ASSESSMENT OF TRABECULAR BONE ADAPTATION IN ADOLESCENT IDIOPATHIC SCOLIOSIS DUE TO ALTERED JOINT LOADING

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INTRODUCTION

Adolescent Idiopathic Scoliosis (AIS) is the most common deformity of the spine, affecting 2–4% of the population. Previous studies have shown that the vertebrae in scoliotic spines undergo abnormal morphological changes. In particular, the rapid progression of vertebral wedging in AIS during the adolescent growth spurt is caused by asymmetrical growth. The latter has been attributed to the Hueter-Volkmann law of mechanically modulated endochondral growth [1].

One aspect of deformity progression that is less well known is whether vertebral body adaptation based on Wolff's law also contributes to deformity progression [2]. This law states that bone tissue adapts to prevailing mechanical demands. While animal studies have shown that vertebral bone adaptation takes place, this finding hasn't been fully confirmed in humans. The study of Adam and Askin showed a marked convex/concave asymmetry in bone mineral density (BMD) for vertebral levels at or near the apex of the scoliotic curve. However, due to lack of *in vivo* CT image resolution no information regarding trabecular architecture was provided.

The purpose of the current study was to test the hypothesis whether altered mechanical loading conditions may lead to adaptation of the trabecular bone microstructure in accordance of Wolff's law.

METHODS

Vertebral levels at or near apex of the scoliotic curve were identified in patients undergoing AIS surgical correction. Bone cores (diameter: 5 mm; length: 10-20 mm) were taken at mid vertebra, at positions were fixation screws are placed. The bone biopsy needle allowed for registration of the vertical position with respect to the loading direction. After extraction, the bone cores were PMMA embedded and subsequently underwent microCT imaging (*Scanco Medical* 50) at 6.8 μm resolution. Image analysis was performed using *ImageJ*.

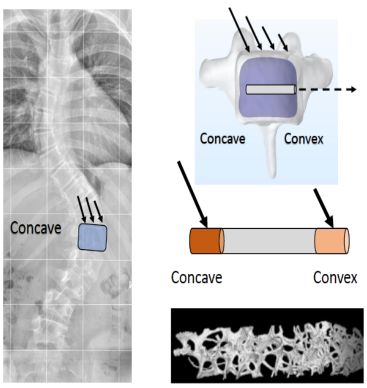

Figure 1: Schematic representation of apex vertebral bone core extraction from AIS patients and microCT analysis. Furthermore, the mechanical loading conditions at the concave and convex side are shown.

RESULTS AND DISCUSSION

Based on microCT image analysis we found that the average trabecular thickness is between 125-160 μm which is within the values reported for mean horizontal thickness of a healthy adult population.

Trabecular orientation is measured with respect to vertical (gravitational) loading direction. Overall, the orientation is quite stable along the bone samples. The orientation is contained between 30 and 60 degrees relatively to the vertical direction which may be linked to altered loading directions in AIS subjects.

We identified representative volume elements (RVEs) of 4 mm x10 mm (diameter x length) to evaluate the respective volume fraction (BV/TV). There is a trend of increased BV/TV at the concave side compared to convex side which would confirm findings from an *in vivo* CT study [3]. Note that due to low image resolution of CT the respective RVEs were significantly larger (2-3 mm) which could mask the transition between cortical and trabecular bone and so overestimate BV/TV.

CONCLUSIONS

We developed an experimental method to extract (undisturbed) bone samples from apical vertebrae in AIS subjects and to register samples with respect to gravitational loading direction. The performed microCT analysis indicates trends of However, more samples are required in order to confirm the statistical significance of current findings.

Another quantity to look at in future studies is the bone quality of trabecular struts and plates which may be altered in AIS subjects due to changed bone modelling and remodelling conditions. Techniques which allow to analyse bone quality include quantitative backscattering electron imaging and Raman spectroscopy.

REFERENCES

[1] I.A. Stokes et al. Mechanical modulation of vertebral body growth. Implications for scoliosis progression. *Spine*, **21**:1162, 1996.

[2] P.L. Mente et al. Progression of vertebral wedging in an asymmetrically loaded rat tail model. *Spine*, **22**:1292, 1997.

[3] C.J. Adam and G.N. Askin. Lateral bone density variations in the scoliotic spine. *Bone*, **45**:799, 2009.