Characterizing the mechanical stability of antibacterial copper deposits on anodized titanium implant surfaces

L. Straumann[1], A. Kessler[1], U. Pieles[1], M. de Wild[1], C. Jung[2],
[1]*University of Applied Sciences Northwestern Switzerland, School of Life Sciences, Muttenz, CH*
[2]*KKS Ultraschall AG, Medical Surface Center, Steinen, CH*

INTRODUCTION: Functionalizing implant surfaces by antibacterial copper represents a promising strategy to reduce the risk of infections immediately or years after implant placement. Besides an efficient antibacterial activity, the copper deposits should show a sufficient adhesion onto the implant surface to ensure stability under surgical handling. Here, we report results of the adhesion strength tape test according to [1] and the insertion test in analogy to [2].

METHODS: Discs (ø14 mm) and rods (ø4 mm, 40 mm long) of cpTi were anodized according to the spark-assisted anodizing method [3]. Copper was electrochemically deposited using proprietary electrolyte and process parameters (KKS TioCel^{TM}), see Fig 1a. The amount of Cu was determined by EDX analysis on a unique location on the discs resp. the rods before the tape test or the insertion test (1000x magnification). On the rods, two well-defined positions, 3 mm and 15 mm from the apical end were distinguished, see Fig. 1b. In the tape test, the flaking effect of three different tapes was investigated. After a pushing period of 90 seconds, the tape was removed rapidly as close as possible parallel to the disk surface.

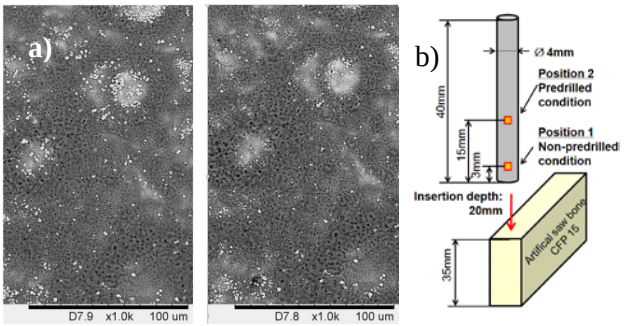

Fig. 1: a) original (left) and taped (right) surface. b) Scheme of the insertion test.

In the insertion test, the rods were pushed into a piece of polyurethane saw bone type CFP 15 [4] with the help of a guide. Subsequently, the artificial bone was cleaved to remove the treated rod. The lower position simulates an insertion into the pristine bone whereas the upper position resembles the implant placement into a predrilled hole. After the mechanical tape or insertion tests, a second EDX measurement was done on the identical surface area to determine the amount of Cu on the individual disc or rod.

RESULTS: In the tape test, the mean loss of copper was 13.0±7.7% for three different tapes, each tested on three different samples (see Fig. 2).

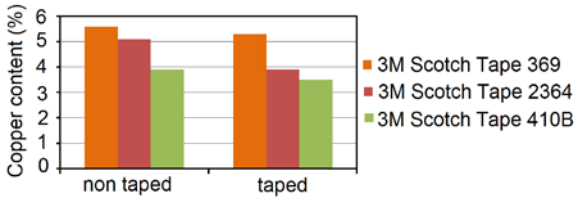

Fig. 2: Amount of copper (determined by EDX considering 5 elements) on discs before (non-taped) and after (taped) the adhesion tape test.

In the insertion tests, higher wear rates were observed at the front position rod (non-predrilled) which caused the Cu amount to be reduced by ~ 24.2% (Fig. 3a). In contrast, the predrilled, upper location simulates an insertion of an implant into a prepared hole with lower shear forces. In our experiment, the Cu amount was not significantly reduced at these locations (~ 1.7%) of the rods.

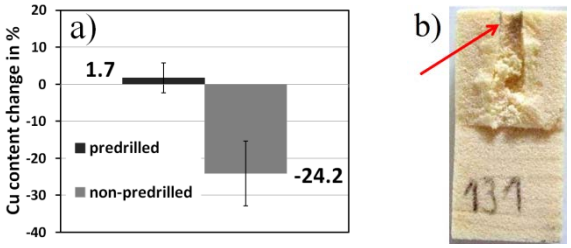

Fig. 3: a) Change in copper concentration on different rods (n=6) after the insertion test in saw bone. b) Residual Cu was detected at the saw bone counterpart.

DISCUSSION & CONCLUSIONS: The maximal loss of Cu from the anodized and Cu functionalized titanium surface after adhesion tape test or insertion test is in a range of ~ 24% which is regarded to be acceptable for application purposes.

REFERENCES: [1]ASTM D3359-02, *Standard Test Methods for Measuring Adhesion by Tape Test*. [2]ASTM F 543-07, *Standard Specification and Test Methods for Metallic Medical Bone Screws.* [3]C. Jung (2010) *European Cells and Materials*, **19** (Suppl. 2):4. [4]ASTM F 1839-08, *Standard Specification for Rigid Polyurethane Foam for Use as a Standard Material for Comparative Testing Orthopedic Devices and Instruments.*

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