Correlation of soft- & hard tissue contrast between SRµCT and NMR imaging

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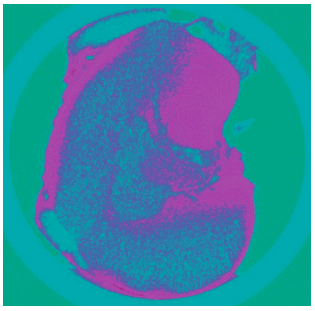
Introduction: Based on their specific tissue contrast Synchrotron microcomputed tomography (SRµCT) and NMR microscopy (µMRT) are used as complementary non-destructive imaging techniques to assess the biological response to artificial implants, with a special focus on the interface between soft tissue and hard tissue. In addition, surface-selective solid-state NMR will provide information on structure and molecular dynamics localized in the boundary phase between the soft tissue and the artificial extracellular matrices.

To combine, visualise and analyse reactions from different tissues the three-dimensional image data from SRµCT and µMRT had to be optimised (A) with respect to their image contrast between the types of tissue, (B) for artefact reduction when metallic surfaces are incorporated and (C) for spatial registration of different raw data geometries.

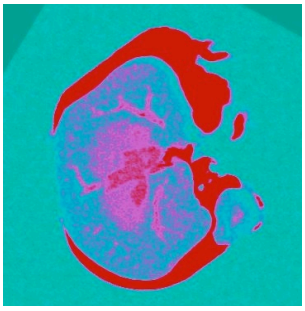
Materials and Methods: For comparative studies ex vivo soft- and hard tissue samples with and without metallic implants were investigated. Rat and mice kidneys were used for soft tissue contrast studies. For the soft tissue preparation completely non-protonated Fluorinert® FC-77 for the µMRT and povidon iod mixture for the µCT experiments were tested. Dental tissue samples were investigated with surface-selective solid-state NMR. The influence of metallic objects to the image quality of the surrounding soft- and hard tissue we studied by measuring titanium coated PEEK foils with the tissues.

For the µCT measurements a synchrotron X-ray source (HASALAB-HZG, image resolution: 9 µm) and an X-ray tube system (SCANCO Medical vivaCT 75, image resolution: 20 µm) were used. NMR imaging has been performed on a Bruker Avance 300 using a micro 2.5 microimaging system. Solid-state NMR experiments have been performed on a Bruker Avance 500 using a 2.5 mm MAS probe.

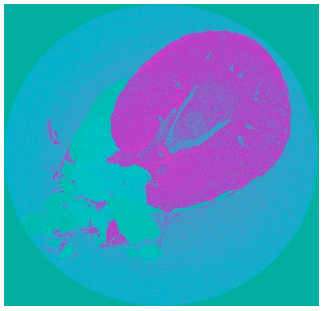
Results and Discussion:



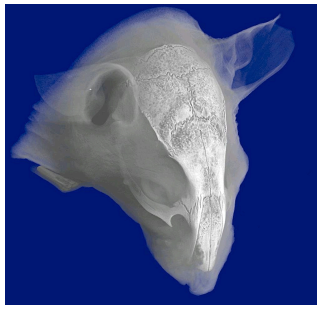
vivaCT image of a rat kidney stained with a iod solution. The magenta color shows the maximum X-ray absorption. Details in soft tissue morphology are hard to locate.



NMR image with a similar slice position with very good contrast for different soft tissue. Without matching structures to the appropriate µCT slice it is difficult to find suitable structures for an image registration.



The SRµCT image of a mouse kidney without contrast agent shows better absorption contrast for soft tissue. Small vessels and cavities are detectable and usable for image registration.



vivaCT 3D image of a mouse head with optimised contrast for high absorbing bony tissue with overlayed data for low contrast skin tissue. The overall aim is to exchange the µCT data for soft tissue with the NMR information.

