Correlation between Osseointegration and Implant Surfaces – Roughness and Coating

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Statement of Purpose: The clinical short- and long-term success of implant fixation in bone is influenced by their geometry and surface topography. The bone apposition is critical for rapid loading and therefore the surface property roughness plays a decisive role in osseointegration at early stages. There are several studies investigating the influence of the surface roughness concerning osseointegration and clinical success. Another effort in improving implant surfaces are HA coatings and bioactive coatings with bone morphogenetic proteins which is attended with overdoses up to BMP-inhibitors formation [Rosen et al.]. The aim of this study is to utilize the advantages of the bone grafting material NanoBone® as a coating material.

Methods: The coating procedure consists of a spray process by using the sol-gel technique. A dispersed phase of synthetic, nanocrystalline hydroxyapatite (ncHA) and a SiO_2 sol coagulate on the implant surface by removing the diluent ethanol. The sol is derived from hydrolysis of TEOS (tetraethylorthosilicate) under acid conditions. The nanocrystalline HA ($Ca_{10}(PO_4)_6(OH)_2$) is a product of a precipitation of calcium chloride ($CaCl_2$) and sodium hydrogen phosphate Na_2HPO_4.

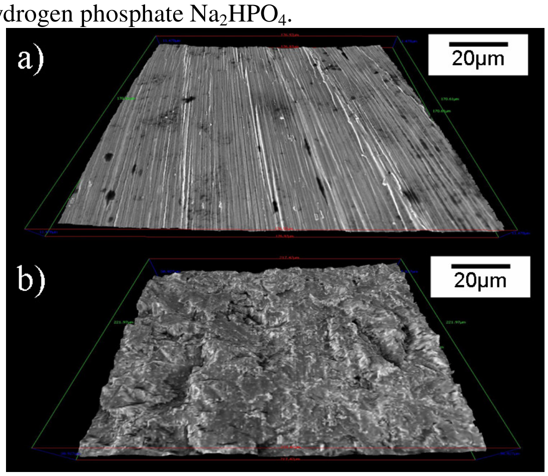

Figure 1: 3D-SEM of rough and smooth surface

Commercial (n=6, rCtrl) titanium implants (tiologic®, Dentaurum, Germany) with high roughness and smooth titanium implants (n=6, smCtrl) from the same configuration but with a low surface roughness were inserted as control groups. Rough (n=6, rNB-C) and smooth implants (n=6, smNB-C) were coated due to the coating routine with a thickness of about 5µm. All implants were inserted in the tibia of New Zealand white rabbits. All animal handling and surgical procedures were conducted according to European Community guidelines for the care und use of laboratory animals and approved by the local veterinary school ethical committee.

Specimens were excised after 2, 4 and 6 weeks and processed according to the sawing and grinding technique and stained with toluidine blue.

For SEM (DSM960, Zeiss) investigations implants were sputtered with 5nm Au/Pd and 3D reconstructions (MeX 5.1, Alicona Imaging) were derived from different electron beam angles. Ti-foil and carbon copper grids were coated and investigated with TEM/STEM (LEO 912, Zeiss).

Results: Figure 1 shows the two different surfaces of smooth (a) and rough (b) implants with mean roughnesses (area analysis) of S_A = 0,3µm (smCtrl) and S_A = 1,6µm (rCtrl). When gelation occurs, the SiO_2 particles get cross linked and form a three dimensional network (SiO_2-matrix, 24wt.%) with embedded ncHA (76wt.%). The network with its porosity in the nanometer scale is demonstrated in Figures 2. All ncHA plates are surrounded by silica matrix. The appearance of the ncHA in TEM are the dark and acicular crystals.

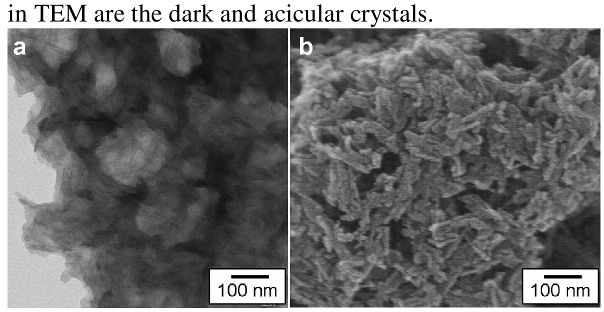

Figure 2: a) TEM: Silica matrix ncHA-crystals b) STEM showing nano porous structure of the coating.

The results of the animal study exhibit a correlation between bone to implant contact (BIC) and surface roughness. A higher surface roughness leads to an enhanced BIC.

Figure 3 consists of two slices of rNB-C (a) and rCtrl (b). The coating material leads to an enhanced bone implant contact in comparison to the control group. Moreover there is an osteoblast settlement and newly formed bone on the implant surface (arrows, rCtrl) at all coated implants.

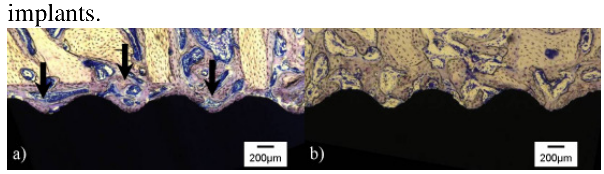

Figure 3: cross section of a) rNB-C 2 weeks. b) rCtrl 2 weeks.

Conclusions: TEM and SEM investigations indicated the porosity of the coating material and its network at the nanometer scale. These pores lead to a high, autologous protein adsorption, which is indicated by the increased BIC rates of coated implant group.

References:

Rosen V. Ann. N.Y. Acad. Sci. 2006, 1068:19-25