Catastrophic ceramic liner failure—The subtle signs of a non-engaged ceramic liner

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ABSTRACT

Ceramic bearings have an established and successful history in total hip replacement. Occasionally, these articulations have problems, which include squeaking and implant fracture.

This report describes a case of catastrophic ceramic liner fracture at 16 months post operatively, due to improper seating of the components. We discuss the lessons, and revision considerations in these rare cases.

1. Introduction

Ceramic bearings for hip arthroplasty have an established and successful history.¹ The articulation displays long survivorship and reduced wear characteristics,² making it the articulation of choice for many surgeons in the younger patient.

Innovations in tribology and technology have led to reduced wear rates, reduced morbidity and fewer complications associated with premature revision surgery. Improved wear resistance also affords the use of larger diameter heads, increasing stability and reducing dislocation rates.³

Ceramic articulations have not been without their problems, specifically squeaking and implant fracture. We report a case report of delayed catastrophic ceramic liner failure due to improper seating of the components, highlighting the technical and radiographic subtleties that can be easily overlooked with catastrophic consequences.

2. Case presentation

A patient underwent a primary cementless Total Hip Replacement (Tri-Lock 1 standard stem, with a 48 mm Pinnacle (DePuy SYntes, Leeds, UK) acetabular shell). A fourth generation BioloX Delta ceramic femoral head (32 mm +5.0) and 32 mm liner (CeramTec GmbH, Germany) were used as bearing surfaces (CoC). Fig. 1 demonstrates the post-operative radiographs.

At 1 year review, her pain persisted, and was aware of a “squeak” in her hip. Infection was excluded. She subsequently presented at 16 months post-operatively with acute onset pain and a crunching

sensation in the right hip. Fig. 2 depicts the AP and Lateral radiographs.

Intraoperatively at the time of revision, the ceramic liner was found in multiple fragments, dissociated from the cup, whilst the ceramic head was intact with gross stripe wear.

The ceramic liner was exchanged for a polyethylene liner and a new ceramic head (CoP).

Explant fractographic analysis felt failure was due to impingement on the liner.

3. Discussion

Ceramic bearings are performing well globally. They are prone to bearing noise in a minority, and various risk factors have been identified for this. As a result of this, ceramic-on-polyethylene combinations are becoming more popular than ceramic on ceramic. Rates of use of CoC bearings have recently declined owing in part to their brittle nature and 4-fold increased risk of implant fracture over COP bearings.⁴

Ceramic fracture is a rare complication of hip arthroplasty. The incidence of implant fractures have been estimated at 0.126% for BioloX Delta Liners and 0.009% for BioloX Delta heads. Head fractures have declined with advances in engineering.³ Despite this, liner fracture risk remains relatively unchanged compared to previous BioloX Forte liner fracture risk of 0.112%.⁵

Failure of ceramic bearings is multifactorial, and risk factors include trauma, high level activity, obesity, rim impingement, inadequate prosthesis design and manufacture and surgeon error.^{6,7}

Literature regarding failure focuses on the prodrome of pain and, particularly, reproducible squeaking, before ultimate catastrophic implant failure. Rates of ceramic on ceramic “squeaking” range from 0.3% to 24.6%, with a liner fracture rate of 0.11%. Of these, half had having audible squeak prior to failure.⁸ Therefore, in a patient with normal radiographs, impingement and audible squeaking, then CT imaging is

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Fig. 1. Post-operative AP and lateral radiographs. The AP appears to show a normally seated acetabular component and liner. Note the lateral radiograph showing malpositioning of ceramic liner with 'two steps' evident inferiorly.

Fig. 2. AP and Lateral radiograph upon emergency presentation. Ceramic debris can be seen by the loss of regular contour on the AP, and fragmentation seen posteriorly on the lateral.

advised, and consideration of hip joint aspirate for mass spectrometry for ceramic micro-debris is suggested, if available.⁸

Damage to the liner during insertion, or improper seating intraoperatively play a role in the failure mechanism.⁶ This can result in persistent toggling of the liner, head subluxation and edge loading, giving rise to the symptom of "squeaking."⁷

Finite element analysis studies have shown that cup orientation influences fracture initiation, with high angles of inclination resulting in increased risk of fracture. Edge loading between the head and liner generate stresses which, when repeated, leads to micro-fractures within the ceramic, particularly at the egress site.⁷

Cyclical impingement at stresses below the material critical stress limit results in fatigue micro-fractures, which are not critical in themselves *per se*, but cumulative damage leads to Discontinuous Crack Growth (DCG) and eventual catastrophic failure. Fourth generation ceramics use small grain sizes and lack internal pores to minimise DCG, and favour crack tip blunting. Biolox Delta uses Yttria-stabilised

zirconia particles dispersed within the alumina to increase toughness, and function to resist crack formation. Additionally, oxide crystal platelets allow for energy dissipation and result in crack deflection, increasing ceramic strength, toughness and resistance to failure.

Technical errors are responsible for most ceramic liner failures. Upon insertion, the liner will toggle, mainly superior to inferior, prior to impaction because of the anteroposterior squeeze on the metal cup and this can be reduced by reaming line to line. Therefore, the liner can appear to be correctly seated superiorly but be proud inferiorly (Fig. 1). Ensuring the liner is evenly seated by having a circumferential view, prior to impaction, is imperative. If not evenly seated the leading edge can chip at the time of impaction, or the taper can misengage leading to continued toggle, high stresses and risk of subsequent breakage. Furthermore, if the liner is not firmly impacted the wettible nature of the ceramic can create a vacuum, which momentarily allows the taper to disengage and reengage eccentrically.

Patient A reported an audible squeak. Macroscopic stripe wear of

the ceramic head was observed. Post-operative radiographs were performed, but signs of improper seating of the liner are subtle, and may only be apparent on lateral radiographs. This highlights the importance of both AP and lateral views of the hip, as advocated by Steinhoff et al,⁹ but highlights the vigilance required by the clinician in recognising this subtle and potentially catastrophic sign.

As in this case it is critical not to use a metal head in revision of such cases because of the risk of residual ceramic debris becoming trapped in the articulation leading to catastrophic metal wear, with case reports of cardiomyopathy induced fatalities.¹⁰

4. Conclusion

Ceramic fracture is rare, but the risk is higher for the liner because of technical errors. Learning points from this case include ensuring perfect alignment of the liner prior to impaction and using a hammer for impaction and not just pressure to ensure correct taper engagement. Also in revising such cases a ceramic rather than a metal head must be used with a taper sleeve. Post-operative anteroposterior and lateral hip views are advised to ensure correct seating of the liner.

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