Stress fracture at the anterior tibia: A finite element analysis of adaptive healing over time

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Stress fractures located at the anterior cortex of the mid-diaphysis of the tibia are particularly troublesome as they are prone to delayed or non-unions. Invasive treatments by the fixation of stabilizing plates externally on the tibia or by the insertion of a long nail into the medullary canal are often needed to achieve healing. These procedures require significant surgical intervention during the initial application. Removal of the implants often leads to discomfort for the patient. A successful, but less invasive, treatment method is therefore needed. This study evaluates a new potential method to treat this type of stress fractures.

In the new method a circular hole is drilled straight through the anterior cortex of the tibia at the site of the stress fracture. The induced hole may potentially decrease the local mechanical stimuli sufficiently to allow for healing of the fracture. This study evaluates the method by means of finite element analysis of the adaptive healing process over time using a poroelastic material model and a mechanoregulatory algorithm. The tissue differentiation process is assumed to be driven by the relative fluid velocity and the octahedral shear strain levels in the local tissue. Biological aspects of fracture healing are incorporated by modelling the migration of mesenchymal stem cells into the fracture site. Only the tibia is modelled and a load corresponding to normal gait is applied to the proximal end of the tibia while constraining the distal end.

The result of the simulated tissue differentiation process shows some indications of partial success of the new method, as the tissue in the drilled hole is predicted to differentiate into rigid bone tissue. However, complete healing of the part of the stress fracture which extends outside the region of the drilled hole is not predicted. The results from the study are preliminary and need further examination before any general conclusions can be drawn about the new treatment method.

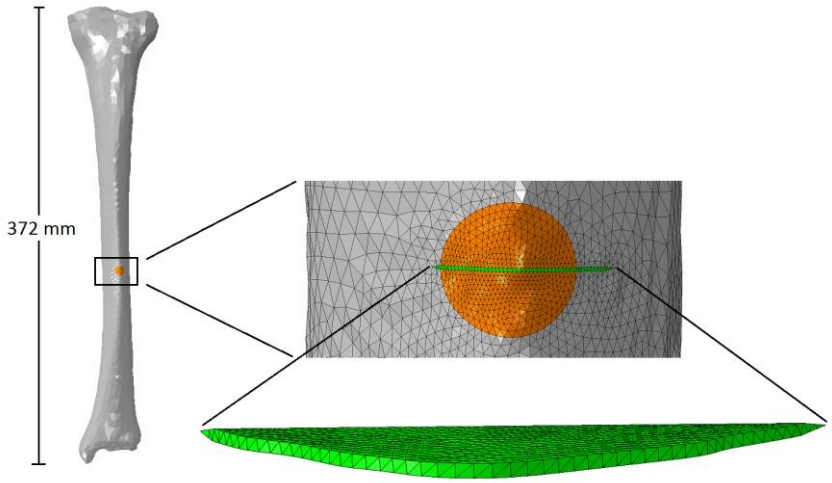

Figure: Anterior view of the FE-model of the tibia, with enlarged view of the drilled hole and the stress fracture crack.