EFFECT OF HEAD/CUP CLEARANCE AND SERUM LUBRICANT CONCENTRATION ON THE WEAR OF CROSSLINKED UHMWPE IN AN OBM TYPE HIP SIMULATION

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INTRODUCTION
Theoretical stress analysis suggests that the head/cup clearance should be as small as possible to reduce the contact stress and to minimize the polyethylene wear rate[1]. One study revealed that clearance had insignificant effects on the wear rate of non-crosslinked UHMWPE cups against cobalt-chrome heads[2]. It was suggested a starved lubrication phenomena may explain the unexpectedly higher wear rate generated by the small clearance group. No study, however, has been conducted to evaluate the effect of clearance on a crosslinked material. This study investigated the effect of head/cup clearance on the wear of a crosslinked UHMWPE cup against a CoCr head using a similar experimental setup to the previous study[2]. Diluted serum was used in the last million cycles of the wear test to investigate the effect of serum lubricant concentration on wear.

MATERIALS AND METHODS
UHMWPE cups were manufactured from 1020 REB bars and paired with eight 28 mm CoCr heads (DePuy Inc, IN). These were arranged into three groups of diametrical clearances, i.e., 0.2 mm (small clearance group, N=3), 0.6 mm (medium clearance group, N=2) and 1.06 mm (large clearance group, N=3). All cups were sterilized at 40 +/- 2 kGy using the Gamma Vac Foil (GVF) method[3]. The test was performed on an 8-station hip joint simulator (MTS, MN) using the Paul-type physiological loading (2000 N max, +/- 2 kGy using the Gamma Vac Foil (GVF) method[3].

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RESULTS
The PE wear of the three clearance groups changed through the whole test and are presented in four stages (Table 1). From 0 to 1 million cycles (stage A), the small clearance group generated the lowest wear rate of all three groups (29.1 ± 0.3 mg/M), while the wear rate for the medium and the large clearance groups were 21% and 29% higher, respectively (Figure 1).

From 1 to 4 million cycles (stage B), all three groups had reduced and stabilized PE wear. The ranking in stage A, however, no longer holds, since the wear rate for the small clearance group was 17% and 4% higher than the medium and the large groups, respectively (Figure 1).

From 4 to 6 million cycles (stage C), the wear rate for the small clearance group increased and was similar to its wear rate as stage A, while the medium and the large clearance groups remained the same as they were in stage B (Figure 1).

From 6 to 7 million cycles (stage D), the serum lubricant was diluted to 25% and the resulting wear rates increased by 42%, 70% and 82% for the small, medium and large clearance groups, respectively (Figure 1).

Table 1. UHMWPE Wear Rate (mg/million cycles)

<table>
<thead>
<tr>
<th>Stage</th>
<th>Cycles</th>
<th>Small</th>
<th>Medium</th>
<th>Large</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0 to 1 M</td>
<td>29.1+/-0.3</td>
<td>35.1+/-1.1</td>
<td>37.5+/-0.5</td>
</tr>
<tr>
<td>B</td>
<td>1 to 4 M</td>
<td>23.7+/-0.9</td>
<td>20.2+/-0.7</td>
<td>22.7+/-0.7</td>
</tr>
<tr>
<td>C</td>
<td>4 to 6 M</td>
<td>29.2+/-2.2</td>
<td>18.6+/-1.0</td>
<td>19.3+/-1.5</td>
</tr>
<tr>
<td>D</td>
<td>6 to 7 M</td>
<td>41.6+/-2.6</td>
<td>31.6+/-3.3</td>
<td>35.2+/-6.5</td>
</tr>
</tbody>
</table>

The surface morphology appeared generally shiny and smooth for all groups when lubricated with 90% serum. A roughened surface was observed after the serum concentration was changed to 25%. In addition, an irregular surface was prominent for the small and the medium clearance groups.

DISCUSSION
Larger contact area and less contact stress at the ball and cup interface might contribute to the PE wear during stage A, suggesting the previous theoretical stress analysis[1] is valid during the wear-in period.

The similar wear rates for all three groups in stage B appeared to be a transition region from the wear-in process of stage A to steady state wear in stage C. In stage C, the medium and the large clearance groups showed similar wear rates to stage B whereas the small clearance group showed a significant increase in wear rate. This increased wear rate might be attributed to lubricant starvation, as reported by Wang et al[2], since the increased contact area of the small clearance group might prevent serum lubricant to properly lubricate the ball/cup interface. The result also suggested that the medium and the large clearance groups will eventually have increased wear rates similar to the small clearance group.

The irregular surface morphology caused by using 25% serum lubricant during stage D suggests that there was insufficient protein molecules at the interface to provide adequate boundary lubrication. Further investigation is necessary to characterize these surfaces and to compare with those of clinically retrieved cups.

The reason that Wang et al[2] did not observe stage A and B in the previous study may be due to the better wear resistance of the crosslinked PE than non-crosslinked PE, which slowed down the wear process. The hypothesis of starved lubrication may happen after the wearing-in process, or it may only happen in the simulator due to the set up in which the cup is stationary and positioned anatomically, whereas the human joint could be lubricated through activities such as sitting and reclining. The experimental setup in this study showed an extreme situation when the cup always stays on top of the femoral head.

Clinical relevance of this study: For cross linked PE against metal heads, the small clearance group generated lower PE wear for the short term period. For long term wear performance, medium or larger clearance groups showed better performance.

Figure 1. Average Interval Wear Rate (mg/million cycles)

REFERENCES

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