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Interconnected Porous Scaffolds for Bone Augmentation

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INTRODUCTION: Tissue engineering based on interconnected porous ceramic scaffolds and autologous cells belongs to promising approaches for filling bone defects. The scaffold's morphology including 3D porosity and interconnectivity is a key issue for optimizing the osseointegration of the generated implants. Tomograms obtained by synchrotron radiation-based micro computed tomography (SRµCT) are the basis for the 3D characterization of the scaffolds on the micrometer scale using sophisticated tools such as distance mapping, component labeling, dilatation/erosion, and image registration.

METHODS: Hydroxyapatite scaffolds in three different designs made layer-by-layer were fabricated using rapid prototyping and sintering.[1]

SRµCT measurements were performed at the beamline W 2 (HASYLAB at DESY, Hamburg, Germany), operated by GKSS, with the pixel size of 3.7 µm using the photon energy of 30 keV.

For the data analysis, software packages were developed for rigid registration with 9 parameters (3 rotation, 3 translation, 3 scaling), for 2D and 3D distance mapping, for component labeling to determine the pores' interconnectivity, and for masking to quantify the scaffold's quality.

RESULTS: The mean distance to material derived from the 2D distance mapping (Fig. 1) is between 133 and 148 µm and depends on the selected design. The 3D analysis provided values without significant spreading (98 - 100 µm).

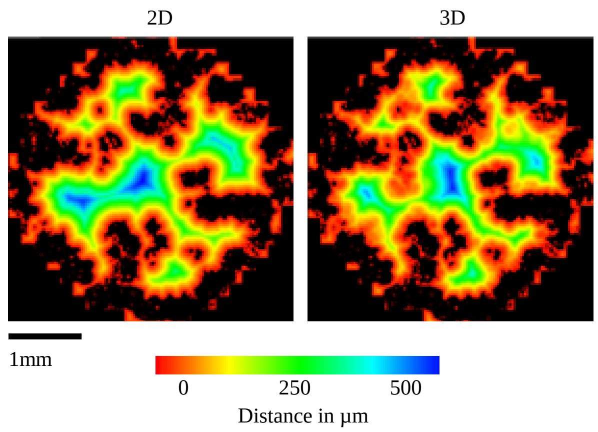

Fig. 1: 2D (left) and 3D (right) distance map: black indicates scaffold material.

The component labeling gives rise to a perfectly interconnected channel network in the scaffold. The major air component covers (99.53 ± 0.09)%. By the definition of a smallest diameter that cells can pass, we are able to determine the parts of the cavity accessible for the cells by migration.

The 3D image registration of the design with the tomograms of sintered scaffolds yields the printing quality (Fig. 2). It allows calculating the shrinking in the three orthogonal directions. The shrinking is almost isotropic and corresponds to (73 ± 2)%.

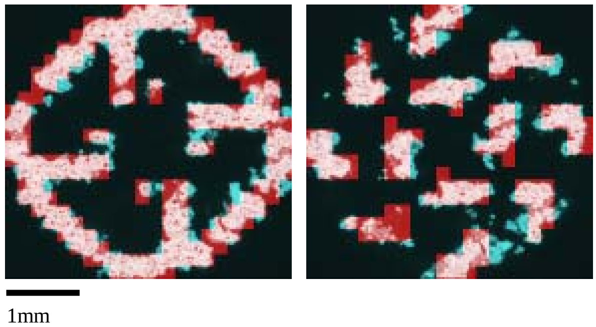

Fig. 2: Image registration of design (mask) and tomogram of scaffold. The mask is red-colored, material outside the mask blue and material printed inside the mask white.

DISCUSSION & CONCLUSIONS: The digital, 3D data nondestructively obtained by SRµCT are the perfect basis for the visualization and quantification of the scaffold morphology. The application of standard software, however, is difficult because of the huge data size in the range of GB and hence specific code was developed. The distance mapping clearly demonstrates that the 2D analysis overestimates the mean distance to the material by 30 to 50%. Component labeling together with appropriately selected minimal diameters for cell migration allows visualizing the parts of the scaffold that are accessible by biological cells seeded. 3D registration algorithms are shown to allow for the precise measurement of the shrinking as the result of the sintering process and for the detailed evaluation of the scaffolds morphology with respect to the planned design.

REFERENCE: [1]S. Irsen et al (2006) *Material-wissenschaft und Werkstofftechnik* **37**:533-537.

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