Do Large Diameter Femoral Heads and Ceramic Bearing Surfaces Impact the Revision and Wear of HXLPE?

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Significance: For more than a decade, changes in femoral head material, femoral head size, and polyethylene formulation have been introduced in THA. The purpose of this multicenter retrieval study was to assess how these factors influence the wear behavior of highly crosslinked polyethylene (HXLPE).

Introduction: In addition to changes in HXLPE formulation over the past decade, there have also been changes in liner design and femoral head bearing materials. Due to improved wear behavior of HXLPEs, manufacturers introduced larger diameter femoral heads (both ceramic and metallic) to improve stability. However, because of its larger surface area, larger femoral heads could be expected to increase the volume of wear debris. Changes have also been made to the head bearing surface. Because of improved wettability and surface finish, alumina ceramic femoral heads were introduced in the 1970s in an attempt to reduce polyethylene wear in total hip arthroplasty. Since then, many different ceramic bearing surfaces have been used in arthroplasty, including zirconia, zirconia-toughened alumina composites (ZTA), and oxidized zirconium. Interest in zirconia has waned since 2001 when a leading producer issued a recall due to higher than expected short-term fractures. With changes in polyethylene formulation, femoral head surface, and liner design being introduced concurrently, it is unclear to what extent each of these modifications has on the wear and reasons for revision in total hip arthroplasty. The purpose of this multicenter study was to assess the wear behavior of HXLPEs in the context of polyethylene formulation, head size, and head bearing surface. We tested the following two hypotheses: (1) large diameter (≥32 mm) heads would exhibit greater wear than smaller heads (28 mm or less); (2) ceramic bearing surfaces would decrease the wear of HXLPE liners.

Methods: 354 hip liners were consecutively retrieved during revision surgeries at 9 surgical centers and continuously analyzed over the past 10 years in a prospective, multicenter study of THA revision outcomes and retrieval analysis. 218 were highly crosslinked and remelted (A-Class, Durasul, Longevity, Marathon, XLPE: Remelted; Implanted 1.9±2.2 years, range: 0-8.8 years), 84 were highly crosslinked and annealed (Crossfire: Implanted 3.8±2.9 years, range: 0.0-10.9 years), and 52 were highly crosslinked and annealed in 3 sequential steps (XL: Implanted 1.2±0.9 years, range: 0.0 – 3.4 years). 201 of the femoral heads had a diameter greater than 28mm and thus were considered “large” femoral heads. 77 of the heads were fabricated from a ceramic surface ( alumina, Bioflex Delta, Oxinium, or zirconia).

Results: Loosening, instability, and infection were the predominant reasons for revision for the annealed, sequentially annealed, and remelted components (p = 0.08; Pearson Test). We observed 7 late cases of catastrophic fracture of zirconia femoral heads (implanted 3.7-10.9 years). This resulted in accelerated wear of the polyethylene due to articulation with the trunnion and the introduction of ceramic debris into the articulation (Fig. 1). Due to this rare complication, these retrievals were excluded from the penetration analysis.

No difference in femoral penetration rates could be detected between the annealed, sequentially annealed, and the remelted highly crosslinked groups (p = 0.05), and thus we pooled them for the purposes of the analysis. No difference in penetration rates could be detected among the different ceramics used, so they were also pooled for the purposes of this analysis (p = 0.73, Kruskal-Wallis Test). Ceramic femoral heads had similar linear penetration rates when compared with metallic femoral heads (mean difference = 0.006 mm, p = 0.57; Wilcoxon Test). No difference in linear penetration rate was detected for liners with a large femoral head as compared with the standard heads: mean difference = 0.001 mm, p = 0.97; Wilcoxon Test).

Conclusions: No unexpected finding of our retrieval program has been the observations of late ceramic head failures, associated with the 2001 recall by the manufacturer. Consequently, even though in vitro studies have demonstrated a benefit with the use of ceramic heads as opposed to a metallic head, the clinical performance of ceramic heads as a general class of materials against highly crosslinked polyethylene (HXLPE) remains unclear. To date, we have not observed accelerated wear of HXLPE liners associated with larger femoral heads, but again these data are limited to short- and intermediate-term explants. Long-term retrieval studies are needed to verify the safety and stability of large diameter femoral heads, as well as ZTA and oxidized zirconium, as alternatives to 28 mm diameter metal femoral heads used historically in hip bearings.

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Figure 1: An annealed liner and fractured zirconia head that was implanted for 10.9 years. Note that the trunnion wore all of the way through the liner. Liner penetration was assessed directly using a calibrated micrometer (accuracy 0.001mm). We excluded liners that were in vivo for less than one year as creep is expected to be the dominant cause of penetration during that time. This resulted in 188 liners available for penetration analysis (57 Annealed, 28 Sequentially Annealed and 103 Remelted).

Figure 2. Effect of head material (A) and size (B) on penetration rates.