Evaluation of Tribocorrosion Kinetics and Biocompatibility of Electrochemically Induced Tribolayer for Hip Implants

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Statement of Purpose: The number of annual total hip replacement (THR) surgeries continues to increase and the longevity of metal based implants, particularly metal-on-metal (MoM), have become a major concern [1]. Research studies on the MoM joints have reported that tribochemical reactions in the presence of plasma proteins on the surface of the implants leads to the formation of protein layer called the tribolayer, [2] which has corrosion resistance properties [3-5]. However, one of the major limitations is the poor uniformity and homogeneity of the tribolayer. Electrochemical deposition of the tribolayer has recently been reported by our group, [3] and it was found that the presence of Molybdates (Mo+) promotes the tribolayer formation. However, the corrosion kinetics and biocompatibility of the electrochemically generated tribolayer has not been studied yet to prove its applicability in hip implants. Hence, in this study our focus is to develop a stable and uniform tribolayer on the on the surface of CoCrMo metal, investigate the corrosion kinetics using potentiodynamic conditions, and evaluate the biocompatibility of the generated tribolayer using osteoblast cells in vitro.

Methods: *(i) Sample Preparation:* 24 pins of CoCrMo alloy disks were mechanically polished to a mirror finish. Tribolayer formation was carried out using a custom standard three electrode corrosion cell and a potentiostat (Interface 1000, Gamary Inc., Warminister, PA, USA). A saturated calomel electrode was used as the reference electrode. Based on a previous study, the film formation was carried out through a potentiostatic treatment at 0.7V vs SCE in BCS supplemented with 8mM of sodium molybdate as the electrolyte [2]. An electrochemical impedance spectroscopy (EIS) test with frequency range of 100,000 Hz-0.005 Hz and ±10mV was performed before and after film formation to validate the film formation. *(ii) Tribocorrosion study:* 4 groups samples were studied applying corrosion only without mechanical motion (NM) and with mechanical motion (M-tribocorrosion) (a) No-Film in BCS (NF-BCS) (b) Film in BCS (F-BCS) (c) Film in BCS with Mo (d) Film prepared with Mo in BCS (F+Mo-BCS). All electrochemical tests were performed at a constant temperature of 37°C. The samples were then subjected to corrosion and tribocorrosion experiments under potentiodynamic conditions in a hip simulating tribocorrosion apparatus [4]. Simulated synovial fluids (30g/L BCS) with and without sodium molybdates (8mM) were used for the corrosion and tribocorrosion tests. Cyclic polarization and electrical impedance spectroscopy tests were conducted. *(iii) Biocompatibility Study:* MG63 Osteosarcoma cells were maintained in 10% fetal bovine serum (FBS) containing minimum essential medium (MEM) with antibiotics. Cells were incubated at 37 °C and 5% CO_2. Cell proliferation of MG63 osteosarcoma cells on BCS and BCS-Mo coated samples was assessed and compared to that of uncoated CoCrMo samples using an alamarBlue assay. 10,000 cells were seeded samples and incubated in the 10% MEM. After 2, 5 and 7 days of incubation optical density was read at 570nm wavelength, using 600nm as a reference. Corresponding images were taken using confocal microscopes after staining actin cytoskeleton with Rhodamine Phalloidin and DAPI.

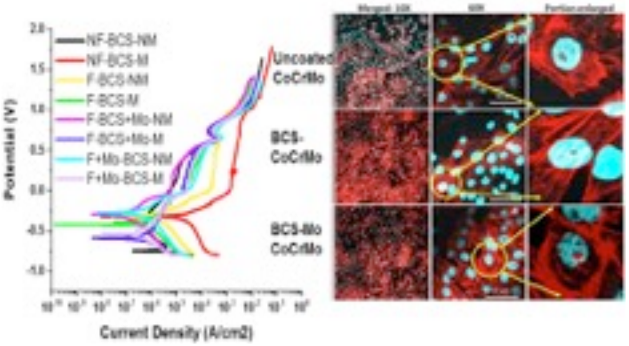

Figure 1

Results: Potentiodynamic curves for all the groups were collected, and the evolution of Icorr, estimated from the Tafel's slope method, is shown in Fig. 1. It is evident that the presence of film improves the corrosion kinetics under mechanical and non-mechanical exposure, and the presence of Mo in the solution has an important role in stabilizing the film even under mechanical rubbing. No significant difference in cell growth between control and samples with tribolayer was observed after 2, 5 and 7 days of culture, revealing that the biocompatibility of the coated surfaces is similar compared to uncoated samples.

Conclusions: This study demonstrates that the presence of an electrochemically generated tribolayer improves the corrosion kinetics of CoCrMo alloy with and without mechanical motion. The stability of the film is evident from the results, as the current evolution shifts to the left during tribocorrosion. The role of molybdates in stabilizing the film and protecting against the corrosion and tribocorrosion exposure is evident from the results, and the osteoblast cell growth and/or proliferation are not affected by film or molybdate presence. In fact, this is the first study which discusses the biocompatibility aspects of the electrochemically generated film. The positive results suggest possibility of using such electrochemical treatment for a future coating application on implant surfaces to reduce tribocorrosion and improve the longevity of hip implants.

References: [1] Kurtz et al., Acta Orthop 2014 [2] Martin et al., Langmuir 2013 [3] Mathew et al, JMBBM 29 2014 [4] Mathew et al., Wear 2009 [5] Wimmer et al., Wear 2003