MECHANICAL PROPERTIES OF 3D PRINTED INTERVERTEBRAL DISCS FOR AN ACTUATED CERVICAL SPINE MODEL

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Introduction

Degenerative cervical myelopathy (DCM) is the primary cause of spinal cord impairment in adults, with increased prevalence in ageing populations [1]. However, long-term management strategies for DCM remain to be fully understood, which motivates the development of an actuated model of the cervical spine (C1-C7) with an accurate range of motion (ROM) and physiological behaviour. Intervertebral discs (IVD) lie between vertebrae from C2 downward, enabling spinal movement. Consequently, this study aims to replicate the mechanical properties of IVD for different age groups using additive manufacturing. This would enable the accurate biomechanical replication of age-specific cervical spine models tailored to individual patients.

Materials and Methods

VarioShore thermoplastic polyurethane (TPU) printed using fused deposition modelling (FDM) and Stratasys Vero using PolyJet 3D printing were investigated. TPU samples were manufactured at temperatures from 200°C to 240°C in 10°C intervals, and flow ratios f from 0.6 to 0.9 in 0.05 increments. Stratasys Vero samples were produced at Shore hardnesses ranging from 30A to 95A. All samples were manufactured at a print speed of 50 mm/s and a layer height of 0.20 mm. Compression tests were conducted on 10 mm diameter by 50 mm gauge length samples at 1 mm/min, based on the ISO 604:2003 [2], using an Instron 5965 series, as depicted in Figure 1(a). The compressive modulus E_c is assessed using the least squares methods [2], while the uncertainty is based on the methodology of [3].

Results

Figure 1(b) presents the variations in compressive modulus for TPU as a function of print temperature for a range of flow ratios, and Stratasys Vero as a function of the shore hardness. These are compared to the compressive modulus of IVD given by [4] for multiple age groups. TPU discs were printed at a temperature of 220°C and flow ratio of 0.75 for the actuated model of the cervical spine presented in Figure 1(c) to match the average patient age in the cadaveric testing of [5]. The model also features variable stiffness pneumatic actuators [6] to replicate the effects of DCM.

Discussion and Conclusions

While Stratasys Vero covers the range of compressive moduli needed to capture all age groups, its high cost (12 times higher than TPU) would only make it viable for young patients, statistically less likely to suffer from DCM. Consequently, TPU has been identified as a suitable material to replicate the compressive properties of IVD, with temperature and flow ratio allowing to tailor the modulus to yield patient-specific properties. These findings provide novel insights to support the development of cervical spine models for the DCM and may contribute to identifying better management and personalised treatment strategies.

References

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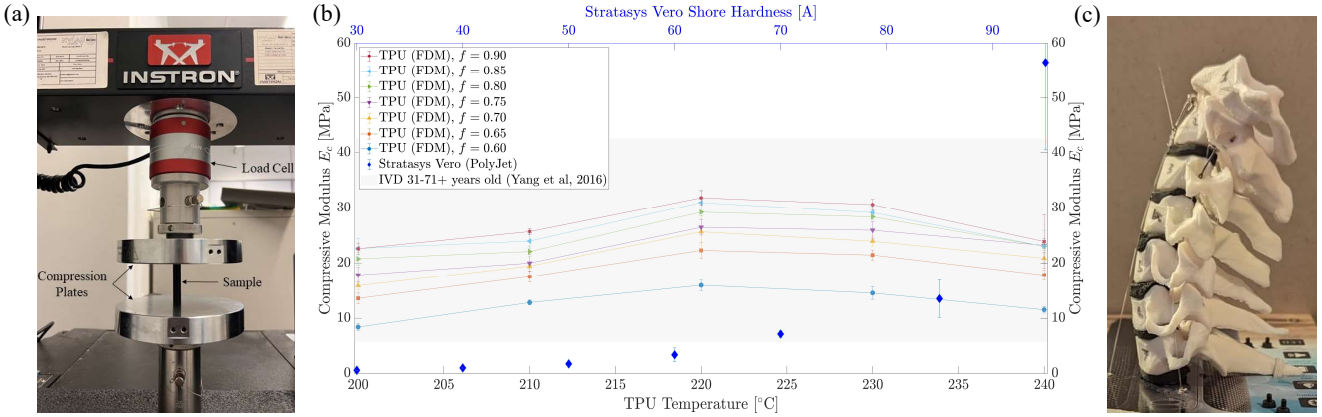

Figure 1: (a) Experimental setup; (b) compressive modulus; and (c) actuated model of the cervical spine.