MECHANICAL BEHAVIOR OF EXTERNAL FIXATOR ON FRACTURE HEALING PROCESS

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Introduction

Succeeding a fracture of a long bone, there are multiple approaches to perform the bone fracture immobilization. The external fixation has traditionally been used under clinical indications, and can be a definitive option in cases where risks of infection are high. The currently used systems cannot predict or measure the complete bone consolidation [1, 2].

The purpose of the present study is to understand the phases of healing and to predict functional bone consolidation. This study was carrying out using the finite element analysis (FEA) to determine the influence of stress distribution along the tibia and the rods of the fixator. This information gathered by the present study is relevant to help medical and scientific communities to know the real fracture healing process.

Methods

In the present work, a model of the tibia (Synbone®) and an external fixator (Hoffmann 3) were selected. The 3D model of the tibia with a transverse fracture and the geometry of the external fixator were created (Figure 1). The length of the tibia was 387 mm and a fracture gap of 3mm was considered in the medial area. The geometry of the callus generated between the fracture gap was modeled as a disc with a diameter of 30 mm. The bone fracture healing was simulated considering different mechanical properties to the callus in the fractured region. The simulation begins before the formation of the callus, then the phases of healing was simulated as a four-stage process.

The simulations were conducted by the finite element method to evaluate stress distribution. The model was imported into FEA software Abaqus®, where each component of the system was defined in term of its mechanical properties: Young's modulus, Poisson's ratio and density. All materials were assumed to be homogeneous, isotropic and linearly elastic. The values used for the tibia, callus and each component of fixator are reported in the literature [2].

Two aluminum supports were created in the 3D model, allowing the tibial fixation and linear orientation. A set of axial loads ranging between 50 to 700 N were applied at the top of the aluminum base in the proximal extremity. The model was fixed at the lower surface of the aluminum base, i.e., in the distal extremity, with no displacement or rotation allowed in any direction. A linear static analysis was carried out to calculate the stress distribution in models.
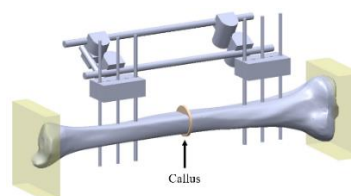

Figure 1: 3D model of the fractured tibia with the external fixator.

Results

Von Mises equivalent stress were chosen as parameter for the evaluation of the results. The model with a tibia fractured induced a high stress concentration in the rods. On the other hand, this stress concentration has a lower value when a disc with the mechanical properties similar to the tibia is considered. In this case, the transfer load is along the bone, as happen in final phase of healing.

Concerning to the fractured region, the results showed that stress distribution decreases with bone consolidation.

Discussion

FEA results indicate that fixation device provide a sufficient stability during the initial phase of the healing process, as well as some load transfer in the external fixation. This biomechanical characterization could provide a complete methodology to determine the state of union when a fixator is used in a long bone.

In order to validate the present FEA model, and also to evaluate the behavior between different phases of the healing process the authors predict to perform experimental tests on tibia, by inserting different materials on the gap of fracture. Moreover, the authors predict to solve the problem analytically by determining the neutral axis of the model.

References

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