UNDER WHICH LOAD COMBINATION AND DEGREE OF DISC DEGENERATION EXISTS THE HIGHEST RISK OF ANNULUS FAILURE AND DISC PROLAPSES?

*Schmidt, H; *Kettler, A; **Rohlmann, A; *Claes, L; +*Wilke, H-J

+*Institute of Orthopaedic Research and Biomechanics, University of Ulm, Ulm, Germany

hans-joachim.wilke@uni-ulm.de

INTRODUCTION:
The intervertebral disc prolaps is considered one cause of acute back pain. This can result due to various complex load situations. However, the influence of disc degeneration on prolaps is not well understood. The aim of this finite element study was to find load combinations that would lead to the highest internal stresses in a healthy and degenerated intervertebral disc.

METHODS:
For this study a three dimensional, non-linear finite element model of a lumbar spinal segment L4-L5 was used (Figure 1). The annulus was assumed to be a homogenous ground substance reinforced by collagen fibers.

![Finite-Element-Mesh of the functional spinal unit L4-L5.](image)

In addition to the healthy disc, three different grades of disc degeneration (mild, moderate, and severe) were investigated. To model these degenerated discs, the disc height and endplate curvature were decreased, osteophytes formed, the compressibility of the nucleus increased and the fiber and ligament stiffness decreased (Figure 2).

![Finite-Element-Mesh of different degrees of disc degeneration.](image)

Pure unconstrained moments of 7.5 Nm in the three anatomical main planes were applied to the upper vertebral body. The load direction was incrementally changed with an angle of 15° between the three anatomical planes to produce not only moments in the principle motionplanes but also moment combinations, for example combinations of flexion + lateral bending.

The intradiscal pressure (IDP) in the nucleus pulposus, the shear strains between the annulus and the adjacent endplates and the tensile strains in the collagen fibers were investigated. It was assumed that the fiber strains can initiate radial fissures, the shear strains between the individual lamellae lead to concentrical fissures and the shear strains between the annulus and the adjacent endplates can result in peripheral rim lesions.

RESULTS:
IDP for healthy and degenerated disc was highest in flexion, followed by extension, axial rotation and lateral bending. Load combinations did not increase the pressure. However, the shear and fiber strains in the annulus under load combinations showed in all discs a strong increase, mostly located in the postero and posterolateral annulus region. The highest stresses in the healthy disc resulted from a combination of lateral bending + flexion and in the degenerated discs resulted from a combination of lateral bending + axial rotation. The mild disc showed an increase of IDP in axial rotation (25%). The shear and fiber strains both increased by 38 and 45%. In the moderately degenerated disc the measurement parameters strongly decreased in all load directions.

DISCUSSION:
The results show that the risks of a disk failure and prolapses mostly occur in the posterior and posterolateral annulus region under a load combination of lateral bending + axial rotation in a non- and mild degenerated disc (Figure 3). In this, the IDP of the nucleus remains nearly intact, while strong mechanical loads produce failure in the annulus. Since in the strongest degenerated disc the fibers remained unloaded, the risk of radial fissures is given over the entire annulus region.

![Regions of annulus failure in dependant of disc degeneration.](image)

AFFILIATED INSTITUTIONS FOR CO-AUTHORS:
**Biomechanics Laboratory, Charité, Campus Benjamin Franklin, Berlin, Germany

ACKNOWLEDGEMENT:
This study was supported by the German Research Council (WI 1352/6-1).