WEAR OF GAMMA RADIATION CROSSLINKED PE ACETABULAR CUPS AFTER AGING AND AGAINST ROUGHENED FEMORAL HEADS

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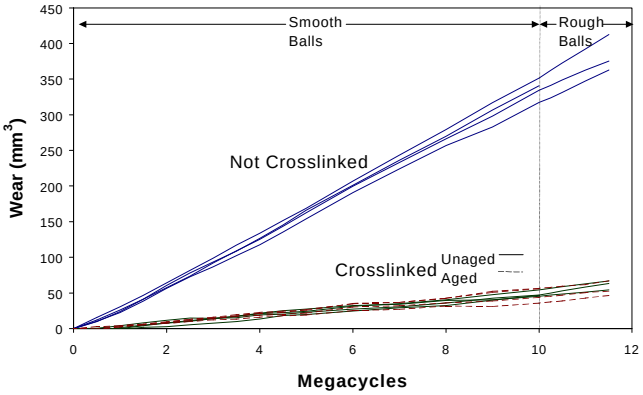
Introduction: Improving the wear resistance of UHMW polyethylene (PE) acetabular cups will reduce the release of wear particles and the severity of debris-induced lysis and loosening of joint replacements. Crosslinking of PE by chemical or radiation techniques has been shown to markedly improve its wear resistance in hip simulator testing (1-5) and clinical trials (6,7). However, joint replacements in vivo often are subjected to third-body abrasive particles (8) which can substantially roughen the femoral ball and, in turn, increase the wear rate of the opposing PE cup. There is concern that crosslinked PE might undergo *greater* wear than conventional PE under these conditions. In this study, a joint simulator was used to compare the wear resistance of conventional PE cups to gamma-radiation crosslinked PE cups, with and without artificial aging, and against smooth or roughened femoral heads.

Materials and Methods: 28mm dia. for conventional and crosslinked acetabular cups were machined from 3 inch dia. ram-extruded bars of GUR 4150 UHMW polyethylene (Poly Hi Solidur). For crosslinking, the bars were sealed in pouches under partial vacuum and exposed to 5 ± 0.5 Mrad gamma radiation. To extinguish residual free radicals and stabilize against long-term oxidation, the irradiated rods were heated in a nitrogen-purged oven at 155°C for 24 hours, cooled slowly, and then machined into cups. All cups were sterilized by gas plasma. To simulate aging, some of the crosslinked cups were heated to 70°C in 5 atm oxygen for 14 days. The oxidation levels were measured on microtomed sections of two cups of each material (one extra and one after the initial 10 million wear cycles) using FTIR (Mattson). Oxidation was compiled as the ratio of the peak height at 1717-1736 cm^{-1} (carbonyl) to a reference peak at 2022 cm^{-1}. Cups were worn in an inverted position in a Shore-Western hip simulator in 90% bovine serum (i.e., with 0.2% NaN_3 and 20mM EDTA) against polished femoral balls (R_a=0.045μm) for 10 million cycles, and then against rough balls (finished to an 800 grit, R_a=0.42μm) for 1.5 million cycles. Roughnesses were measured on a Perthometer profilometer with a non-contact laser probe prior to wear testing, and again at 0.25 and 1 million cycles to assess any polishing during the wear test. The 800 grit surface was chosen because the roughness was comparable to the roughest zones measured on a set of femoral components (R_a=0.5 μm) selected because they exhibited substantial third-body abrasion damage in vivo. Volumetric wear was measured by weight loss/density, corrected using soak-controls, and dimensionally using a coordinate measuring machine (CMM; Mitutoyo BRT504, with a Renishaw TP-200 probe). CMM data was numerically integrated over the wear zone to calculate the apparent loss in volume.

Results: Oxidation was very low in all materials, with maximum ratios ≤0.1 in the conventional cups, ≤0.3 in the non-aged crosslinked cups and ≤0.4 in the aged crosslinked cups. Against *smooth* balls, the mean wear rates were 34.3 mm^3/Mc for the conventional cups, 5.1 mm^3/Mc for crosslinked cups and 4.9 mm^3/Mc for the crosslinked-aged cups. Against roughened balls these averaged 32.8, 8.4 and 6.7 mm^3/Mc, respectively (p=0.68, 0.04 and 0.05, respectively, for a t-test comparing smooth to rough). The apparent overall volume loss from the integrated CMM data consistently exceeded that from weight loss by 50 to 75 mm^3, presumably due to creep deformation of the cups.



Discussion: The substantial reduction in mean wear rate for the crosslinked cups was consistent with previous reports for a comparable radiation dose (1,3,4). The effectiveness of the remelting procedure in removing residual free radicals from the crosslinked PE was evident from the very low levels of oxidation after artificial aging, and from the comparable wear rates for the non-aged and aged crosslinked cups (Fig). The *lack* of a substantial increase in wear rate on switching to the roughened balls was surprising. Using a uniaxial pin-on-disk test lubricated with 30% bovine serum in water, Marrs et al (9) found that the wear of acetylene-radiation crosslinked PE was comparable to that of conventional PE against smooth disks (R_a=0.01), but about 1.5 times *greater* than the conventional PE against roughened disks (R_a=0.09). In a hip simulator study similar to ours, Wang (10) reported that switching from polished balls to balls roughened with 320 grit sandpaper increased the wear rate of conventional PE cups by 53% and of crosslinked cups by 87%. It seems likely that the greater difference observed by Wang was due to the greater roughness of the balls. However, Wang's experiment also differed from the present study in that the cups were run in the upright orientation, and the lubricant was alpha serum diluted to 50% of its original volume. Both of these factors tend to increase the baseline wear rates of PE cups (10,11), and might have rendered the cups in Wang's study more sensitive to abrasion by roughened balls. These factors will be evaluated in follow-up experiments. Nevertheless, it is reassuring that, in both simulator studies, the wear rate of the crosslinked cups was substantially lower than for conventional cups even against damaged femoral heads.

Reference

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