Growth as outcome for growth friendly systems

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Surgical treatment of early onset scoliosis (EOS).

- One of the biggest challenges for pediatric spine surgeons is the surgical treatment of early onset scoliosis (EOS).

- When the spine is corrected and fused during growth, a disproportionately short trunk can result in lung and thoracic wall deficiency.

- Current surgical treatments allow for growth of the spine while correcting the scoliosis.
Main growth friendly techniques

• Distraction based techniques
  – Traditional growing rods (TGR)
  – Vertical expandable prosthetic titanium rib expansion technique (VEPTR)
  – Magnetically controlled growth rods (MCGR)

• Growth guidance procedures
  – Luque-trolley trolley
  – Shilla
Growth as an outcome

• How do we measure spinal growth
  – What spinal segment is used?
  – What kind of measurement is used?
  – What time-frame is used?

• What is normal spinal growth
  – What is the spinal growth in a normal population?
  – What is the spinal growth in an idiopathic scoliotic population?
Spinal segments

- T1-T12 Spinal Segment
- T1-S1 Spinal Segment
- Instrumented Segment
Different distances

- T1-S1 Height
- T1-S1 Length
- T1-S1 Freehand
True growth of the system

Initial implantation surgery

True spinal growth

Final fusion surgery
Time frames

Initial implantation surgery

True spinal growth

Follow-up spinal growth

Total reported spinal growth

Final fusion surgery
Articles combine short follow-up, long follow-up and fusions

Initial implantation surgery

Final fusion surgery

Total reported spinal growth patient 1

Total reported spinal growth patient 2

Total reported spinal growth patient 3
Methods

• Aim
  (1) Assess what outcome measurements are used
  (2) Identify the system that allows most length gain

• Extensive literature search with meta-analysis

• Only Included TGR, Shilla, VEPTR, MDGR or Luque systems

• Only included articles with average age of surgery between 5 and 10 years

• Weighted means were calculated for every outcome (based on included patients)
Systematic review

PubMed (n=848)  
Embase (n=299)  
Cochrane Library (n=20)

Records after removal of duplicates  
(n=1048)

Records screened  
(n=1048)

Excluded title/abstracts:
- Posterior spinal fusion (n=70)
- Case report/series <5 (n=81)
- Animal/cadaveric/lab/Biomechanical (n=74)
- Review/expert opinion (n=182)
- No EOS, growth data, either at various follow-ups or no growth system at all (n=487)
- Language (n=13)
- Other (n=16)

Full-text articles assessed for eligibility  
(n=125)

Excluded full-text articles:
- Poster abstract (n=29)
- Other growth system (n=1)
- Age <5 or >10 (n=16)
- Only revision/conversion (n=1)
- Language (n=2)
- No growth information (n=26)

Included articles  
(n=50)
## Results of the literature search

<table>
<thead>
<tr>
<th>Systems</th>
<th>Traditional growing rod</th>
<th>MDGR</th>
<th>Luque</th>
<th>VEPTR</th>
<th>Shilla</th>
<th>Mixed treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Articles</td>
<td>24</td>
<td>12</td>
<td>4</td>
<td>6</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

**Mixed treatment**: Two articles compared Shilla with TGR and one article compared MCGR with TGR.
### Segments measured

<table>
<thead>
<tr>
<th>Articles that only reported 1 segment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement</td>
</tr>
<tr>
<td>Articles</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Articles that reported on 2 segments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement</td>
</tr>
<tr>
<td>Articles</td>
</tr>
</tbody>
</table>

None of the included articles reported on all 3 segments.
## True growth rate

Four studies reported on graduates and the true growth rate in the T1-S1 segment

<table>
<thead>
<tr>
<th>Segment</th>
<th>True spinal growth in cm/year (Excluding initial and final fusion surgery)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1-S1</td>
<td>TGR (174) 0.6 [0.4-1.1]</td>
</tr>
<tr>
<td>T1-T12</td>
<td>TGR (110) 0.3</td>
</tr>
<tr>
<td>Instrumented</td>
<td>TGR (36) 0.9 [0.9-1.0]</td>
</tr>
</tbody>
</table>

