Intervertebral disc impact on stresses in growthplates of an adolescent idiopathic scoliotic spine following unilateral muscle weakening

[1*]Zeinab Kamal, [2]Reza Kakavand, [2]Amin Komeili
[1]Department of Oral and Maxillofacial Surgery, University Medical Center Groningen, University of Groningen, Netherlands
[2]Department of Biomedical Engineering, University of Calgary, Calgary, AB, Canada
[*]Email: z.kamal@umcg.nl

Introduction

The purpose of this study was to look into the role of an intervertebral disc (IVD) in the stress distribution in an apical growthplate (GP) in an adolescent idiopathic scoliosis (AIS) trunk with intact and after a concave-sided debilitating of the multifidus-lumborum (MFL) and longissimus-thoracis-pars-thoracis (LGPT) muscles. IVDs were not simulated in some studies for the sake of simplification. It was hypothesized that IVDs simulation could accurately predict the GP stresses which in turn leads to a better understanding of unilateral muscle weakness (UMW) effects on an AIS trunk stresses [1].

Methods

A motion segment finite element (FE) model of one scoliotic 11.5-year-old adolescent comprising the caudal GP of L2, each in two scenarios of including (FEI) and excluding (FEE) the IVD was developed (Fig. 1). The L2-L3 muscle and gravitational loads in the standing-posture [2], were applied to the GP (Fig. 1). The models were examined with intact and unilaterally-paralyzed muscles. Muscle-weakening was simulated [2,5] by reducing the physiological-cross-sectional-area of the concave-sided LGPT+MFL muscles to reach the 95% loss in the strength.

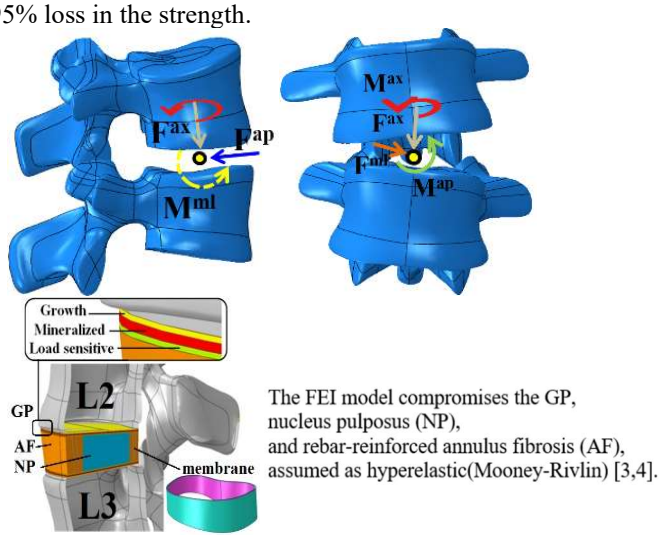

Figure 1. *Reaction loads (F^{CoR} and M^{CoR}), reported in [2], applied to the L2-L3 IVD centroid (yellow point). The IVD was substituted with a rigid-plate in the FEE model for an even load distribution on the GP.*

Results and Discussion

A similar intradiscal-pressure (0.19MPa) was found for FEI models with intact and unilaterally-debilitated muscles which agrees the in-vivo data[6].

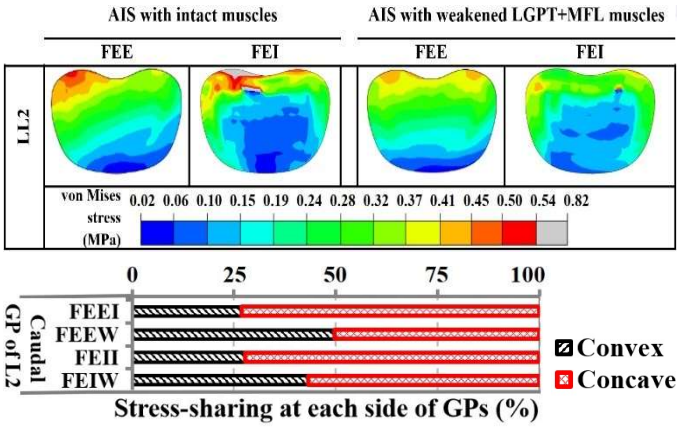

Figure 2. *The average calculations of von Mises stress at both convex and concave sides were normalized to the overall mean von Mises stress values in the GP.*

Muscular unilateral-paralysis reduced the von-Mises stress ratio of the concave-over-convex side of the apical GP in the FEI and FEE models by 50% and 63%, respectively. The difference between the maximum von-Mises stress in the GP predicted by the intact-muscular FEI and FEE models was found to be 0.28 MPa (Fig. 2). The ratio of the von-Mises stress on the concave-over-convex side of the GP in the FEI and FEE models was found to be 2.6 and 2.7 for the intact-muscular situation, respectively, which correspondingly decreased to 1.3 and 1.0 after unilaterally-weakening of muscles (Fig. 2). The results propose that employing an IVD in a simulation is a necessity to study GP stress failures due to high stresses in an AIS spine with intact muscles in agreement with radiological and histological observations on a rat [6].

Conclusions

Higher stresses on GPs in a FE model including than excluding an IVD was obtained which consequently indicates different vertebral bone-growth patterns according to Hueter-Volkmann's law [1]. Accordingly, this study indicated the significance of simulating IVDs in the predicted pattern of vertebral growth and deformity-progression of an immature AIS spine.

References

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