Computational modelling of a stress fracture

Alexander Wingård

Stress fractures are cracks in the bone with poor healing ability. To develop new and better treatments, we first need to understand why the crack do not heal. This study used computational modelling to improve understanding why stress fractures do not heal during daily activity.

A stress fracture is an injury that originates from small micro cracks in the bones that are not able to heal. When repetitive load is applied over a period, the crack can either grow in size or generate new cracks that eventually form a stress fracture. Despite its small size, the stress fracture can induce a lot of pain and discomfort , where elite athlete Carolina Klüft and Susanna Kallur are two of many that have been diagnosed with a stress fracture.

Computational modeling is a promising tool within the field of biomechanics. It enables mechanical simulations without performing the actual experiment. To do the simulations, a three dimensional geometry was generated. Medical images at two scales of resolution was used (figure 1). They came from an older female patient that had suffered from a stress fracture at the middle of her thigh-bone. With the help of these images, two three dimensional geometries were created, illustrated at the bottom of figure 1. To the left representing the thigh bone (femur) and to the right representing the stress fracture.

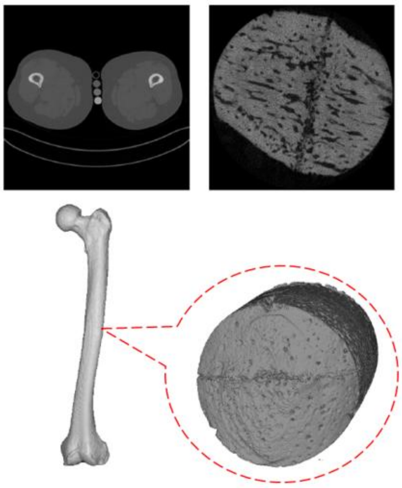

Figure 1: From top to bottom: Images of the femur and the stress fracture and its corresponding 3D geometry

To understand the mechanical milieu in the crack during daily activity different loading cases were studied. The activities studied included walking with different speeds and climbing stairs. The applied load results in stress and strain pattern within the structure of the femur and stress fracture. Two parameters that are related to stress fractures poor ability to heal are the strain and the fluid velocity, which are illustrated in figure 2.

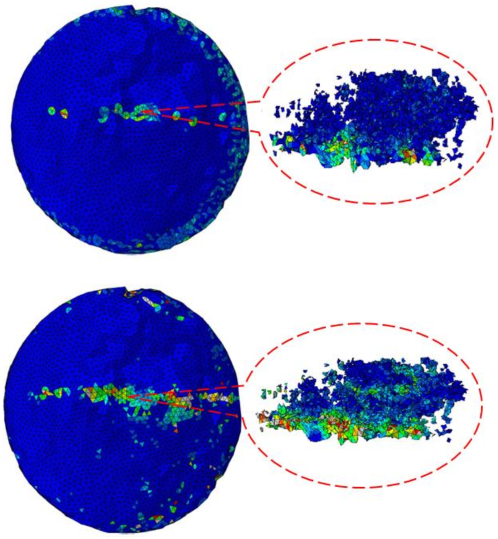

Figure 2: From top to bottom: The strain and fluid velocity of the stress fracture, the enlarged area represent the crack.

Areas colored in red represent high values of strains and fluid velocities, a green colored represent moderate values and the color blue describes low values. The image to the left shows the frontal view of the stress fracture model and the image to the right shows the enlarged area of the crack.

Within the images of figure 2, it can be seen that there are many areas within the crack that have either a red or green color, i.e. high- or moderate values of strains and fluid velocities. The rest of the model and representing bone, predicted low strain- and fluid velocity values.

Each studied load case representing normal activity predicted that certain areas of the stress fracture are under the influence of high values of strains and fluid velocities. They are of such magnitude that the stress fractures will not be able to heal.