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MODELLING THE FAILURE MECHANISM OF THE ANNULUS FIBROSUS

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Introduction

A number of surgical techniques in the intervertebral disc, such as needle puncture during nucleus replacement, discography, or simple annulus suturing, can cause direct or progressive damage leading to degeneration. The aim of this study was to assess the damage and failure strength of the anterior annulus fibrosus (AF) under radial tension with the goal of including damage in in-silico models of interventions.

Methods

Twelve discs were extracted from frozen mature ovine thoracolumbar spines. Cuboid AF specimens were dissected and divided into three groups: outer AF (N=6), inner AF (N=8) and specimens across the AF thickness (N=12). Tensile radial tests were performed at 1mm/min and load was recorded. The mechanical behaviour of the specimens was defined by the linear modulus, stress and strain values at occurrence of damage, initial local failure and macroscopic failure.

A 1D variable-stiffness spring model was designed to replicate the damage part of the experimental data. Springs were assembled in series representing the lamellae or the inter-lamellar connections. Each spring was given an initial stiffness value derived from a linear model [Mengoni et al., WCB2014]. The damage variation was computed for each group of specimens with an optimization process to minimize the difference between in-vitro and in-silico stiffness.

Results

Significant differences were found between the outer annulus group and the other groups for the stress at which apparent damage or failure occurred. No significant difference was observed within each group between the stress at the occurrence of first failure and at macroscopic failure.

The optimization converged to damage values reproducing the sample stiffness within 10% of the experimental value. At a given strain level, the predicted damage of the lamellae was higher than that of the inter-lamellar connections.

Discussion

The experimental data suggests that, in radial loading, the annulus has an almost linear behaviour up to about 20% strain followed by a modulus decrease until the first instance of local failure. Several local failures follow at similar stress levels before macroscopic failure. The in-silico results show the lamellar damage is predominant in the damage mechanism of the samples. In conclusion, this study demonstrated that damage can be adequately modelled using 1D variable-stiffness springs, and this approach can now be applied to models of the whole annulus to examine clinical interventions.