
Bone Fracture Prediction: From Experimental Determination of Material Properties to Phase Field Model Implementation

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Abstract

Bone fracture prediction by CT-based finite element analysis based on maximum principal strain criterion can predict fracture initiation load within 80% accuracy (conservative prediction) (1). It cannot predict the crack path which may also be of interest for clinical application.

Phase Field Models (PFMs) may improve bone fracture predictions (2), however, PFM predictions are highly influenced by the heterogeneous critical Energy Release Rate (ERR) , critical ultimate stress and Young modulus of the bone.

To improve fracture initiation and crack path predictions in human long bones by PFM we apply numerical-experimental methods to determine the material properties of bone tissue so to be used in conjunction with CT-based FEA. We firstly focus on the femoral cortex and failure in transverse direction (perpendicular to osteons).

Human fresh frozen femurs were CT-scanned to obtain bone density along the femur, then sliced to create three point bending specimens in which crack like defects were inserted. These specimens were then micro-CT scanned before loaded to fracture.

Using standards designed for metals and concrete, we computed the critical Stress Intensity Factor () through a three-point bending test setup combined with Digital Image Correlation (DIC). This allowed us to establish a qCT-based correlation for , which was validated using PFM and FEA. Additionally, fracture experiments on unnotched bone specimens were conducted to estimate the critical strain through DIC measurements and the results were compared with data available in the literature.

Preliminary FE results are presented to investigate the influence of the newly computed material properties on the fracture loads of human humeri and femurs.

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