MACRO- AND MICROMECHANICAL PROPERTIES OF HUMAN AND BOVINE ANNULUS FIBROSUS

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Introduction

The literature on intervertebral disc mechanics is vast, both because of its contribution to spinal biomechanics and, from a clinical perspective, its role in disc degeneration and spinal deformities such as scoliosis. The bovine tail disc is often used as an animal model because of its similarities in shape and structure to human disc. While several studies compared disc mechanics in different species, direct comparison between cow tail and human disc has been neglected [1].

In this work, the macromechanical properties and micromechanical behavior of *annulus fibrosus* were measured in human and bovine samples through combined mechanical testing and second harmonic generation microscopy.

Methods

Seven patients undergoing spinal fusion were included in this study (56±15 years old). The anterior portion of the L5/S1 (n=6) or L4/L5 (n=1) degenerated disc was excised, and strips of *annulus* (11mm x 6mm x 2mm thickness) were cut along the circumferential direction. When possible, sequential strips were cut at increasing depths through the *annulus* so, in total, twenty strips of annulus were tested. Using a similar procedure, twenty strips of *annulus* were prepared from tail discs of cows obtained from the abattoir.

Samples were strained using a purpose-made apparatus in 1 % steps at 1 mm/min speed until 6 % strain. Load was measured with a 20 N load cell; elastic modulus at 6% strain was calculated from stress-strain curves. The apparatus was mounted on the stage of a microscope configured for second harmonic generation imaging [2], which revealed collagen organisation with sub-micron resolution. Image analysis, using custom written Matlab software, allowed the calculation of intra-bundle and inter-bundle strains.

Differences were analyzed with Mann-Whitney non-parametric test (α – 0.05). Results are reported as median [1st quartile, 3rd quartile].

Results

The elastic modulus at 6% applied strain was 2.8 [2.0, 5.0] MPa in degenerated human *annulus* and 3.0 [2.5, 4.8] in cow tail; the difference was not significant ($p = 0.88$, Figure 1). Inter- and intra-bundle strains were lower in human than in cow tail annulus, but the differences were not significant ($p > 0.05$). Intra-bundle strain was lower than inter-bundle strain both in human ($p = 0.0001$) and in cow tail ($p = 0.0004$).

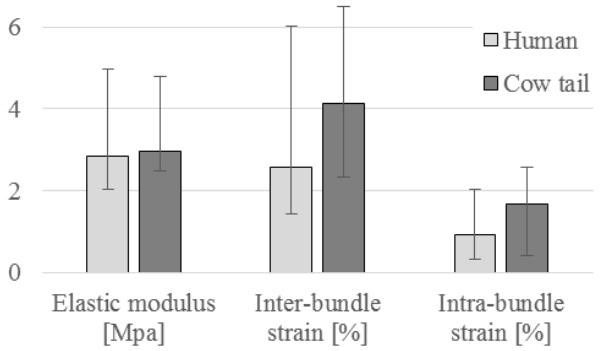

Figure 1: Comparison of macro- and micromechanical behavior between human and cow tail annulus fibrosus. Differences between species were not significant ($p > 0.05$).

Discussion

Human and cow tail *annulus* showed micro-structural differences, the most striking being the absence of collagen crimp and less distinct boundaries between bundles in human annulus.

Intra-bundle strain represents the lengthening or shortening of bundles of fibers forming the lamella. Inter-bundle strain represent the relative movement of these bundles (towards or away from each other). These strains were significantly higher than the strain within the bundles, as observed previously [2-3]. Both inter- and intra-bundle strain were higher in cow tail, suggesting that microstructural rearrangement is more important in healthy cow tail than in degenerated human disc, albeit not significantly although elastic moduli were similar.

In conclusion, cow tail *annulus* is confirmed to be a good model for human disc in terms of macroscopic mechanics, but its structure and micro-mechanical behavior present some differences which may be important in some studies.

References

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Acknowledgements

This work was supported by the Henry Smith Charity and facilitated by the NIHR Exeter Clinical Research Facility for human sample collection.