IMPORTANCE OF LOADING CONDITIONS FOR MECHANOREGULATION IN A BONE DEFECT MODEL

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Introduction

Finite element (FE) modelling offers a solution to quantify the mechanical environment under different loading conditions at a bone fracture or defect site. However, in these models the complex in vivo biomechanical loading is often simplified to axial compression only. Neglecting the complexity of the in vivo loading may lead to an inaccurate prediction of the actual biomechanical environment. The goal of this study was to investigate the influence of realistic in vivo versus simplified axial loading on mechanoregulation stimulus values for an existing large defect model in the rabbit tibia [Bakker, 2008].

Methods

The FE model of a rabbit tibia (acquired from CT) with a custom-made unilateral fixator and scaffold placed in the defect was validated for axial compression (axial stiffness). Two different loading conditions were applied to the validated model: (1) the realistic in vivo loading [Grover, 2007] and (2) a simplified axial compression loading equal to the ground reaction force of rabbit hind leg. The mechanoregulation stimulus was based on Huiskes et al. [1997] and equals a linear combination of distortional strain and fluid velocity .

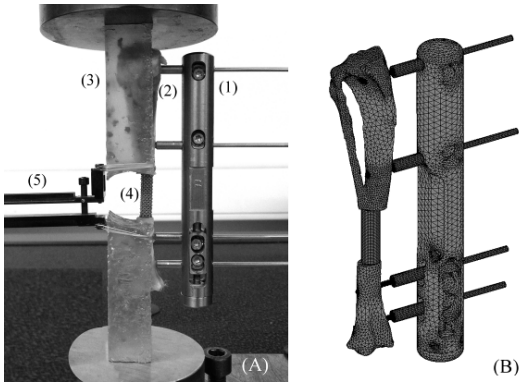

Figure 1: (A) Experimental set-up: fixator (1), rabbit tibia (2) embedded in epoxy resin (3) and titanium scaffold (4). The interfragmentary displacement was measured by means of an extensometer (5). (B) Corresponding FE model.

Results

The fluid velocity, distortional strain (normalised to threshold values) and mechanoregulation stimulus along the center line of the proximal surface of the scaffold in the anterior – posterior direction is shown in figure 2. Although the distributions are similar for both loading conditions, in vivo loading leads to 76% higher stimulus values on average. As a result, a smaller portion of the center line (30% decrease) encounters values that are supposed to favour (direct) bone formation (stimulus values less than 1).

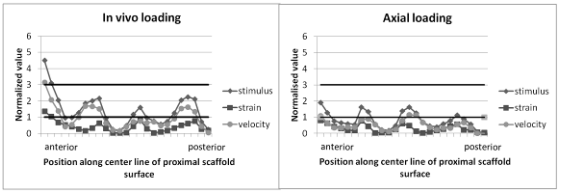

Figure 2: Mechanoregulation stimulus, normalized distortional strain and fluid velocity under in vivo loading and axial compression. According to Huiskes et al. [1997] stimulus values below 1 favour bone, values between 1 and 3 favour cartilage and values above 3 favour fibrous tissue.

Discussion

This study shows the importance of applying realistic in vivo loading in FE models for fracture or defect healing simulations. Simplified loading conditions may lead to substantial errors in the prediction of stimulus values and hence healing, which in turn is also key for scaffold design.

References

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