Tribocorrosion of a Nickel-free High Nitrogen Steel *vs.* LC-CoCrMo in Simulated Synovial Fluids

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CoCrMo-alloys are well-established, worldwide used metallic biomaterials for orthopedic joint replacement implants. Still, such alloys have been associated with clinical problems leading to implant failure [1]. These problems are related to the release of wear and corrosion debris caused by tribocorrosion [2]. A new generation of nickel-free austenitic high nitrogen steels has been developed for biomedical applications over the last decades [3]. The aim of this study was to investigate the tribocorrosion behavior of the Ni-free austenitic high nitrogen steel FeCrMnMoN0.9, as potential alternative to LC-CoCrMo for certain biomedical applications, in simulated synovial fluids including oxidizing (inflammatory) conditions by added hydrogen peroxide.

Wear tests with monitoring of the open circuit potential were conducted in triplicates, with LC-CoCrMo and FeCrMnMoN0.9 disk samples against a ceramic ball (Al_2O_3). Tests conditions were: 37°C, reciprocating sliding wear with 40° amplitude and 2 Hz, 86400 cycles (12 h), and a load of 37 N. Simulated synovial fluids were prepared with the following chemicals: Dulbecco's phosphate buffered saline solution; newborn calf serum; hyaluronic acid (sodium hyaluronate) powder (HA); and 35 wt% hydrogen peroxide ultrapure analytical reagent (H_2O_2). Wear was quantified by measurements of wear scar volume (OrthoLux, Redlux), while the surfaces were evaluated by electrochemical parameters and SEM/EDS analyses. Factorial ANOVA tests (IBM SPSS premium software version 26) were conducted to examine the effects of H_2O_2 concentration (0, 3, and 10 mM), and test material (CoCrMo and FeCrMnMoN0.9) on wear- and corrosion- related dependent variables.

Wear of LC-CoCrMo increased with increasing H_2O_2 concentration, while this was not the case for FeCrMnMoN0.9 (**Fig.**). There was no statistical significant difference in wear between LC-CoCrMo and FeCrMnMoN0.9 in fluids w/o H_2O_2. With 3 mM H_2O_2, wear of LC-CoCrMo was bigger than of FeCrMnMoN0.9, with a difference of 0.016 mm^3 ($p = .046$). With 10 mM H_2O_2, this difference increased to 0.029 mm^3 ($p = .001$).

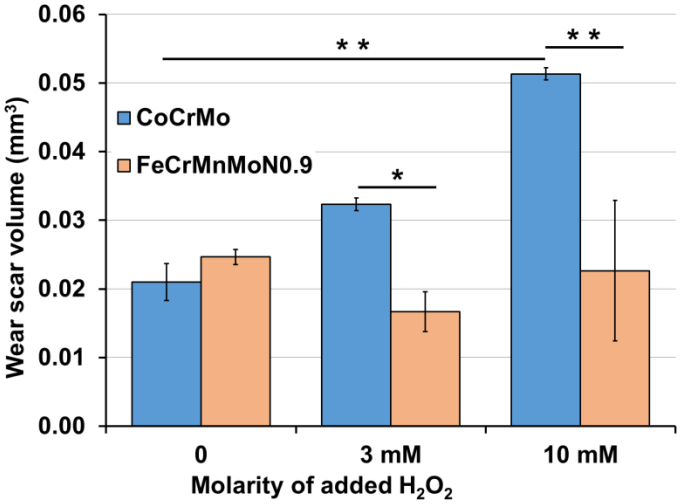

Fig. Mean values of wear scar volume from tests in fluids with different molarities of H_2O_2 for CoCrMo vs FeCrMnMoN0.9. Statistical differences from simple main effects analysis of metal and H_2O_2, with $p \leq .05$ (*), .01 (**).

The wear performance of the nickel-free high nitrogen steel was comparable to CoCrMo in the simulated synovial fluid w/o H_2O_2, and better in case of added H_2O_2. The presence of nitrogen in FeCrMnMoN0.9 is supposed to mitigate the tribocorrosive action of H_2O_2. Further investigations are needed to understand the mechanisms behind this new finding.

Inflammatory responses are likely to take place following implantation of an orthopedic device. Our test conditions are therefore of clinical relevance, and our results encourage further research on nickel-free high nitrogen steels for biomedical applications.

[1] Eltit F. et al. in: Front Bioeng Biotechnol 7 (176) (2019); [2] Laaksonen I. et al. in: The Journal of Arthroplasty 33 (2018); [3] Tahla M. et al. in: Materials Science and Engineering C 33 (2013).