## Remaining growth results

<table>
<thead>
<tr>
<th>Method</th>
<th>Follow-up spinal growth in cm/year (Excluding initial surgery)</th>
<th>Total reported spinal growth in cm/year (Including initial surgery)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>T1-S1</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TGR (799)</td>
<td>1.0 [0.5-2.3]</td>
<td>TGR (663) 1.8 [1.0-2.7]</td>
</tr>
<tr>
<td>MCGR (212)</td>
<td>0.9 [0.3-1.9]</td>
<td>MCGR (207) 3.4 [1.5-5.5]</td>
</tr>
<tr>
<td>VEPTR (113)</td>
<td>0.5 [0.0-1.0]</td>
<td>VEPTR (125) 1.9 [1.0-3.0]</td>
</tr>
<tr>
<td>Shilla (76)</td>
<td>0.7 [0.6-0.8]</td>
<td>Shilla (95) 1.4 [1.4-1.6]</td>
</tr>
<tr>
<td>Luque</td>
<td></td>
<td>Luque (47) 1.8</td>
</tr>
<tr>
<td><strong>T1-T12</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TGR (175)</td>
<td>0.7 [0.2-1.5]</td>
<td>TGR (128) 0.8 [0.7-1.1]</td>
</tr>
<tr>
<td>MCGR (181)</td>
<td>0.6 [0.2-1.2]</td>
<td>MCGR (116) 2.4 [1.9-3.6]</td>
</tr>
<tr>
<td>VEPTR (99)</td>
<td>0.3 [0.2-0.6]</td>
<td>VEPTR (119) 1.3 [0.6-2.1]</td>
</tr>
<tr>
<td>Shilla (40)</td>
<td>0.6</td>
<td>Shilla (40) 0.9</td>
</tr>
<tr>
<td>Luque</td>
<td></td>
<td>Luque</td>
</tr>
<tr>
<td><strong>Instrumented</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TGR (135)</td>
<td>1.0 [0.8-1.1]</td>
<td></td>
</tr>
<tr>
<td>MCGR (9)</td>
<td>1.1</td>
<td></td>
</tr>
<tr>
<td>VEPTR</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shilla</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Luque (68)</td>
<td>0.8 [0.3-1.0]</td>
<td></td>
</tr>
</tbody>
</table>
Average age at start of treatment

Age at surgery and end of follow-up

TGR (805)  6,9  1,0 cm/y  11,2
MCG (212)  8,0  0,9 cm/y  9,6
VEPTR (113)  6,0  0,5 cm/y  8,8
Shilla (95)  6,4  0,7 cm/y  11,1
Luque (68)  7,3  0,8 cm/y  11,7
Influence of cobb angle

Initial implantation surgery
- 32° COBB
+3,64 CM T1-S1

True Growth period
+15° COBB
+3,56 CM T1-S1

Final fusion surgery
-15° COBB
+2,33 CM T1-S1
The growing spine: how spinal deformities influence normal spine and thoracic cage growth

Alain Dimeglio · Federico Canavese

• T1-S1 Growth
  – First 5 years of life; **2 cm/year**
  – Between 5 and 10; **1 cm/year**
  – Between age 10 and skeletal maturity; **1.8 cm/year**

• T1-T12 growth
  – The first 5 years of life; **1.3 cm/year**
  – Between 5 and 10; **0.7 cm/year**
  – Between age 10 and skeletal maturity; **1.1 cm/year**
Thoracic Spine Growth Revisited

How Accurate Is the Dimeglio Data?

Ozgur Dede, MD,* Kadir Büyükoğlan, MD,† Halil Gökhan Demirkiran, MD,‡ Erhan Akpinar, MD,§ and Muharrem Yazici, MD†

• Cross-sectional CT study in 133 patients (did not follow growth over time)

• T1-T12 growth
  – Between 1 and 4 years; **1.71** cm/year
  – Between 4 and 8 years; **0.55** cm/year
  – Between 8 and 10 years; **0.74** cm/year
  – Between 10 and 12 years; **0.69** cm/year
  – Between 12 and 16; **1.61** cm/year
Growth in Boston Brace

- Selection of all JIS patients treated with Boston brace at OLVG
  - Ordered when a curvature was between 25° and 45°
  - Worn > 20 hours a day
  - Radiographs present from before brace, after removal of brace and at skeletal maturity

