COMPARISON OF PHANTOM-BASED AND PHANTOMLESS CT CALIBRATION ON FE MODELS TO PREDICT HIP FRACTURE

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Introduction

Finite element (FE) models built from computed tomography (CT) images have largely been employed as digital twins to predict bone fracture [1] [2]. These models rely on the definition of elastic properties assigned heterogeneously to the bone based on the CT Hounsfield Units (HU). This involves primarily the assessment of a HU-density relation through a calibration procedure. Traditionally, that is done by placing a calibration phantom inline or scanning it offline with the same CT parameters. However, a phantom-based calibration might result rarely feasible in the clinical practice. In this perspective, CT phantomless calibration, i.e., a calibration performed taking advantage of the patient's tissues visible in the CT, could represent a viable alternative. This study aimed to compare the outcomes of CT-based FE models developed from phantom-based and phantomless calibration procedures.

Methods

This study was based on a cohort of 101 women aged 55 years or older (mean age of 68 years) with CT scans available from Rizzoli HipOp collection. The CT images were calibrated adopting phantom-based and phantomless procedures as explained in the following. The phantom-based calibration involved scanning the European Spine Phantom, consisting of 5 components with varying densities. Average HU values were computed for each component, and a linear regression performed against the known densities. The phantomless calibration instead was based on the methodology reported in [3], where air, adipose, and muscle tissues were employed to carry out calibration using reference density values (ρ_{QCT}) of -840, -80 and 30 mg/cm^3, respectively. A custom MATLAB script allowed to select a 9 slices-wide region of interest (ROI) centred at the middle point between the femoral head and knee centres, and which included air, adipose, and muscle tissues. The reference HU values for selected tissues were extracted by identifying the peaks from the HU distribution within the ROI and patient-specific calibration lines identified through linear regression between the HU and known ρ_{QCT}. For both methods, Young's modulus was assigned elementwise (*Bonemat*, IOR, Bologna, Italy) using validated density-modulus relationships [4] [5]. The FE simulations run (Ansys Inc., PA, USA) replicated a sideways fall loading scenario: a 1000N load was applied at femur head centre and a rigid frictionless contact plane perpendicular to the load direction was created at the greater trochanter. Twenty-eight different FE simulations were performed varying the femur's impact pose [2]. Principal strains (tensile: ε_1; compressive: ε_3) were considered to compare the two calibration procedures.

Results

Principal strains comparison between the two calibration procedures is shown in Fig. 1 for one of the impact poses simulated (femur aligned to its own anatomical reference system). Average relative differences of 5.8% for ε_1 and 5.45% for ε_3 were found. Considering all the impact poses, average differences of 5.68% (ε_1) and 5.52% (ε_3) were obtained.

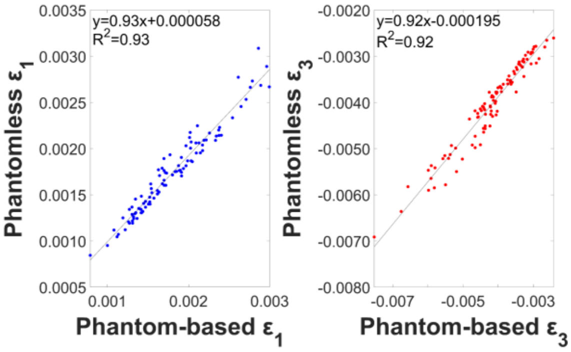

Figure 1: Highest ε_1 (left) and lowest ε_3 (right) values got from the phantom-based and phantomless FE simulations for the whole cohort.

Discussion

This study compared FE outcomes obtained from a CT phantomless calibration with those coming from a phantom-based calibration. A good agreement was found between the two, which encourages, when needed, the adoption of phantomless calibration. A reliable and standardized phantomless calibration procedure might in fact support the use of opportunistic CT images to implement digital twins solutions.

References

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