Tissue engineering of intervertebral disc

C.C. van Donkelaar, J.M.R.J. Huyghe, F.P.T. Baaijens

Eindhoven University of Technology,
Faculty of Mechanical Engineering,
Section Materials Technology,
P.O. Box 513, 5600 MB Eindhoven, the Netherlands

Introduction

Intervertebral discs are flexible parts that connect vertebral bodies in the spine (Fig 1). Disc pathologies (Fig 1, right) are a severe social and economical problem for which no appropriate treatment exists. Available prostheses do not restore normal function, and problems with respect to fixation and joint stiffening occur. New approaches are encouraged.

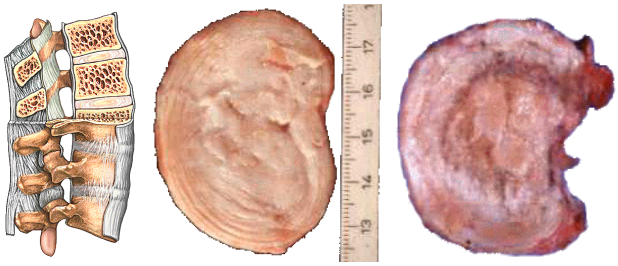

Figure 1: Part of the spinal column with 4 intervertebral discs (left). Cross-sections through healthy (middle) and degenerated (right) intervertebral discs show distinct pathological changes.

The advances in tissue engineering are such that a tissue engineered disc is within reach. An advantage is that a disc has neither innervation nor vasculature. This poster explains why successful disc tissue engineering importantly depends upon the scaffold material used.

Disc constitution

A disc contains a gelatinous nucleus, surrounded by a fibrous lamellar annulus. Both contain a matrix of negatively charged proteoglycans (PG), entangled with collagen fibers (Fig 2 & Table 1).

	water (% ww)	collagen (% dw)	PG (% dw)	Cells (% dw)
nucleus	80-90	30	50-60	0.5
annulus	60-70	50-60	20	1

Table 1: Constitution of an intervertebral disc (ww=wet weight; dw=dry weight). Note the low cell density.

A remarkable difference with all other tissues is the biochemical environment of the cells (Table 2).

	Disc	Plasm
Na^+	210-450	140
K^+	7-11	5
Cl^-	70-110	140
Osmolality	350-440	280-310

Table 2: Differences in electrolyte concentration and osmolality (mmol/l) between the environment of disc cells and other cells.

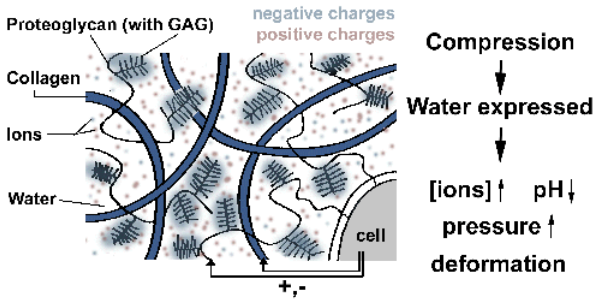

Figure 2: Schematic view of the disc matrix (left) and an example of the interaction between electrical, chemical and mechanical effects (right).

Cell-matrix interaction

Cells respond to their continuously changing electro-chemo-mechanical environment (Fig 2) by building or breaking down matrix components. These changes are significant as a disc looses 20% of its water diurnally. Because of the peculiar matrix composition and the low cell density, the cell-matrix interaction is delicate for maintenance of matrix properties.

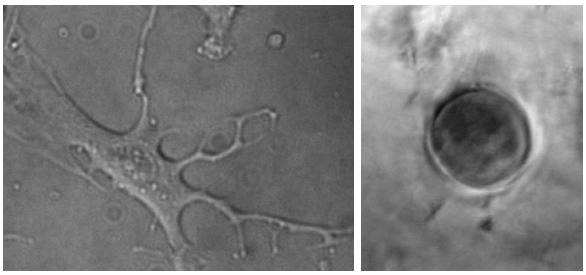

Figure 3: A nucleus cell in adhesion culture (left). Nucleus cells loose their processes in alginate (right).

The interaction between cell and matrix, and hence the suitability of a scaffold material, is reflected in cell morphology. For instance, nucleus cells form large processes in collagen gels and in monolayers (Fig 3, left), but not when suspended in agarose or alginate (Fig 3, right). Processes are observed, yet less prominent, *in vivo*. Their function and why they develop in the one scaffold and not in the other is unclear. Yet, it is hypothesized that in an appropriate scaffold, cells will form processes like they do *in vivo*.

Conclusions

Intervertebral disc tissue engineering is expected to become important within years. For successful disc tissue engineering, we focus on the interaction between cell and matrix.