Biomechanical Simulation of the Immediate and Long Term 3D Correction of Anterior Vertebral Body Tethering in Pediatric Idiopathic scoliosis

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POLYTECHNIQUE MONTRÉAL

LE GÉNIE EN PREMIÈRE CLASSE

NSERC-Medtronic Industrial Research Chair in Spine Biomechanics

Canada Research Chair in Orthopedic Engineering

Centre de Recherche du CHU Sainte-Justine

Le centre hospitalier universitaire mère-enfant

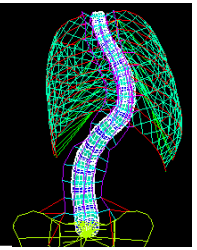
Pour l'amour des enfants

Disclosures

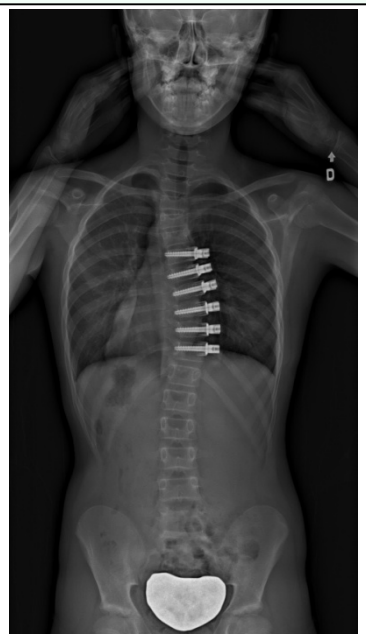
N. Cobetto	Natural Sciences and Engineering Research Council of Canada (a)
C.E. Aubin	Natural Sciences and Engineering Research Council of Canada (a), Medtronic (a, b, c)
S. Parent	Spinologics (d), AOSpine (e), Depuy Synthes (a,c), EOS Imaging (a,c), K2M (a), Medtronic (a, c)

(a) Grants/Research Support
(b) Other Financial Support
(c) Consultant
(d) Stock/Shareholder
(e) Speaker's bureau

PROBLEM STATEMENT



Anterior Vertebral Body Tethering



- Compressive loads on curve convexity
- Allows spine flexibility

- Surgical planning = mostly empirical
  - Nb instrumented levels
  - Tension in tether
  - Initial correction (due to lateral decubitus positioning vs. tether tightening)

Problems:

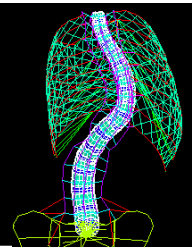
→ Progression/Over-correction of the curve

→ Lack of control on 3D correction (sagittal plane and axial rotation)

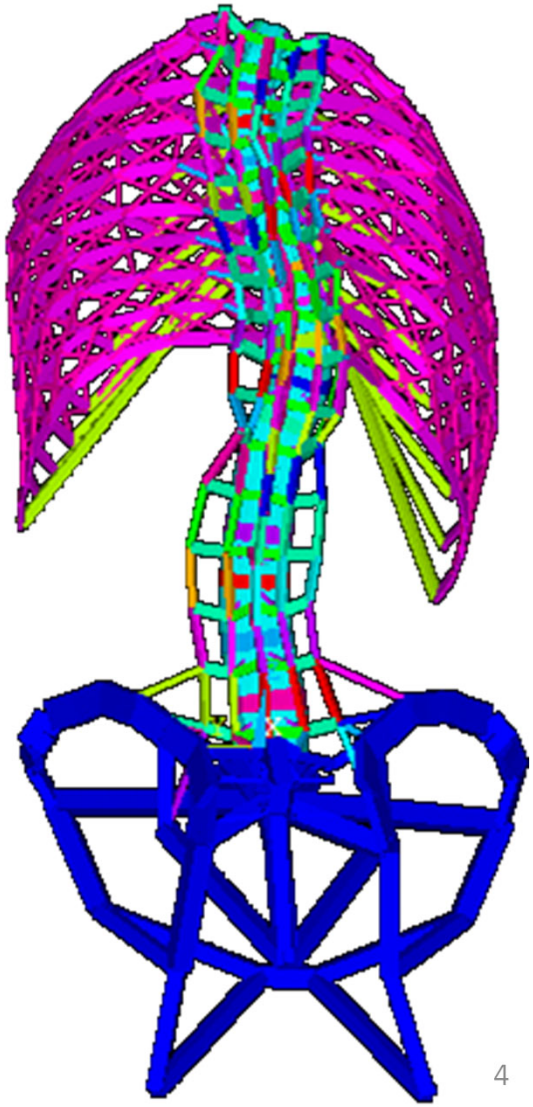
→ Possible intervertebral disc degeneration for high compressive loads

References: Lenke 2011, Crawford 2010, Skaggs 2014, Stokes 2013, Driscoll 2011

OBJECTIVE



To develop a clinically useful planning tool based on a computational model (FEM) of pediatric scoliosis integrating growth, enabling to predict the short and long term 3D correction of various configurations of *Anterior Vertebral Body Tethering (AVBT)*



EXPERIMENTAL STUDY DESIGN

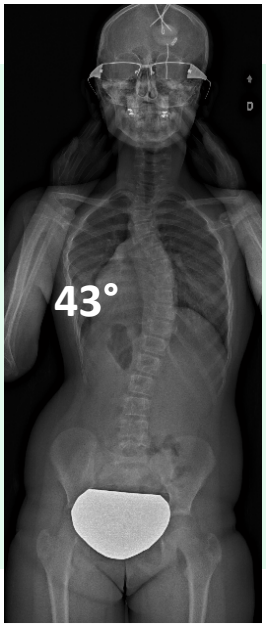
33 cases of patients instrumented with AVB Tether at our institution

Consecutively recruited over a 1 year period

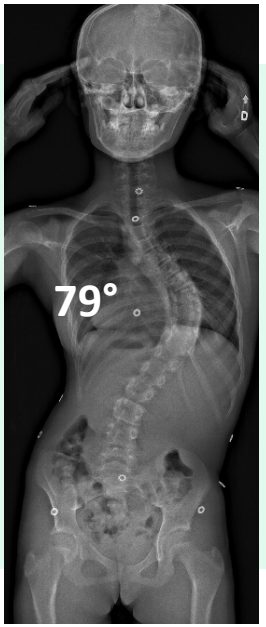
Inclusion criteria

- Idiopathic scoliosis
- Progressive curves
- Cobb angle between 40° and 80°
- Age: 8-13 years
- Risser sign: 0-1

