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The stress distribution on Nailing and Bone during the Healing Process – A numerical model

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Background, Motivation and Objective

Intramedullary nailing has been used to fix broken bones by sharing the loads during healing process. In the early stage, of the inflammation phase, the intramedullary nailing is positioned and would be the only way to resist the load if it was applied. As long as the healing process progresses the fractured bone experiences a gradual growing of its stiffness, which in turn produces modifications in the stiffness ratio between intramedullary nailing and bone. Therefore, for this reason the healing process induces a continuous adjustment of the loadshare between intramedullary nailing and bone. The understanding of this loadshare evolution during the healing process and the resulting stress distribution in diaphyseal region of each parts, a finite element elastic model is proposed. The F.E. results can, at last, provide relevant information, for instance, to improve the intramedullary nailing design and application.

Methods

The commercial finite element ANSYS was used to implement a bone/nailing elastic model, with both, human femur and intramedullary nailing being modelled preserving their main characteristics. The loading case was picked from (Taylor *et al.*, Med Eng Phys. 1996 Mar;18(2):122-31) with four main forces localized at proximal femur: Joint Reaction, Abductors, Ilioopsoas and Ilio-Tibial Tract forces,as in Fig.1. Both materials, cortical bone and stainless steel, were treated as isotropic ones. The callus region, in a diaphyseal cross section, was chosen to present the stress distribution results for both bone and nailing parts. These results were presented for two phases: soft callus and hard callus.

Results

The principal results of this numerical approach were: the description of the evolution of the loadshare between bone and nailing set as the healing process evolves; and the resulting stress distribution for both bone and nailing set at callus region of a diaphyseal cross section. For bone it were provided longitudinal/principal stresses and for nailing it were provided both longitudinal/principal and von Mises stresses. In addition to usual F.E. output, with colour scale, it were implemented the utilization of paths to make the stress values available in a more accurate way, as it can be seen in Fig.2 and Fig. 3.

Discussion and Conclusions

The estimation of stress distribution evolution for both bone and nailing, at callus region, in a diaphyseal cross section; revealed the stress decayment in nailing cross section as long as the callus regions became stiffener but not in a significant way to guarantee the necessary load values to enable a successful healing process, confirming the utmost importance of the utilization of the nailing dynamization procedure.

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Keywords. Load Sharing; Healing Process; Stress Analysis; Numerical Model.

Figure 1 –Applied Forces

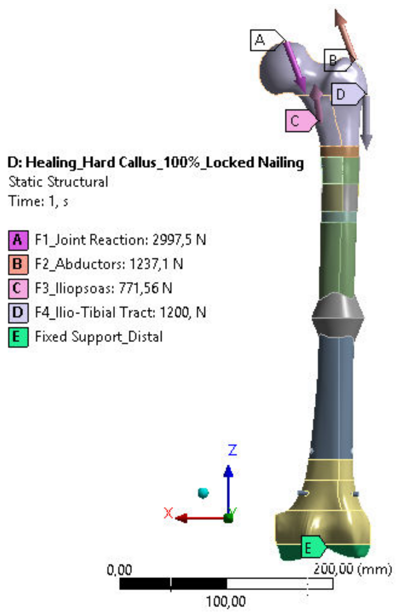

Figure 2 – Normal Stress – Path Hard Callus

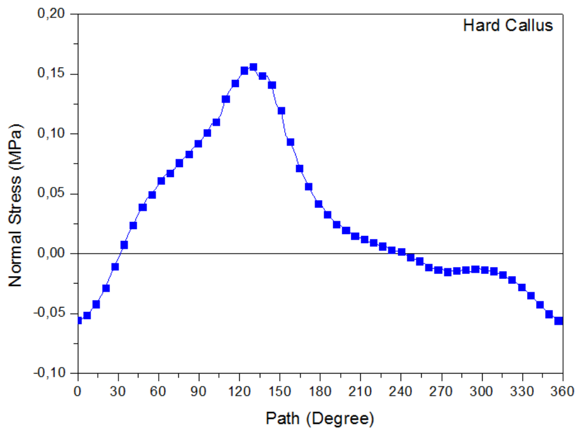

Figure 3 – Normal Stress – Nailing