A Novel Inverse Finite Element Analysis to Assess Bone Fracture Healing in Mice Receiving Bone Marrow Mesenchymal Stem Cell Transplantation

J.A. Weis, F. Granero-Moltó, T. Myers, A. Spagnoli, and M.I. Miga

Approximately 10-20% of the 6.2 million annual bone fractures in the US result in fracture healing failure, causing significant morbidity and mortality. This has led to significant research efforts towards enhancing the fracture repair process. However, functional assessment of the fracture repair process has proved difficult. Bone fracture calluses are inhomogeneous, irregular materials and this complexity has led to considerable uncertainty in the assessment of biomechanical property improvement or impairment during various therapeutic interventions and genetic models of pathological fracture healing. We present a novel approach using an inverse problem methodology to improve upon biomechanical property assessment of healing bone fractures through material property estimates for the fracture calluses. Briefly, our approach includes acquisition of microCT image volumes, biomechanical testing, finite element mesh generation, and an iterative optimization (using finite element analysis) of the fracture callus material property that minimizes the error between the observed and predicted biomechanical testing data. Using this approach, we have analyzed bone fracture healing from mice at 14 and 21 days post-fracture (an active healing phase) either receiving or not receiving a therapeutic transplantation of bone marrow mesenchymal stem cells (MSC) immediately after fracture. We found a statistically significant increase of ~2-3 fold in the elastic modulus of mice receiving MSC transplantation as compared to mice not receiving MSCs at 21 days post-fracture ($p < 0.05$).