

Degenerative Changes Of Intervertebral Discs After Vertebroplasty

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Introduction Information about the long-term effects of vertebroplasty on adjacent intervertebral discs and augmented bone is lacking. Discs may be at higher risk of degeneration due to nutritional constraints. Bone loss may occur due to mechanical stress-shielding or toxicological effects. The effect of vertebroplasty on intervertebral discs and bone tissue after 6 and 12 months was investigated using an animal model.

Methods In 12 sheep, 2.0 ml PMMA (Simplex P) were injected into three adjacent lumbar vertebrae. Four weeks before euthanasia, animals received tetracycline injections for bone labeling. Postmortem, T1- and T2-weighted sagittal and axial MR images of the spines were taken. Specimens containing one intervertebral disc and half of the two adjacent vertebrae were processed for histology. Discs two levels above the first augmented vertebra served as controls. Microsections were stained with H&E, Goldner, Alcian blue-PAS and Safranin O. MRI images and histology sections were evaluated qualitatively.

Results There was no distinguishable loss of MRI signal intensity of discs in between augmented vertebrae. Cement injection resulted in blocking 50-75% of the length of endplates. Most discs (~83%) that were in between augmented vertebrae showed signs of degeneration (chondrocyte proliferation, necrosis) both after 6 and 12 months. Inflammatory reaction to PMMA was observed in some specimens, mainly after 6 months. Cement had been covered with fibrous tissue in all augmented vertebrae, but tetracycline labeling revealed new bone formation in the vicinity of PMMA.

Discussion Vertebroplasty of three adjacent vertebrae initiated degenerative changes of intervertebral discs. These changes may have been due to impaired nutritional supply to the nucleus. Present results are in contrast to a recent animal study which reported no degenerative changes up to 6 months after cementing one endplate. The risk of degenerative changes of intervertebral discs should be considered in patients undergoing vertebroplasty.

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Further Characterisation Of An Ovine Model Of Lumbar Disc Degeneration Using Enzyme Digestion

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INTRODUCTION: Sheep have been used successfully to model lumbar disc degeneration associated with annular rim lesions, although this may take several months to show an effect. Disc degeneration occurs more rapidly when the proteolytic enzyme Chondroitinase ABC is injected directly into the nucleus. The aim of this study was to characterise the dose response and pathophysiology of disc degeneration in this model.

METHODS: In ten adolescent Merino sheep five lumbar discs were exposed. Alternate discs were injected with 10 units, 1 unit and 0.1 unit respectively of Chondroitinase ABC to quantify the dose response effect of the enzyme. The intervening control discs were injected with normal saline. The sheep were X-rayed at monthly intervals to measure disc height. The sheep were scanned by MRI at three months and sacrificed after which sagittal sections of each disc were prepared for histopathology.

RESULTS: Radiological measurements showed a significant reduction in disc height from about 4 weeks indicating progressive degeneration, with a pronounced difference between the three doses administered. MRI demonstrated decreased NP signal intensity, endplate destruction and subchondral oedema increasing in extent with increasing enzyme dose. Macroscopic and microscopic features supported this finding. The highest dose resulted in severe disc degeneration and the changes were subtle in the lowest dose. At the intermediate and highest doses there was extensive degradation of the nucleus resulting in disc narrowing. Endplate perforation with chronic inflammation and subchondral marrow fibrosis was a feature. There was no significant degeneration in the discs injected with saline.

DISCUSSION: At an appropriate concentration Chondroitinase ABC reliably produces disc degeneration in a shorter period of time than annular incision in the same model. The effect is detectable by radiographs, MRI and histology. This model is suitable for further research of treatments for degenerative disc disease.

Prediction Of Failure Progression In A Lumbar Disc Due To Cyclic Loading- A Finite Element Model Study

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INTRODUCTION: The intervertebral disc is susceptible to ruptures and degenerative processes. The aim of this investigation is to model the development of annular tears and endplate fissures and study the propagation of these degenerative processes in a lumbar motion segment in the presence of cyclic loading.

METHODS: A previously validated three-dimensional poro-elastic finite element model of the L4-L5 motion segment including biological parameters was used for this study. Failure initiation and progression was modeled using a "user-supplied-material" function which allows the failure prediction at a microscopic level. Percentage of disc failure volume at the end of each load cycle was calculated by dividing the number of failed integrating points by the total number of integrating points in the disc for a spinal load corresponding to a push-pull activity.

