Evidence of Direct Cell Induced Corrosion of CoCrMo Implant Systems

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Statement of Purpose: Tribocorrosion of orthopedic implants has gained significant attention recently as a result of increased reports of clinical consequences resulting from wear debris[1] and mechanically assisted corrosion of bearing[2] and modular taper surfaces[3]. Although the byproducts of wear and corrosion are known to stimulate the immune system and activate an inflammatory response in the adjoining tissues, to date, there has been no documented evidence of activated immune and/or inflammatory cells directly attacking and corroding CoCrMo implant surfaces in-vivo. This study reports on the occurrence of inflammatory cell induced corrosion (ICIC) on retrieved CoCrMo components of total hip and total knee implants.

Methods: In total 69 components belonging to 51 implant systems were analyzed in this retrieval study. The implant components were received, decontaminated, and disassembled. They were analyzed using nondestructive means. These include acquiring high magnification images of the implant surface using a digital optical microscopy (DOM). High-resolution images to identify corrosion morphology, material microstructure and elemental composition were obtained using scanning electron microscopy (SEM) with energy dispersive X-ray spectrometry (EDS). EDS spectra were acquired for different regions on the component to determine elemental composition and to distinguish organic matter from corrosion byproducts on the implant surface.

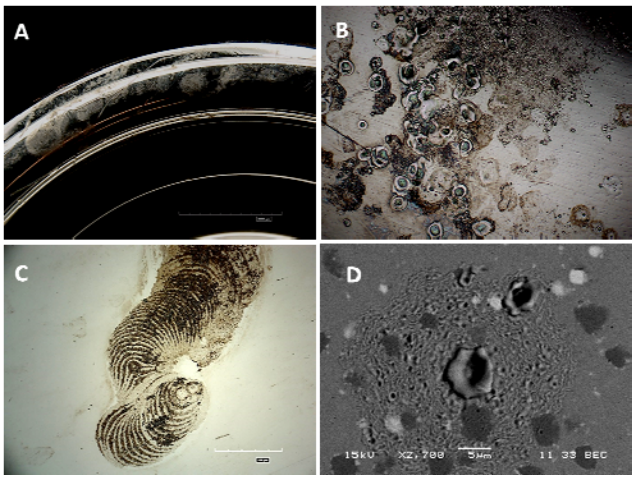

Figure 1. A. Low magnification image of the rim of a metal acetabular liner component with a frosted appearance that is visual evidence of ICIC (Bar = 5 mm). B. higher magnification optical image of ICIC on liner bearing surface, C. optical micrograph of a migrating cell on head bearing surface that underwent attack shows a concentric ring like pattern , D. backscatter image of an individual cellular attack and the underlying microstructure.

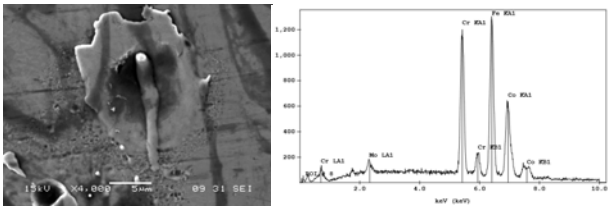

Figure 2. The SEM micrograph shows region on the bearing surface of head that was attacked by cells. Note: the linear streak in the center of the image. EDS spectra acquired from this streak showed peaks for iron, which was deposited as a product of Fentons reactions.

Results: Cell induced inflammatory attack was observed on 51/69 components (74%). ICIC was observed on both bearing and nonbearing surfaces, and independent of the acetabular liner material (metal or polymer). The corrosion patterns in Fig. 1C & 1D are similar to the ruffled border patterns made by osteoclasts remodeling bone[4]. Similar patterns were observed by Cadosh et al.,[5] when activated osteoclast grown on titanium formed an actin ring after sealing down on the metal surface it wants to resorb. The ring-like patterns on the metal surface show successive sealing, secretion of acidic and reactive oxygen species, and migration of activated cells with a ruffled membrane. All implants with ICIC showed linear streaks of deposited iron in regions that underwent cellular attack (Figure 2). This shows that the cells participating in this aggressive attack resorted to Fenton reactions[6] to produce reactive oxygen species, which is known to directly impact the electrochemical behavior of CoCrMo.

Conclusions: The results of this study have, for the first time, identified direct cell attack of CoCrMo implant surfaces by cells of the immune and/or inflammatory systems. Corrosion patterns on the CoCrMo directly reflect the attack of cells by way of Fenton-like reactions (hydrogen peroxide and iron ions), and result in attack of the implant. Cell-induced corrosion was seen in metal-on-polymer as well as metal-on-metal hip implants, MOP knees, across manufacturers and across alloy type. The extent and role of this form of corrosion on the overall biological response to CoCrMo is unknown at this time.

Reference:

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