A COMPARISON OF TWO-BODY AND THREE-BODY ABRASIVE WEAR PROCESSES IN TOTAL HIP REPLACEMENTS


Introduction: The generation of wear particles due to abrasive processes in total joint replacements is of critical importance. Abrasive wear may be due to two distinct mechanisms: two-body abrasion (a rough femoral head articulating on an UHMWPE cup) and three-body abrasion (hard, third-body particles such as bone fragments, metal particles, PMMA particles present in the articulating interface, producing UHMWPE wear). Both these processes may act separately or in tandem. Depending on the nature of the tribosystem, one of these processes may play a dominant role in abrasive wear relative to the other process, which may be of secondary importance. In this study, simulations of both these processes are attempted using a hip joint wear simulator to isolate the relative importance of the two-body and three-body abrasive processes as they relate to UHMWPE acetabular cup wear in total hip joint replacements.

Materials and Methods:

Two-body Abrasion Test: 32 mm diameter UHMWPE acetabular cups were machined from extruded GUR 4150 rod stock (Westlake Plastics). The cups were gamma-irradiated in air at 3 MRads. 32 mm femoral heads made of Vitallium alloy (Howmedica, Inc., Cat. #: 6284-0-132) were subjected to a roughening process by rubbing against silicon carbide paper of different grit size. The resulting cups had a center-line average roughness Ra ranging from 0.01 µm to 0.20 µm.

Three-body Abrasion Test: 32 mm diameter UHMWPE cups were machined from extruded GUR 1020 rod stock (Poly-Hi, Indiana). The cups were gamma-irradiated in air at 3 MRads. 32 mm femoral heads (Howmedica, Inc., Cat. #: 6284-0-132) were used as the counterface material. A polymethylmethacrylate (PMMA) mixture (Surgical Simplex P*, Howmedica International, Limerick, Ireland) was crushed for 2 minutes using a SPEX 6700 Freezer/Mill. This produced a mixture of PMMA (bone cement) particles with a mean size of 162.3 ± 670 nm.

Lubricant: A 20 mM EDTA was added to the serum before use to reduce serum degradation rates. Bone cement particles were added to the serum in a concentration of 10 mg/ml to simulate third-body particles.

Apparatus: An MTS hip joint simulator was used in testing. Testing was conducted in the anatomical position, with the cup on top and held stationary while the head was on the bottom and articulated inside the cup. The head was inclined at an angle of 23° to the horizontal. A Paul profile with a peak load of 2500 N and a rotation speed of 1 Hz were used.

Results and Discussion:

Two-body Abrasion Test: Figure 1 shows the wear rates of air-irradiated UHMWPE cups against rough femoral heads. The data indicate that the wear increase is not as dramatic as suggested by other researchers [1-2] who hypothesized a ten-fold increase in wear from a single scratch based on pin-on-disc studies. The results presented here support the clinical retrieval studies by Hall et al. [3] who observed only a moderate influence of the femoral head roughness on UHMWPE wear. Rq of femoral heads by orthopaedic manufacturers tends to lie around 0.02 µm. In clinically retrieved heads, roughness values do not usually exceed 0.2 µm. In the range 0.01 to 0.20 µm, the Rq value for air-irradiated cups is 0.04, indicating a weak correlation between femoral head surface roughness and UHMWPE cup wear.

Three-body Abrasion Test: This test studies the effect of abrasive bone cement particles present in the serum lubricant on air-irradiated UHMWPE acetabular cups. The results are shown in Figure 2. The addition of bone cement dramatically increases the wear rates of UHMWPE acetabular cups. The wear rate of air-irradiated cups increases from 66.4 mm/106 cycles to about 270 mm/106 cycles in the presence of bone cement, a 300% increase. Surprisingly, in the presence of bone cement, the scratches produced on the femoral heads were not significant although the acetabular cups had a dull appearance and severe scratches.

Conclusions: Based on this study, it may be concluded that

1. In the clinically observed femoral head surface roughness range, the effect on UHMWPE acetabular cup wear is minimal.
2. Hard, third-body particles cause significant increases in wear rates for UHMWPE acetabular cups.
3. For retrieved hip components, it may be erroneous to correlate the roughness of femoral heads with the wear of UHMWPE acetabular cups. Accelerated wear was most likely due to the presence of third-body particles rather than the scratches on the femoral head.

References:


Figure 1: Two-body abrasion Effect of femoral head surface roughness on the wear behavior of air-irradiated UHMWPE acetabular cups.

Figure 2: Three-body abrasion Effect of abrasion due to bone cement particles on air-irradiated UHMWPE acetabular cups.

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