Antibacterial functionalization of the surface of titanium implants by electrochemical copper deposition

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INTRODUCTION: The growing number of cases of implant-associated infections is a serious problem not only for the patient but also for the healthcare system. Furnishing the implant surface with antimicrobial properties is regarded to be promising to prevent infection because it acts locally at the site of infect initiation. We have deposited the antimicrobial agent copper on the rough, fine-porous surface of titanium samples and studied the antibacterial effect.

METHODS: Discs of cp Ti (gr. 4, ∅ 14 mm, 1.5 mm thick) were mechanically pre-treated and ultrasonically cleaned. Samples were anodized according to the spark-assisted anodizing (SAA) method [1] to produce a rough, fine-porous surface. Copper was electrochemically deposited using proprietary electrolytes and process parameters. The copper deposits were characterized by REM/EDX. For determination of the total amount the deposited copper was digested in nitric acid, quantified by AAS and set in relation to EDX values. The copper release kinetics was studied in simulated body fluid. Antimicrobial activity was determined by dilution series with *E. coli K12 DH5α* and *Staphylococcus aureus* and live/dead staining of the modified surfaces. The lethal dose for MG-63 osteosarcoma cells was determined by serial dilutions of a copper standard solution and a colorimetric assay.

RESULTS: The anodized samples show a fine-porous oxide layer with Cu deposits of different cluster forms and surface distribution (Fig. 1).

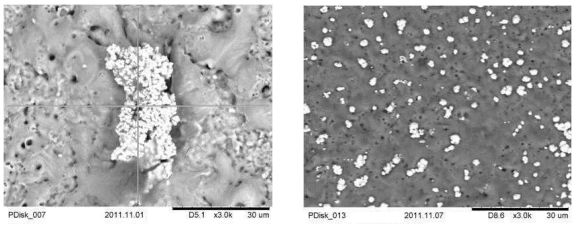

Fig. 1: REM pictures of the surface of the titanium discs (3000 magnification). Copper appears as white spots in clusters (left) or as small single deposits (right).

The lethal copper doses for *E. coli K12 DH5α*, *S. aureus* and MG-63 osteosarcoma cells have been determined to be 100µg/ml, 5µg/ml and 60µg/ml, respectively [2]. Fig. 2 demonstrates the rate of release of the deposited copper from the titanium discs. Release experiments after 10 days were continued at 80°C to simulate the long-term effect [3].

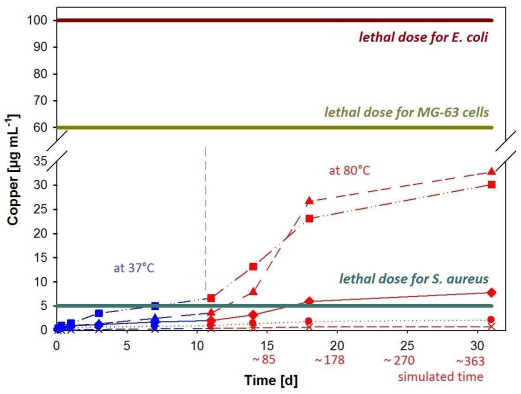

Fig. 2: Released copper from the titanium surface into simulated body fluid at 37°C for 10 days and at 80°C after 10 days. The horizontal lines indicate the lethal doses which have been determined in independent experiments.

DISCUSSION & CONCLUSIONS: Copper has been successfully deposited on SAA-modified titanium surfaces. Further studies are required to improve the homogeneity and size of the copper deposits. *S. aureus* can be completely killed after ten release days while much longer time is required for *E. coli K12 DH5α*. Further tests on other bacterial strains will show whether this is a general effect. Antibacterial functionalization of titanium implants by copper is possible.

REFERENCES: [1] C. Jung (2010) *European Cells and Materials*, **19** (Suppl 2):4. [2] N. Ryter (2011) *Master Theses, Fachhochschule Nordwestschweiz, Muttenz*. [3]*ASTM* F-1980-02.

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