INFLUENCE OF BONE SCREW CONFIGURATIONS ON BONE HEALING BIOMECHANICS USING LOCKING COMPRESSION PLATE FIXATION

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Introduction

Locking compression plates (LCP) are increasingly being used as effective internal fixation devices of long bone fractures. It is agreed that the configuration of bone screws influences the support provided at the fracture site and can hence directly impact the bone healing process [1]. Previous studies have investigated the efficiency of LCP plates in limited cases of long bone fractures [2]. This study aimed to develop an algorithm based on a meta-model analysis of finite element (FE) modeling that estimates optimal screw configurations using biomechanics. The precision medicine approach provided by the algorithm promises to improve surgical outcomes and sheds light on the biomechanics of bone healing.

Materials and Methods

An FE model of the distal anatomical LCP plate attached to fractured bone was developed to analyze the biomechanics of an internal fixation system using ABAQUS (V6.12-1) (Fig. 1). The geometry of the FE model was extracted from a CT-Scan of the right tibia (Male, 65 yr.). To simulate a transverse fracture in the distal region of the tibia, a 3mm gap was created and filled with soft callus membrane mimicking the early healing stage. Upon model validation, the screw configurations were iteratively changed (Fig. 2), and the inter-fragmentary displacement, stress in the fixation plate, bone, and callus membrane were analyzed. Using a direct-search optimization code, the optimum solution was obtained. The repeatability of the algorithm was validated by changing the fracture region in 5 simulated models and repeating the calculations.

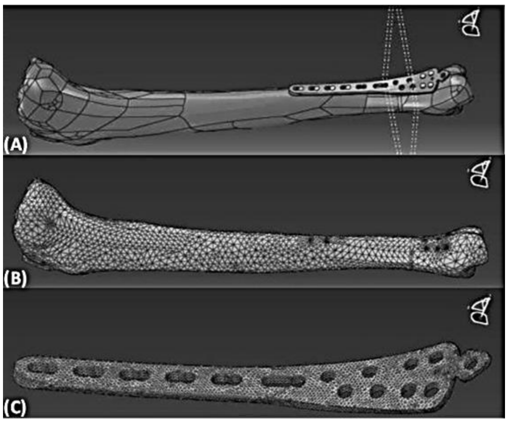

Figure 1: FE model of the distal anatomical LCP plate attached to the fractured bone.

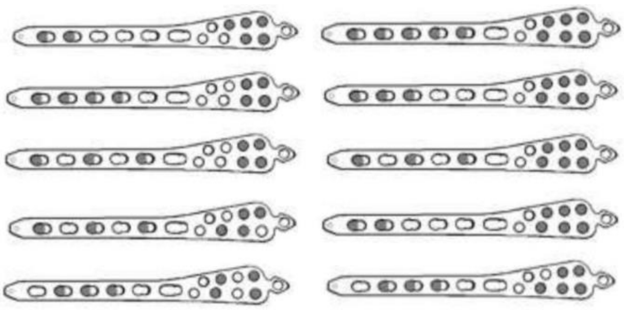

Figure 2: Samples of screw configuration for the optimization algorithm. Dark holes represent the positions of the screws.

Results

The ranges of stress and strain in the fixation plate and bone were well comparable with results from literature [3] confirming the validity of the FE model. The maximum Von Mises stress, axial, and shear displacement in the callus for optimal screw configuration were 3.68 (±1.04) MPa, 6.38×10-7 (±3.87×10-7) mm, and 1.25×10-4 (±0.56×10-4) mm, respectively for the 5 different fracture models. In alignment with literature, the results confirmed that the screws should be positioned as close as possible to the fracture gap on either side for optimal healing [4].

Discussion

The optimization algorithm developed in this study can be used by clinicians as a biomechanically driven quantitative guideline during the critical surgical planning phase and by the biomedical orthopedic device industry to inform design and manufacturing decisions. Future work is needed to improve the optimization criteria based on observed clinical and biomechanical outcomes from post-op patient data.

References

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