VALIDATION OF A FRACTURE HEALING ALGORITHM ACROSS MULTIPLE FIXATION STABILITIES

George Morgan (1), Lucas Low (1), Arul Ramasamy (1,2), Spyros Masouros (1)

1. *Department of Bioengineering, Imperial College London, London, UK; 2. Academic Department of Trauma and Orthopaedics, Royal Centre for Defence Medicine, ICT Centre, Birmingham, UK*

Introduction

Despite improvements in fracture treatment, non-union rates persist and best-practices to avoid them remain debated. Specifically, the optimal surgical fixation method for distal femoral fractures remains unknown due to constraints of *in vivo* and *in vitro* trials, such as limited patient and surgeon recruitment capacity [1] and limitations of *in vitro* callus development. *In silico* trials have previously addressed these gaps in other areas [2]. Fracture healing algorithms, such as the Ulm Fracture Healing Model [3], simulate the progression of fracture healing and have been used to compare fixation methods and configurations. Chondrogenesis and ossification are modelled based on mechanical strain in the callus. A finite-element (FE) model calculates strains due to expected loading. A healing algorithm calculates updated material properties of each callus finite element. The simulation is performed iteratively.

Despite the progress of fracture healing algorithms, they have not been validated across different fracture geometries, healing metrics, and applied strains [3-4]. This study presents the validation of a fracture healing model against corresponding experimental data from literature [5] across 3 initial interfragmentary gap sizes and 2 initial interfragmentary strains (IFS).

Methods

An FE model was developed in MSC.Marc (v2021, MSC Software) of a simple transverse mid-diaphyseal metatarsal ovine osteotomy secured with an external fixator with a pre-defined callus domain. A 40 mm long section of the fracture region was modelled. The external fixator was represented as an axial spring according to design criteria of the original experiment [5]. An axial compressive load of 500 N was applied.

A fracture healing algorithm was developed based on a modified version of the Ulm Fracture Healing Algorithm [3-4]. 6 initial fracture conditions were simulated, representing the experimental conditions of Claes et. al. (Table 1) [5]. Simulations were run for 56 iterations, representing 56 days.

Group	Gap size (mm)	Strain (%)
A	1	7
B	1	31
C	2	7
D	2	31
E	6	7
F	6	31

Table 1: Different combinations of gap size and allowed IFS simulated, matching published experiments [5].

Bending stiffness of the simulated facture region at the final iteration was assessed using an *in silico* four-point bending rig. The bone fragments were extended in length to match the experimental conditions [5].

Results

The simulated bending stiffness of the callus region at 8 weeks for groups A-F were 19.8, 19.7, 19.8, 1.8, 18.5, and 0.3 N mm^{-1}, respectively. These results are compared against experimental data in Figure 1 [5].

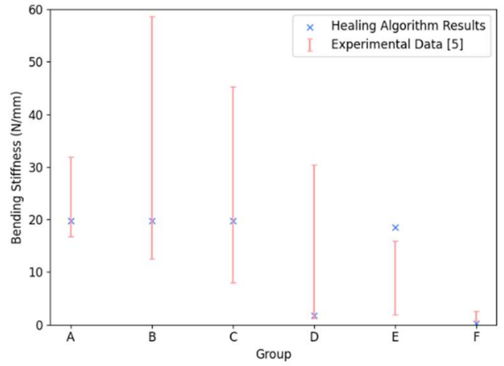

Figure 1: Bending stiffnesses the callus regions at 8 weeks post-op compared against corresponding experimental results measured by Claes et. al. [5].

Discussion

The simulated callus bending stiffnesses at 8 weeks post-op fall within the corresponding published experimental values [5] for Groups A, B, C, and F. However, the negative effect of high strain is over-stated (Group D) and the negative effect of large initial gap size is under-stated (Group E).

This study demonstrates an initial validation for four of the six simulated fracture configurations. Discrepancies between the presented model and experimental data will be addressed with a sensitivity study of the model.

References

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