Cracking intervertebral disc herniation

Cracking Intervertebral Disc Herniation

Famke Kraaijeveld, Jacques M. Huyghe and Frank P.T. Baaijens
Eindhoven University of Technology, Department of Biomedical Engineering

Introduction

During intervertebral disc (IVD) degeneration global (osmotic) pre-stress decreases, while chance of an injury increases. This is a paradox. Is it then genetically driven? No, mechanics must play a role.
Materials like tissues endure instability during swelling or shrinking [2]. This can lead to localization [6] and therefore fracturing. We believe this is the cause of intervertebral disc (IVD) herniation during degeneration and not just genetics or chance.

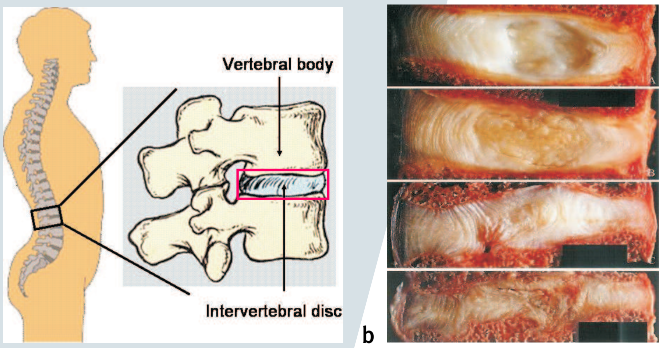

Figure 1: *a) Schematic of IVD position. b) Different stages of IVD herniation: A: Grade I (15-40) years; B: Grade II (35-70) years; C: Grade III (Male 31) Annulus bulging into nucleus; D: Grade VI (Male 31) Internal collapse of annulus*

Objective

We hypothesize that existing cracks open and propagate under decreasing osmotic pressure, i.e. global decrease of pre-stress. [3,4] This will be tested by FE simulations on a small piece of annulus (see figure 2).

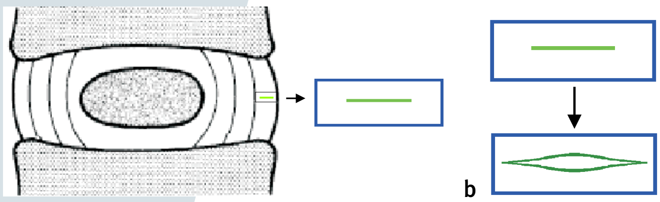

Figure 2: *a) Schematic cross-section of IVD; calculation domain is a part of the annulus. b) Opening and growth of crack under decreasing osmotic pressure*

Materials and Method

Materials

Lanir's theory [3] is used to represent the bulk behavior. Shear faulting (*mode-II*) causes high pressure gradients which are approximated by jumps $[\mu^f]$ (see also fig. 4).

Opening of the crack (*mode-I*) causes fluid flow into the crack (μ^f_Γ). This balance of mass can be derived from figure 3.

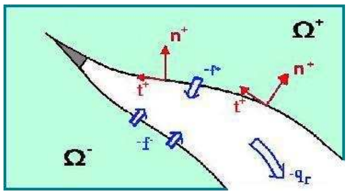

Figure 3: *Schematic overview of forces (t) and fluid flow (f and q_Γ at crack*

In figure 4 the total distribution of chemical potential is given for arbitrary (mixed-mode) loading, so with both $[\mu^f]$ and μ^f_Γ.

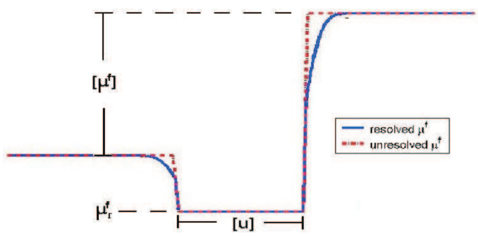

Figure 4: *Chemical potential distribution: jumps approximate high gradients, luid flow into the crack goes with.*

Method

Partition of Unity (PU-FEM) is used.[1] This method is mesh-independent. Total behavior is separated into bulk behavior and crack behavior. The crack behavior is included by increasing the degrees of freedom of the nodes and not by additional (interface) elements.

Future Work

The FE formulation will be implemented at TU Delft for the MMCM cooperation. The FE formulation is validated partly by comparison with analytical solution [3]. Different damage laws will be compared. Having proof of principle, crack propagation through a disc will be investigated (see figure 5). Then IVD herniation is cracked.

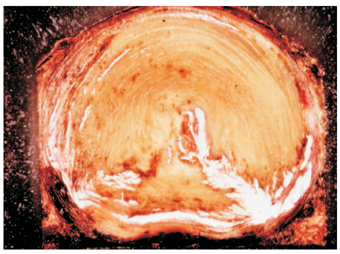

Figure 5: Idea for simulation: a radial crack followed by delamination annulus.

References

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