WEAR OF UHMWPE AND PTFE IN A HIP SIMULATOR: COMPARISON OF FLUID VOLUME AND PROTEIN CONCENTRATION AND ANATOMICAL VS INVERTED POSITIONING

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Introduction: In-vitro wear assessment has relied on ranking of materials against the THR gold standard of UHMWPE/CoCr. Unfortunately, rankings do not always reflect the true clinical situation. Charnley first noted this discrepancy with PE and polytetrafluoroethylene (PTFE). In-vitro PE was 250 times more wear resistant than PTFE but clinically it had only a 20-fold improvement. Edidin and Kurtz reported that Delrin wore much less than PE yet clinically it was known to have much higher wear-rates than PE. Therefore, one might ask if this same discrepancy has happened with other materials such as highly crosslinked PE, metal/metal and ceramic/ceramic. Might these ratios that in-vitro showed a marked improvement over standard PE be artificially inflated? Four studies have shown that wear-rates can be modified by the proteins in serum, and one study showed that the volume of fluid had a marked effect on the wear of UHMWPE. Thus the aim of this study was to examine the fluid volume effect on PTFE and the effect of positioning: inverted, anatomical horizontal and anatomical oblique on UHMWPE and PTFE.

Materials and Methods: Non-sterilized PTFE and GUR 4150 UHMWPE (2.5 Mrad/air and 2.5 Mrad/N2) cups were run with 32mm CoCr heads in a 12 channel biaxial hip simulator. Cups were mounted either in the inverted (cup on the bottom), anatomical horizontal or anatomical oblique (angle of 23°) position. A Paul load curve was used with a 2 kN peak at 1Hz. Two types of serum were used: bovine serum (Hyclone Inc. Logan, Utah: 65 mg/ml protein) diluted to 30% without additives and alpha calf serum (Hyclone Inc.; 45 mg/ml protein) diluted to 50% with EDTA added to UHMWPE tests. Serum volumes were 450 and 250ml. Wear was measured gravimetrically and wear-rates were determined by linear-regression techniques and converted to volumetric wear using the reported densities of; PTFE = 2.16, UHMWPE (2.5 Mrad/air) = 0.933 and 2.5 Mrad/N2 = 0.935 mg/mm3. Test duration for the UHMWPE and PTFE were approximately 2Mc and 0.5Mc respectively.

Results: Wear-rates for UHMWPE and PTFE are shown in Table 1 and Fig. 1 with rankings and differences in table 2.

<table>
<thead>
<tr>
<th>Position</th>
<th>PTFE 30% serum 250ml</th>
<th>PTFE 30% serum 450ml</th>
<th>PTFE 50% alpha Serum 450ml</th>
<th>2.5Mrad UHMWPE 50% alpha Serum 450ml</th>
<th>PTFE/PE 50% alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inverted</td>
<td>4055</td>
<td>6207</td>
<td>6576</td>
<td>54 (N2)</td>
<td>98</td>
</tr>
<tr>
<td>Anatomical Horizontal</td>
<td>4398</td>
<td>5270</td>
<td>54 (N2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anatomical Oblique</td>
<td>4062</td>
<td>4843</td>
<td>57 (air)</td>
<td>52 (N2)</td>
<td>85</td>
</tr>
</tbody>
</table>

Table 1 PTFE and UHMWPE Wear-rates (mm3/Mc) 2.5 Mrad in N2 and air.

Discussion: Wear of UHMWPE was reduced by 9% with 2.5 Mrad/N2 vs. 2.5 Mrad/air. There was only a slight difference (4%) in wear between anatomical positions for UHMWPE. On the other hand, PTFE showed a consistent difference (oblique < horizontal << inverted) in both types of serum. Wear for both UHMWPE and PTFE was lowest in the anatomical oblique position. A possible explanation was that in the oblique position fluid had less distance to travel before reaching the contact zone, thereby ensuring a fluid covering (Fig 2). Wear of PTFE was consistently lower in the 19.5 mg/ml of protein (30% bovine serum). This was in keeping with previous results from other laboratory studies. These studies also showed that lower protein concentrations produced Charnley's clinical PTFE/PE ratio. Our PTFE/PE ratio in 50% alpha serum was still approximately 1.5 fold too high. Comparison of fluid volume for PTFE was consistent with an UHMWPE study by Wang et al. They found that as volume decreased protein precipitate increased. Thus the protein precipitate could be artificially protecting the cup surface causing decreased wear.

Conclusions: We have shown that
a) the volume of fluid,
b) concentration of proteins in the fluid and the
b) THR orientation
can have a significant effect on the wear of PTFE and UHMPE. This becomes very important for materials that have wear magnitudes that are closer to UHMWPE. Therefore, it is essential to identify the correct variables that will reproduce wear magnitudes and ranking of known clinical materials.

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