A SUBJECT-SPECIFIC ANALOGUE MODEL FOR SPINAL MOTION SEGMENTS

Constantinos Franceskides (1), Emily Arnold (1), Ian Horsfall (1), Gianluca Tozzi (2), Peter Zioupos(1)

1. Cranfield University, UK; 2. University of Portsmouth, UK

Introduction

Human cadaveric tissues are incredibly variable and difficult to preserve [1], thus making frequent biomechanical testing with these materials challenging. Available funds and ethical procedures will also limit their availability [2]. Due to these restrictions, animal bone models are often used. However, as all biological tissues, those models present variable mechanical properties depending on a number of factors [3]. For the above reasons subject-specific analogues are very attractive, particularly in the field of forensic and injury biomechanics. The analogue proposed in this study was 3D-printed from micro-CT (Computed Tomography) dataset of real bone, through generation of a 3D model. Both cadaveric and analogue segments were mechanically tested in axial compression. And surface displacement was computed via digital image correlation (DIC). The proposed protocol has the potential to be applied in the prediction and modelling of bone behaviour.

Methods

A porcine spine was obtained where four motion segments from the thoracolumbar region were de-fleshed and sectioned into a single motion segment, four intervertebral disc segments and six vertebral bodies. The samples were scanned in a micro-CT (Nikon Metrology XT H225 at $75Kv$, $95\,\mu A$ and $500\,ms$ with a resultant voxel size of $0.062\,mm$) and reconstructed using CT Pro 3D. A stereolithographic type file (.stl) was created by importing the CT volume file (.vol) into Scan IP for further 3D image data analysis. All analogue components were printed with a Stratasys uPrint SE 3D printer using ABS*plus*-P430 material. All intervertebral disc segments were formed with PT Flex 70 material. A speckle pattern was applied to all samples for Digital Image Correlation (DIC) analysis, with speckle size ranging from 0.35 mm to 6.35 mm in diameter. The optimal speckle size was 3 – 5 pixels [4], calculated to be 0.78 mm – 1.3 mm. An Instron 5567 fitted with a 10 kN load cell was used to compress each sample at a quasi-static strain rate of 0.1 on vertebral discs and 0.05 on vertebral bodies. All samples were subjected to a 10 N preload before compression to reduce contact errors. DIC data were collected with two Phantom High speed cameras (V1212 and V2010 with Nikon 50 mm f/1.4 lenses) recording at 100fps. Analysis of data captured was done with ARAMIS, GOM at a facet size and point distance of 11 and 9 pixels respectively.

Results

The proposed method produced VB analogues that were similar in stiffness to cadaveric vertebral bodies, as shown in Figure 1.

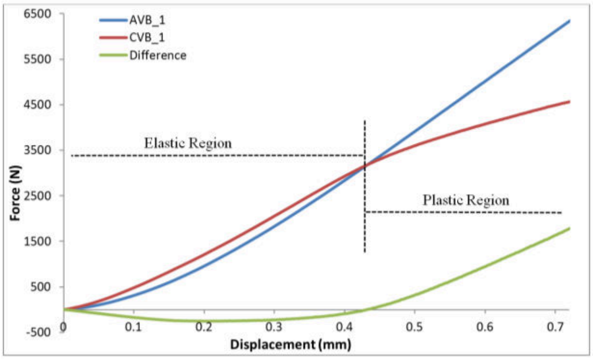

Figure 1: Elastic-plastic loading variation in vertebral body loading (AVB-Analogue Vertebral Body; CVB-Cadaveric Vertebral Body; Difference from the two profiles – AVB-CVB)

The polyurethane chosen for the intervertebral disc analogue was significantly less stiff than the cadaveric samples. DIC data reported comparable stiffness for cadaveric and analogue motion segment samples. The intervertebral discs were significantly stiffer than the vertebral bodies, though cadaveric intervertebral discs deformed noticeably less than analogue intervertebral discs.

Discussion

The preliminary results highlighted that further work should be conducted on the stiffness of the motion segment by varying the polyurethane making up the intervertebral disc. Polyurethane of a higher Shore hardness should produce a motion segment with higher overall stiffness. Facet joints loading should also be considered with the addition of a cartilage analogue.

Following achievement of correct stiffness of analogue vertebral discs and motion segments the method may be applied to create human spinal motion segment analogues.

References

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