Studies with high resolution synchrotron-tomography of regenerated bone tissue using rapidly resorbable bone substitute materials

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The current gold standard for bone reconstruction in implant dentistry is the use of autogenous bone grafts. But the concept of guided bone regeneration (GBR, [1]) has become a predictable and well-documented surgical approach using biomaterials (bioactive calcium phosphate ceramics) which qualify as bone substitutes for this kind of application as well [2]. An animal study was performed in which these novel rapidly resorbable bone substitute materials were implanted in sheep. We applied high resolution synchrotron-tomography (S-CT) and subsequent 3d imaging in order to visualise bone formation and degradation of the bone substitute material in a threedimensional manner.

Experiments were caried out at the BAM*line* [3]. Corresponding to the size of the samples a 2048x2048 pixel CCD detector (Princeton Instruments VersArray:2048B) was chosen. The effective pixel size of 7 µm (zoom optics combined with CCD chip's pixel size) leads to a 14x14 mm^2 field of view. As scintillator an approx. 10 µm thick Gadox powder screen was used, the resulting spatial resolution is 20 µm and better. 1500 projections were recorded per 180° scan. The X-ray energy was set to 27 keV with the help of the installed double multilayer monochromator. For the reconstruction in parallel beam geometry PyHST was used to create the volume images [4]. The 3d rendering was done with VolumeGraphics VGStudio*Max* [5].

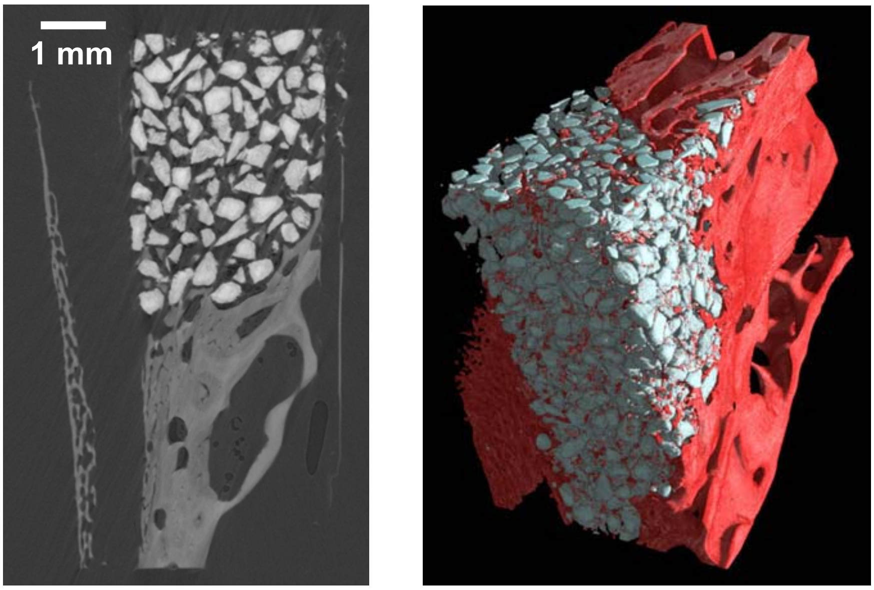

Fig. 1. Tomographic slice of a sheep sinus (light gray) with ceramic particles (white) 3 months after implantation (left) and corresponding 3d image after segmentation (right)

A typical tomographic slice of a sheep bone with ceramic particles three months after implantation is displayed in figure 1 (greyscale). Morphological objects (bones, ceramic particles) were separated by using a threshold hysterisis in combination with a 3d region growing algorithm [6]. Pixelwise multiplication of so created Boolean images with the input image creates noiseless data sets of each material phase which can be rendered in one image, see again figure 1.

A comparison with histologic images as shown in figure 2 allows to distinguish newly formed bone in spongy state from the fully evolved hard bone due to the density contrast in CT vs. chemical contrast in histologic images.

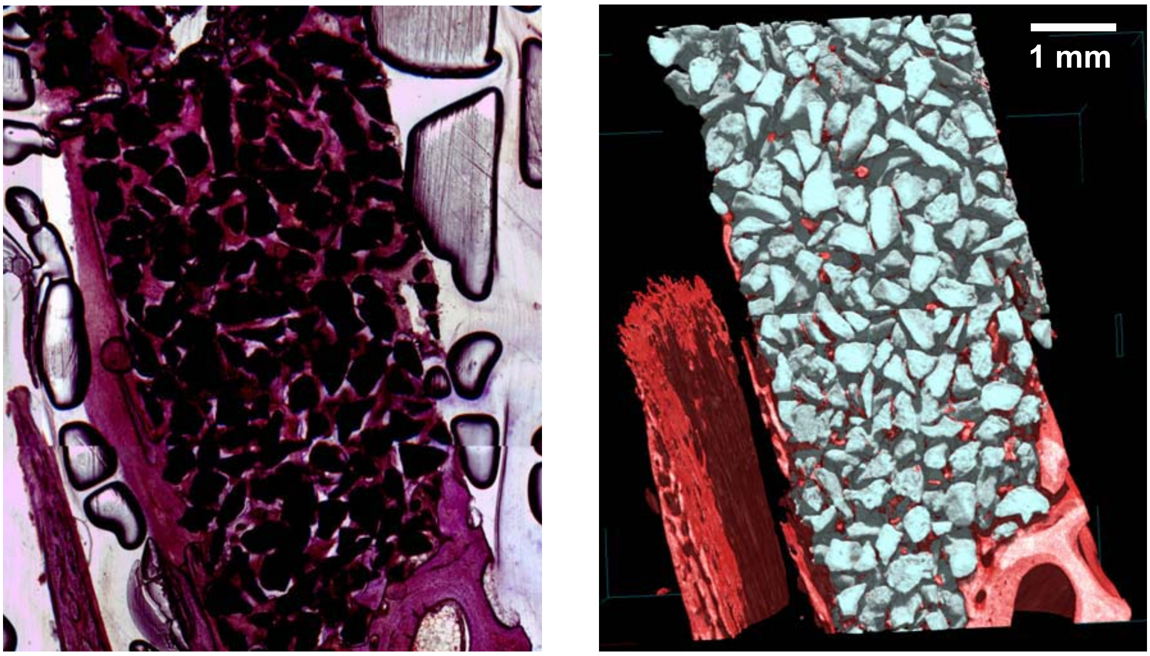

Fig. 2. Histologic image of bone substitute particles in sheep sinus – corresponding to the sample in figure 1 (left) and 3d rendering of a comparable sample section from the 3d data set (right)

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