A NEW VISCO-HYPERELASTIC-DIFFUSION MATERIAL MODEL FOR INTERVERTEBRAL DISCS
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Introduction
Biomechanical investigations of human tissues and cartilages have greatly helped to improve people’s health over the last several decades. The study of cartilage’s underlying mechanical characteristics is a key issue for its successful application and integration in the human body. Based on experimental tests and on cartilage histosstructural data, including fiber orientation, a suitable material model is developed. This allows us to numerically study the mechanical behaviour of an intervertebral disc, consisting of a cartilaginous ring surrounding a fluid core. Herein, we present a three dimensional finite element (FE) model an intervertebral disc under various loading conditions. The paper concludes with a detailed description of the process simulation and a comparison of its results with experimental data.

Methods
To study the behavior of an intervertebral disc, several experimental tests were carried out in a bioreactor with a tempered nutrient solution. This ensures a steady nutrient supply to the intervertebral discs over a long period of time [Stoffel, 2012]. The observed results characterize the material’s hyperelastic ([Gasser, 2006] and [Holzapfel, 2010]), viscoelastic and diffusion properties. Consequently, the continuum framework is based on the additive split of the stress rate as

$$\dot{\sigma} = \dot{\sigma}^{h} + \dot{\sigma}^{ve} + \dot{\sigma}^{d}$$  \hspace{1cm} (1)

into hyperelastic $\dot{\sigma}^{h} = C \dot{\varepsilon}$, viscoelastic $\dot{\sigma}^{ve} = \dot{\bar{C}} (\dot{\varepsilon}) \dot{\varepsilon}$, and diffusion $\dot{\sigma}^{d} = -D_0 \dot{\varepsilon}$ parts. Here, $C$ and $\dot{\bar{C}}$ are tensors of hyperelastic and viscoelastic coefficients. Additionally, the diffusion parameter $D = D_0 + D_1 \varepsilon_\nu$ is defined to be dependent on the volume strain $\varepsilon_\nu$, where $D_0$ and $D_1$ are the parameters which should be verified by experiments. An implicit numerical solution algorithm to calculate the stress increment is implemented into ABAQUS via a user material subroutine UMAT.

Results
To see the merits of the proposed approach, we determine the stress on the intervertebral disc of a sheep (Fig. 1). We make a compression test on a sheep’s intervertebral disc in a bioreactor to validate the numerical results (Fig.2).

Figure 1: Distribution of the stress on a sheep’s intervertebral disc.

Figure 2: Compression test on a sheep’s intervertebral disc in a bioreactor

References