INTERVERTEBRAL DISC BEHAVIOUR UNDER AXIAL COMPRESSION, EX VIVO EXPERIMENTS AND IN SILICO MODELLING

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Introduction
The Intervertebral Disc (IVD) is an heterogeneous cartilage, that ensures rachis mobility and optimal stress redistribution between vertebrae. These two main properties are linked to both the hydric content and the in a natural process throughout life. This degenerative process is in some case accelerated, leading to the Degenerative Disc Diseases (DDD) or troubles. The diagnosis of DDD is difficult during the earlier stage of the disease since conventional imaging methods, like CT-Scan or MRI, do not provide quantitative information about the internal structure of the disc. The use of spin density weighted MRI technique in our study, enabled the determination of the porosity in porcine IVDs by the means of simple mechanical assumption and different geometric conformations of the IVD. For this purpose we realized ex vivo stress relaxation tests of IVD in a MRI device. By the use of inverse method, results are exploited to determine, a set of mechanical parameters of the disc according to a poroelastic model.

Methods
Description of the Mechanical test bench
The device (fig 1) was made from non-magnetic materials so as to operate in an intense magnetic field environment. The humid chamber that contains the disc is placed at the center of a 4.7-Tesla horizontal superconducting magnet [(47/30 Biospec Avance; Bruker, using a proton RF coil: RF RES2001H; Bruker BioSpin)]. Spin density-weighted imaging with Multi Slices Multi Echo sequences is used to investigate the water content in the IVD.

Parameters identification using Inverse Method
We used Mimic (Materialise) software, to reconstruct the IVD volume. The mean gray value of the disc volume is computed for each stage of the relaxation test. Assuming the disc is an incompressible media the water content of the disc, or disc porosity, $\varphi$, is related to the dilatation $J=V/V_0$ and to the porosity $\varphi_0$ in the stress free reference configuration by following relation:

$$\varphi = 1 - \frac{1-\varphi_0}{J}$$ (1)

Measuring $\varphi/\varphi_0$ and $J$ by MRI allowed us to compute $\varphi_0$ by using a golden section search minimization algorithm.

A 3D FE poromechanical model (Magnier 2009) was also used to compute the optimal permeability, elastic modulus and Poisson coefficient that fit the experimental data.

Results & Discussion
Figure 2 shows the evolution of the ratio $\varphi/\varphi_0$ for three porcine IVD within relative dilatation.

For the minimal stretch ratio used (min $\lambda_z=0.9$) the IVDs expelled more than 10% of its water content with a strong internal rearrangement including significant movements of water from the nucleus pulposus to the external annulus. The biphasic FE 3D model with the optimal set of mechanical parameters, is able to reproduce the IVDs behaviour, despite a very simple approach.

Reference
Fackson et al, Eur Spine J, 2008, 17 : 432–440