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DIGITAL VOLUME CORRELATION OF THE OSTEOARTHRITIC FEMORAL HEAD, A VALIDATION TOOL FOR COMPUTATIONAL MODELS

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The application of micro-finite element (μFE) analysis to biological structures such as bone is used extensively to estimate full field displacement and strain distributions under various loading conditions. Previously, validation of such models was restricted to deformation or strain comparisons at the surface, or to predictions of structural properties. However, the evolution of digital volume correlation (DVC) has enabled full-field measurement of local deformations. The DVC method is not without its own limitations; to understand the uncertainties of a given approach, it is recommended that the DVC output is quantified on a known deformation field, (i.e. zero-load)[1]. The aim of this study was to evaluate the uncertainties in computing the strain fields within an entire human femoral head using two known deformation fields, namely a zero-load, and virtually deformed load condition.

An osteoarthritic femoral head excised during a total hip replacement was analysed. Repeated microCT scans (isotropic voxel size of 39μm) under zero load were performed. Images were rigidly registered, (Amira, v6.1) and three volumes of interest (VOIs) were defined representing regions containing different bone micro-structures. For the virtual compression a uniaxial compression of 5% was induced to the second scan. A deformable image registration toolkit (BoneDVC)[2] with an isotropic grid-size of 50 voxels was applied to the images, and was used to compute the displacements and strains at grid nodes. For every node the average of the absolute value of the six components of the strain tensor (eAvg) was computed. The standard deviation of the error (SDER) was computed as the standard deviation of the eAvg over all the nodes. Moreover, the standard deviation of the Cartesian components of the displacement (SDdx, SDdy and SDdz) was computed over all nodes.

SDER was below 900με for all VOIs, allowing discrimination between yielded and non-yielded regions[3]. SDER ranged from 280 to 330με for the zero load case, increasing up to 770με when the virtual compression was applied. SDER was lowest for the VOI that was fully contained within trabecular bone. Uncertainties in displacement below 9.61 μm (0.004 voxels) were found for the zero-strain analysis in all Cartesian components.

These preliminary results show that the DVC method with nodal spacing of 50 voxels can be used to validate the displacement output of μFE model for the osteoarthritic femoral head and provides acceptable uncertainties to identify the regions deformed above yield.

REFERENCES

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