Effect Of Femoral Head Size, Material, Surface Roughness And Serum Concentration On The Wear Of 5 Mrad Crosslinked- Remelted UHMWPE Acetabular Cups

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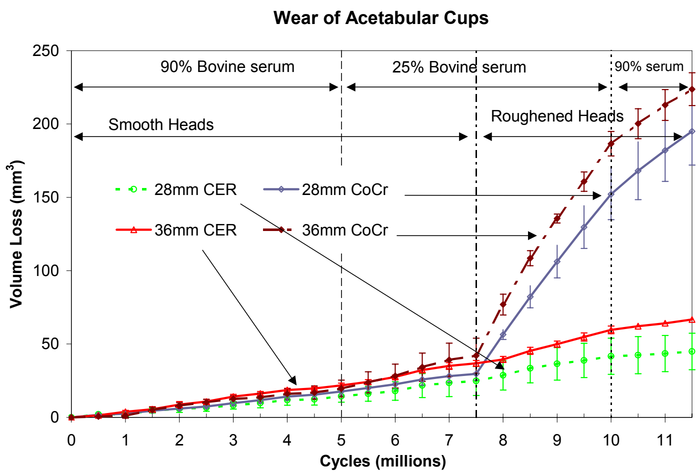
Introduction: Efforts to minimize the generation of polyethylene wear debris in total hip prostheses have included the development of highly wear-resistant crosslinked polyethylenes for acetabular cups, and of stronger, scratch-resistant ceramics for femoral heads. This study compared the wear of 5 Mrad crosslinked-remelted UHMWPE (Marathon™, DePuy Orthopaedics, Warsaw, IN) against two diameters of femoral heads of conventional cobalt-chrome alloy and of alumina-zirconia composite ceramic, before and after the heads were tumbled in an abrasive grit to simulate potential third-body damage in-vivo.

Materials and Methods: Extruded bars of GUR 1050 UHMW polyethylene (Poly Hi – Solidur, Ft. Wayne, IN) were placed in foil bags, flushed with inert gas, evacuated, crosslinked using 5 Mrads of gamma radiation, remelted to extinguish free radicals, and then machined into acetabular cups of 28 or 36 mm I.D. Final sterilization was by gas plasma. The cups were inserted into Pinnacle® titanium alloy shells (DePuy Orthopaedics), mounted in an OBM-type hip simulator (Shore Western, Monrovia, CA) in the inverted position using urethane molds, and then wear tested against femoral balls of ASTM F-1537 CoCrMo or Biolox® Delta ceramic (DePuy Orthopaedics), under a Paul-type load (2000 N max.) at 1 Hz. The lubricant was bovine serum (HyClone, Logan, UT). Delta ceramic is a blend of 74% alumina and 25% zirconia, with additives of CrO_2 and SrO. The blended ceramic has a strength and toughness superior to that of pure alumina, but without the susceptibility to phase transformation of pure zirconia (1). Three cups were tested with each of the four combinations of diameter and ball material. The protein concentration was 63 mg/ml (~ 90%) from zero to 5 million cycles and from 10 to 11.5 million cycles. The serum was diluted with distilled water to 17.5 mg/ml (~ 25%) from 5 to 10 million cycles. At both protein concentrations, the serum contained 0.2% sodium azide and 20mM EDTA. From 7.5 to 11.5 million cycles, roughened heads were used. For roughening, the heads were tumbled for 30 minutes with a bauxite/alumina abrasive media (H-33, Abrasive Finishing, Chelsea, MI) in a tabletop tumbler (A.E. Aubin Co., Marlborough, CT). At 500K cycle intervals, the cups were cleaned ultrasonically, vacuum-desiccated and then weighed to determine the wear, with cyclically loaded soak controls used to correct for fluid absorption. Weight loss was converted to volumetric wear using a density of 0.93 g/cm^3. The individual wear rates were calculated using linear regression.

Results: Against smooth heads, the cups wore slightly faster against CoCr than ceramic, with the exception of the 36mm heads in 90% serum (Table 1). The cups wore faster in low concentration serum for both ball materials and head conditions, with the differences ranging from 40% to 210%. Tumbling in grit increased the roughness of the CoCr heads from 0.01 and 0.04 µm to 0.3 and 1.2 µm (Ra and Rpm, respectively), values that are comparable to femoral heads damaged in-vivo (2,3). In contrast, the Rpm of ceramic heads increased only from 0.03 to 0.04 µm, and the Ra values remained unchanged. Correspondingly, the cup wear increased between 500% and 900% against roughened CoCr (for the 36 and 28 mm dias., respectively). However, the wear increased only about 50% against roughened ceramic heads in 25% serum while the wear against the 28 mm roughened ceramic heads actually decreased in 90% serum.



Ball Material	Smooth Heads		Roughened Heads	
	0-5 M Cycles 90% Serum	5-7.5 M Cycles 25% Serum	7.5-10 M Cycles 25% Serum	10-11.5 M Cycles 90% Serum
	Wear Rate (mm^3/Mc)			
28 mm Delta	2.8 ± 0.8	4.5 ± 2.6	6.7 ± 1.1	2.2 ± 0.1
28 mm CoCr	3.6 ± 0.6	5.0 ± 0.8	48.9 ± 7.5	28.5 ± 3.8
36 mm Delta	4.6 ± 0.3	6.4 ± 0.8	9.4 ± 0.4	4.6 ± 0.9
36 mm CoCr	4.2 ± 1.2	9.4 ± 2.6	57.2 ± 7.6	24.9 ± 2.1

Discussion: The greater resistance to roughening exhibited by the Delta ceramic heads was consistent with the ceramic being substantially harder than the CoCr heads. If the tumbling process is a reasonably accurate model for roughening in-vivo due to third-body abrasive particles (e.g., fragments of bone, PMMA or metal) then the present results indicate that the ceramic heads would produce much less polyethylene wear, with the advantage increasing with the amount of third-body contamination. Although the cup wear rates were systematically higher in the lower concentration serum, this effect was overshadowed by the marked effect of surface roughness.

References: 1) P. Merkert in Bioceramics in Joint Arthroplasty, H. Zippel & M. Deitrich, Eds. 2003, Steinkopff Verlag: Darmstadt. p. 123-126; 2) H. McKellop et al., CORR 369, p. 73, 1999; 3) V. Good et al., ASTM STP 1445, p. 104, 2003

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