Quantitative Assessment of Radial Bone Structural Distribution in the Proximity of Degradable Implants by Micro-Computed Tomography

P489

T. Damm[1], R. Barkmann[1], S. Galli[2], R. Willumeit-Römer[3], C.-C. Glüer[1]

[1] Section Biomedical Imaging, Clinic of Radiology and Neuroradiology, University Hospital Schleswig-Holstein (UKSH), Campus Kiel, Germany
[2] Faculty of Odontology, University of Malmö, Sweden
[3] Institut für Materialwissenschaften, Technische Fakultät, Christian-Albrechts-Universität, Kiel, Germany and Helmholtz-Zentrum Geesthacht, Germany
Corresponding author's email: ***timo.damm@rad.uni-kiel.de***

Background

Degradable bone implants may provide improved long term healing, tissue remodelling and quality of life. Magnesium (Mg) alloys have shown promising results regarding these aspects. In order to optimize alloy composition and degradation properties, *in-vivo* monitoring of the degradation process and its impact on bone formation is essential, because degradation progresses differently *in-vivo* versus in vitro).

We aim to understand how implant degradation of Mg implants influences bone remodelling and bone structure using Micro-Computed Tomography (µCT). Measures to quantify the degradation have to be developed for very different scenarios: We have to face pure surface degradation as well as an implant/bone melange.

We hereby declare no conflicts of interest.

Materials & Methods

Mini-screw implants of three different magnesium alloy compositions (Mg2Ag, Mg10Gd, WE43) and titanium (Ti) are presented. After implantation, the mini-screws remained for 3 month in the rat femurs before the complete femur samples have been excised and preserved at -20°C in a gauze soaked with 70% ethanol.

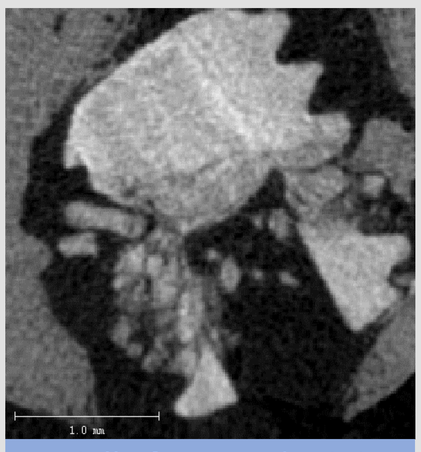
µCT scans have been performed on a Scanco VivaCT 80 with 70kVp, 114mAs and 1500 projections/180°. Reconstruction has been carried out with a voxel size of 15.4µm using a kernel with beam hardening reduction and a bone calibration mgHA/cm³.

For the samples of low degradation, we carry out our layering approach to investigate the lamellar changes perpendicular to the implant surface. For the samples in a further progressed degradation stage, density histograms restricted to volume of interests around the initial (guessed) implant position are evaluated.

Perspectives

In case of strong degradation and non-uniform progression of this process, the separation of bone and implant material is challenging.

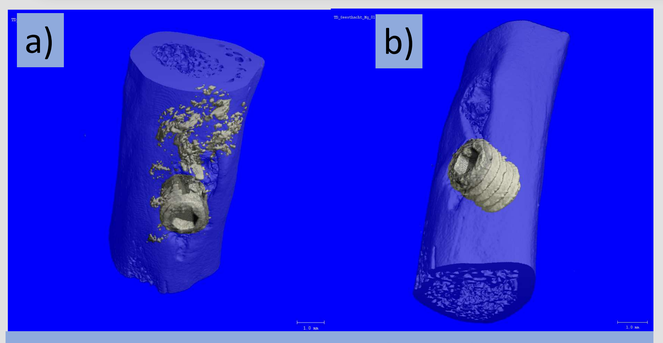
A time-lapse *in-vivo* µCT study can elucidate the progression of the degradation, especially if the corrosion process is not taking place exclusively at the surface of the implants. Our data shows such progression along (possibly weak) zones into the alloy, which appears "fractured" due to this degradation scheme afterwards.



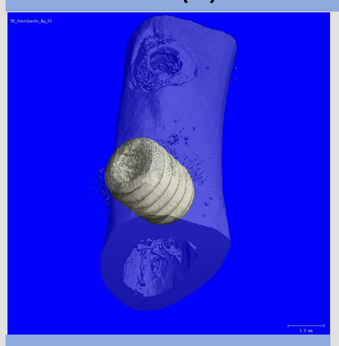
Partially fractured mini-screw of Mg10Gd

Because the characterization of the bone-implant interface is very important for the understanding and refinement of degradable implant materials due to its influence on implant fixation, ultra-high resolution imaging should be combined with our µCT data in a hierarchical approach. Also multimodal approaches with histology, spectroscopy, molecular imaging and others will help to better understand the complex processes involved in bone healing in the presence of degradable implants.

