Plasma Surface Modification for Reduction of Metal Implant Ion Release
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INTRODUCTION
Metal ion release from Orthopaedic implants has become an increasingly important problem to overcome in the industry. The corrosion of wear particles in vivo has important clinical implications. Metal ion release from metallic materials (Stainless steel, Cobalt-Chromium alloy and Titanium alloys) implanted into human bodies can cause inflammatory reactions of histiocytes to wear debris in tissues around implants. This inflammation could cause peri-implant bone resorption leading to aseptic loosening. Ion release can come from initial break in wear of an implant, corrosion, micro motion, and mechanical dysfunction. If ion release can cause bone resorption and implant loosening this could lead to further implant wear from micro-motion. This cycle could lead to more wear and ion release in turn leading to more inflammation. Cobalt and Titanium are more soluble and are therefore removed from the body faster than Aluminum and Chromium. Corrosion leading to Chromium ion release, especially from metal-on-metal implants, needs further consideration clinically.

Surface oxide films on metallic materials play an important role as an inhibitor of ion release and they change the release in vivo. Chromium oxide has proven to be more resistant to corrosion than other oxides present in CoCrMo alloys. By increasing the amount of Chromium oxide or the passive layer on the metal surface using novel surface chemistry modification we could improve metal ion release from the implant. Using the Chromium oxide knowledge, commercially available passivation has already greatly improved ion release. The objective of this study was to show reduction of metal ion release from CoCrMo alloy using commercially available passivation and a novel oxygen plasma surface modification passivation process. The experiment involves a static BioCorrosion environment with no traditional wear potential.

METHODS

Sample Description- Three sample types made from CoCrMo Wrought disks (1” in diameter, 0.25” height) were used. Surface treatments were Non-Passivated, Commercial Passivated, Ultra-Passivated (Oxygen Plasma Surface Modification).

Plasma Surface Modification (PSM) Description- PSM was performed using a 7200 PVA TePla America (Corona, CA) radio frequency Plasma Chamber. Oxygen plasma surface modification passivation process. The objective of this study was to show reduction of metal ion release from CoCrMo alloy using commercially available passivation and a novel oxygen plasma surface modification passivation process. The experiment involves a static BioCorrosion environment with no traditional wear potential.

XPS Protocol- To verify surface modification and chemistry before BioCorrosion testing, X-ray photoelectron spectroscopy (Quantera, Physical Electronics PHI, Eden Prairie, MN) was used. Disks were placed on a specially designed aluminum plate in a vacuum chamber. XPS Depth Profile parameters are detailed here. Three elements were examined (Co2p, Cr2p and Mo3d) at Pass Energy of 224.00 EV and step size 0.4 EV. Using Argon at a sputter setting of 2kv2x2 the 200µm x 200µm (200x45w15kv) area.

BioCorrosion Protocol- Three Teflon molds were obtained and 4 disks from each group were placed in molds. The Teflon molds were then placed into a large Petri dish with 20mL of 90% bovine serum added to the dish and sealed. The dishes were kept in a 37°C incubator on a rocking platform set at 1.5 rpm. Each week the serum was changed and collected in labeled 50mL centrifuge tubes. The Trefoil molds with disks were also removed from the Petri dishes and placed in new dishes. Fresh 20mL 90% bovine serum was then added to the Petri dish. This change took place for 6 weeks. After six weeks the serum samples from each time point were analyzed using Inductively Coupled Plasma-Mass Spectrometry (ICP-MS). After ICP-MS results were obtained data analysis was completed.

RESULTS and DISCUSSION

It is apparent from XPS depth profiles that commercial passivation alone greatly improves the thickness and concentration of Chromium on the surface of CoCrMo disks. Figure 1 shows the atomic concentration of Co and Cr as a 1:1 ratio on the surface of untreated CoCrMo disks. Essentially 50% Co and 50% Cr with a thickness of only about 5 Å. After commercially available passivation, Figure 2 shows an increase in Cr oxide concentration and thickness. There is about 70% Cr and 25% Co with a thickness of approximately 15 Å.

Figure 3 shows XPS depth profile data for Ultra-Passivated CoCrMo alloy. The difference in Cr to Co ratio and thickness is dramatic when compared to Figures 1 & 2. The profile demonstrates 90% Cr and 2% Co with a thickness of 45 Å. Figure 4 shows 6-week cumulative ICP-MS data for BioCorrosion testing. When just comparing Cr ion release (the least soluble ion) there is a 50% reduction from Non-passivated to Passivated and a further 50% reduction after Ultra-Passivation. Each individual ion shows a reduction in release after each surface treatment. The plasma modification shows the least amount of ion release for all ions individually and as a whole. The reduction of total ions from passivation to ultra-passivation is even greater than 50%. Clinically this could be the solution to metal ion release in the body.

SUMMARY

The data presented here shows that the novel surface chemistry modification using Oxygen plasma achieves at least a 50% metal ion reduction in a static corrosion environment. The plasma surface modification could lead to a reduction in wear and metal ion release clinically. This could lead to improved implant survival and wear.