**Tribology of Artificially Damaged Ceramic Femoral Heads**

**Materials and Methods:** Six 28 mm diameter Mg-PSZ (ASTM F2393) femoral heads were used in this study. The heads were commercial samples (Signal Medical Corp.) with no surface anomalies except the phrase "DO NOT IMPLANT" laser etched in a circle at an angle of 30° from the pole. Baseline roughness (average roughness, Sa) of the pole region of each femoral head and the height of the raised edge caused by the laser etching was measured by optical profilometry at 10x magnification (Fogale ZoomSurf 3D; Figure 1). Nine UHMWPE acetabular cups (six test specimens and three soak controls) were machined from GUR 1050 bar stock that had been cross-linked to 10 Mrad and re-melted. The cups were pre-soaked at room temperature until weight gain ceased. Specimens were tested in a MATCO hip wear simulator (an inverted design) using a Paull curve [9] at 1.2 Hz with peak loads of 2.4 kN. A solution of 25% bovine serum with 20 mM EDTA and 0.3% sodium azide was used as a lubricant, and a peristaltic pump dripped distilled water into each station to replace evaporated water during the tests. After each stage of 500,000 cycles, XLPE wear was measured gravimetrically and corrected to the soak controls. Damaged Mg-PSZ wear data were compared to previous wear data from undamaged CoCr and Mg-PSZ femoral heads [8], which were generated using the same hip wear simulator and test conditions and used acetabular liners from the same lot, with p < 0.05 for significance.

**Results:** Pre-test roughness measurements revealed the specimens had a "baseline" roughness of Sa = 12.7 nm, which increased to over 1 μm in laser-etched areas. Each laser-etched line was about 250 μm wide × 4 μm deep, with a raised edge about 1 μm tall along each side (Figure 1). During the wear tests, all liners initially gained weight relative to their soak control, and test liners became qualitatively scratched compared to soak controls (Figure 2). At 3M cycles, liners bearing against damaged Mg-PSZ heads were significantly more worn than undamaged Mg-PSZ (p < 0.001) but comparable to wear of liners bearing against undamaged CoCr (p = 0.93; Figure 3). At 6M cycles, liners bearing against damaged Mg-PSZ heads exhibited 61% less wear than liners bearing against undamaged CoCr (p = 0.24; Figure 3). The height of the raised edge did not appear to be worn down after 6M cycles, and the "baseline" roughness was not significantly different (Sa = 13.2 nm). No other scratches in the heads were observed, implying that the raised edge did not break down and generate third-body wear particles.

**Discussion:** This study found that an artificially damaged Mg-PSZ ceramic femoral head causes significantly higher XLPE wear than that of an undamaged ceramic head, but wears at a lower rate compared to undamaged CoCr alloy femoral heads. Unlike CoCr alloy bearing surfaces [1,8], the raised edge on the ceramic heads was not gradually polished smooth during the test, which may serve to accelerate acetabular liner wear. In pin-on-disc tests, 1 μm of pile-up along a scratched stainless steel pin was found to increase the wear rate of non-cross-linked UHMWPE by a factor of 70 after the equivalent of 10 years of wear [5], while hip wear simulator studies found severely roughened CoCr heads to increase wear by an order of magnitude against liners cross-linked to 5 Mrad [10]. While ceramic femoral heads are less likely to be damaged in vivo than metal heads, particular care should be noted in cases where a fractured alumina component is revised [11-13] or when multiple closed reductions have been performed following recurrent dislocation, leading to metal transfer on ceramic heads [14].

In summary, Mg-PSZ ceramic femoral heads damaged to create a 1 μm tall raised edge led to a lower XLPE wear rate compared to undamaged CoCr alloy femoral heads, and the raised edge was not polished away by normal articulation. Future work will extend this study up to at least 7M cycles, to monitor whether damaged ceramic heads can lead to runaway wear.

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**References:**