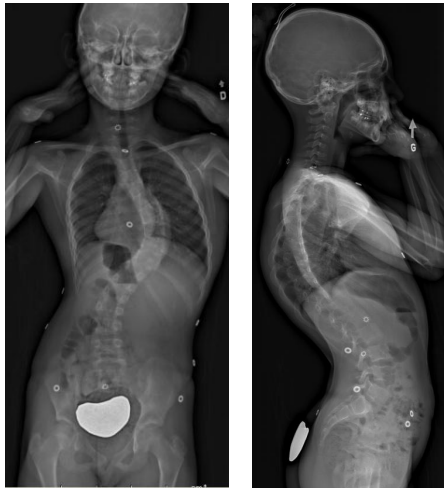
Case #13



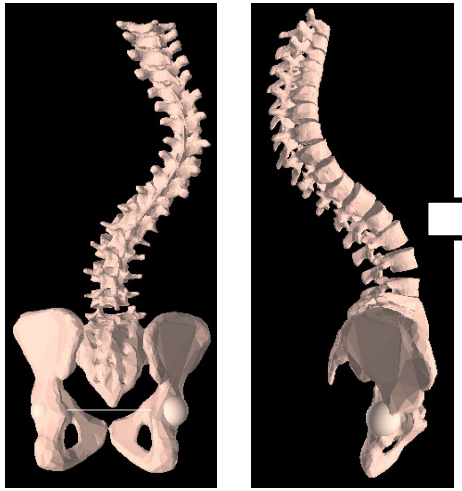
Case #10



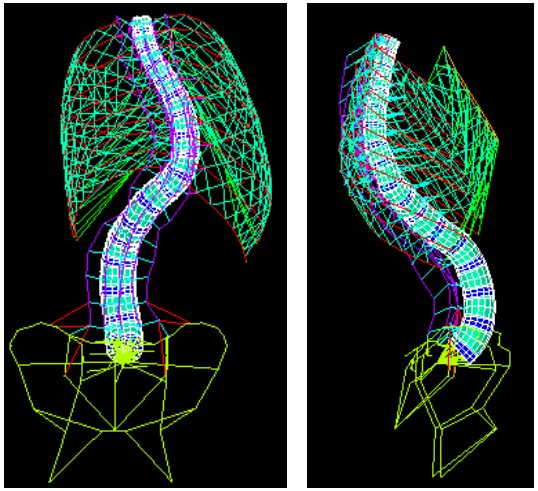
3D RECONSTRUCTION AND FEM



Bi-planar radiographs

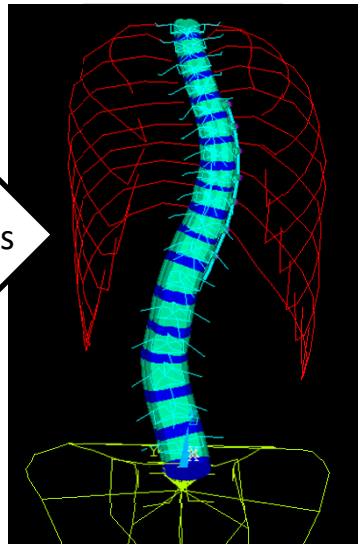


3D Reconstruction



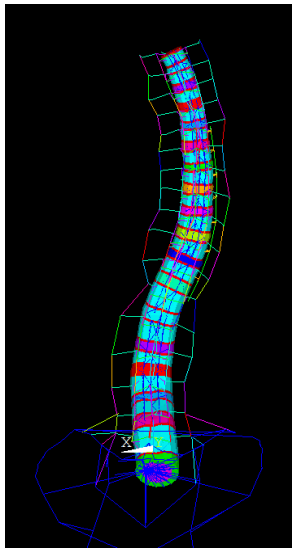
Osseo-ligamentous Finite Element Model

Simulations



Tether installation
Immediate post-op

Stresses on growth plates
Immediate post-op



3 years Growth

Vertebrae T1 to L5
Discs, Ligaments
Rib cage
Pelvis

Growth Modulation Model

$G = G_m * (1 - \beta * (\sigma - \sigma_m))$

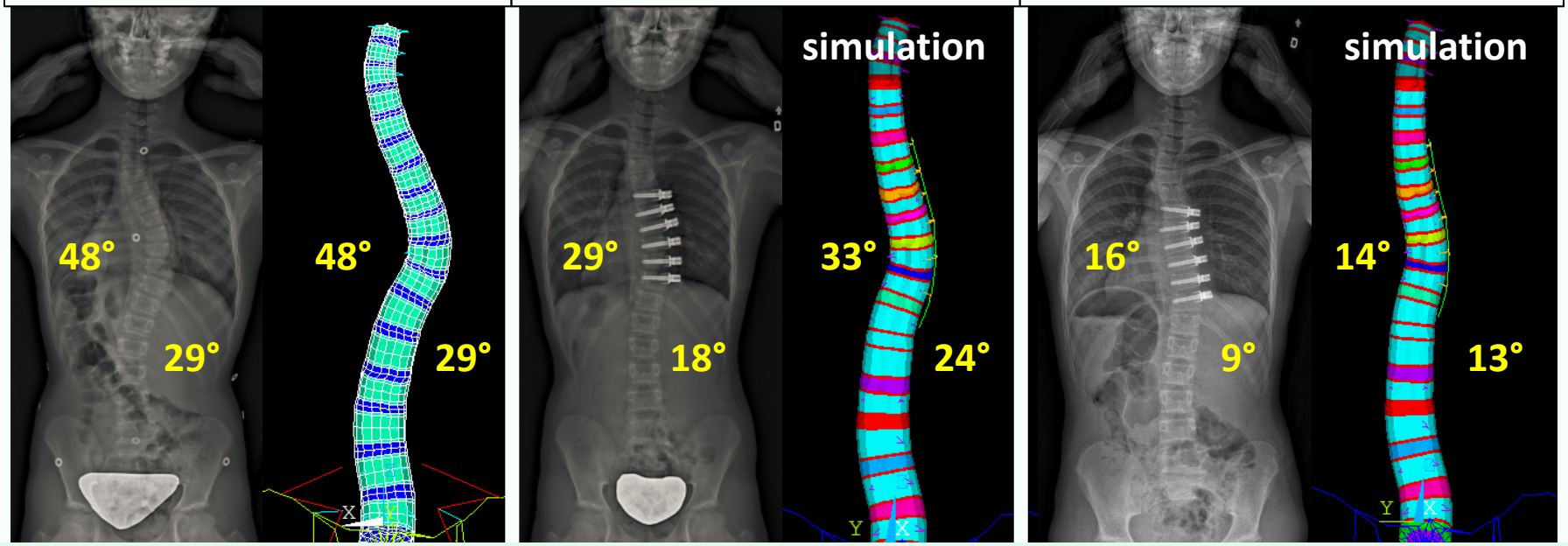
G_m = 1.1 cm/year (average)
(Canavese & Dimiglio 2013)

