Development of an artificial intervertebral disc

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Introduction

Low back pain is a widespread problem associated with degeneration of the intervertebral disc (Fig 1). Because nonoperative treatment often fail, surgical intervention is needed. Fusion of adjacent vertebrae can relieve pain, but has major drawbacks like loss of motion, which might accelerate degeneration of adjacent discs [12, 4]. A nucleus prosthesis gives problems like expulsion, subsidence, and migration of the implant [7, 2]. Hence, a total disc replacement is often inevitable.

Total disc replacement

An artificial intervertebral disc (AID) should relieve pain, provide physiological motion, shock absorption, and stability. The Charite III [9] (Fig 2) prosthesis is most successful, but studies on the success rate are criticised for their methodologies, long term data are scarce, and current results are comparable with fusion [6, 10]. The ProDisc design [1] (Fig 2) is comparable to Charite III. Hence, no real improvement is expected. These designs only aim at restoring motion. Other designs [5, 8] (Fig 2) try to incorporate also the (visco)-elastic material behaviour, but still lack the swelling behaviour of the natural disc. Next, all these designs are inserted ventrally, while the anterior longitudinal ligament is cut, and long term consequences are unknown.

Goals

Hence, our first goal is to develop a new artificial intervertebral disc, which allows physiological motion, provides viscoelastic behaviour, and swelling. Through the swelling properties the AID can be inserted in a minimal invasive way. As long term data are lacking, our second goal will be to determine the long term effects of an AID implantation on the spine, using finite element analysis of vertebral bone remodeling.

Material and methods

Material

The current design is a combination of a fibre reinforced hydrogel. The hydrogel is a visco-elastic and swelling material. Hence, it is a good substitute for the nucleus. The fibre reinforcement replaces the swelling restraining properties of the annulus fibres.

Methods

The AID will be tested for maximum load and fatigue life in compression, bending and torsion, according to ISO standards (ISO/DIS 18192-1). In house FEA models are available as a start for determining long-term consequences of the proposed design.

Results

In a preliminary tests an AID test sample was compressed up to 8kN without damage (Fig 3), which is the required maximal failure load [3]. A fatigue test (100-1500N) resulted in an undamaged sample after 58100 cycles. The samples showed visco-elastic behaviour (Fig 3).

Conclusions

A new concept for an AID is proposed, based on a fibre reinforced hydrogel. Preliminary tests show encouraging results for future work.

References: