Effect of Disc Degeneration on the Mechanical Behavior of a Lumbar Functional Spinal Unit

A. Rohlmann[1], T. Zander[1], H. Schmidt[2], H.-J. Wilke[2], G. Bergmann[1]

[1] *Biomechanics Laboratory, Charité, Campus Benjamin Franklin, Berlin, GER*
[2] *Department of Orthopaedic Research and Biomechanics, University of Ulm, Ulm, GER*

INTRODUCTION: Intervertebral discs provide flexibility of the spine and transmit and distribute large loads. In a degenerated disc the compressibility of the nucleus pulposus is increased and the disc height is reduced compared to a healthy disc. It is not fully understood how this affects the mechanical behavior of a functional spinal unit.
The aims of the study were to develop a finite element model of a lumbar motion segment which allows the simulation of different degeneration grades and to investigate the effect of disc degeneration on the mechanical behaviour of a functional spinal unit.

METHODS: A three-dimensional, nonlinear finite element model of the functional spinal unit L3/L4 was created (Fig. 1). Volume and rebar elements were used for the annulus fibrosus. The rebar elements represent the fibres. The nucleus was modelled as a fluid-filled cavity. All seven ligaments were integrated in the model and represented by tension-only spring elements with non-linear material properties. Besides a healthy disc, three different grades of disc degeneration (mild, moderate, and severe) were studied. Compared to a healthy disc their height was reduced 20%, 40% and 60%, respectively. With increasing disc degeneration the fibres and most ligaments buckle. The change in element length due to reduced disc height was compensated by offsetting their nonlinear stiffness curves. The compressibility of the nucleus was linearly increased from 0.0005 mm²/N (healthy disc, like water) to 0.15 mm²/N (severely degenerated, like annulus fibrosus). Pure moments of 10 Nm were successively applied to simulate flexion, extension, lateral bending and axial rotation.

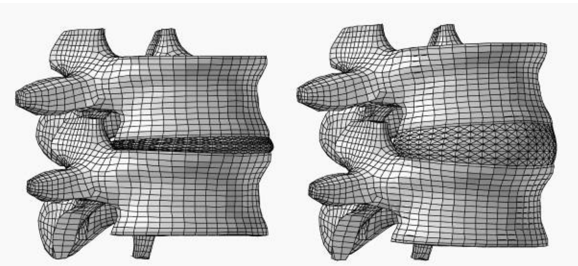

Fig. 1: Element meshes of a motion segment with a severely degenerated (left) and a healthy (right) disc.

RESULTS: The finite element model predicts the same trends for intersegmental rotation and intradiscal pressure as obtained by others in *in vitro* studies [1, 2]. A mildly degenerated disc increases intersegmental rotation for all loading cases studied. With further increasing disc degeneration intersegmental rotation is decreased. There is a strongly non-linear relationship between intersegmental rotation and applied moment. With increasing disc degeneration the curves become more linear. The change of intradiscal pressure during loading is lower in a degenerated disc than in a healthy one. For axial rotation, the force in the facet joint increase with increasing disc degeneration. For extension and lateral bending, facet joint forces are higher for a mildly than for a moderately or severely degenerated disc. The maximum von Mises stress in the ground substance of the annulus increases with increasing disc degeneration for all loading cases studied.

DISCUSSION & CONCLUSIONS: The created finite element model simulates the global mechanical behavior of a degenerated disc very well. The predicted trends agree with in vitro measurements on cadaver specimens. Integration in a multisegmental finite element model of the spine will allow to study, for example, the effect of a degenerated disc on the adjacent segments.

REFERENCES: [1] D.S. McNally and M.A. Adams, (1992) *Spine* 17, 66-73. [2] M. Mimura, M.M. Panjabi, T.R. Oxland, et al (1994) *Spine* 19, 1371-1380.

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