| ESRF | **Experiment title: High resolution SAXS/WAXS investigations of mineral nanoparticles in fractured bone and correlations with the osteocyte cell network** | **Experiment number**: SC-4512 |
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| **Beamline**: ID 13 | **Date of experiment**: from: 23 April 2017 at 08:00 to 28 April 2017 at 08:00 | **Date of report**: Feb. 2020 |
| **Shifts:** 18 shifts | **Local contact(s)**: Dr. Manfred Burghammer | *Received at ESRF:* |


**Names and affiliations of applicants** (* indicates experimentalists):

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**Report:**

Part of the results from this experiment has been already published:
*Hoerth, R. M., Kerschnitzki, M., Aido, M., Schmidt, I., Burghammer, M., Duda, G. N., ... & Wagermaier, W. (2018). Correlations between nanostructure and micromechanical properties of healing bone. Journal of the mechanical behavior of biomedical materials, 77, 258-266.*


## Abstract:

All hierarchical levels in bone are known to contribute to its mechanical behavior. The basic building block is the mineralized collagen fibril which is assembled into larger structures with varying fibrillar organization. The collagen organization increases from unordered woven bone in the callus which is gradually replaced by higher ordered lamellar bone during bone development and healing and finally results in cortical lamellar bone with highest degree of organization. The structural and mechanical description of these organizational motifs is not yet complete.

We investigated a femoral osteotomy mouse model and analyzed newly formed callus tissue and mature lamellar bone in the cortex. This model exhibits three bone types with different fibrillar organization: (i) woven, (ii) moderate lamellar and (iii) lamellar. Using high resolution synchrotron small angle X-ray scattering in combination with back-scattered electron imaging we characterized the ultrastructure of the different regions in terms of degree of

mineralization, averaged mineral particle thickness and mineral particle orientation. We further used microindentation to correlate hardness, induced crack lengths and crack patterns with the bone ultrastructure.

The newly formed callus tissue contains highly mineralized woven bone islands, featuring thick but poorly ordered mineral particles. Such islands are surrounded by layers of lamellar bone with a low mineralization level and thin but well aligned particles. Callus tissue shows lower hardness values and longer cracks than the cortex. Callus woven bone exhibits shorter cracks than callus lamellar bone. However, the poorly mineralized callus lamellar bone shows crack propagation mechanisms similar to cortical bone due to its very similar lamellar organization and high degree of mineral particle orientation.

In conclusion we demonstrate that woven and increasingly higher oriented lamellar bone do not only differ in collagen fibril organization, but also that the amount, orientation and different shape of mineral particles are also likely to contribute to the reduced mechanical competence of woven as compared to lamellar bone. This may explain why many organisms replace less organized bone types with higher organized ones.

**Outlook:**
Furthermore, we are currently preparing a second publication on the more detailed correlation between the bone mineral characteristics and the osteocyte network architecture. This manuscript also includes synchrotron μCT data from experiment SC-4593 (Investigation of the osteocyte network in healing mouse bone by synchrotron microCT).

*Current working title of the manuscript:*
Heterogeneity of the osteocyte lacuno-canalicular network architecture and material characteristics across different tissue types in healing bone

*Planned authors:*
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