy (ETO) were unsuccessful. The operating surgeon chose to abort the procedure and replaced the components with a MoP articulation (cobalt-chrome).

In clinic, the patient complained of persistent pain in the groin and the lateral aspect of his right hip. The patient walked with an antalgic gait and the hip was extremely irritable. X-rays showed a well-fixed stem (JRI-Furlong) and acetabular component (Trident, Stryker®). Metallosis shadowing around the component and proximal femoral osteolysis was noted (Figure 2A). Cobalt and chromium levels were 7960 and 540 nmol/l respectively.

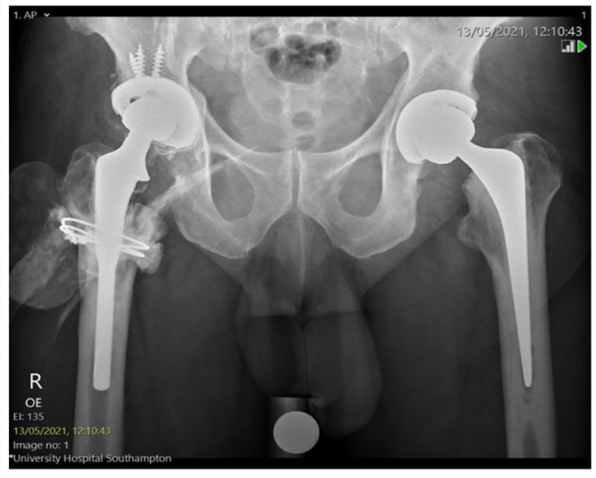

Figure 2a: Pre-operative x-ray, note the metallosis shadow lateral to the femoral stem and the proximal osteolysis.

The patient's symptoms were attributed to metallosis caused by abrasive wear of the new metal head against the ceramic debris. The patient was counselled, consented and listed for a re-revision.

A standard posterior approach was utilized. A large collection of metallosis soup that was under tension was drained (see figure 2b). Marked asymmetrical wear of the femoral head was noted (Figure 3).

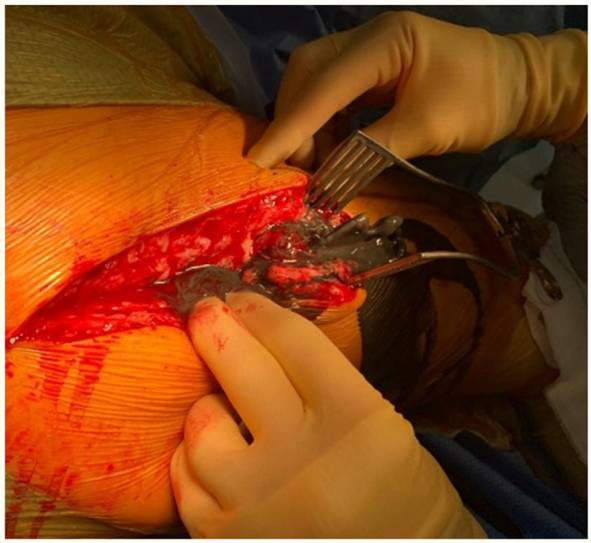

Figure 2b: Photo of the release of the metallosis soup under tension.

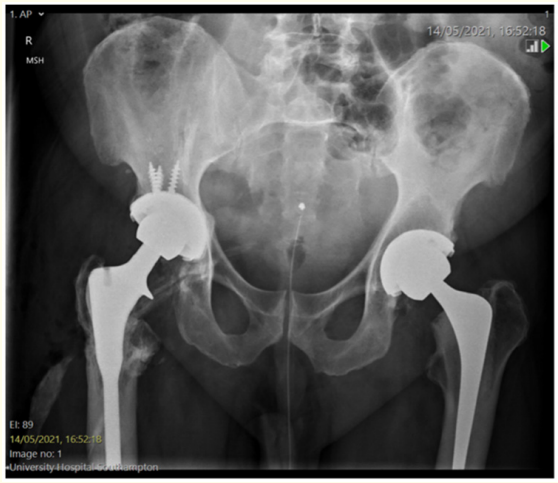

Figure 2c: X-ray depicting decreased opacity of shadowing of metallosis.

Significant trunnion damage was observed but was deemed fit for use. Surprisingly there was no evidence of wear on the femoral head at the head/trunnion interface. Ceramic particles embedded within the polyethylene liner could be seen grossly (Figure 4).

Following extensive debridement and synovectomy, a new polyethylene liner was inserted and a Bio-ball adaptor (Merete Medical Inc.) was mounted on the trunnion and a ceramic head mounted on the adaptor.

