EXPERIMENTAL VALIDATION OF FINITE ELEMENT MODELS OF CERVICAL FUNCTIONAL SPINAL UNITS

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Introduction

The complex motion and geometry of the spine in the cervical region make it difficult to determine how loads are distributed through adjacent vertebrae or between the zygapophysial (facet) joints and disc. Whilst finite element (FE) models allow these distributions to be investigated, the models need to be demonstrated to be robust. The objective of this study was to develop a method to validate specimen specific FE models of functional spinal units (FSUs) using local measurements as well as the overall stiffness**.**

Method

Three FSUs were excised from three-year old ovine spines from within the cervical region. Small markers were then affixed to the facet joints to track motion. The vertebrae were mounted in PMMA cement. Another marker disc was fixed to the upper PMMA surface to indicate the position of load application for the experiments and the corresponding FE models. The specimens were then µCT imaged (µCT100, Scanco, Switzerland).

Prior to testing, the facet joint capsules were cut, allowing a thin film pressure sensor (6900, Tekscan, USA) to be positioned between the cartilage surfaces. The specimens were then tested under axial compression, using a materials testing machine (Instron 3365, USA). A loading rate of 1mm/min was applied, and halted after 2mm of deflection had been reached. Photographs were taken at every 0.5mm of deflection using a digital camera.

To determine the material properties of the disc, the specimen was then retested following removal of the posterior elements and facet joints. The microCT image data was used to create specimen specific FE models of the FSUs. The models were generated using image processing and meshing software (ScanIP, Simpleware, UK). Bone material properties were determined by the image grayscale obtained from the µCT [Tarsuslugil, 2010]. Cartilage material properties such as friction and Young's modulus were varied to investigate the models sensitivity to these parameters. The intervertebral disc was assigned material properties in the form of nine engineering constants [Elliot, 2001] following a process of tuning specimen specific FE models (without posterior elements) to the corresponding experimental data.

Results

Load displacement data from a single specimen is presented in Fig. 2. The optimum value for friction coefficient for the cartilage interaction (μ_c) was 0.05, this corresponds well to values found experimentally for cartilage on UHMWPE [Chan, 2011].

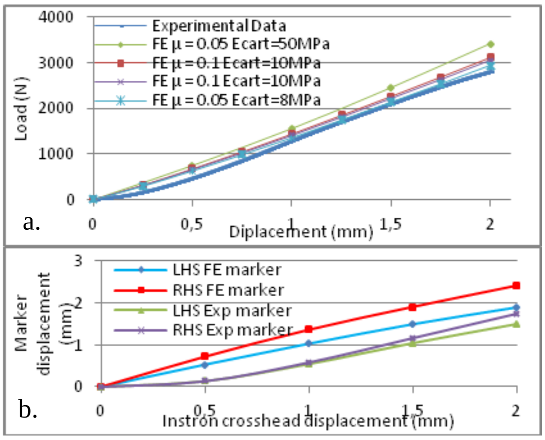

Fig. 2a) FE vs. Experimental data showing model sensitivity of E_{cart} & μ_c. b) FE predicted vs. experimental marker position (E_{cart}=50MPa, μ_c=0.2).

Discussion

The models appeared to be more sensitive to the Young's modulus of the cartilage surface compared to the friction coefficient. Models predict the overall stiffness of the FSU and marker location well. Further investigation is required to apply this modelling technique to additional specimens in order fully validate the methodology.

References

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