- Control group was matched on age and sex

50 JIS patients treated with Boston brace  
77 controls without scoliosis

(T0) Before brace  
(T1) after brace  
(T2) skeletal mature  
VS  
(T2) skeletal mature
## Results

### (T0) Before bracing

<table>
<thead>
<tr>
<th>N = 50</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Female (%)</strong></td>
<td>44 (88%)</td>
<td></td>
</tr>
<tr>
<td><strong>Mean age at diagnosis</strong></td>
<td>7.4 y (±1.7)</td>
<td></td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td>10.4 y</td>
<td></td>
</tr>
<tr>
<td><strong>Cobb</strong></td>
<td>33°</td>
<td></td>
</tr>
<tr>
<td><strong>T1 – T12 freehand</strong></td>
<td>24.5 cm</td>
<td></td>
</tr>
<tr>
<td><strong>T1 – S1 freehand</strong></td>
<td>39.1 cm</td>
<td></td>
</tr>
<tr>
<td><strong>Total body height</strong></td>
<td>153.0 cm</td>
<td></td>
</tr>
</tbody>
</table>

### (T1) After bracing

<table>
<thead>
<tr>
<th>N = 36</th>
<th><strong>Only Brace treatment</strong></th>
<th>N=14</th>
<th><strong>Surgery after Brace</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td>14.7 y</td>
<td></td>
<td><strong>Age</strong></td>
</tr>
<tr>
<td><strong>Cobb</strong></td>
<td>26° (±8.9°)</td>
<td></td>
<td><strong>Cobb</strong></td>
</tr>
<tr>
<td><strong>T1 – T12</strong></td>
<td>29.0 cm</td>
<td></td>
<td><strong>T1 – T12</strong></td>
</tr>
<tr>
<td><strong>T1 – S1</strong></td>
<td>46.4 cm</td>
<td></td>
<td><strong>T1 – S1</strong></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>171.7 cm</td>
<td></td>
<td><strong>Total</strong></td>
</tr>
</tbody>
</table>
Results

• Comparing Dimeglio’s growth data from 10 years to skeletal maturity with growth during brace treatment (T0 – T1)

<table>
<thead>
<tr>
<th>N=50</th>
<th>Spinal growth during brace treatment</th>
<th>Dimeglio’s spinal growth data(^1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total growth</td>
<td>Growth/year</td>
</tr>
<tr>
<td>(T1-T12) freehand</td>
<td>4.22 cm (±2.6)</td>
<td><strong>1.08 cm/ year</strong> (±0.5)</td>
</tr>
<tr>
<td>(T1-T12) freehand</td>
<td>7.00 cm (±4.6)</td>
<td><strong>1.74 cm/ year</strong> (±0.7)</td>
</tr>
</tbody>
</table>


* One sample T-test
# Results

<table>
<thead>
<tr>
<th>T2: Only braced JIS patients (n=36)</th>
<th>T2: controls (n=77)</th>
<th>Height vs Controls</th>
<th>Freehand vs Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td>18.1 y</td>
<td>18.6 y</td>
<td></td>
</tr>
<tr>
<td><strong>Cobb</strong></td>
<td>27.7 (±9.5)</td>
<td>0°</td>
<td></td>
</tr>
<tr>
<td><strong>T1 – T12</strong></td>
<td>28.9 cm (±1.8)</td>
<td><strong>29.9 cm (±2.2)</strong></td>
<td>0.014* 0.227</td>
</tr>
<tr>
<td><strong>T1 – S1</strong></td>
<td>46.2 cm (±3.3)</td>
<td><strong>47.6 cm (±3.3)</strong></td>
<td><em><em>0.036</em> 0.299</em>*</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>172.3 cm (±8.4)</td>
<td>175.3 cm (±8.8)</td>
<td></td>
</tr>
</tbody>
</table>

*compared between brace JIS and controls at skeletal maturity with two sided t-test
Conclusion

• Reporting on growth and measurement methods is substandard

• Growth can be achieved with growth friendly systems

• Majority of growth is achieved with initial and final fusion surgery

• The true growth reported in the literature is lower than the reported growth of Dimeglio