Characterization of femoral nonlinear behavior through patient-specific CT-based FE modeling

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Abstract

Pathological bones are characterized by a significant loss of mechanical integrity and, therefore, by an increased fracture risk. Understanding the failure mechanisms in the human femur is essential to develop clinical strategies for preventing fracture. Engineering methods integrating finite element (FE) modeling techniques with patient-specific diagnostic imaging such as Computed Tomography (CT) have allowed an increased understanding of the mechanical features and failure mechanisms of the femur. However, the most of the FE procedures have considered femur as an isotropic linearly elastic material, neglecting any damage and irreversible effect (e.g., yielding-like response). During daily activities, the femur is subjected to cyclical loadings, leading to damage accumulation that is a significant factor associated with fracture [1]. As a result, the bone stress-strain response is characterized by a highly nonlinear behavior with softening state beyond a certain yield level. Thus, the characterization of the realistic femur response under functional loading requires more sophisticated modeling techniques. The present work aims to include a non-linear constitutive model in CT-based FE modeling of femur for comparing and contrasting strain and stress patterns arising in femur structures under functional loads. The femoral solid model was reconstructed from CT images and discretized via unstructured mesh. The femoral constitutive response was described via an ideal elasto-plastic behavior, characterized by a softening part when local strain exceeds a certain value. Local elastic and plastic properties were set in agreement with CT-based Hounsfield Unit (HU) distribution [2]. Compressive functional loadings were considered. Stress and strain patterns arising in the femur were computed and compared to those obtained using linearly elastic constitutive model. By using the proposed nonlinear constitutive model, stress and strain patterns resulted significantly different to the linearly elastic case. The study suggests that the inclusion of nonlinear constitutive laws may enhance our understanding of bone failure risk and the fracture load prediction. That is an essential requirement for developing preventive treatment strategies against fracture in pathological bones.

Keywords: **Computational modeling, bone non-linear constitutive response, femur biomechanics.**

References

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