Biomechanical analysis of scoliosis correction using a novel fusionless intravertebral epiphyseal device

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Disclosures

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Natural Sciences and Engineering Research Council of Canada (a), Canadian Institutes of Health Research (a), Medtronic (b, c), Depuy Spine (c), Spinologics (f)

(a) Grants/Research Support  
b) Other Financial Support  
(c) Consultant  
d) Honorarium  
(e) Board of medical organization and/or orthopedic publisher  
(f) Stock/Shareholder
Introduction

- Many fusionless growth sparring instrumentation devices have been developed. Their influence on intervertebral disc and growth plate health, and on the control of the growing spine still remains a subject of attention.

- A new device (the “hemi-staple”; US 8,409,258) which locally compresses the growth plate without spanning the disc was developed and successively tested on two different animal models (1,2,3):

  Rat tail model (1)

  Pig model (2,3)

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Objective

• To further analyze the hemi-staple biomechanical action on a human finite element model
Cases

• 10 thoracic scoliosis cases (11.7± 0.9 yr; MT Cobb: 35°±7°; TL/L: 24°±6°)
• For each case:
  • Spine, pelvis and rib cage reconstructed in 3D
  • Finite Element Model (FEM):
    • Vertebrae, Discs; Articular joints; Ligaments; Rib cage; Soft tissues; Pelvis; Growth plates

bi-planar calibrated radiographs  3D Reconstruction  Finite Element Model
Growth dynamics governed by the *Hueter-Volkmann* principle integrated in FEM

Controlling equation:

\[ G = G_m \left[ 1 - \beta \left( \sigma - \sigma_m \right) \right] \]

- \( G_m \) = growth rate (0.8-1.1 mm/year)
- \( \beta \) = bone sensitive factor (1-3 MPa\(^{-1}\))
- \( \sigma \) = stress in pathologic spine
- \( \sigma_m \) = normal stress

Validated model to predict scoliotic progression (Villemure 2002, Stokes 2007, Lin 2011)
Growth Modeling Validation
(2 yrs growth simulation; case #1)
Instrumented FEM

Hemi-staple model (shell elements)
Tested configurations

**Config #1:**
5 instrumented levels
(MT spine)
Single growth plates

**Config #2:**
5 instrumented levels
(MT spine)
Both growth plates

**Config #3:**
9 instr. levels
(MT & TL/L spines)
Single growth plates

**Config #4:**
9 instr. levels
(MT & TL/L spines)
Both growth plates
Case #1 – 2 yrs simulation

<table>
<thead>
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<th>Natural Growth</th>
<th>Conf #1</th>
<th>Conf #2</th>
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Synthesis (average for all cases)

- **MT Cobb**
- **TL/L Cobb**
- **Wedging** (apical vertebra)
- **Axial Rotation** (apical vertebra)
- **Kyphosis**
- **Lordosis**

Legend:
- Pre-op
- Natural Growth
- Config #1
- Config #2
- Config #3
- Config #4
Discussion & Conclusion

- Biomechanical potential of the hemi-staple device to control the scoliosis progression

- Relevant alternative for the early treatment of idiopathic scoliosis

- Importance of the instrumentation configuration to correct the spinal deformity: a ‘two hemi-staples per vertebra’ strategy is more effective

- Model limitations: spinal loading due to gravity (no muscle), linear growth modulation, … An extended validation is necessary.