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INVESTIGATING METHODS OF MODELLING AUGMENTATION IN HUMAN LUMBAR VERTEBRAE

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Summary: There are an estimated 65,000 osteoporotic vertebral compression fractures reported annually in the UK, with 27% of women over 70 years of age affected globally. Vertebroplasty is a method of treating such fractures, however, questions about the efficacy of the procedure have been raised. The aims of this study are to accurately model the bone-cement interface, validate augmented models against experimental data and to understand the effects of patient and procedure variation on the mechanical outcomes of vertebroplasty.

Fourteen cadaveric lumbar vertebrae were μCT scanned, tested, augmented, rescanned and retested in the laboratory. Finite element (FE) models were generated to understand the effect of variation in vertebral structure and geometry, and variations in procedure, for example cement fill volume and location. Models were made pre-/post- augmentation in order to understand and capture the mechanical response to vertebroplasty. An accurate description of the bone-cement interface was an important factor in modelling augmentation, hence, different approaches were investigated: a yielding material interface, representing trabecular bone partially captured in injected cement, a reduced Young's modulus, representing the air-gaps created from cement shrinkage, and using image registration combining the structure and material properties from pre-/post- augmentation. Validation of the models was achieved through a comparison of the computational and experimental stiffness.

The results indicated good agreement for non-augmented models between computational and experimental stiffness (Concordance Correlation Coefficient, CCC = 0.85). The method developed here reduced the scanner dependence on the material properties of models and increased the definition of the internal bone structure, while keeping the computational cost benefits of 1 mm3 voxel size models. The methods investigated for modelling augmentation and specifically modelling the bone-cement interface, suggested simple descriptions of the injected cement were not enough to provide an accurate representation of vertebroplasty. An improved agreement was observed when using registered images of pre/post augmentation scans for augmented models along with using more sophisticated material properties.

This study will allow further work to investigate the effects of vertebroplasty over larger quantities of vertebrae to assess the effects of patient and procedure variations.