The Effect of Surface Treatments on the Fretting Behaviour of Titanium

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Statement of Purpose:
Modular stem designs offers great flexibility in total hip arthroplasty to address intraoperatively specific anatomical situations. However, additional tapered joints are introduced that are subjected to cyclic loading in the gait cycle thereby causing low-amplitude oscillatory sliding in the micrometer range between the contacting surfaces [1]. This may provoke material release due to fretting and may evoke adverse host-tissue responses. Migrating particulate debris may accelerate polyethylene wear of the acetabular cup articulating against the femoral head that may induce osteolysis and mobilization of the implant, followed by aseptic loosening. Fretting damage has been reported on the taper joint between the titanium alloy stem and the CoCrMo femoral head of modular hip implants (e.g. [2]), but little attention has been paid to the material release from additional taper joints in modular stems. The effect of several industrially available surface treatments on the fretting release from Ti-6Al-4V has been investigated by screening tests.

Methods: For the screening experiments semi-spherical, surface treated, medical grade Ti-6Al-4V fretting pads were pressed with a normal force of 70 N on polished, flat, dog-bone shaped Ti-6Al-4V fatigue samples that were subjected to axial cyclic loading at 4 Hz. Such cyclic loading caused displacement cycles with a 20 µm amplitude along the contact surfaces. Screening tests were performed in deionized water for 2×10^6 displacement cycles. Fretting release was quantified by means of radiotracers that were introduced in the surfaces of Ti-6Al-4V fretting pads by proton irradiation. For this purpose the deionized water was substituted every 100000 fretting cycles, its radioactivity content was determined and converted into weight loss, i.e., fretting release. With its extremely low detection limit of 0.05 ng/ml the radiotracer method discriminates well between small release differences due to different surface treatments [3]. The proton irradiation defines an area of interest and allows discriminating material released elsewhere (e.g. on mounting screws) from that originating from the sliding contact surfaces even if it is chemically identical [3].
The fatigue samples were mechanically polished to mirror quality. The surface roughness of the mating surfaces was determined by laser profilometry (Rodenstock RM 600).
The surface treatments applied to the fretting pads were (i) metallographic polishing, (ii) electrochemical polishing, (iii) a three-step barrel polishing procedure and (iv) an industrially applied Anodic Spark Deposition (ASD) processes (TiHard™) [NanoSurfaces s.r.l., Cadriano di Ganarolo Emilia, (BO), Italy] that resulted in a high quality surface film with high hardness, high adhesion strength and improved wear resistance. The TiHard™ treatment involved two sequentially applied ASD processes using two different electrolytes (phosphoric acid solution and a silicon containing solution). One batch of specimens (v) received a finishing by barrel polishing.

Results/Discussion: Figure 1 demonstrates that among the tested surface treatments, a combined treatment by deep ASD and barrel polishing resulted in a four times lower material release with respect to untreated, machined fretting pad surfaces. The improvement is reflected in the reduction of the accumulated release as well as by the scatter between different experiments. The scatter is indicated by error margins given at about 1×10^6 and 2×10^6 fretting cycles. Small differences in the surface roughness of the fretting pads were not decisive for the release behaviour after surface treatments.

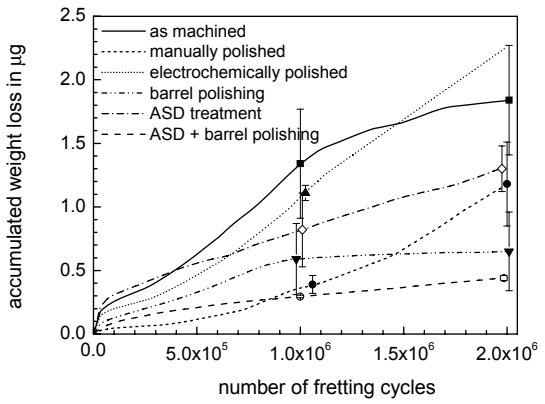

Figure 1. *Evolution of the accumulated weight loss of fretting pads that received different surface treatments*

Conclusions: The fretting release of medical grade Ti-6Al-4V can be reduced significantly by simple, industrially available surface treatments. Radiotracer methods can supply sensitive and selective in-situ data for precise screening studies. In order to quantify the material release from real taper joints this radiotracer method can also be applied to modular hip components using load and lubrication conditions to better simulate the *in vivo* situations.

References:
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