SUBJECT SPECIFIC FINITE-ELEMENT-MODEL OF THE HUMAN LUMBAR SPINE

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Introduction

Dorsal pain belongs to one of the most common disease patterns in the world today. To find and analyse the origin of the pain, there are different established possibilities like in-vitro and in-vivo tests or the simulation with Finite-Elements (FE).
The goal of the present study was to build a subject specific FE-Model of the human lumbar spine from L2 – L5 to simulate and analyse biomechanical research questions [Schärli, 2011].

Materials and Methods

The spinal model was built with the commercial available FE-Tool ANSYS Workbench 13. The vertebrae are based on CT-data, whereas the intervertebral discs (IVD) were individually designed using common CAD software, depending on the surrounding bony geometries and specific literature data (Figure 1).

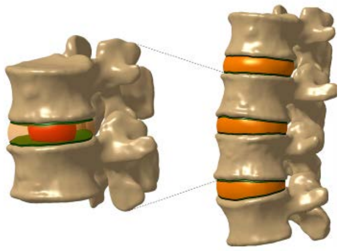

Figure 1: Analytical Spine in CAD

The ligament structures as well as the circumferential fibres of the anulus fibrosus are based on non-linear springs and internal FE-constraints. For the purpose of comparison two hyper elastic material laws based on "Neo-Hookean" and "Mooney-Rivlin" were used for the ground substance (GS) of the IVD with different parameterization [Little, 2009].
The FE-model was extended successively from a simple linear model, consisting solely of vertebrae and IVDs, to a highly nonlinear model including the previously neglected structures and nonlinear material laws. Finally the most representative lumbar spine model consists of 202'320 Nodes and 536'254 elements (Figure 2).

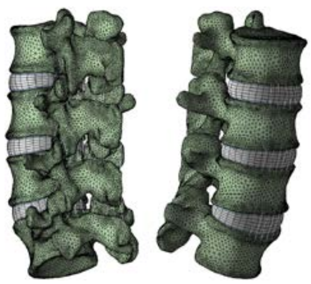

Figure 2: FE-model of the lumbar spine

To simulate the flexion/extension, lateral bending and axial rotation load cases, a torsional moment of 7.5Nm was applied in the three principal anatomical planes. Every FE-Model was further numerically verified and compared with appropriate in-vitro tests [Schmölz, 2009].

Results

The coloured charts indicate the RoM of the spine in flex/ext and lateral bending, respectively (Figure 3). Four in-vitro tests were used to define an average RoM with single standard deviation to compare the simulation with.

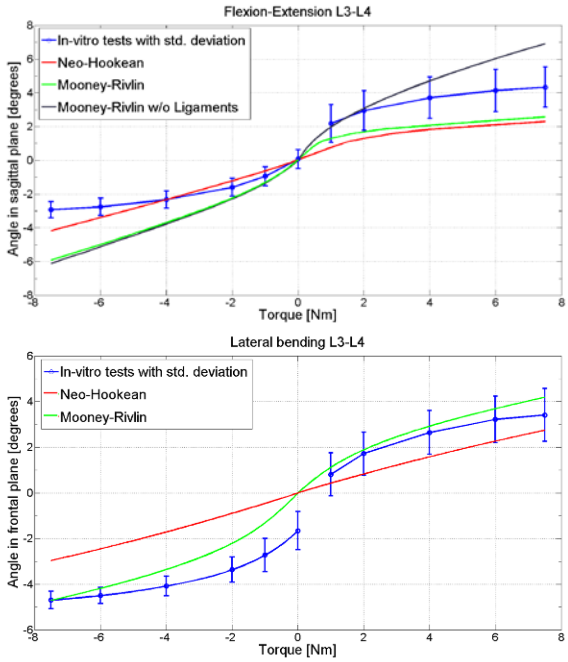

Figure 3: Results flex/ext and lateral bending

Discussion

The spinal FE-Model showed good qualitative, nonlinear behaviour in all load cases. Whereas the quantitative results, especially in flexion and extension, differ slightly from the in-vitro tests. These characteristics are based mainly on the parameterization of the IVD- and ligament material properties as well as the shapes of the facet joints and their interaction. Due to these findings, specific enhancements of the spinal FE-Model will lead to a further improved kinematic motion behaviour.

References

Little *et al*, PhD Thesis 2009, Queensland University of Technology
Schärli *et al*, Masterthesis 2011, University of Bern
Schmölz *et al*, European Spine Journal, 2009