A CT-Based Limit Analysis Approach for Collapse Prediction of Human Proximal Femur

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Abstract

This study promotes a computational framework that integrates Limit Analysis theory with patient- specific Computed Tomography (CT) imaging to estimate the collapse load of the human proximal femur. Unlike conventional finite element models, that often require complex post-elastic constitutive assumptions, the proposed method focuses on predicting the onset of the femoral failure using the static theorem of Limit Analysis. The approach employs an iterative numerical procedure that redistributes stresses through successive elastic analyses until a plastically admissible stress state is achieved. CT data are utilized to reconstruct femoral geometry and to derive density-dependent strength parameters for cortical and trabecular tissues via empirical relationships. A sensitivity analysis evaluates the influence of different compressive strength– density correlations on collapse load predictions. Validation against experimental data from a cadaveric femur demonstrates that the method provides reliable lower-bound estimates of femur collapse load, particularly when exponential-type strength–density relations are adopted. The findings highlight the potential of this approach to deliver clinically relevant insights into femoral fracture risk while reducing the need for extensive material characterization. Although preliminary and limited to a single loading condition, the obtained results suggest that CT-based Limit Analysis could serve as a practical tool for human fracture risk assessment. Future ongoing work will extend the methodology to alternative loading scenarios and more accurate strength characterization to enhance the overall predictive accuracy and clinical applicability of the method.

Keywords

Collapse human proximal femur prediction, Patient-specific modeling, CT-based Limit analysis.