Backside Polyethylene Wear: The Influence of Different Surface Finish on Debris Morphology and Size Distribution

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Statement of Purpose: Polyethylene (PE) wear debris is recognized as a major cause of osteolysis and failure of total knee replacements. Furthermore, it has been shown that submicron-sized PE particles produce bone resorbing activity at lower volumetric dose than larger particles. Investigators have hypothesized that particles from backside wear are smaller than those generated at the knee articular surfaces.[Hirakawa 1999] To date, however, no study has assessed the characteristics of PE particles from backside wear. In this study, the effects of metal surface roughness, metal alloy and micromotion amplitude, on PE particle morphology was assessed.

Methods: A novel fretting wear simulator [Ebramzadeh 2005] was used to reproduce loads and motions typical of the backside of fixed-bearing tibial inserts of TKR implants. A $\pm 3^o$ rotational motion of the pin was combined with linear displacements of 200 or 50 µm, corresponding to cross-path overall sliding distances of 296 and 211 µm per cycle, respectively. Pins of UHMWPE (10mm dia, gamma sterilization in foil barrier package) were tested against disks of Ti6Al4V and CoCrMo alloy with polished or blasted surfaces. A double-peak Paul curve load profile was applied with a maximum stress of 10 MPa for 3 million cycles.

PE particles were isolated from the serum collected at the end of each test following a protocol already established.[Campbell 1995] The final solutions were filtered on a 0.01 µm polycarbonate filter. The particles were then analyzed using field emission scanning electron microscope analysis (JEOL 6700F). On average, 200 particles per sample were then characterized using digital image analysis (Metamorph v.6.1r3, Molecular Devices).

Results/Discussion: The percentage of submicron PE particles produced by polished metal surfaces was higher than that of rough surfaces, regardless of metal alloy. (Fig 1) However, taking into account the total wear of all PE pins against the four different metals and surfaces, polished surfaces still generated a smaller total volume of submicron particles.

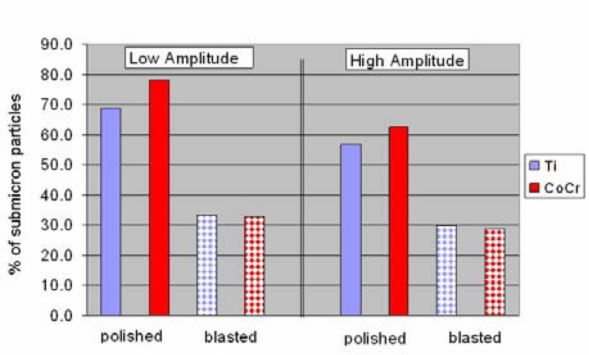

Figure 1

For PE pins against polished surfaces, there was a predominance of round and elongated particles, and the percentage of round particles was even higher with the lower displacement amplitude. In contrast, for rougher surfaces, particles of larger dimension and irregular texture were observed. Furthermore, at the higher displacement amplitude, elongated particles of large dimension were observed.

Specific biological activity (SBA) (relative biological activity per unit volume) and functional biological activity (FBA) (product of volumetric wear and SBA) were also calculated following Fisher et al.'s approach.

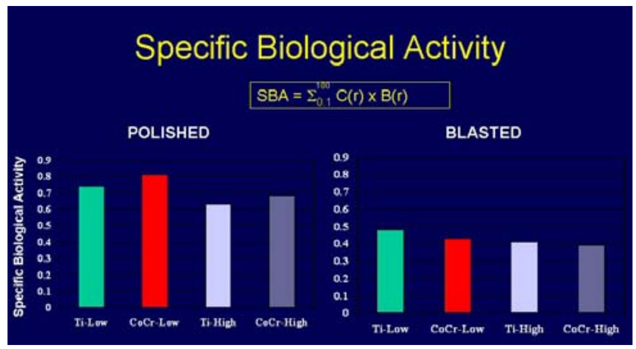

Figure 2

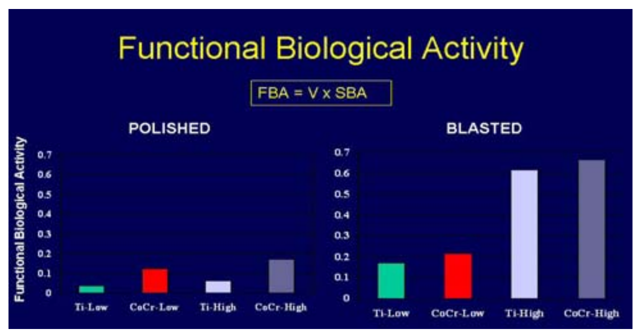

Figure 3

Conclusions: Under load and motion conditions typical of well functioning implants, surface roughness played an important role in the production of submicron-size particles ($p<0.05$; ANOVA). Specifically, polished surfaces produce a higher percentage of submicron particles compared to the blasted ones (more than double). However, when considering the higher percentage of submicron particles produced by the polished surface, it should be recognized that the total number of particles generated is strictly dependent on the total amount of wear. In the present study, polished surfaces produced up to five times less wear than blasted surfaces. The end result was a higher FBA for blasted surfaces regardless amplitude of motion.