Introduction

The purpose of this study was to determine the occurrence and extent of fretting corrosion on the backside of DM acetabular liners made from CoCrMo alloy by two different manufacturers in the context of design features, alloy microstructure, and malseating.

Materials and Methods

20 surgically retrieved DM acetabular liners with mean in-situ duration of 14.1 months (range 1-83) were examined.

Implants

<table>
<thead>
<tr>
<th>Implant Features</th>
<th>Type A</th>
<th>Type B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall Thickness</td>
<td>4.1 mm</td>
<td>3.1 mm</td>
</tr>
<tr>
<td>Microstructure</td>
<td>Wrought CoCrMo</td>
<td>Cast CoCrMo with heat treatment after casting</td>
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<tr>
<td>Final Manufacturing Step</td>
<td>Machining</td>
<td>Roughened surface finish indicative of sand blasting</td>
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Implant Wear and Material Evaluation

- Optical coordinate measuring machine (CMM) was used to quantitate volumetric material loss and generate heat maps to illustrate the location of fretting and corrosion damage.
- One cup per manufacturer was sectioned for evaluation of grain structure and determination of the bearings’ wall thickness.
- Using a stereo microscope at 10 to 50x, two independent graders (RP, DJH) scored each liner.
- Based on the analysis of SEM damage features, all type A liners exhibited chemically induced corrosion resulting from OOR as material loss, whereas type B liners exhibited no measurable material loss.
- Damage features observed by light microscopy initially suggested the occurrence of imprinting but SEM revealed these parallel lines on the surface to be organic residue with an appearance similar to that of fibrous tissue.
- Based on the analysis of SEM damage features, all type B liners were re-evaluated as no or mild damage.
- None of the type B liners were malseated.

Results

Type A
- Exhibited symmetric out-of-roundness (OOR) that appeared to originate from the machining process (e.g., clamping tool) (Fig 2).
- Local damage scars were isolated, local volume was computed, and loss from local scars was added up for a total volume loss determination (Fig 3).
- Liner A volumetric material loss at the backside occurred in 4 cases (3 with severe and 1 with moderate mGS) with an average material loss of 0.39 mm ± 0.22 and maximum liner penetration of 10.04 µm ± 6.77.
- Damage features on all liners of type A were consistent with fretting and fretting corrosion (Fig 4).
- One case additionally exhibited chemical etching in areas that were not in contact with the acetabular shell due to OOR.
- Five liners were malseated, including 3 cases with severe mGS with measurable volumetric loss and 2 cases with only mild damage.

Type B
- 3 of 9 liners could not be measured by CMM because these were heavily deformed during surgical removal.
- While most of the remaining liners also exhibited OOR, these liners appeared mostly asymmetrical and could be either a result of the casting process or deformation caused during assembly.
- Type B liners also exhibited a nub at the pole for centering during seating.
- SEM analysis revealed no fretting or corrosion damage features.
- Damage features observed by light microscopy initially suggested the occurrence of imprinting but SEM revealed these parallel lines on the surface to be organic residue with an appearance similar to that of fibrous tissue (Fig 5).
- Based on the analysis of SEM damage features, all type B liners were re-evaluated as no or mild damage.
- None of the type B liners were malseated.

Discussion

Our study showed that different designs cannot be directly compared due to broad design, surface finish and material differences. Our findings, however, provide important insights to the corrosion performance of each individual liner type.

Type A is a sturdier liner based on design (wall thickness) and material (wrought CoCrMo has generally a higher strength compared to cast). It does not appear to deform during assembly but exhibits mild initial OOR.

- The combination of these factors may result in reduced contact area after seating, potentially making micromotion during patient activities more likely.
- Malseating may increase the risk of micromotion further, however, while malseated liners were associated with greater material loss, they also had a longer mean in situ duration. Thus, an independent association of malseating on liner corrosion could not be determined.
- Fretting corrosion was observed mostly in areas that were in contact with the acetabular cup. However, one case also exhibited chemically induced corrosion in an area that was likely out of contact, indicating a chemical change within the crevice was possibly caused by cell accelerated corrosion.

An important limitation of this work were the small group sizes. It is important to note that the findings here do not necessarily reflect the overall in vivo performance of these devices. Therefore, this study is ongoing to increase the groups of both liner types to confirm the observed trends, and eventually draw direct comparisons and correlations to clinical performance.

Significance:
The use of DM THR is rising as it provides many advantages to the patient. However, great care has to be taken that the problem of modular junction corrosion at the femoral head/neck interface is not being repeated at the acetabular liner/cup side. Fundamental knowledge of the acting corrosion mechanisms and synergistic interactions between design, material and surgical factors is essential to guarantee implant longevity.

References:

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Contact:
deborah_Hall@rush.edu