Scratching Vulnerability of Conventional vs. Highly Crosslinked Polyethylene Liners with Reproducibly Embedded Third Body Particles

+Heiner, A D; Brown, T D
University of Iowa, Iowa City, IA
Senior author anneliese-heiner@uiowa.edu

INTRODUCTION:
In total joint arthroplasty, third body particles can migrate into the articular bearing surface and cause accelerated wear. They can directly abrade the polyethylene liner and also scratch the metal femoral head, with counterface roughening further increasing the polyethylene wear rate. Third body particles embedded in polyethylene acetabular components are a well-documented finding in total hip retrieval studies, and they are suspected of being a major contributor to the variability of wear.

For hip simulator testing of metal-on-polyethylene THA implants in the absence of third body challenge, highly crosslinked polyethylene (HXPE) acetabular liners wear far less than do conventional polyethylene (CPE) liners. However, HXPE has compromised fracture toughness, fatigue resistance, and tensile properties, as compared to CPE. This may make HXPE relatively more susceptible to damage from large local asperities on the metal counterface, such as scratches from third bodies, thus reducing the wear advantage of HXPE vs. CPE under severe third body conditions.

The hypothesis of this study was that liner vulnerability to scratching from heads roughened by third bodies is only mildly reduced for HXPE, as opposed to CPE.

METHODS:
Six CPE and six HXPE 28mm acetabular liners were each reproducibly embedded with five CoCrMo beads (F-75 alloy) measuring 300 – 320 µm diameter (Figure 1). One bead was embedded at a site which an earlier FEA had determined to be maximally problematic for accelerating liner wear due to roughening of the femoral head counterface. The other four beads were embedded at registered sites on a 10 mm diameter circle centered about that location.

Each liner was run for 10,000 level walking cycles in a joint motion simulator, articulating against an Orthochrome femoral head. The heads and liners were then photographed. The severity of liner scratch damage was evaluated by an experienced orthopaedic surgeon, who rank-ordered the pictures of the liner scratch fields.

RESULTS:
The femoral heads each had five macro-scratch families (Figure 2a), which corresponded to the five embedded beads on their respective liners. The damage to the acetabular liners included macroscopically-visible scratches, which were variable in number and severity among the liners (Figures 2b&c). The acetabular liners also displayed microscratches (not visible to the naked eye) and smoothing of the liner machining marks. The embedded beads wore flat and were retained in their original positions after testing.

Most of the HXPE liners were more severely scratched than most of the CPE liners. The rank-order of the CPE (C) and HXPE (H) acetabular liners, from most to least scratched, was:

<table>
<thead>
<tr>
<th>Liner Type</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPE</td>
<td>H</td>
</tr>
<tr>
<td>HXPE</td>
<td>C</td>
</tr>
</tbody>
</table>

DISCUSSION:
For acetabular liners articulating with CoCr femoral heads, highly crosslinked polyethylene did not offer appreciable protection against severe scratching induced by large embedded third body particles. In fact, the HXPE liners were generally more scratched than the CPE ones, as indicated by visual rank-ordering. This finding was consistent with results from a short-term retrieval study, in which heavy scratching was more frequently noted on HXPE liners than on CPE liners.

While remelting of HXPE liners removes small scratches, indicative of plastic deformation rather than wear, remelting recovery of more severe surface damage is much less complete, ostensibly because of material loss. The relative dominance of plastic deformation vs. material loss in scratching from large third body particles merits further investigation.

In conclusion, under controlled conditions of third body embedment, highly crosslinked polyethylene liners were generally more vulnerable to scratching than were otherwise-similar conventional polyethylene liners.

REFERENCES:

ACKNOWLEDGEMENTS:
This study was funded by NIH 5R01 AR047653. The authors also thank DePuy Orthopaedics, Inc. for providing the implants, and Dr. Nicolas Noiseux for collaborative advice.