**INTRODUCTION**

The majority of current artificial hip implants use a material combination of ultra-high-molecular-weight polyethylene against metal or ceramic. However, it is well documented that the wear debris from these prostheses contributes to osteolysis and ultimate failure of the prosthesis, hence alternative materials have been sought, such as metal-on-metal and ceramic-on-ceramic [1]. More recently, ceramic-on-metal bearing couples have been developed [2].

Metal-on-UHMWPE implants were first employed due to the low frictional properties of the UHMWPE material. Excessive frictional torque was cited as the cause of failure for first generation metal-on-metal implants [3]. However, it is generally accepted that the frictional torque generated in modern metal-on-metal implants would be insufficient to cause immediate mechanical failure. Nevertheless, friction studies provide a valuable indication of the tribological performance of a system.

This study aimed to examine the effect of material, lubricant and swing phase load conditions on the friction of hip replacements.

**MATERIALS AND METHODS**

Various 28mm hip replacements (Table 1), supplied by DePuy International, UK, were tested using a friction simulator (Prosim, UK).

<table>
<thead>
<tr>
<th>Head/Cup</th>
<th>Bearing Combination</th>
<th>Number of Samples</th>
<th>Mean radial clearance/mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>CoCrMo/CoCrMo</td>
<td>MOM</td>
<td>6</td>
<td>0.029</td>
</tr>
<tr>
<td>CoCrMo/UHMWPE</td>
<td>MOP</td>
<td>4</td>
<td>0.132</td>
</tr>
<tr>
<td>Alumina/UHMWPE</td>
<td>COP</td>
<td>4</td>
<td>0.123</td>
</tr>
<tr>
<td>Zirconia toughened Alumina</td>
<td>COM (ZTA)</td>
<td>4</td>
<td>0.034</td>
</tr>
<tr>
<td>Alumina/CoCrMo</td>
<td>COM (alumina)</td>
<td>4</td>
<td>0.037</td>
</tr>
<tr>
<td>Alumina/Alumina</td>
<td>COP</td>
<td>4</td>
<td>0.030</td>
</tr>
</tbody>
</table>

Components were tested in an inverted position, with a flexion-extension motion of ± 25° applied to the femoral head. Tests were performed at 1Hz, with a simple sinusoidal waveform through 60% of each cycle to apply a dynamic load, with a peak load of 2kN, and swing phase loads of 25N, 100N and 300N. Water, 25% (v/v) and 100% newborn bovine serums were used as lubricants. Each test was performed in a forward, and a reverse direction, and a mean taken, to eliminate errors due to misalignment. Lubricant was removed, and the prostheses cleaned between each test.

**RESULTS**

Metal-on-metal hip implants produced significantly higher friction factors under all testing conditions compared with the other bearing materials (ANOVA p<0.05). The difference in friction factor between the other material combinations was not found to be significant; however, ceramic-on-ceramic implants had the lowest friction factors under all conditions. Interestingly, both types of ceramic-on-metal couple had significantly lower friction factor values than the metal-on-metal bearings, with values similar to ceramic-on-ceramic.

Increasing protein concentration in the lubricant significantly reduced the friction factor in the metal-on-metal implants (ANOVA p<0.05). A significant increase in friction factor with increasing serum concentration was seen in the ceramic-on-ceramic and the ceramic-on-metal implants. Increases in friction factor were observed in the ceramic-on-UHMWPE and metal-on-UHMWPE implants, but these were not significant (Figure 1).

**DISCUSSION**

For most bearing couples, an increased force would be required to shear the higher concentration of proteins in the lubricant and this may result in the raised friction factor with increasing serum concentration. The friction reduction of the metal-on-metal bearings with increased serum concentration may be due to the proteins acting as solid-phase lubricants at the metal-metal interface, reducing the adhesive forces. The friction factors measured were higher with increased swing phase loads. A previous study found a similar trend in metal-on-metal components [4]. The higher swing phase load may result in a depleted lubricating film, hence elevated friction was found due to increased contact.

Metal-on-metal and ceramic-on-ceramic bearings are being used increasingly worldwide, to address concerns regarding polyethylene wear particles. Ceramic-on-metal bearings are now undergoing initial clinical trials. In the 28mm diameter bearings both ceramic-on-ceramic and ceramic-on-metal have significantly lower friction than metal-on-metal. In larger diameter bearings, the influence of increased entraining velocity and improved fluid lubrication is expected to reduce friction further.

**ACKNOWLEDGEMENTS**

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**REFERENCES**


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