Mechanical analysis of tibial stress fractures: A finite element study investigating the potential of a new surgical treatment

By: Emil Fågelberg

Tibial stress fractures at the anterior mid-diaphysis of the tibia are prone to delayed unions and non-unions. Surgical intervention, including nailing and plating, may be inevitable to achieve healing. Fracture healing is not fully understood, but biomechanical factors are known to be among the most important variables that controls bone repair. A biomechanical study of a new surgical method, which has been tested with promising results in a few patients suffering from stress fractures in the mid-diaphysis of the tibia, is presented in this thesis. In the surgical method, a hole is drilled through the crack into the middle of the bone.
The purpose of this work is to identify and quantify the key differences of the tibia pre- and post-surgery to increase the understanding of the potential success of the surgical method.

Finite element models of an intact tibia and a tibia with a stress fracture pre- and post-surgery are established using clinical CT images. The tibio-femoral bone to bone contact force is applied at the proximal head and the distal end is constrained to prevent rigid body motion. Orthotropic material properties are used for the cortical bone, whereas isotropic material properties are used for the trabecular bone and bone marrow. The stiffness of the intact model is validated against in vitro experimental data. A comparative study of the stiffness and stress intensities is done. The state of stress and strain in the granulation tissue in the fracture gap is studied and compared with tissue differentiation theories.

The results show a slight decrease of the stiffness of the tibia as a whole post-surgery. However, the risk of crack propagation remains unchanged, despite that the stress intensities increases in the portion of the crack that remains after surgery. The stresses and strains in the granulation tissue in the fracture gap decreases significantly post-surgery.

It is concluded that the key difference pre- and post-surgery is the state of stress and strain in the granulation tissue in the fracture gap. Before surgery, the strain and hydrostatic pressure in the fracture gap is not beneficial for fracture healing according to tissue differentiation theories. Hence, no bone will be formed. After surgery, the strain and hydrostatic pressure decreases significantly, leading more likely to formation of bone in almost the whole fracture gap.

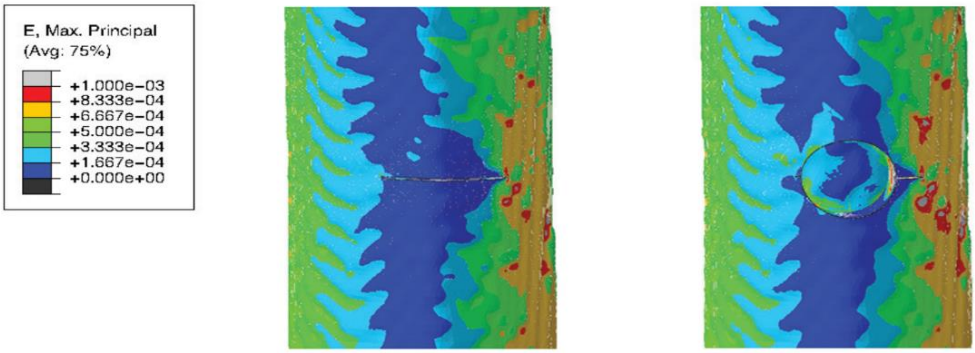

Figure: Maximum principal strain of the tibia with a stress fracture pre- (left) and post-drilling surgery (right) during the first peak of the tibio-femoral contact force.