RESULTS: Annular failure initiated on the interface surface between the bottom endplate and inner annulus while the endplate failure initiated at the top endplate. As the load cycle increased, endplate failure progressed towards the center of the endplate while annulus failure progressed outward as the number of load cycles increased. The analyses also showed that the disc failure volume increased from 2.5% to 6% as the load cycle progressed when the assumed decrease in drained elastic modulus due to failure increased from 5% to 30%.

DISCUSSION: The current study shows that the failure progression due to cyclic loading exponentially increases as the assumed drained elastic modulus of the failed disc components decrease. Since the push-pull activity produced a large anterior directed shear, failure consistently occurred on the inferior surface of the annulus. The results presented here is a conformation that the current concepts used in modeling the failure progression in a lumbar disc are reasonable.

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Quantitative Evaluation Of Lumbar Segmental Instability Using A New Intraoperative Measurement System

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INTRODUCTION: In vivo quantitative evaluation on lumbar segmental instability have not yet been established. We developed a new measurement system to determine intraoperative lumbar stability. The purposes of this study are to measure in vivo segmental stability and to clarify relationships between preoperative radiographic findings and results of biomechanical parameters.

METHODS: The system is consisted of spinous process holders, motion generator, load cell, optical displacement transducer, and computer. A cyclic displacement (2.0 mm/s, 15 mm in max) of the holders produces flexion-extension with all ligamentous structures intact. Biomechanical parameters: stiffness, neutral zone (NZ), and absorption energy (AE) are determined via load-deformation data. Twenty lumbar segments in 19 patients (M/F = 10/9, mean age 59.3 years, 21-83 years) with degenerative lumbar disease were studied. Range of motion (ROM) and horizontal displacements (HD) were determined by Dupuis' method. MRIs of all discs were divided into Thompson's five grades and further into three groups: None (grade 1&2, n = 6), Mild (grade 3, n = 10), and Severe (grade 4&5, n = 4). Relationships between the radiographic findings and the biomechanical parameters were analyzed.

RESULTS: In all cases, intraoperative measurement was completed within ten minutes without any complication. There was no significant relationship between results of radiographic and biomechanical parameters. Stiffness of Mild group was significantly lower than other groups (None vs. Mild $p < 0.005$, Mild vs. Severe $p < 0.05$). NZ of Mild group was higher than that of other groups. AE in each group showed same tendency as stiffness without significance.

DISCUSSION: Our measurement system established a method to determine stiffness, NZ, and AE through continuous data in vivo. There were no significant relationships between functional radiographic results and biomechanical data, suggesting that conventional X-ray examinations cannot distinguish segmental instability. Mild group showed lower stiffness and higher NZ than other groups, possibly indicating instability in the patient with mild disc degeneration.

Finite Element Simulation As a Predictive Tool for Lumbar Spine Surgery

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Introduction: Finite Element spine modelling can be useful for computer assisted surgery planning providing help in assessing the risk of mechanical failure. The aim of this study is to provide a patient specific finite element model of the lumbar spine where surgical gesture was considered and to assess its relevance as a predictive tool for lumbar spine surgery.

Methods: A three-dimensional FEM of the L1-Sacrum lumbar spine with geometrical personalization was developed. Mechanical properties were based on published data. Then, main characteristics of degenerative pathologies and surgical gestures were considered, and posterior implants were modeled. The sacrum was fixed and Flexion compression loads were applied on the L1 vertebra depending on patient characteristics (weight, imbalance). Then, results of simulations were post-processed to assess stresses in the discs and along implants.

Clinical cases were collected to evaluate the models relevance. 24 cases instrumented with rigid screw rod systems were considered, respectively 6 at L4- S1 and 16 at L5-S1. 5 of the collected cases were “failed cases” in which patients had screw breakage.

Blind simulations were performed for all these patients and the results were qualitatively compared with the clinical outcome.

Results: Numerical results highlighted the specific behavior of 4 models for which loads on screws and rods were markedly higher than those of all others. The analysis of the clinical outcome emphasized that these models corresponded to patients with a screw breakage

Discussion: For the first time a patient specific model was proposed for lumbar spine surgery planning. Even if the proportion of clinical cases is unbalanced between successes and failure cases, finite element simulations allowed to identify four of the five “failed” cases. Then, by increasing the number of modeled clinical cases, it could be possible to improve this model and to provide an help for surgery planning.