Wear of Ceramic-on-Metal bearings in a hip simulator study

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Introduction
Osteolysis and aseptic loosening in total hip replacement (THR) is often associated with polyethylene (PE) wear. This caused interest in alternative bearing surfaces. Since the mid nineties research focused on hard-hard bearings like metal-on-metal (MOM) or ceramic-on-ceramic (COC). However, concerns remain about failure of the ceramic components or biological reactions to metallic wear debris. A new approach to reduce wear with a minimized risk of failure may be the use of a metallic cup in combination with a ceramic head, the so called ceramic-on-metal bearing (COM).

The aim of this study was to estimate the wear behaviour at an early stage of this COM bearing type in comparison to COC bearings using a hip simulator.

Methods
Simulator studies were carried out on a single station hip simulator (MTS 858 Mini Bionix II, Eden Prairie, USA) performing motions of flexion/extension, internal/external rotation plus adduction/abduction. Bovine serum was used as the test medium. Four 36mm diameter COM bearings were used. The head was made of a mixed-oxid ceramic (Biolox Delta®) paired with a high carbon wrought CoCrMo cup. Four 36mm diameter COC bearings with both components made of a mixed-oxid ceramic (Biolox Delta®) were used as control.

Simulation was run to a total of 2.4x10^6 cycles. Wear measurements were performed in intervals of 0.2x10^6 cycles using a gravimetric method (Sartorius Genius ME235S, measuring solution: 15 µg, Sartorius, Göttingen, Germany). To achieve a high accuracy of measurement a complex purification method and a comparative measuring method in a temperature controlled environment were used.

Results
Wear of the COC pairings are shown in Figure 3. During the first 200,000 cycles a mean wear rate of 0.163mm/10^6 cycles was found followed by a decreased wear rate of 0.039mm/10^6 cycles. The overall wear of the COC implants ranged from 0.017mm to 0.167mm, with a mean of 0.118 mm^3.

There was found a high variability in the wear progression between the four COM implants (Figure 4). A mean wear rate of 0.134mm/10^6 cycles was determined during the first 200,000 cycles followed by a decreased wear rate of 0.046mm/10^6 cycles. The overall wear of the COM implants ranged from 0.017mm^3 to 0.212mm^3, with a mean of 0.129 mm^3.

Observing the mean ratio between cup and head overall wear, the COM bearings mostly worn on the metallic cup whereas the COC bearings worn in an equal measure on cup and head (Table 1).

<table>
<thead>
<tr>
<th>Bearings</th>
<th>Head Wear [%]</th>
<th>Cup Wear [%]</th>
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<tbody>
<tr>
<td>COC</td>
<td>43.1 ± 9.2</td>
<td>56.9 ± 9.2</td>
</tr>
<tr>
<td>COM</td>
<td>2.8 ± 3.5</td>
<td>97.2 ± 3.5</td>
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Table 1: Mean wear ratio (head/cup) of the COC and COM bearings

All ceramic heads from the COM bearings showed metallic material transfer in form of stripes (Figure 3). In comparison, no visible wear traces were found on the COC heads (Figure 4).

Discussion
The COM implants showed very low wear levels that were similar to the COC bearings and far below wear levels of conventional MOM bearings [1].

However, there was a spreading up to the thirteen fold between lowest and highest wear volume of the COM at the end of the study. Concerning COM implants such high variabilities were also seen by other investigators [2]. These variabilities may be related to the usage of a single station simulator in this study, whereas manufacturing related parameters may also play a role.

Only minimal wear was detected on the heads of the COM bearings. Because metallic material was transferred from the cups to the heads and wear was determined gravimetrically these results need to be interpreted with care.

This study was performed without implementing subluxation effects which might increase wear as shown by others. This effect together with the influence of third body wear should be investigated in further studies.

In conclusion, we noticed that the COM pairing delivers ultra low wear levels. The results of this study are promising and can support limited clinical use of COM implants.

References