Polyethylene Wear In Total Hip Replacements: Effects of Crosslinking & Head size

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Statement of Purpose: Wear debris induced osteolysis is recognized as a major problem in THR. Thus there is a need to reduce the wear particles by improving the wear performance. Simulator studies in the past with Metal on polyethylene (M-P) bearing couples showed increasing wear with femoral head diameter (1). The goal of the current study is to compare the dual effects of increased wear resistance of crosslinked polyethylene (XP) bearings to conventional M-P bearings and of femoral head size.

Materials and Methods: Four different sized hip bearings were selected for the present study. Metal-conventional polyethylene (M-P), was tested in 28 & 32mm bearings. Metal-crosslinked polyethylene (M-XP) was tested in 28, 32, 42mm and 46mm bearings. Femoral heads were manufactured from cast ASTM F75 CoCr alloy and subsequently subjected to a hot isostatic pressurization followed by solution annealing. Conventional acetabular bearing liners were machined from extruded GUR 1050 UHMWPE while the crosslinked liners were machined from compression molded GUR 1020 UHMWPe that was crosslinked with 7.5MRad of gamma radiation followed by annealing above the melt temperature. All liners were subjected to EtO terminal sterilization.

Prior to the start of the test all the liners were soaked in test lubricant for 48 hours. Hip testing was performed on a Shore Western Orbital Bearing Hip Wear Machine in the anatomically oriented position with liners above and heads below .A simulated gait profile (triple peak load profile) with a minimum and maximum force of 200N and 2000N respectively was applied to the bearings. The duration of a single simulated gait profile was 1 second. The loading was synchronized with a +/-23 degree biaxial rocking motion. The lubricant used for the testing both groups was 25% bovine serum with 0.2 % sodium azide, 20 mMol EDTA and distilled water The test was interrupted at regular intervals of 0.5 Mc from 0-1Mc and thereafter for every 1Mc for gravimetric assessment of the bearing wear.

Results and Discussion: Figure 1 shows the effects of material on cumulative wear and wear rates. M-XP bearings demonstrated 92-94% lower cumulative wear & wear rates compared to conventional M-P bearings. The lower wear of M-XP bearings was statistically significant for both 28&32mm bearings (t-test, $p<0.001$).

Figure 2 shows the effects of femoral head size on cumulative wear and wear rates of M-XP bearing couples. Among M-XP bearings 28mm bearings exhibited lowest wear while 46mm bearings exhibited highest wear. The 28mm M-XP bearings demonstrated 41% lower wear than 46mm M-XP bearings. Femoral head size showed a statistically significant difference in wear rates for M-XP bearings ($p=0.002$, ANOVA), Pair wise multiple comparison procedures showed statistically significant differences in wear and wear rates only between 28mm and 46mm XP bearings ($p<0.001$, Tukey test) and no significant difference between other sizes.

Published simulator studies showed that increasing the head diameter by 1mm added approximately 10% wear (1) for conventional polyethylene bearings. From these data, it would be expected that changing from a 28 or 32mm to 46mm size would have added 140-180% more wear volume. In contrast, 46mm XP bearings demonstrated approximately 70% higher wear rate compared to 28mm XP bearings, and had approximately 90% lower cumulative wear and wear rates compared to 28 & 32 mm conventional M-P bearings. The lower wear from large diameter M-XP bearings is statistically significantly lower than 28 or 32mm conventional M-P bearings ($p<0.001$).

Conclusion: Based on the results, M-XP bearings should result in lower clinical wear compared to conventional M-P bearings even with large diameter bearings. Significant differences in wear and wear rates in M-XP bearings were observed with femoral head sizes up to 46mm.

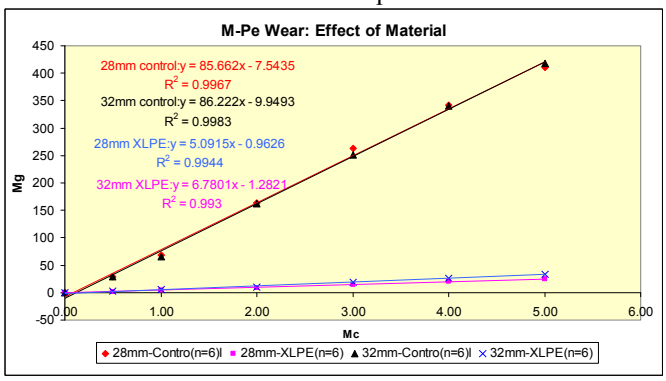

Figure 1: Effect of material on cumulative wear

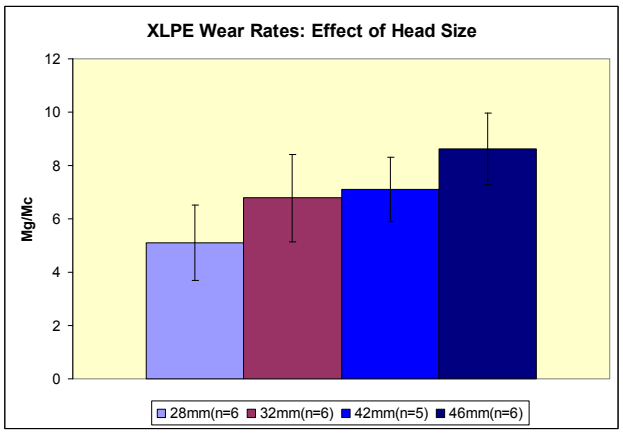

Figure 2: Effect of femoral head size on wear rates of M-XP bearings

Reference:

1. Clarke et al., Charnley wear model for validation of hip simulators-ball diameter versus polytetrafluoroethylene and polyethylene wear. Proc. Inst Mech Engrs 211(H): 25-36, 1997