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Multi-method characterization of bone to find correlations between biological and material properties

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The complex hierarchical structure of bone undergoes a lifelong remodeling process, where it adapts to mechanical needs. Hereby, bone resorption by osteoclasts and bone formation by osteoblasts have to be balanced to sustain a healthy and stable organ. Osteocytes orchestrate this interplay by sensing mechanical strains and translating them into biochemical signals.
The osteocytes are located in lacunae and are connected to one another and other bone cells through small channels, the canaliculi. Lacunae and canaliculi form a network (LCN) that is able to transport ions and enables cell-to-cell communication. Osteocytes might also contribute to mineral homeostasis by direct interactions with the surrounding matrix. If the LCN is acting as a transport system, this should be reflected in the mineralization pattern. Our hypothesis is that osteocytes are actively changing their material environment. Characteristical methods of solid state and surface physics are used to achieve the aim of detecting traces of this interaction between osteocytes and the extracellular matrix.

The measurement strategy included routines that make it possible to analyze the organization of the LCN and the material components (i.e., the organic collagen matrix and the mineral particles) in the same bone volumes and compare the spatial distribution of different data sets. The three-dimensional network architecture of the LCN is visualized by confocal laser scanning microscopy after Rhodamine staining and is then quantified. The calcium content is determined via quantitative backscattered electron imaging, while small and wide-angle X-ray scattering are employed to determine the thickness and length of local mineral particles.

In each of the three model systems, this study found that changes in the LCN architecture spatially correlated with bone matrix material parameters. While not knowing the exact mechanism, these results provide indications that osteocytes can actively manipulate a mineral reservoir located around the canaliculi to make a quickly accessible contribution to mineral homeostasis. However, this interaction might be an interplay between osteocytes and extra-cellular matrix, since the bone matrix contains biochemical signaling molecules that can change osteocyte behavior. Bone (re)modeling can therefore not only be understood as a method for removing defects or adapting to external mechanical stimuli, but also for increasing the efficiency of possible osteocyte-mineral interactions during bone homeostasis. With these findings, it seems reasonable to consider osteocytes as a target for drug development related to bone diseases that cause changes in bone composition and mechanical properties.

Category

Other

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