SHEAR LOADING IS MORE CRITICAL TO FRACTURE HEALING THAN AXIAL LOADING – A NUMERICAL STUDY

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Introduction

Secondary fracture healing processes are strongly influenced by interfragmentary motion [Pauwels, 1960; Einhorn, 2005; Carter, 1988]. Shear movement is assumed to be more critical than axial movement, however experimental results are controversial [Bishop, 2006; Augat, 2003]. Numerical fracture healing models allow to simulate the fracture healing process with variation of single input parameters and under comparable normalized mechanical conditions. Therefore, a direct comparison of different in vivo scenarios is possible. The aim of this study was to simulate fracture healing under several axial compressive, and shear movement scenarios and compare their respective time to heal. We hypothesize that under comparable normalized displacement magnitudes, shear strain is always more critical than axial loading.

Methods

A previous published numerical fracture healing algorithm was used which combines fuzzy logic with finite element methods [Simon, 2011]. An idealized geometry of an ovine diaphyseal transversal fracture was created. Within a predefined healing region the tissue composition changes over time depending on the local mechanical strain stimuli [Claes, 1999]. Numerous variations of the movement amplitude, the fracture gap size and the musculoskeletal loads were simulated for axial compressive and shear load cases. Thus, characteristic maps of healing times were created. To directly compare the different mechanical situations of axial compression and shear, a normalization of the local mechanical conditions (load and movement) within the gap was performed.

Results

For all different combinations, axial compressive movements led to shorter healing times than shear movements (Fig. 1). Direct comparison (i.e. interfragmentary loads and movements are equal) as well as comparison under normalized conditions (i.e. shear load is approx. 0.75 axial load, and interfragmentary shear movement is approx. twice as large as the according axial movement) shows that fracture healing under shear movements is always inferior to comparable axial compressive situations. Only under axial compression cartilaginous tissue was developed in several regions within the healing zone.

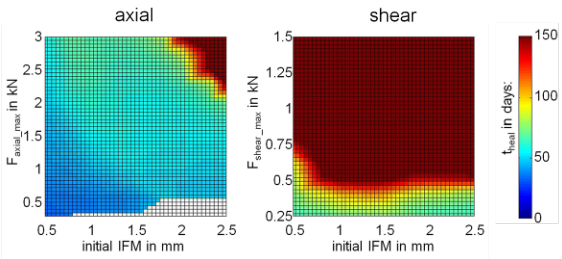

Figure 1: Characteristic maps of healing time under different axial compressive (left) and translational shear (right) combinations of interfragmentary load (y-axis) and initial interfragmentary movement (IFM – x-axis).

Discussion

In the present study we performed a numerical comparison of different isolated mechanical conditions acting on an ovine fracture site. For these cases we were able to confirm our hypothesis that shear movements are more critical for the fracture healing outcome in general. In contrast to shear situations, under axial compression the development of cartilage led to an early fracture stabilization which accelerated the healing process. Thus, from a pure biomechanical point of view, our findings suggest osteosynthesis implants to be optimized to limit shear movements under musculoskeletal loading.

References

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