Wear of metal-on-metal 'off-the-shelf' HA-coated/beaded hip bearings

Introduction

Wear studies of metal-on-metal (MOM) bearings in hip simulators have historically involved 'custom' acetabular cups, i.e. having neither beaded layers nor biological coatings [1]. Such custom designs improve the accuracy of the gravimetric wear assessments. However, it is not always feasible to obtain custom cups for various reasons. Thus, another possibility would be to machine off the implant coatings on 'off-the-shelf' cups [2]. However, this raises questions regarding metallurgical changes or cup deformation [3] and even the possibility of third-body wear damage, all potentially leading to erroneous predictions. Therefore removing these beaded layers may be impractical [3].

To date, no studies have attempted to use the gravimetric method with 'off-the-shelf' beaded and hydroxyapatite (HA) coated MOM cups. Therefore, the aim of this study was to investigate wear using such MOM bearings and evaluate the potential for error in the gravimetric assessment. Primary wear of Co-Cr bearings was estimated from Co and Cr ion concentrations in the serum lubricant [4]. The study hypothesis was that the gravimetric analysis would create unacceptably large errors in predicted MOM wear-rates with beaded cups (> 25%).

Materials and Methods

Six 38mm, high-carbon Co-Cr bearings were supplied with diametral clearances averaging 230 microns (Global Inc, Australia). The cups were received in 'off-the-shelf' condition with a cast Co-Cr beaded/HA-coated backing (Fig.1). The diameter of the cast beads was approximately 1.7mm. To remove the HA-coating, the cups were pre-soaked in lemon juice for 4 days (articular surfaces shielded). The cups were then soaked in bovine calf serum (BCS) until their average weights stabilized within 1mg. All components were cleaned using a standard protocol (ASTM F1714-96). Custom plastic fixtures were machined to fit the beaded contours of the cups (Fig. 1) with a 40" mounting angle in an orbital hip simulator (Shore Western Manufacturing, Monrovia, CA). All metal fixtures were plastic coated to minimize ion contamination. Serum lubricant was a diluted BCS (ISO 14242-1). Four MOM bearings were run to 5Mc using standard Paul load profile, while two MOM were retained as soak-controls. Serum samples were collected at every test interval and stored frozen (-25 °C).

MOM wear was estimated from serum ion concentrations using the following equation: Wear (mm3) = (C × Vf)/(m × ρ), where C = combined Co and Cr ion concentration (ppm), Vf = final chamber volume (cm3), m = mass fraction of Co and Cr combined (0.91) and Co-Cr density (8.3 g/cm³). The serum samples were digested in hydrochloric acid and the Co and Cr ion concentrations assessed using an ICP/MS (Weck Laboratories Inc, CA). For gravimetric assessment, all components were cleaned and weighed using standard protocols [1,2]. Persistent biological contaminants were removed with a lint-free cloth. Overall wear rate (OWR) was defined as the total wear at end of test divided by the total number of cycles. Co-Cr surface roughness was assessed by white light interferometry (NewView 600, Zygo).

Results

The majority of the HA-coating was removed from the cups after 4 days of soaking in lemon juice and after 21 days of soaking all cup weights appeared stable (Table 1: within 1mg). Reflected-light microscopy (RLM) showed no discernable signs of HA (Fig.1) and the total weight loss due to HA removal averaged ~400mg.

During the wear study, the two non-wearing beaded cups (soak controls) remained stable in weight (~1mg) to 5Mc duration. There was no visual evidence of deterioration in the wearing cups, i.e. lost or broken beads, elevated wear, 3rd-body abrasion, cup damage or distorted wear scar shapes.

Discussion and Conclusions

- Soak conditioning the beaded-HA cups in lemon juice and BCS proved effective in removing the coating. This appeared exactly analogous to soak conditioning UHMWPE liners for their fluid absorption (3 weeks).
- The beaded cups remained stable in weight during the wear study and caused little discrepancy in gravimetric analysis (8% overshoot).
- The methods described did not lead to breaking of beads, elevated 3rd-body abrasion, cup damage or distorted wear scar shapes.
- Therefore, our hypothesis that gravimetric analysis would create large errors was negated. Standard gravimetrically techniques can be successfully used on beaded MOM cups of this type when the HA-coating is removed.

Acknowledgements

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References


Fig 1. Removal of HA-coating from cast Co-Cr beads (RLM images).

Table 1. Average weight loss of cups during pre-test soaking period.

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<th>21 days</th>
<th>29 days</th>
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<tr>
<td>Average Cup Weight Loss</td>
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Table 2. Wear from metal ions compared to gravimetric analysis.

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<th>Estimated wear from metal ions</th>
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Fig 2. Estimated Co-Cr volumetric wear versus number of cycles for bearing#1 (highest wearing).

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