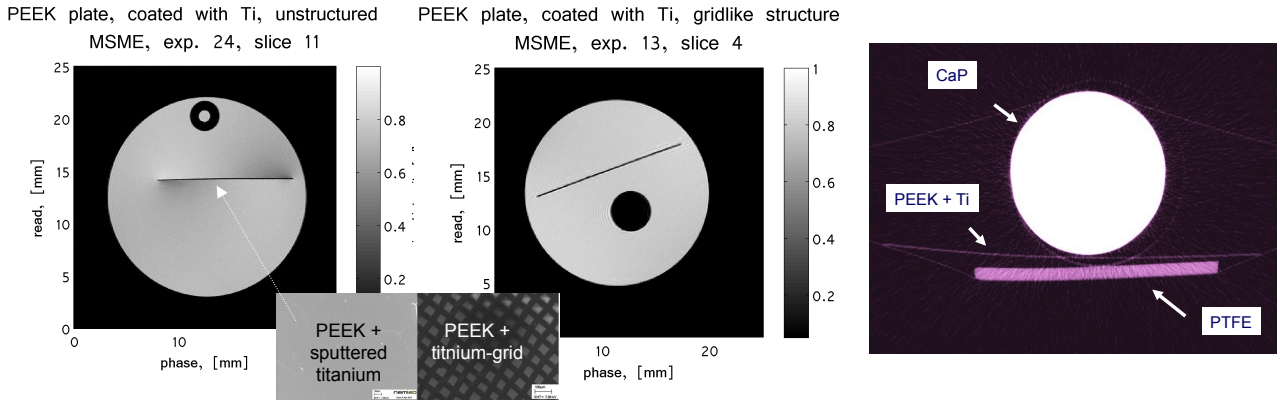


Fig. 2 Investigation of titanium coated PEEK films by NMR and μCT to reduce artifacts originating from the metal. The position of the film parallel to the RF-field and a titanium grid on the PEEK implant reduces metal artifacts in NMR imaging. For μCT imaging the titanium coated PEEK foil is clearly visible, produces no artifacts and is useable as a reference object in the 3D data for image registration.

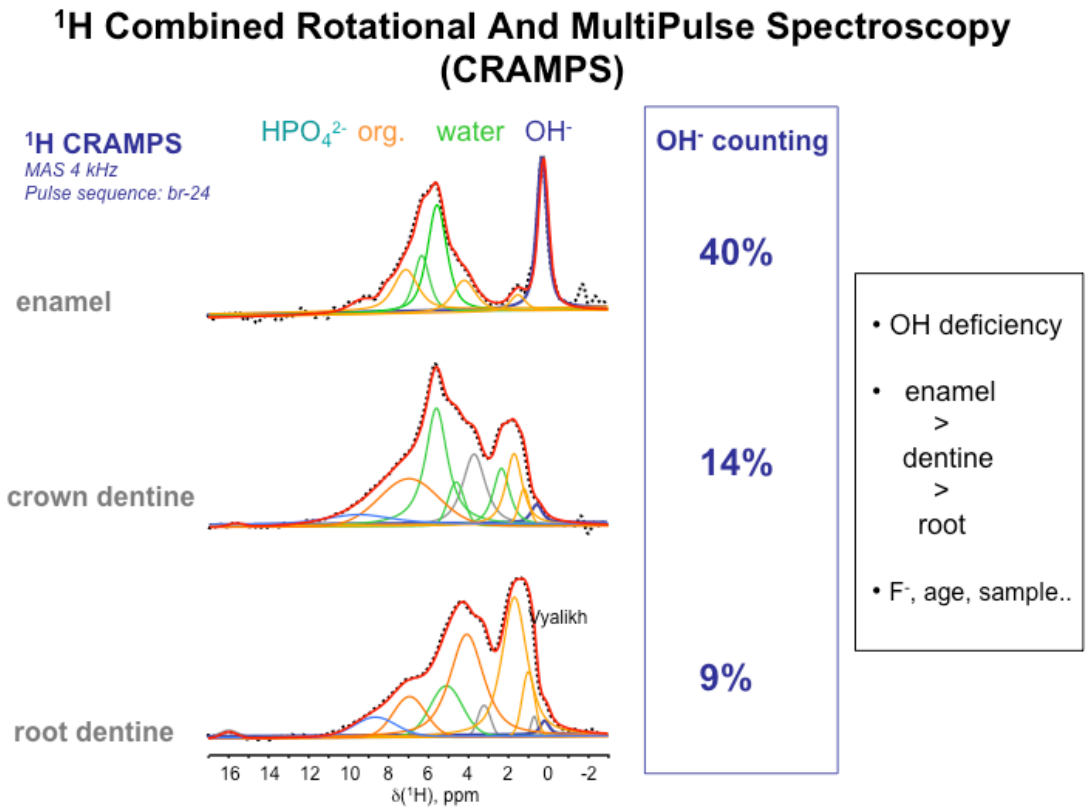


Fig. 3 Results of a combination of rotation and multipulse-spectroscopy (CRAMPS) for non-threaded dental samples. Hydroxide groups in apatite environment (OH^-), different water states, bone lipids and organic matrix, and HPO_4^{2-} units can be resolved. The estimation of the relative concentrations of the structural OH-groups in enamel, crown dentine and root dentine was found with 40%, 14% and 9% respectively.

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