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BOVINE BONE REMODELING ANALYSIS FOR VETERINARY APPLICATIONS

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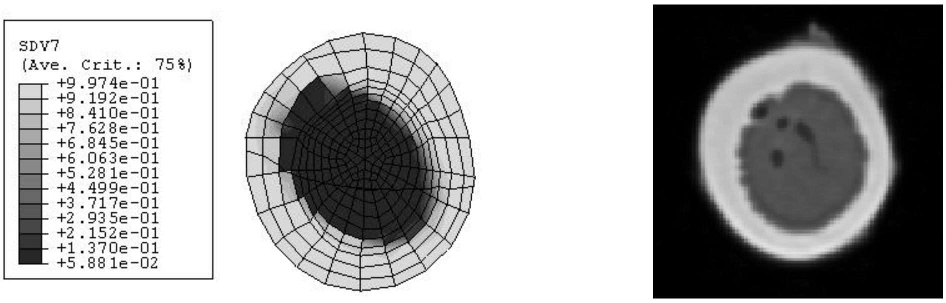
ABSTRACT

Remodeling is a biological phenomenon that is present in all the stages of development of bone tissue. Understanding how bone tissue adapts to a certain biomechanical environment is crucial for reliable computational simulations. The purpose of this work is to study the remodeling of a calf bone having in mind the development of an intramedullary interlocking nail for orthopedic veterinary applications. In fact, the treatment of fractures of bone diaphyses of large animals, such as horses and bovines, is still a challenge in orthopedic veterinary. The main products available are adapted from human devices and they are too expensive.

In this work, a computational remodeling model is applied to compare the performance of a polymeric nail with a conventional metallic implant. To achieve this, a three-dimensional finite element mesh of a bovine femur diaphysis is obtained, using a CAD-based geometric modeling pipeline that relies on computed tomography images [1]. Material properties, load and boundary conditions are provided to the model in order to perform biomechanical analyses using a suitable remodeling code [2]. In this study, the remodeling law results from the solution of an optimization problem that includes the structural performance and the metabolic cost to maintain bone tissue. It is assumed that bone adapts to the mechanical environment so that the stiffest bone structure for the given applied loads is obtained.

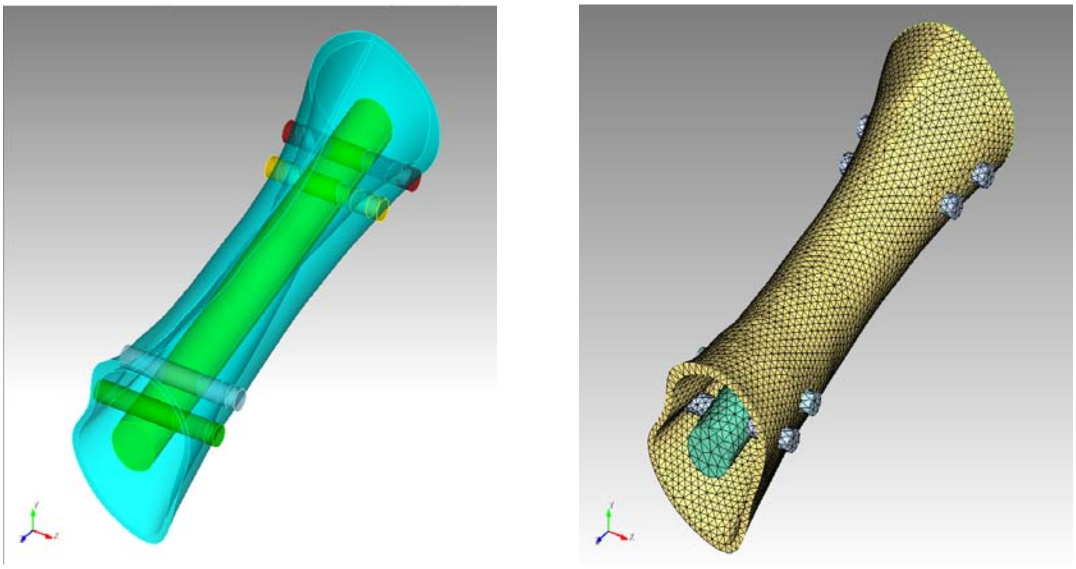
First a healthy bone is considered. The full cross section of the bone is discretized. The optimization analysis yields the density distribution of cortical tissue in the bone (Figure 1). The objective of this analysis is to calibrate the parameters of the remodeling code. Results show that the model reproduces morphologic features of a healthy bone, namely a peripherical distribution of cortical tissue. The first three outer layers of the cross section, shaded with a light grey color, contain elements with maximum density ($\cong 1$) corresponding to cortical tissue. The central region represents the bone marrow where the element density is near zero.



(a) (b)

Figure 1 – Cross section of the model (a), and corresponding bone section (b).

Then the implanted bone is analyzed. In this case, only the region of cortical tissue is considered. The bone is implanted with an intramedullary interlocking nail that is fixed with stainless steel screws (Figure 2). In order to choose an appropriate type of polymer, several analyses are performed with three different polymeric nails and comparison is made with results obtained with a metallic nail.



(a) (b)

Figure 2 – Geometric (a) and tetrahedral mesh (b) representations of diaphysis with the implant.

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