EFFECT OF FACET JOINT DEGENERATION ON SPINAL UNIT BIOMECHANICS

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Introduction

Facet joints contribute to the motion and stability of the spine. They are small cartilaginous synovial joints and with ageing, present with osteoarthritis [1]. While of importance in assessing the effect of spinal treatments, they are understudied and the mechanical effect of their degeneration is not well understood [2].

In this study, we used imaging and computational modelling data to assess the effect of different features of facet joint degeneration: cartilage thinning, joint calcification and changes in synovial fluid lubrication.

Method

First and following ethical approval, donated human posterior elements of the lumbar spine were imaged with HR-pQCT at an isotropic resolution of 44 microns. A total of 16 posterior elements from 5 spines (ages 42 to 83) were imaged. The images were segmented to isolate the cartilage by direct thresholding and semi-manual correction, computing the cartilage thickness, volume, and the volume of the calcified regions.

Then, a generic finite element model of a L3-L4 functional spinal unit (FSU) was used to assess the effect of degeneration features on the FSU apparent stiffness in axial compression, on the ratio of load going through the facet joints, and on the mean facet joint contact pressure. The model consisted of one FSU, where the bone was simplified as homogeneous and linearly elastic and the disc tissues as incompressible isotropic hyperelastic materials (annulus with a Yeoh model, and nucleus with a Mooney-Rivlin model) [3]. The cartilage and contact behavior of the joint were modelled using a soft contact interaction with bi-linear pressure-overclosure representing the cartilage thickness and its modulus followed by a contact penalty. Baseline values representing a "healthy" joint were a thickness of 0.5 mm, cartilage apparent modulus of 1.6 MPa and frictionless behavior [2]. These three parameters were systematically altered to generate 13 simulations with different degeneration features: thickness decreased to minimum 0 mm; modulus increased to maximum 2.4 MPa; and friction increased to maximum 0.9. A final model of fused facet joints was developed with a rough contact and no cartilage thickness. Models were completely fixed on one side and submitted to 1 mm axial compression (free rotations) centered posterior to the vertebral body.

Results

The image analysis demonstrated that all facet joints had some degeneration, with calcification present in all joints from 1% of the cartilage volume to 40% calcification.

The computational study showed that biomechanical changes in cartilage thickness alone is different to changes due to a combination of degenerative features (Fig. 1). Including the increase in calcification (through an increased apparent tissue modulus) and in friction, the stiffness of the FSU increases more than with a decrease of thickness alone, and is accompanied by a decrease of the force going through the facet joints but a larger change in contact area, leading to an increase of mean contact pressure.

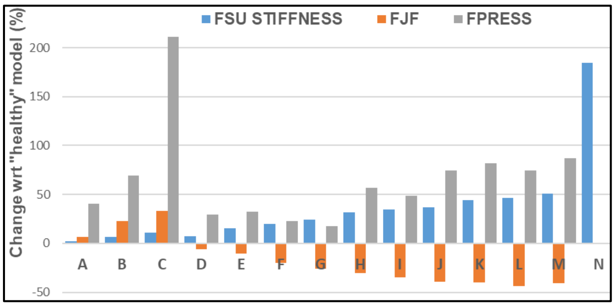

Figure 1: Effect degenerative features (models A to C with decrease of thickness only, D to M with combined features; model N fused) on the FSU biomechanics. Changes w.r.t. baseline "healthy" model (FJF= facet joint force, FPRESS=mean contact pressure).

Discussion

Features of facet joint degeneration with osteoarthritis (cartilage thinning and calcification) were found to occur simultaneously. When incorporating into a computational model of a generic FSU, facet joint degeneration was found to have a significant effect on the FSU biomechanics. While this computational model was not validated for each of the degeneration cases, its baseline behavior was similar to that found in the literature [4]. Combined with previous studies analyzing the effect of joint-specific anatomy on the biomechanics [1], this work demonstrated the importance of including specimen- or patient- specific information of the facet joint when assessing FSU biomechanics.

References

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