An interface damage model that captures crack propagation at the microscale in cortical bone using XFEM

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Bone tissue is optimized to carry load and withstand fracture and, like wood, bone is easier to split than to break. This is because bone has a well-defined structure at the microscale where tube-like structures, so called osteons, are arranged in parallel and embedded in a cement-like matrix (Fig 1A). When bone tissue is split, the crack propagates along these tubes which results in a smooth and straight crack. If instead the crack propagates perpendicular to the osteons, a rough crack surface is created as the crack twists and turns when encountering the osteons and more energy is needed to cause a fracture. However, the capability to resist fracture is decreased with age and as a result old people have a higher risk of breaking their bones. One reason for this is believed to be caused by changes in the tissue microstructure and this is seen as smoother crack surfaces in old bone. The problem is that the changes in the tissue are mostly unknown. With the current technique it is very difficult to study crack propagation in experiments as fractures happen very fast and important mechanisms take place at the microscale. Therefore, computer models can be used as complementary methods to increase our understanding of crack propagation in bone. In this study, we have developed a computer model consisting of one osteon with the aim to study different possible crack paths that can arise when a crack reaches the osteon border (Fig 1B). In our model, the interface between the osteon and the surrounding tissue plays a key role for the crack path, where a weak interface can redirect the crack and cause an irregular crack path. The next step for this project will be to analyze crack propagation in models containing more osteons to simulate a more realistic scenario and pinpoint differences between young and old bone that affect the crack path and fracture resistance. The future challenge will be to combine the crack propagation models with models of entire thigh bones to understand more about the risk for hip fractures in elderly.

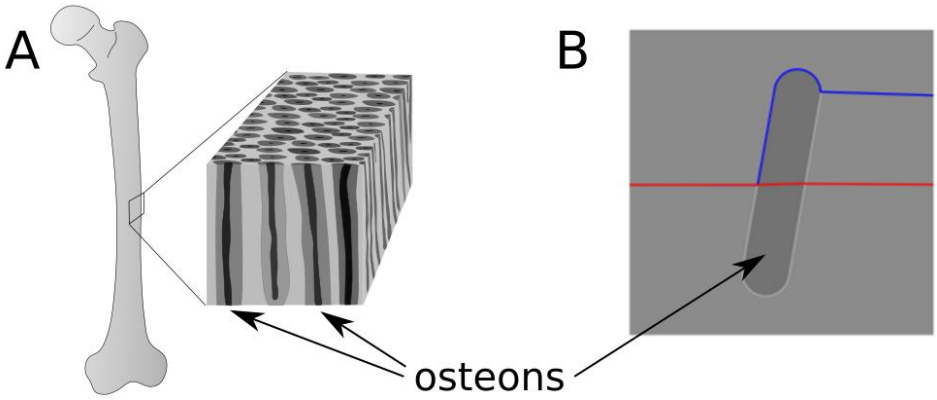

Figure 1: (A) Thigh bone with schematic illustration of the tissue microstructure with osteons arranged in parallel. (B) Computer model with one osteon showing two possible crack paths: red crack propagating through the osteon and blue crack turning at the osteon border following the interface.