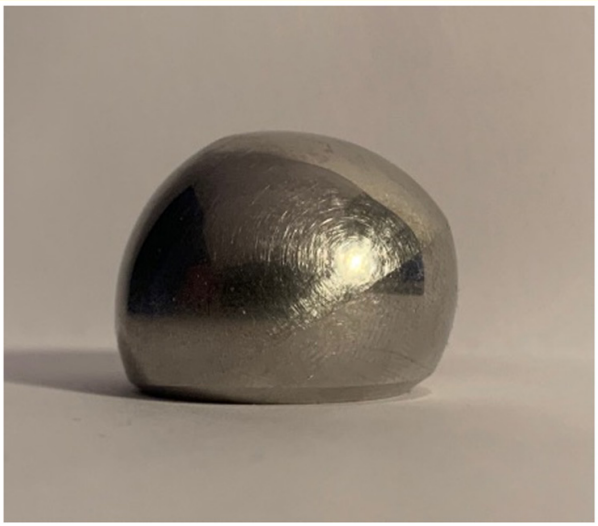

Figure 3: Tangential view of femoral head showing marked deformity due to wear.

Figure 4: Black particulates of ceramic embedded in the original polyethylene liner acting like sandpaper on the femoral head.

Postoperative x-ray demonstrates the resolution of the radio-opaque metallosis soup (Figure 2c).

Upon review of the original revision components. A CT scan of the retrieved PE showed ceramic debris embedded on its articulating interface (Figure 5). The metal head lost 15% of its mass in the 18 months after index revision.

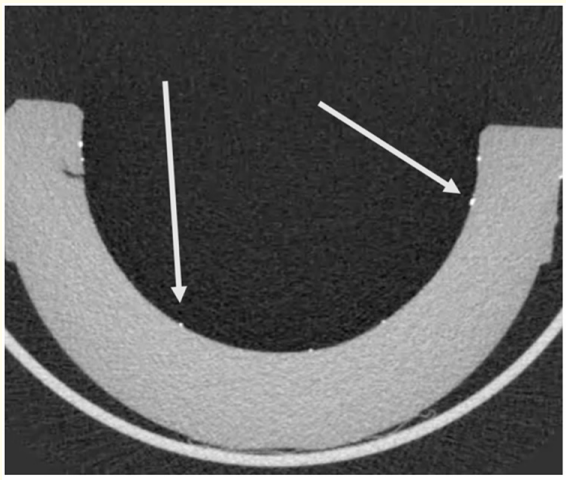

Figure 5: CT scan showing embedded ceramic particles (arrows) in the liner

Discussion

Our findings of a deformed metal femoral head at the head/liner interface, ceramic dust within the liner and the significant metallic debris within the joint all support the third body abrasive wear theory.

Similar findings were reported extensively in the literature [6,7,10,11]. The harder ceramic debris is embedded in the soft polyethylene and acts as sandpaper rubbing against the metal femoral head releasing metallic debris. The debris mimics failing MoM replacements and is known as an adverse reaction to metal debris (ARMD). Allain., *et al*. reported the biggest series to date [7]. A higher revision rate and worse outcomes were associated with the use of stainless heads compared to other combinations as it is more liable to the sandpaper effect. Traina and Trebše reported higher rates of radiologic loosening with the use of a MoP compared to ceramics [6,9]. The systemic effects of the resulting metallosis cannot be understated. Zyweil reported fatal cardiomyopathy following the use of a MoP combination in a revision of a fractured ceramic liner [12]. Locally, irreversible soft tissue damage due to ARMD can lead to a high dislocation rate [4].

The use of a ceramic bearing surface matches the hardness of the ceramic debris and decreases the risk of abrasive wear. Trebše

reported good outcomes with a CoC combination [9]. This carries the risk of refractures which was reported in 2 out of 4 cases in a case series [10]. An alternative is to use a CoP combination, and even though it has inferior wear resistance, it has a lower fracture rate [1]. Zagra revised 12 cases of ceramic fractures using a CoP articulation and reported no head fractures with an average follow-up of 6 years [4].

The use of a MoP combination in revisions with emphasis on a complete and extensive debridement with removal of all ceramic particles can prevent metallosis [3,7]. This allows maintenance of the femoral component even with trunnion damage without the risk of femoral head fractures due to the higher ductility of metals. In our experience, which is also echoed by Traina, despite extensive debridement, small ceramic particles will always remain [6].

The acetabular component was not changed as it was changed in the index revision. Intraoperatively and radiologically, it was well fixed and well oriented. Allain., *et al*. reported better outcomes with cup exchange [7]. Whilst Traina only revised the cup when it contributed to the ceramic component fracture [6].

We elected not to change the femoral component. The risk of fractures, prolonged operative time and infection with another attempt of removing it was deemed high, especially with a previous failed attempt, a previous ETO and in the presence of proximal femoral osteolysis. An adapter was used to bypass the worn segment of the trunnion. It is reported that change of the stem is not essential but could be done when Koo., *et al*. reported no complications in his case series when there is trunnion damage [6,10].