Results

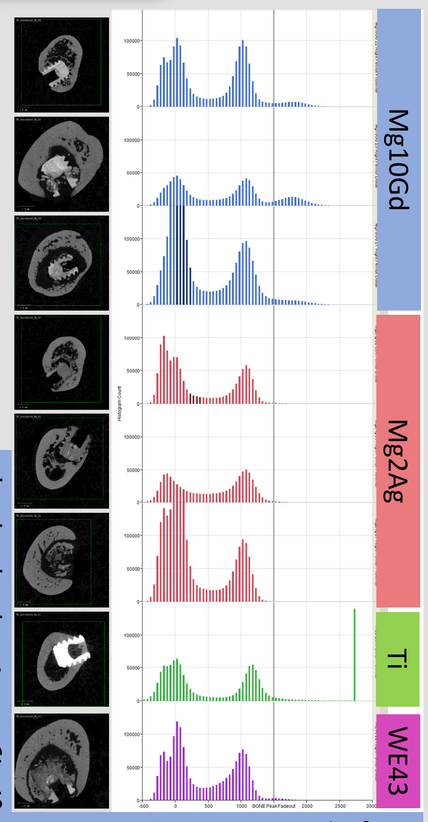


Mg10Gd mini-screw defined by automatic (a) and manual segmention.

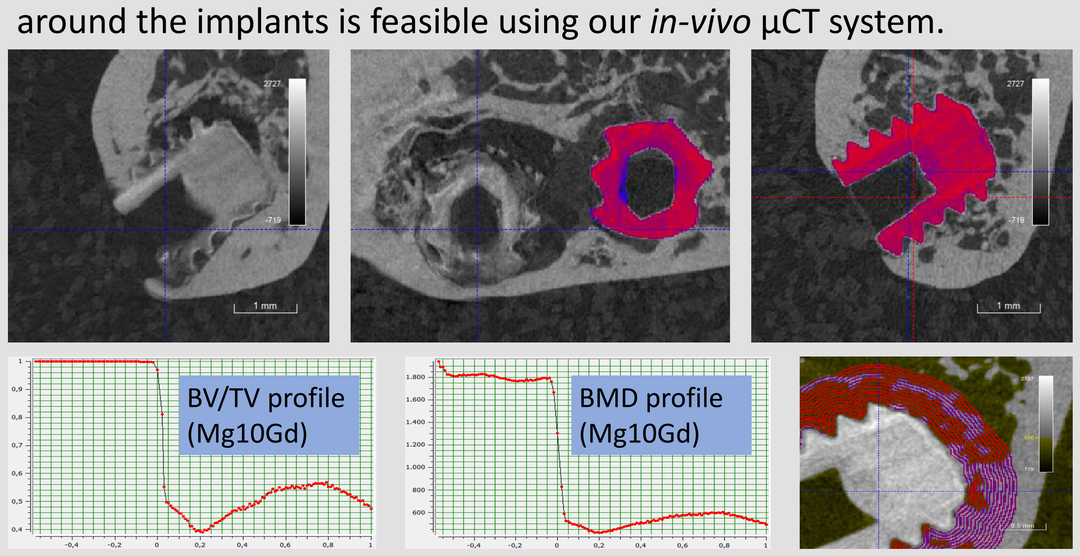


Manually segmented Ti mini-screw

Left) Next to representative cross-sections the histograms show significant differences. Above 1500mgHA/cm³ the metal influence is dominant.



Compared to Ti-implants, imaging of Mg-alloys in µCT is less affected by metal artefacts, so the extraction of meaningful density profiles around the implants is feasible using our *in-vivo* µCT system.



Conclusions

- **Mg-alloy implants can be imaged by Micro-CT and do not show significant artefacts.**
- **Degradation and bone reaction can be quantified using our „Layered Segmentation" approach.**
- **After severe degradation and/or fracture of the implant, a histogram quantification is a feasible tool.**
- **All these quantifications can be carried out in *in-vivo* studies and also in time-lapse µCT, allowing to trace degradation over time.**

ZUKUNFTSprogramm Wirtschaft
Investition in Ihre Zukunft
Financed by the European Union, European Regional Development Fund (ERDF), the Federal Republic of Germany and the Land of Schleswig-Holstein

MOIN Molecular Imaging North

Sektion Biomedizinische Bildgebung
Klinik für Radiologie und Neuroradiologie