HOW HUMAN IS THE OVINE INTERVERTEBRAL DISC? FINITE ELEMENT MODEL STUDIES

Hendrik Schmidt[1], Sandra Reitmaier[2]

[1] *Julius Wolff Institut Charité - Universitätsmedizin Berlin, Berlin, Germany*

[2] *Institute of Orthopaedic Research and Biomechanics, University of Ulm, Ulm, Germany*

Introduction

The sheep is one of the most frequently used animal models for experimental intervertebral disc research questions. Although there are large differences in size between human and ovine discs, recent in vivo and in vitro studies indicate similarities in the internal disc stresses. The present finite element model study, therefore, intended to detect the parameters that, despite the different geometry, ensure mechanical comparability between both species.

Methods

At first, a 3D poroelastic nonlinear finite element model of the human L4-L5 lumbar intervertebral disc was developed (Fig. 1). The predicted displacement and nucleus pressure response were validated with experimental in vivo and in vitro data. Starting with adapting the model geometry from the human to the ovine disc, several material and biochemical parameters, which might contribute to the preservation of the mechanical disc response across both species, were successively adapted to ovine properties.

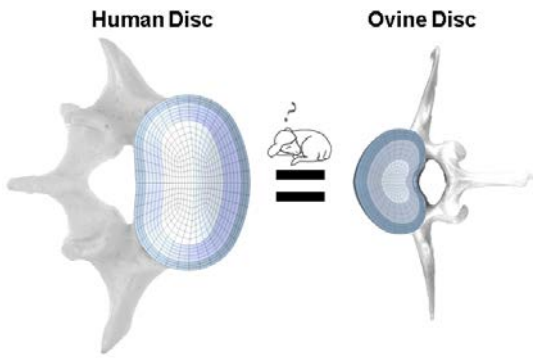

Figure 1: Finite element models of the human and ovine disc (axial view).

Results

Replacing the geometry yielded a substantially higher disc stiffness and lower nucleus pressure compared to in vitro measurements performed on ovine discs (Fig. 2). Additional reduction of annulus and nucleus elasticity led to an improved correlation between model predictions and measurements. Changes in the glycosaminoglycan content and endplate permeability improved the predicted pressure, but only slightly affected the displacement response. Only the combination of all parameters yielded a good agreement between the predictions and measurements (Fig. 2).

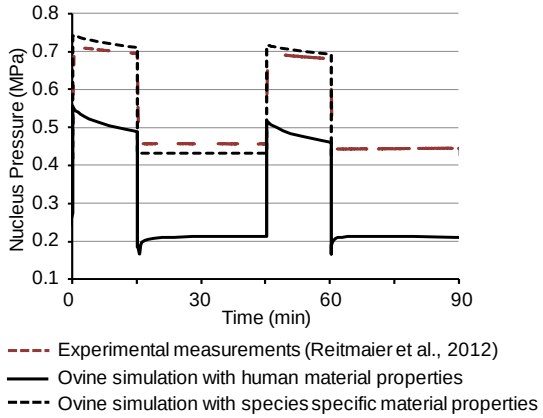

Figure 2: Numerical adaptation process of time-dependent nucleus pressure to experimental results on ovine specimen.

Discussion

This study demonstrated that there are profound differences between model and in vitro results if an ovine simulation is run with human material properties. However, once the species-specific material properties are included in the ovine model, the predictions fit the in vitro results. There appears to be good evidence of a convergence of mechanical response between both species. Results justify the use of sheep as an animal model for in vivo disc research questions, for example on nucleus replacement strategies that are based on cellular approaches tending to initiate regeneration. Such approaches necessitate a mechanical environment which is comparable to human discs. Furthermore, these data are helpful to interpret the results of an in vivo study performed in a sheep model and to plan future studies that contemplate the use of sheep as a model for the human disc.