The Influence of abduction angle on the wear characteristics of a second generation highly crosslinked polyethylene

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INTRODUCTION

The introduction of highly crosslinked polyethylenes with improved wear performance has allowed for the marketing of thin acetabular liners [1]. Previous studies have shown that acetabular angle can affect the wear performance of implants [2-6]. Steep angles (>55°) reduce femoral head coverage thereby decreasing contact area and can subject the acetabular rim to excessive stresses [7]. These stresses have the potential to induce fracture to materials with suboptimal mechanical properties [8]. This can be especially concerning for thinner polyethylene constructs. Therefore, the objective of this study was to isolate and examine the effects of varying cup abduction angles on the wear of a thin (3.8mm) second generation highly crosslinked polyethylene.

METHODS AND MATERIALS

Five sets of sequentially crosslinked (X3® Stryker Orthopaedics, Mahwah, NJ) Trident® design acetabular inserts (n=15) with internal diameters of 44mm and a wall thickness of 3.9 mm were evaluated in this study. Sequentially crosslinked liners were machined from compression molded GUR1020 UHMWPE that had been γ-irradiated to 30 kGy followed by annealing 3 times (total dose=90 kGy, X3®). After machining inserts were gas plasma sterilized. The inserts were mounted in titanium acetabular shells. The shells were mounted in polyethylene fixtures using titanium bone screws. Matching diameter (44 mm) cobalt-chrome femoral heads were mated with the inserts.

Testing was conducted using a hip joint simulator (MTS, Eden Prairie, Minnesota). All cups were fixed, positioned superiorly to its matched femoral head at a neutral version angle, and divided into five groups of varying inclination angles from the horizontal plane: 0°, 20°, 30°, 50° and 70° (Fig 1). The joint force in vivo is approximately 10° to 15° medial to the superior direction [6], therefore, due to the MTS simulator’s vertical load path, the cup inclination angles of 0°, 20°, 30°, 50° and 70° simulate the in-vivo conditions of approximately 10°-15°, 30°-35°, 40°-45°, 60°-65° and 80°-85° abduction angles, respectively.

The MTS simulator applies a biaxial rocking motion to the femoral head by a rotating block inclined at 23°. A physiological load similar to that described by Paul [9] was applied to each cup/head couple via a hydraulic actuator. The minimum and maximum loads applied were 50 N and 2450 N, respectively. Testing was conducted at 1 Hz using a joint fluid analog of Alpha Calf Fraction serum (Hyclone Labs, Logan UT) diluted to 50% with a pH-balanced 20 mMole solution of deionized water and EDTA (protein level ≈ 20 g/l). Serum was changed every 0.5 million cycles at which time, samples were cleaned and weighed. Weight was converted to volume and plotted as a function of cycle count. Using linear regression analysis, volumetric wear rates were attained. The testing was carried out for 3.0 million cycles. In addition, all UHMWPE inserts were microscopically analyzed for any gross damage and areas of deformation. Any surface damage, such as cracking or pitting was recorded.

RESULTS

Results are shown in Table 1 and Figure 2. Figure 2 show wear rates plotted against inclination angle; this plot exhibits poor correlation between wear rate and angle (R²=0.253). Student’s t-tests revealed significant differences (p<0.05) between 0° and 70°, and between 50° and 70° angles, there was no statistical differences (p>0.05) for any of the other tested angles. Visual inspection of the tested liners revealed wear scars of increased areas of polishing on inserts positioned at lower abduction angles. No deformation, cracking or pitting of the liners was observed.

<table>
<thead>
<tr>
<th>Abduction Angle (deg)</th>
<th>Volume loss (mm³)</th>
<th>Wear Rate (mm/10⁶cycles)</th>
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<tbody>
<tr>
<td>0°</td>
<td>0.6 ± 3.6</td>
<td>1.3 ± 1.2</td>
</tr>
<tr>
<td>20°</td>
<td>2.3 ± 4.6</td>
<td>2.0 ± 1.5</td>
</tr>
<tr>
<td>30°</td>
<td>4.3 ± 6.1</td>
<td>3.0 ± 2.5</td>
</tr>
<tr>
<td>50°</td>
<td>-3.8 ± 2.5</td>
<td>0.3 ± 0.5</td>
</tr>
<tr>
<td>70°</td>
<td>12.3 ± 1.5</td>
<td>4.8 ± 0.3</td>
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</tbody>
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Table 1: Cumulative volume loss and wear rate at 3 million cycles.

DISCUSSION

These results indicate a low correlation (R²=0.253) for abduction angles in hip simulator testing, when using sequentially crosslinked polyethylene. Visual inspection of the liners revealed an increase in overall area of polishing with a reduction in abduction angle. This indicates that load is concentrated over a smaller area for higher angles resulting in increased contact stress for steeper cups; however, this did not translate into a correlation of high abduction angle and high wear. This suggests that the sequentially crosslinked polyethylene is able to maintain its low wear characteristics at various abduction angles with a thin (3.8 mm) liner.

REFERENCES