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Mechanical Testing 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). When surgical intervention is needed, fusion of adjacent vertebrae can relieve pain. However, fusion leads to loss of motion, which may accelerate the degeneration of adjacent discs. An alternative to fusion is a disc prosthesis or artificial intervertebral disc (AID).

Artificial Intervertebral Disc

An AID should relieve pain, provide physiological motion, shock absorption, and stability. Current AID designs (Fig 2) only aim on restoring motion and do not mimic the material behavior of the natural disc. Encountered problems are migration, subsidence, wear, and increased facet joint stress. Available studies on the success rate are criticized for their methodologies and current results are comparable with fusion [3].

A new type of AID is under development. The core of this design is a hydrogel, which is a visco-elastic, swelling material [1], like the natural nucleus. This AID will allow for more physical motion, and also mimic the material behavior of the natural disc better than current designs.

Material and methods

The AID was tested under static and dynamic loading in axial compression, in 0.15M salt solution at 37°C (based on ASTM F2346-05) using a 858 Mini Bionix test system (MTS Systems Corporation, USA). Static loading was applied with 2kN/s in 6 steps up to 12kN. In Dynamic loading every 24h were divided into 16h of compression and 8h of rehydration. 10 million load cycles were applied at 10Hz, between 0.2-2kN or 0.6-6kN. Stiffness was calculated by dividing force by displacement.

Results

The new AID withstood loads up to 12kN without damage (Fig 3), which is more than the required maximal failure load of 8kN [2]. A stiffness was measured between 2-14kN/mm, which is comparable to the natural disc.

In dynamic loading the stiffness for 2kN and 6kN was about 15 kN/mm and 35 kN/mm, respectively. The AID showed visco-elastic behavior (Fig 4, right) and compressing and rehydration of the AID during the day (Fig 4, left). This resembles the diurnal cycle of the natural disc.

Conclusion and Future Work

A new concept for an AID was tested, which showed promising results under static and dynamic loading. Experiments will be continued and extended with multiple load cases and wear testing. A finite element analysis will be performed to investigate the influence of implanting the AID on the kinematics of a motion segment compared to the intact situation.

References: