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Additive manufacture of a spine surrogate for assessing injury risk during under-vehicle explosions

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Abstract

Introduction

Spinal injuries sustained by occupants during under-vehicle explosions were common in recent conflicts [1]. Mitigation technologies are currently assessed using Anthropometric Test Devices (ATDs) which are designed to respond biofidelically to external loading [2]. The transmissibility of load through these devices is of paramount importance to accurately assess injuries. Currently, the design of the spine in these devices is particularly crude. Recent advances in additive manufacturing offers the opportunity to create anatomically accurate representations of the spine. Therefore, the aim of this project was to additively manufacture deformable representations of the human intervertebral discs (IVDs) that match the stiffness of a human IVD such that they could be used in an ATD.

Methods

Geometries were obtained through segmentation of CT scans of a human lumbar motion segment. Stainless steel vertebrae were manufactured using a ConceptLaser system (Lichtenfels, Germany) and IVDs were printed in a flexible polymer using a Prusa i3 (Praha, Czech Republic). As the required stiffness of the IVDs was not known, a number were manufactured with varying wall thicknesses (1-4mm) and infill percentages (10-60%).

Experiments were carried out on one human cadaveric motion segment (L3-L4, 26 years), and sixteen additively manufactured IVDs. The experimental setup was the same for both human and additively manufactured samples and involved axially compressing samples at a strain rate of 0.1/s to a maximum strain of 15%. Force was measured using the servo-hydraulic machine’s inbuilt load cell.

Results

A close match, regarding force-displacement behaviour, was found up to a displacement of 1mm between the human sample and the additively manufactured sample with a wall thickness of 4mm and an infill percentage of 10% (Figure 1).

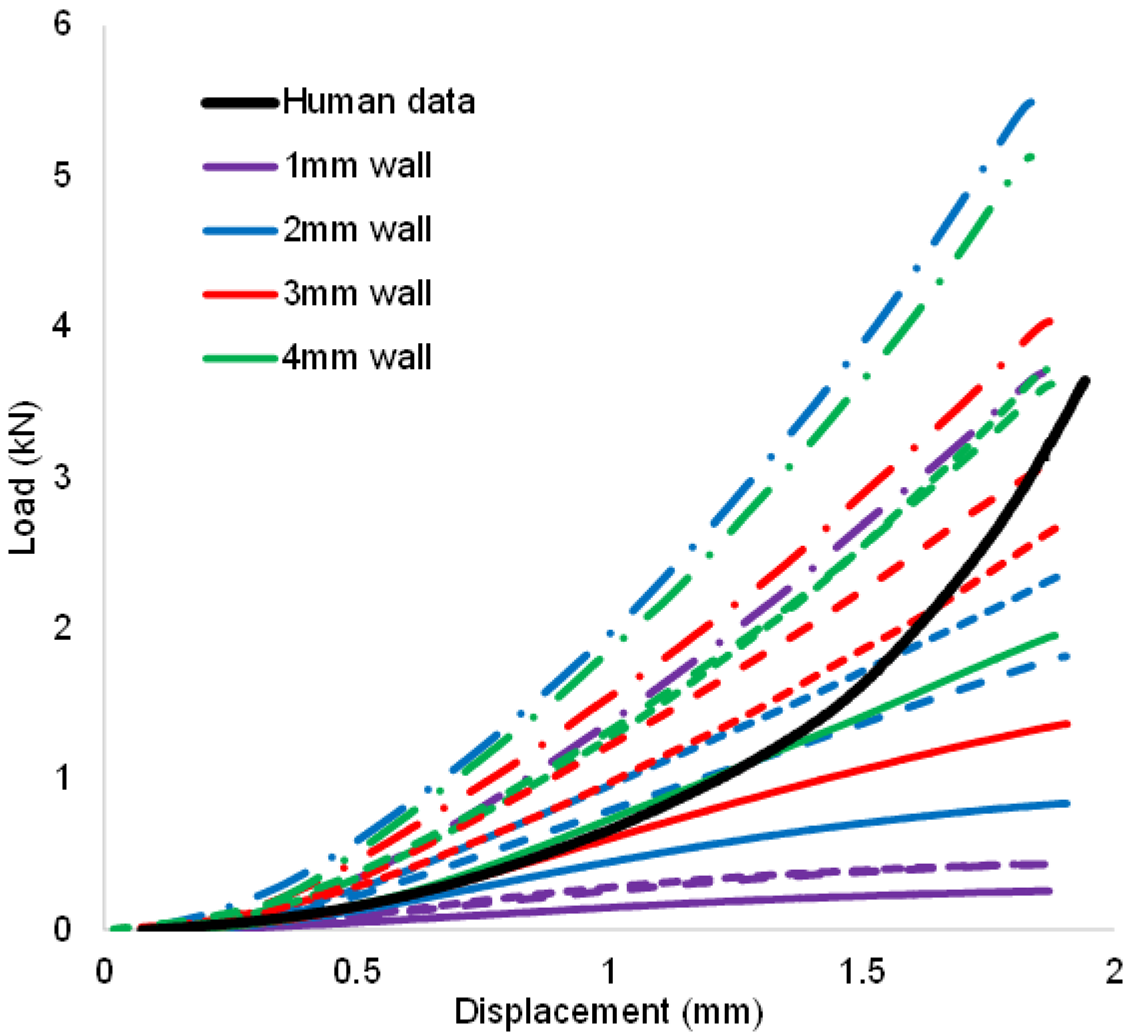

Fig.1 Load-Displacement curves for the human and 3D printed samples. Each colour represents a wall thickness. Solid lines represent 10% infill, dashed lines represent 20% infill, dotted lines represent 40% infill, and long dash-dot lines represent 60% infill.

Discussion

The response of the human IVD was able to be replicated by additively manufactured IVDs up to a displacement of approximately 1mm. After 1mm of displacement, the rate of increase in stiffness was considerably greater in the human sample in comparison to the additively manufactured sample. Increasing the wall thickness, and infill percentage both increased disc stiffness. Future work is required to capture the non-linearity of the human disc response with additively manufactured representations.

References

1. Schoenfeld, A.J. et al. (2013). *J. Trauma Acute Care Surg*, **74**(4), p1112–1118.

3. North Atlantic Treaty Organisation HFM-148/RTG (2011).