ROYAL ACADEMY OF ENGINEERING
Panel for Biomedical Engineering

Young researchers futures meeting

Engineering for orthopaedic applications

On the inter-lamellar behaviour effect in a finite element model of the annulus fibrosus

Mengoni M.[1], Wijayathunga V.N. [1], Jones A.C. [1], Wilcox R.K. [1]

As presented by: Mengoni M., University of Leeds

1 Institute of Medical and Biological Engineering, University of Leeds, Leeds, UK

m.mengoni@leeds.ac.uk

Introduction

A realistic virtual model of the inter-vertebral disc (IVD) can give insights into the significance of deformation patterns of the IVD in its naturally loaded configuration as well as post-trauma or interventions. The structural behaviour of the Annulus Fibrosus (AF) depends on its lamellar architecture and the interaction between the lamellae [1]. This study aim was to compare different computational approaches for the inter-lamellar behaviour.

Methods

A geometrical model of a mature ovine IVD was used, assuming the annulus is composed of concentric lamellae. Considering the nonlinear behaviour of the collagen fibres, an anisotropic hyperelastic model was chosen for the lamellar tissue [2] and calibrated against ovine data [3]. Axial compression was simulated applying 10% strain. A 750kPa pressure at the internal surface of the AF accounted for the nucleus deformation. Four modelling assumptions were tested for the inter-lamellar behaviour: fully bonded, sliding contact, Coulomb friction, and delamination. The bulk response was quantified as the change of AF thickness along its circumference. A model with a homogeneous AF was used as baseline. In this case, two fibre directions were defined at each point.

Results

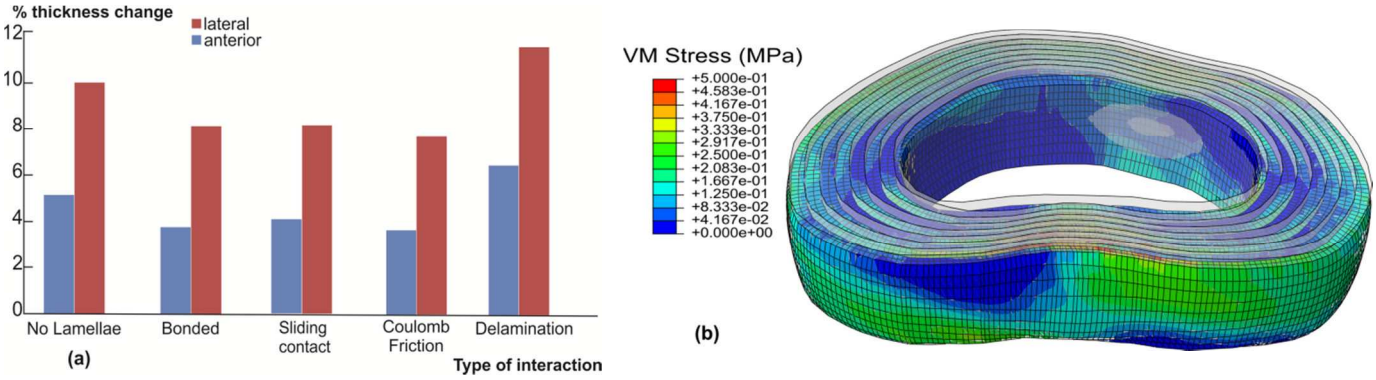

Figure 1: (a) change in annulus thickness at two locations; (b) stress map for the Coulomb friction case.

Inclusion of the lamellae in the model along with classical contact formulations reduces the thickness change (Figure 1 a) due to loading. The type of friction behaviour does not have a significant effect on the thickening of the AF but show distinct shear bands at the lamellar interfaces (Figure 1b). However, inclusion of possible separation of the lamellae increases the expansion of the AF under compression.

Discussion

The overall behaviour of a homogeneous AF is significantly different from a model including separate regions, even if these are bonded together. Moreover, inclusion of the inter-lamellar behaviour, particularly allowing delamination, increases the differences in the overall bulge of the disc. In the future, including validated inter-lamellar behaviour will enhance our ability to theoretically represent the inter-vertebral disc mechanics.

Funded by: WELMEC, a Centre of Excellence in Medical Engineering funded by the Wellcome Trust and EPSRC

References

[1] Mengoni et al, 2013, “Structural Modelling of the Annulus Fibrosus - an Anisotropic Hyperelastic Model Approach at the Lamellar Level” Proceedings of the 3rd International Conference on Computational & Mathematical Biomedical Engineering, pp 162-165
[2] Holzapfel et al, 2000, “A New Constitutive Framework for Arterial Wall Mechanics and a Comparative Study of Material Models”, Journal of Elasticity, 61, pp 1-48
[3] Schmidt et al, 2013, “Is the ovine disc a small human one? A finite element study” Journal of Mechanical Behaviour of Biomedical Materials, 17, pp 229-241