Generation of Different UHMWPE Particle Shape by Wear through Surface Texturing

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Introduction Ultra-high molecular weight polyethylene (UHMWPE) wear particles in replaced joints have been linked to biochemical reactions that eventually lead to loosening of prosthesis (1). Several studies have shown that UHMWPE produces a wide range of particle sizes and shapes under wearing conditions (2-3). Whether a particular size or a particular shape has higher bioactivity is not known. From surface energy consideration, small particles in the nm range should be more reactive. From a biological perspective, different shapes may induce different responses. This study aims to develop a method to produce narrowly distributed wear particle of different sizes and shapes so that subsequent study on bioactivity can be carried out. The concept is to use surface texture on the metal counterface to produce desired size and shape under carefully controlled rubbing conditions.

Experimentation Unsterilized GUR415 UHMWPE pins of 6.35mm in diameter and 25.4 mm in length were used in this study to produce wear particles. Stainless steel 316 plates (38mm in diameter and 6.35mm in thickness) were polished to a surface roughness of less than 0.025 μm for the texturing step.

Texturing of the steel plate was achieved by making systematic one directional grooving passes using a 120 grit SiC abrasive disk. The grooving passes were made under a nominal contact pressure of 2 kPa. Each pass was 150 mm long. The surface was then returned to the starting position and scratched again. For unidirectional grooving, twenty passes were made. A typical surface texture in shown in Fig. 1a. To produce a cross hatched pattern. The steel plate was rotated 90^o after each pass for a total passes of twenty passes. A typical surface textured this way is shown in Fig. 1b. A single grit size of SiC abrasive disk was used to texture each stainless steel plate. When a different abrasive grit size was used, adjustments were made to ensure consistency of the surface features. The textured plate was then cleaned ultrasonically in solvents and detergent, followed by rinsing with de-ionized water and drying with nitrogen.

The polymer pin and the textured disk were mounted on a reciprocating wear tester. The wear experiment was conducted under the following conditions: load=196 N (nominal contact pressure~6 MPa), stroke length=19.05 mm, frequency=1.5 Hz; average sliding velocity=57.2 mm/s, duration=2 h. Filtered purified water was used as lubricant.

After the wear test, the UHMWPE particles were collected by repeated rinse (purified water, adjusted to a pH=5.5 with hydrochloric acid) of the sample, sample holder, and parts that came into contact with debris onto a 0.1 μm membrane filter holder. The particles collected on the filter paper were examined by using a scanning electron microscope. Micrographs of the particles were then analyzed by using an image analyzer software to measure their dimensions. Measurements were made for at least 300 particles in each case.

Results Fig. 2a shows the particles produced from a parallel-grooved stainless steel plate using a 120 grit SiC abrasive disk. Mostly elongated particles were generated. The size ranged 30 μm to 70 μm with a relatively wide distribution. The average length was 45 μm ± 5 μm. The aspect ratio of the particles is about 2 to 4. Fig. 2b shows the particles produced by a cross-hatched grooved surface using a 320 grit SiC abrasive disk. The particles were mostly circular in shape with a range from 5 μm to 20 μm. The average size was 8 μm ±2 μm. The aspect ratio is about 1.5. Clearly, the wear particles generated from the textured surfaces produced two distinct wear particle size and shape.

Discussion This set of experiments demonstrated the feasibility of generating different size and shape of UHMWPE wear particles through surface texturing. The basic concept is that the wear debris size and shape of an elastic material can be controlled by the micro-cutting edges and the geometric constraints superimposed by the micro-volume defined by the groove edges. The parallel-grooved texture presented an array of parallel edges in the steel surface. During sliding, these edges cut into the UHMWPE and produced elongated particles. The cross-hatched texture, on the other hand, presented diamond-shaped edges with an internal volume. While the edges cut into the soft elastic UHMWPE material, the diamond shaped volume controlled the round particle size. Therefore, uniform texture of the surface edges produced is important in controlling the production of narrowly distributed particle size distribution and shapes.

Note: ± denotes standard uncertainty

Reference

1. Friedeman et al., J. Bone Jt Surg, 75-A (1993) 1086.
2. Mosleh and Suh, STLE Trib Trans, 39 (1996) 843.
3. Ruben et al., J. Mater. Sci., 28 (1993) 1045.

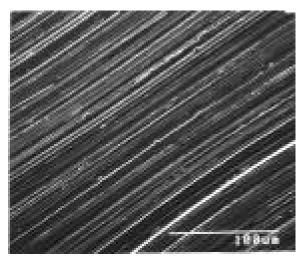

Figure 1a

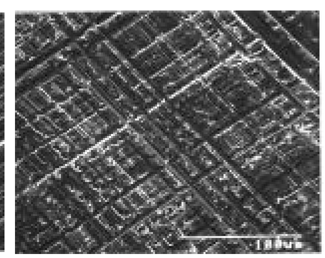

Figure 1b

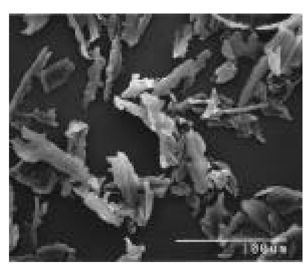

Figure 2a

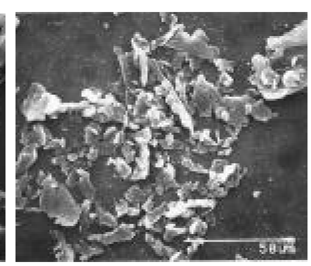

Figure 2b