Linking multiscale deformation to microstructure in cortical bone using in situ loading, digital image correlation and synchrotron X-ray scattering

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Bone fractures especially in elderly are a growing problem and to improve fracture risk predictions we need to better understand how bone fractures happen. Bone is a composite material built up by stiff mineral crystals and soft organic fibers. It has a complex structure where up to seven different levels or length scales have been identified from molecules to the whole bones. Every level has its own structure and you can find structures similar to brick walls, plywood or reinforced concrete. The deformation is transferred all the way down to the molecules and if the bone is deformed too much the molecules get damaged. Each level of bone has its own way of protecting and preventing the damage to spread in order to avoid a complete bone fracture. How this works in detail is still an open question.

The aim with this study was to analyze deformation at four length scales in bone tissue simultaneously to see how the deformation is transferred from the whole bone all the way down to the basic building blocks. X-rays were used to measure the deformation at small length scales, in crystals and fibers, and video films were used to follow the deformation at the bone surface. The results show that the tissue is deformed more than the fibers and mineral crystals, which means that not all deformation is transferred between the levels. This could be a protective mechanism. Analysis of the fracture surfaces showed that cracks tend to follow the tissue structure. This underlines the importance of the bone structure and the fact that bone tissue is organized to carry load and resist fracture in certain directions. Finally, we show new possibilities of combining different measurement techniques to simultaneously study deformation at several length scales. The future challenge is to combine all length scales to understand more about the damage transfer from the point where damage appear at the molecular scale up to a fractured bone.