Summary

Paper	Authors	Study Type, Participants and Revision	Key Findings
Results of revision of total hip arthroplasty for alumina ceramic-on-ceramic bearing fracture [9]	R Trebse A Mihelic V Levasic A Cor	Comparative case series. 16 patients 6 to CoC, 9 to MoP, 1 to CoP.	Minimum of 5 years follow-up completed. HHS 89 for CoC and 84 for MoP. 3/9 of MoP showed radiographic poly wear with osteolysis and 2 patients showed deformed head. No detrimental changes in CoC or CoP.
Revision total hip arthroplasty performed after fracture of ceramic femoral head [7]	J Allain F Roudot J Delecrin P Anract	Comparitive case series 105 patients 53 steel heads, 12 alumina, 9 cobalt, 3 zirconia, 18 ceramic.	Statistically significant procedural processes: Exchanging cup (5ys of 68% vs 36%), Ceramic head (5ys 76% vs steel 49%), Full synovectomy (5ys 73% vs partial 49.5%). 20/77 metallic revisions led to metallosis. 20/26 stainless steel hips were distorted.
Revision total hip arthroplasty for ceramic head fracture [3]	V Sharma A Ranawat V Rasquinha	Case series 8 hips All revised to MoP	10 year follow-up. Mean HHS 95. No revisions in either group. Wear similar to control group. Clear procedure for complete synovectomy.
Fracture of ceramic bearing surfaces following total hip replacement: a systematic review [6]	F Traina M De Fine A DI Martino C Faldini	Systematic review 52 manuscripts 1644 hips	Treatment strategy: "Surgery should always include extensive synovectomy." Limited evidence to suggest most suitable material. Original morse taper may remain in situ if no major damage evident in surgery. CoC and CoP reduce third body wear of revised implants.
Revision of ceramic head fracture after third generation ceramic on ceramic total hip arthroplasty [10]	K Koo Y Ha S Kim K Yoon B Min	Comparative case series 24 revisions 20 unchanged stems- 4 CoC, 16 MoP 4 changed stems- 3 CoC, 1 MoP	Average follow-up of 57.5 months (36-80) 5 complications when stem retained: 2 CoC fractures 2 metallosis 1 osteolysis and loosening No complications when stem changed.

Revision total hip arthroplasty with metal on metal bearing for ceramic bearing fractures [8]	Park KS Chan CK Li QS Im CJ Yoon TR	Case series. 22 patients. MoM.	Total synovectomy, irrigation and debridement. Ceramic liners and heads all removed. Follow-up 4 years (2-7 years). HHS 90.3 (78-100). No signs of osteolysis, wear, ceramic or metallosis. 1 dislocation post-operatively. 1 deep infection at 3 months- 2 stage reconstruction. Serum Co and Cr findings were insignificant.
Revision Total Hip Arthroplasty after Ceramic Bearing Fractures in Patients Under 60-years Old; Mid-term Results [5]	C Im KJ Lee BW Min KC Bae SW Lee HJ Sohn	Case series 8 patients. CoC. Full synovectomy performed.	No loosening or osteolysis HHS to 91.8 (86-96). Mild pain after revision all relieved conservatively. Follow-up 9 years (6-13 years).
Revision Total Hip Arthroplasty for Fractured Ceramic Bearings: A Review of Best Practices for Revision Cases [15]	R Rambani DM Kepecs TJ Makinen OA Safir AE Gross PR Kuzyk	Literature review	Complete synovectomy should be performed in all cases. Any taper damage requires replacement with liner. CoC or CoP articulation preferred over MoP due to risk of head erosion and chromium/colbolt toxicity.
Revision of ceramic fracture with ceramic-on-polyethylene in total hip arthroplasty: Medium-term results. [4]	L Zagra L Bianchi R Ceroni	Case series 12 patients. CoP revisioms Cup + head + liner replaced in 4. Liner + head in 8.	Methods included "meticulous removal of all visible ceramic fragments; aggressive debridement…accurate synoviectomy." Follow-up 6 years (1.5-13y). HHS 92 (92-99). 2 re-revisions. 4 dislocations (1 required revisions). 1 revision for aseptic loosening (failrd bone graft- poor surgical technique). 1 failure at 9y for osteolysis (tribology related).

Appendix 2

This case report highlights a serious complication of using a MoP combination in revision hip replacements for ceramic fractures. The key takeaways are that MoP articulations should be avoided. CoP and CoC are viable options with good outcomes. The stem trunnion should be evaluated and plans to revise the stem should be made preoperatively if significant damage is noted. The cup position should be evaluated and revised if suboptimum.

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