Cell-Induced Corrosion on Co-Cr-Mo Acetabular Liner Taper

Jeremy L. Gilbert, Shiril Sivan
Syracuse Biomaterials Institute, Department of Biomedical and Chemical Engineering, Syracuse University, Syracuse NY 13244,

Statement of Purpose: Modular taper interfaces have been used in a wide array of orthopedic implant designs from head-neck, neck-stem, modular body and acetabular liners. The corrosion processes in metal/metal tapers have been ascribed to mechanically assisted crevice corrosion processes[1]. This mechanism is a complex multifactorial process that involves mechanical, electrochemical, materials, and biological factors. To date, there has been little focus paid to the biological contributions to the corrosion. Here, we show evidence from two retrievals that support a hypothesis that cells of the body directly corrode CoCrMo alloy surfaces and may be involved with corrosion in the taper junction of these acetabular liners.

Methods: A pool of 20 retrieved MOM implants were investigated in this study of which two CoCrMo (ASTM F-1537) liners were seen to have noticeable corrosion in the taper region. These two were selected for more in-depth analysis. The samples were steam sterilized prior to investigation, however, this was not seen to destroy or remove the evidence of cells on the surface. Three different SEM imaging techniques were applied to help delineate and identify the constituents present. Secondary electron imaging (SEI) at 13 to 15 kV (high kV), backscattered electron imaging (BEC) at 15 kV and secondary electron imaging at 2 to 4 kV (low kV) were used. High accelerating voltage (10 to 15 kV) yields topographic information (SEI) and compositional information (BEC). Low kV (2 to 4 kV) secondary electron imaging shows cellular membranes and other biological materials because the low energy electrons scatter from the cell surface and do not penetrate through the cell. High kV SEI and BEC electron beams penetrate the cell membrane and can show the topography and composition of the substrate alloy (and some evidence of biological material). Taken together, the three imaging modes are complimentary and help to provide a more complete picture of cells and biological materials, and alloy surface topography and composition.

Results and Discussion: An example of how low kV SEI reveals cells is shown in Fig. 1. Cell membranes and details of biological material are highlighted when using low kV SEI on the non-conducting membranes. Energy dispersive x-rays confirmed a carbon-rich chemistry (i.e., biological). Examples of corrosion within the taper are unlike mechanically assisted corrosion processes previously published[2]. The corrosion morphology is devoid of fretting damage or other indicators of mechanically assisted corrosion, and instead reveals fissures (Fig. 2b), and intergranular corrosion and pitting corrosion (Fig. 2a). Cell bodies (Fig. 2a) are attached to and integrated with the corroded Co-Cr-Mo alloy surface. Cells were seen accumulated at the perimeter of the taper junction (not shown). The corroded taper regions were populated with cells and biological substances (Fig. 3).

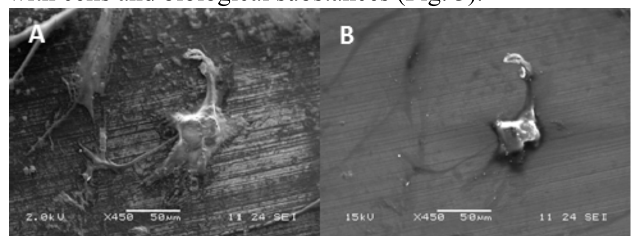

Fig. 1: a) Low kV SEI, b) high kV SEI of cell on CoCrMo liner.

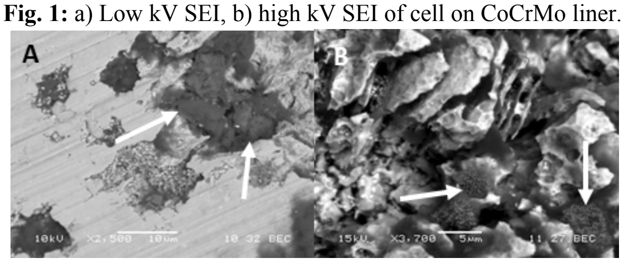

Fig.2: BEC of cells on corroded liner taper a) edge) and b) interior. Arrows point to cell examples. Note fissures in (b).

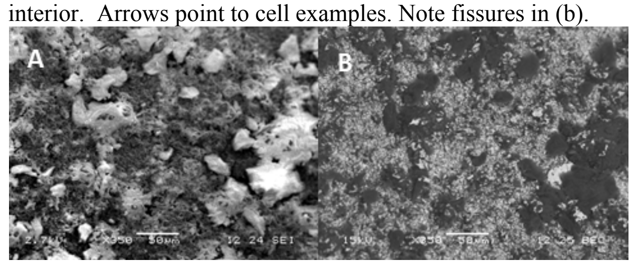

Fig. 3: a) Low kV SEI and **b**) high kV BEC of identical region. Bright contrast in (a) and dark in (b) highlights cells/biological material in corroded region

Large numbers of micron and submicron sized intermetallic and oxide particles were observed on the corroded surface (Fig. 2a). These are the dispersion strengthening precipitates distributed throughout the CoCrMo microstructure. As the alloy is corroded away, precipitates are more resistant to the cell-based corrosion processes and are left behind in the surface.

Conclusions: Cell induced corrosion in-vivo is a newly discovered process where direct attack the surface of CoCrMo implants takes place[3]. It has been documented to occur on CoCrMo bearing surfaces, non-bearing surfaces, and now inside the modular taper junctions. The electron microscopy techniques used provide detailed complimentary information about the corroded metal, the remnant particles and the cellular structures associated with the corroded material. These findings are supported by recent in-vitro work showing cell based corrosion on titanium[4] and SS[5].

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References: 1. Gilbert and Jacobs, ASTM STP 1301, 1997, p 45. 2. Gilbert, et al., JBMR-A 1993, 3. Gilbert et al., ORS Trans 2014, 4. Cadosh et al., JBMR-A, 2010. 5.4 Cadosh, JOR, 2009.