Improving the knowledge of integration of medical devices in bone; a comparison of 3D SRµCT data to histomorphometrical data obtained on cut and ground sections

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Introduction
Despite the long-term clinical success rate of oral implants there are several questions that still are un-answered. Moreover, there are more complicated cases, i.e., compromised bone beds treated today compared to former days. Research is aiming at improving the osteoconductivity or the biological potential of the medical devices surfaces in various ways in order to speed up the integration. With the “hard-ware” in focus, we are able to technically and controllable mimic the biomaterials related factors whereas the “soft-ware factors” are less controllable.

Retrieval of human biomaterials as well as research animal samples including bone tissue, with subsequent analysis in our laboratories, most often involve sample processing to undecalcified cut and ground sections of 10 µm thickness. One could refer to this as a “destructive technique” albeit it is the “state of the art technique” when one wants to investigate integration of hard biomaterials in bone tissue. Due to the time consuming techniques involved most often only one central section in one plane is prepared from each sample. The section is histologically stained and histomorphometrical analysis of for example bone to implant contact and bone area surrounding the implant is conducted with the aid of semi-quantitative computer-based techniques.

The aim of our research is to try to find, and apply additional techniques that will help us to understand the mechanisms of integration of biomaterials in bone tissue. We will combine in vivo biomechanical data with the traditional histomorphometrical data and add the SRµCT data. We foresee that adding various parameters obtained with various techniques would help us to gain the understanding of integration of biomaterials.

Materials and Methods
Bone blocks with screw shaped implants of commercially pure titanium were retrieved from rabbit bone (samples from cortical bone). Two of the animals (samples with spongeous bone) had been in vivo labeled with fluorescent dyes (clinical antibioticum). Laboratory processing resulted in embedment of all samples in resin. Most of the samples had an outer diameter of 12 mm whereas the larger samples (spongeous bone beds) had an outer diameter of 16 mm.

All samples were imaged with the SRµCT device of the GKSS at beamline W2 using a photon energy of 64 keV. The tomographical scan was performed by acquiring 720 X-ray attenuation projections equally stepped between 0° and 180°. For the smaller samples the field of view of the X-ray detector was set to 12.2 mm × 8.2 mm (width × height) with a pixel size of 8.0 µm showing a measured spatial resolution of about 17.2 µm. The larger samples were
larger than the field of view of the detector. Therefore a scanning technique was used. The
detector was set to a field of view of 9.1 mm × 6.0 mm, pixel size 5.9 µm, and a measured
spatial resolution of about 15.6 µm. The rotation axis was then set near the border of the
detector and the scan was performed obtaining radiograms between 0° and 360°. Before
reconstruction combination of the projection of 0° – 180° and 180° – 360° were built. A
filtered back projection algorithm was used to obtain the three-dimensional data of X-ray
attenuation for the samples. A slice through a reconstructed data volume can be seen in Figure
1 (left).

Currently
Computer aided analysis of the reconstructed radiographs is ongoing. A preliminary result of
segmentation of the data into three classes, implant, bone, and non-bone regions is visualized
in Figure 1 (right). A challenge is to see if it possible to separate new bone growth from older
bone, in the SRµCT data. Cut and ground sections are under processing resulting in “routine
sections” of the implants. The histomorphometrical data of bone area / volumes outside the
implants will be compared to “similar slices / sections” in the radiographs. With the samples
retrieved from the in vivo labeled bone – the aim is to additionally investigate if the
fluorescence is still in the bone or if it is faded due to treatment in the W2. If still occurring in
the bone tissue, as deduced on unstained cut and ground sections – the aim is to investigate if
this information can be observed in the radiographs.

Figure 1: SRµCT image of commercially pure titanium implant inserted in rabbit-tibia bone for 10
weeks. Left: Slice through the reconstructed data. Right: 3D rendering of a preliminary segmentation
of the data into implant (red) and surrounding bone material (yellow).

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