Influence of Cup Orientation on the Wear Performance of Metal-on-Metal Hip Replacements

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Introduction: A revived interest in metal-on-metal (MoM) hip bearings has emerged over the past 20 years. These bearings have shown excellent wear properties and are becoming widely implanted, both as surface replacement and for total hip replacements (THR) [1]. It is well established that the range of outcomes from THR is variable, and therefore there is a growing need to understand the factors that can influence the performance. It has been suggested that the acetabular cup abduction angle may influence the outcome [2, 3], determining the long-term successful performance of THR. The orientation of the acetabular component is critical for preserving the range of motion (ROM) as well as preventing dislocation [4]. The aim of the current study was to assess the influence of the acetabular cup orientation on the wear of MoM hip implants, with the hypothesis that the angle of the acetabular cup influences the wear rates generated during a simulator test.

Materials and Methods: Six 40 mm diameter MoM hip bearings (high carbon CoCrMo alloy to ASTM F75) with a mean radial clearance of 150 μm (ranging from 145 – 156 μm) were supplied by Corin (Cirencester, UK) in the double heat-treated condition (HIPed and solution annealed). Wear tests were performed using an orbital hip joint simulator (MTS Systems, USA), using a lubricant of 25% new-born calf serum, 17 mg/ml protein content (500 ml). The cups were orientated at 35°, 50° and 60° to the horizontal (Fig 1a-c).

Walking tests were performed up to 6 × 10⁶ cycles with a maximum load of 2500 N, at a frequency of 1 Hz [5]. Wear rates of the acetabular cups and femoral heads were measured gravimetrically, determined approximately every 0.3 × 10⁶ cycles. The wear scars were investigated by visually identifying the roughened area and marking the boundary. The surface roughness (Ra) values for each femoral head were obtained using a profilometer.

Results: The total volumetric wear loss against the number of cycles for each of the specimens is shown in Figure 2. The wear rates generated from the run-in and the steady state (SS) phases are shown in Table 1.

Table 1. Wear rates generated during the run-in and steady state (n represents the number of data points)

<table>
<thead>
<tr>
<th>Cup Angles (Degrees)</th>
<th>RUN-IN (0-6 × 10⁶ cycles)</th>
<th>STEADY STATE (6 × 10⁶ cycles)</th>
<th>Mean Ratio Run-in:SS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wear (μm³)</td>
<td>n</td>
<td>Wear (μm³)</td>
</tr>
<tr>
<td>35°</td>
<td>5.79</td>
<td>33</td>
<td>0.29</td>
</tr>
<tr>
<td>50°</td>
<td>5.14</td>
<td>30</td>
<td>0.36</td>
</tr>
<tr>
<td>60°</td>
<td>5.04</td>
<td>30</td>
<td>1.63</td>
</tr>
</tbody>
</table>

Discussion: For the first time wear results have been presented from a simulator study that show that the cup abduction angle influences the overall wear rate and moved the position of the wear scar in MoM bearings. This may be an indication that perhaps once the scratches develop due to rim contact, it would become difficult for the implants mounted at steep cup angles to recover through the self-polishing capability, which MoM bearings possess. It has been reported clinically that acetabular cups with high abduction angles defined as greater than 50°, may result in higher wear rates, elevated Co and Cr ion concentrations and increased revision rates [3, 4]. The results of the current study provide surgeons with additional knowledge of the wear behaviour of MoM bearings. Acetabular cup positioning in-vivo is a trade-off between several factors, including adequate bony coverage and ROM. These results suggest that the potential for increased wear, related to cup inclination, should also be part of the surgeon’s decision making process when deciding upon cup position.

References:

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All bearings at 35° showed a biphasic wear pattern, i.e. generating higher wear during the first 0.6 - 1 × 10⁶ cycles, followed by a lower SS condition, as indicated by the run-in:SS ratio of 17.9. Similar behaviour was observed for the components oriented at 50° with a high run-in phase wear; however, in the late stages of the test, the 50° components showed a less stable, yet still SS condition compared to components at 35°; the run-in:SS ratio decreased to 5.5. Finally, the bearings placed at 60° persistently produced the highest wear rates tested, with no SS region observed by 6 × 10⁶ cycles, and a very low run-in:SS ratio of 2.2.

Fig 1. Images of specimen fixtures and assembly used during testing, showing the cups oriented at (a) 35°, (b) 50° and (c) 60°, with schematic showing wear scar analysis at (d) 35°, (e) 50° and (f) 60°, identified at 2 × 10⁶ cycles.

Fig 2. Total accumulated wear loss (μm³) up to 6 × 10⁶ cycles, for implants tested at various cup inclination angles.

Figure 1d-f illustrates schematically the wear scar analyses for each of the angles. At 35°, the contact area was well within the body of the cup. At 50°, the contact area moved to the edge of the cup, and finally the contact area at 60° was reduced due to the cup not fully supporting the loaded area.

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