A COMPARISON OF REMODELING APPROACHES APPLIED TO AN IMPLANTED RAT TIBIA

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Introduction

Studies involving bone pathologies or prosthesis optimization are based on the understanding of bone adaptation to mechanical stimuli. Although several bone adaptive modeling laws have been proposed in the last decades, they have not been compared with the same test benchmark. For this purpose, the authors developed a coupled experimental-numerical analysis through which several models can be compared. Bone adaptation is investigated on an implanted rat tibia with external activation in order to mimic conditions seen in dentistry where implants are subjected to high external loads. The results of the numerical analysis involving three bone adaptive modeling laws are analyzed and discussed.

Methods

Two implants are housed in the proximal part of the tibia: the distal one is screwed bicortically while the second one is left free floating in the trabecular bone [Wiskott, 2012]. After two weeks of integration, an external load is applied to the implants' heads (1Hz, 900 cycles/day, 5 days/week, 4 weeks). At the end of the stimulation period the rat is euthanized and the implanted tibia is ablated. The specimen is scanned with a micro Computer Tomography (µCT) system to acquire 20µm resolution images and processed to obtain an FE model [Piccinini, 2012]. The remodeling laws proposed by Weinans [Weinans 1992] and by Rietbergen [Rietbergen 1992] along with a custom model based on octahedral shear strain are implemented in an iterative framework that updates the node-based bone density with respect to the measured mechanical deformation. Two maximum loads are considered: 5 and 10 N.

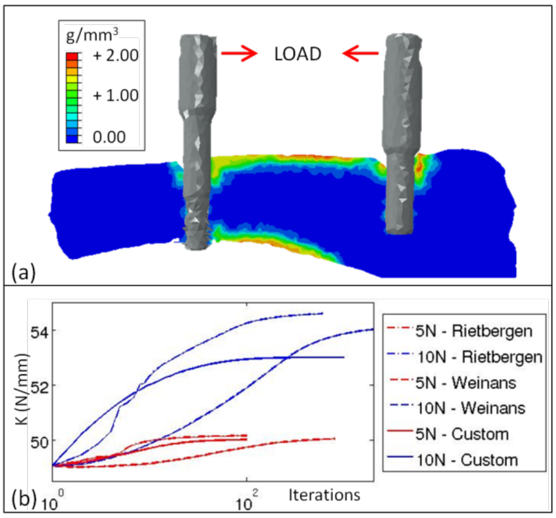

Figure 1: (a) local increase of bone apparent density (10N, Rietbergen model) and (b) Inter-Implant stiffness convergence trend.

Load	Weinans	Rietbergen	Custom
5 N	2.01	2.25	1.96
10 N	10.13	11.30	8.07

Table 1. Increase of Inter-Implant stiffness when convergence is achieved (percentage).

Results and Discussion

An example of local bone density adaptation is shown in Fig. 1(a), where the increase of density takes place mostly in the cortical shell. The trends of the inter-implants stiffness with respect to the iterations are represented in Fig. 1(b). The curves are different because the selected models propose a regulation of the tissue density that relies on different mechanical inputs and bone apposition rates. Table 1 summarizes the increase in stiffness calculated when convergence is achieved. The models' differences are highlighted in particular at 10N load. An experiment involving in-vivo µCT scans and different load-frequency conditions is in progress to further compare these numerical results.

References

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