The Effect of In Vivo Damage of Oxinium Femoral heads on the Wear of Highly Cross-linked Polyethylene

Bragdon, C.R; Wannomae, K. K.; Lozynsky, A.; Micheli, B.; Malchau, H.
Harris Orthopaedic Biomechanics and Biomaterials Laboratory, Massachusetts General Hospital, Boston, MA 02114
Senior author cbragdon@partners.org

INTRODUCTION: Oxidized zirconium (Oxinium™) is a bearing surface introduced for use in THA to minimize wear in vivo. Oxinium femoral heads are manufactured by oxidizing wrought Zr-2.5Nb alloy (ASTM F 2384) in air at an elevated temperature to produce an approximately 4 to 5 micron thick zirconium oxide on the surface[1]. As with any femoral head, it can be damaged by abrading against a rough metal surface (shell) during dislocation and manipulation during a closed reduction procedure. Kop et al[2] and Evangelista et al[3] reported retrieval case studies where Oxinium femoral heads were severely damaged *in vivo* due to dislocation. Both postulate that the damage may lead to accelerated polyethylene wear. The purpose of this study was to evaluate wear of highly cross-linked polyethylene (XLPE) acetabular liners articulating against surgically retrieved Oxinium heads which have been damaged in vivo using a 12 station AMTI Boston Hip Simulator.

METHODS: Six Oxinium femoral heads retrieved from revision surgery secondary to dislocation and repeated closed reduction were identified. The femoral heads, three 28mm and three 32mm diameter, had various amounts of abrasive damage confined to one quadrant of the surface. These were coupled with the appropriate sized XLPE liner. In addition, three new 32 mm Oxinium heads were coupled with new XLPE liners. For comparative purposes, three new 32 mm CoCr heads were coupled with conventional, non-irradiated polyethylene liners. All liners were gas sterilized.

Hip simulator testing was performed on a 12-Station AMTI Boston Hip Simulator using a standard walking gait program with the peak load of 3000 N at a rate of 1 Hz. Two additional liners for each group were subjected to load without motion. These 'load-soak' liners were used for correction of the fluid uptake of the polyethylene. All stations were temperature controlled at 37°C with circulating 100% bovine serum, stabilized with 10.7 millimoles of ethylenediamine tetraacetate and 33 mL of penicillin-streptomycin solution per 500 mL. The damaged area of the retrieved heads was positioned so that it contacted the polyethylene surface during the highest load phase of the gait cycle. The test will be carried out to a total of 5×10^6 cycles. The total number of cycles at this writing was 2.5 million cycles.

Weight change was determined after each 0.25×10^6 cycle interval according to ISO 14242. The weight loss of each liner was used to calculate a wear rate after correction for fluid absorption. The actual wear rate of each liner was calculated by linear regression. Due to the inhomogeneous damage on each retrieved femoral head, the individual data from each retrieved component was compared to the average values of the two control groups. All surfaces were examined by optical microscopy and photographed at each weighing interval.

RESULTS: The damage on the retrieved femoral heads was characterized by severe plastic deformation of the substrate leading to cracking of the oxide surface, several areas of oxide breach, extensive Ti transfer indicative of contact with the acetabular shell and presence of Fe, Cr indicative of surgical instrument damage.

The weight loss of each component is shown in figure 1A+B. The three control, non-cross-linked polyethylene components wore at a near steady average rate of 37.8 ± 2.8 mg/million cycles with an average total net weight loss of 94.6 ± 7.0 mg. The three XLPE liners which articulated against new 32 mm Oxinium femoral heads had an average net weight gain at a near steady average rate of 2.64 ± 0.6 mg/million cycles with an average total net weight gain of 6.6 ± 1.5 mg. In contrast to the two control groups with new femoral heads, the weight change of the XLPE liners which were coupled with the in vivo damaged Oxinium heads varied in relation to the magnitude of the damage present on the femoral heads. One 32 mm XLPE liner had a weight loss throughout the test having a total wear rate of 1.9 mg/million cycles with a total net weight loss of 4.8 mg. A second 32 mm XLPE had a net weight loss after 1.75 million cycles having a total wear rate of 0.1 mg/million cycles with a total net weight loss of 0.35 mg. While the other four XLPE liners in this group maintained a net weight increase thorough out the testing, this net weight change was less than that of the XLPE control liners, indicating that a small amount of wear occurred.

