The Effect of Femoral Head Diameter and Material on the Wear of Highly Crosslinked Polyethylene Liners

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Introduction:

The improved wear resistance of highly crosslinked UHWMPE has led a number of clinicians to transition from implanting traditionally popular femoral head sizes (28 mm and 32 mm) to implanting 36 mm heads. Desire to further increase stability and range of motion has spurred interest in even larger sizes (> 36 mm). While the long-term clinical ramifications are unknown, in-vivo measurements of highly crosslinked UHMWPE liners indicate increases in head diameter may be associated with increased volumetric wear [1, 2]. In addition to head diameter, head material is an important factor that can affect the wear of crosslinked UHMWPE. The goal of this study was to evaluate the effect of head size and head material, as well as any interaction they may have, on the wear of highly crosslinked UHWMPE.

Methods:

Ram-extruded GUR 1050 UHMWPE (MediTech, Ft. Wayne, IN) was crosslinked by gamma irradiation to 10 Mrad (10-XPE), remelted, and machined into acetabular liners. CoCr heads were manufactured from wrought bar (ASTM F1537). The starting material for OxZr (OXINIUM™) heads was Zr-2.5Nb (ASTM F2384) [3]. All implants were manufactured by Smith & Nephew (Memphis, TN).

Liners were terminally gas-sterilized, mounted at a 35° angle, and articulated against femoral heads on a hip simulator (AMTI, Watertown, MA). Lubricant was a 20mM EDTA, 0.2% NaN_3 (wt. %), serum (Alpha Calf™ Fraction, Hyclone Labs, Logan, UT) solution with an approximate protein concentration of 40 g/L. Two different load/motion waveforms were alternated every 10,000 cycles for approximately 6 million cycles (Mcycle) [4]. Both waveforms, originally based on walking at 1 Hz, were modified to simulate fast walking/jogging by increasing the peak load to 4000 N and frequency to 1.15 Hz [5, 6].

Gravimetric measurements, taken at least once every 1 Mcycle, were corrected for fluid absorption using load-soak controls and converted to volumetric measurements using the density of UHMWPE. The slope of the least squares best-fit line of cumulative volume loss vs. cycles was determined for each liner and defined as the wear rate. In order to evaluate the effects of head size and material, as well as their interaction, on wear rate, a two-way analysis of variance was performed ($\alpha = 0.05$).

Table 1: Summary of two-way ANOVA evaluating the effect of head material and diameter on wear rate

Source	DF	SS	MS	F	P
Head material	1	8.7963	8.79627	27.47	0.001
Head size	1	0.4521	0.45209	1.41	0.269
Interaction	1	0.1445	0.14445	0.45	0.521
Error	8	2.5620	0.32025		
Total	11	11.9548			

S = 0.5659 R-Sq = 78.57% R-Sq(adj) = 70.53%

Results:

The predominant feature displayed on the articular surfaces of liners was burnishing. There were no signs of fatigue wear or delamination. Mean wear rates (± standard deviation) of 10-XPE liners articulated against 36 mm and 44mm CoCr femoral heads were 4.2 ± 0.6 mm^3/Mcycle and 4.8 ± 0.9 mm^3/Mcycle, respectively. Mean wear rates (± standard deviation) of 10-XPE liners articulated against 36 mm and 44 mm OxZr femoral heads were 2.7 ± 0.1 mm^3/Mcycle and 2.9 ± 0.4 mm^3/Mcycle, respectively (Figure 1). Statistical analysis is summarized in Table 1. While femoral head diameter did not have a significant effect on the wear rate ($p = 0.27$), femoral head material was found to have a significant effect ($p < 0.01$). There was no interaction between the two parameters ($p = 0.52$).

Discussion:

In-vivo measurements indicate that volumetric wear of highly crosslinked UHMWPE liners may increase significantly with head diameter [1,2]. While the data from this study corresponds with this trend, the difference in wear rate observed between liners paired with 36 mm and 44 mm heads was not significant at the level tested. Head material had a greater effect on the wear of 10-XPE liners than head diameter within the size range evaluated (36 mm - 44 mm). Implantation of large diameter heads with a ceramic surface allows concerns regarding wear to be addressed without compromising stability and range of motion.

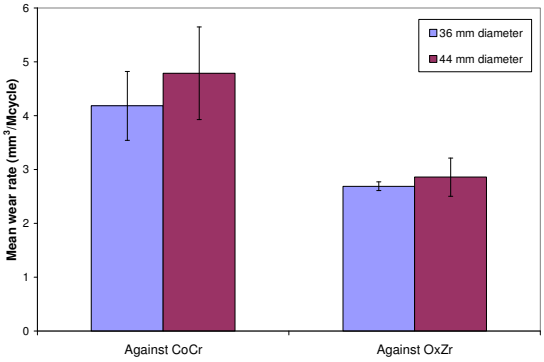

Figure 1: Wear rates of 10-XPE liners against 36 and 44 mm CoCr and OxZr femoral heads (error bars indicate standard deviation).

References:

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