There were no changes in the appearance of any of the femoral heads in this study as judged by optical microscopy. The articular surface of the non-cross-linked liners had a polished reflective appearance typical of adhesive wear. The cross-linked liners that were coupled with the new Oxinium heads showed little to no wear – minimal scratching was observed, but the original machining marks could still be seen in all quadrants and near the dome of the liners. The cross-linked liners coupled with the *in vivo* damaged Oxinium heads showed relatively more damage. The highly loaded quadrant (coinciding with the damaged portion of the heads) showed more scratching polishing. The original machining marks were no longer visible. However, the machining marks were seen in the other quadrants and near the dome.

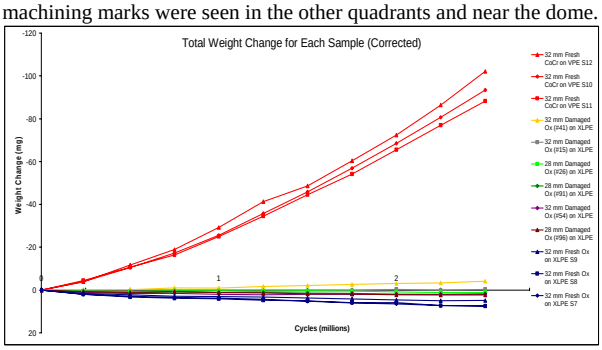

Figure 1A The weight change of each liner after load soak correction. As expected, the non-cross-linked liners had a significant wear rate and the XLPE liners articulating against new Oxinium heads had a net weight increase.

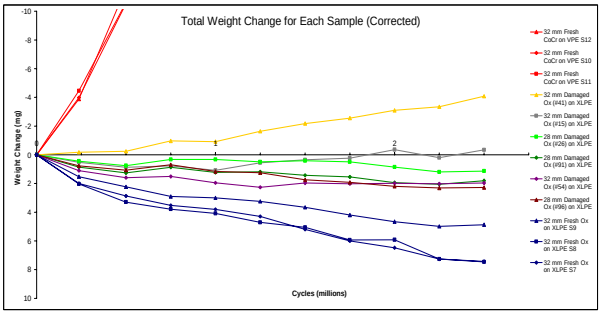

Figure 1B The scale of the Y axis has been changed in order to highlight the weight change of the XPLE liners. The XLPE articulating against in vivo damaged Oxinium had varying amounts of weight change, indicating some wear in this group.

DISCUSSION: The dislocation damaged Oxinium femoral heads resulted in a measurable increase in the wear of the XLPE liners compared to the XLPE liners coupled with new Oxinium heads. However, this change was relatively small in light of the substantial wear of the non-cross-linked liners and remained below what some have described as a wear threshold for osteolysis[4]. This study of the effect of in vivo damage to Oxinium femoral heads on the wear of XLPE liners is somewhat complicated by the fact that the load soak controls do not account for all of the fluid uptake of the test components. Bragdon et al[5] showed that this small differential in weight correction, which can only be seen with low wear polyethylene components, is due to the increase in temperature at the articular surface resulting from interface motion. The damage to the femoral head due to dislocation and repeated closed reduction is primarily confined to the inferior aspect of the head which has minimal contact with the interface under high loads for most daily activities. By positioning this damaged area such that it contacts the liner in the high load region of the gait cycle, this study represents the worst case scenario for accelerated wear evaluation. While the amount of in vivo damage can vary widely, this study suggests that it would not lead to catastrophic run away wear of XLPE.

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