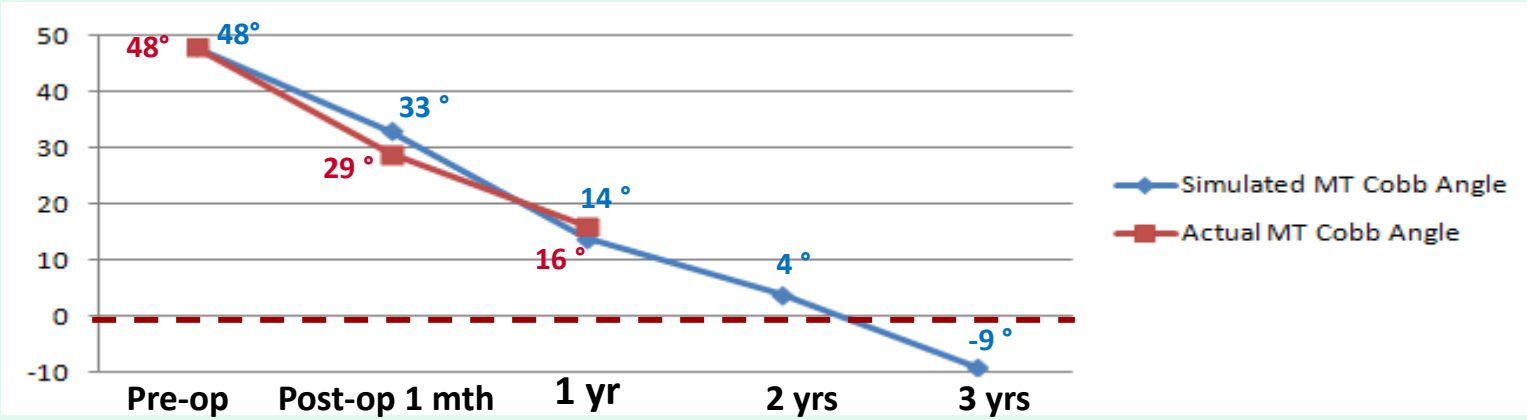
β = 1.7 Mpa^{-1} (average)
(Villemure 2009)

RESULTS - SIMULATION

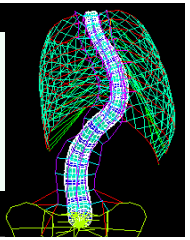
Case # 1

Pre-operative	Immediate Post-operative	1 year f-u





RESULTS – 33 cases



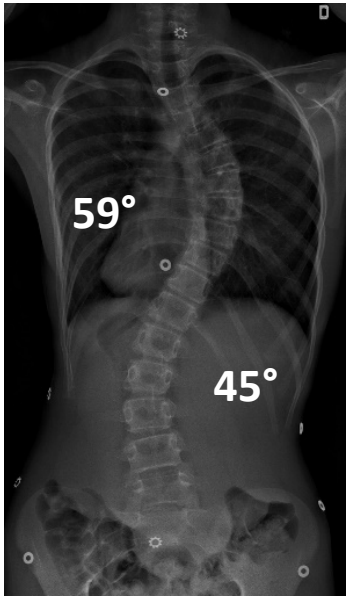
Average difference b/w predicted (model) vs. actual post-op

❑ **Immediate post-op:**

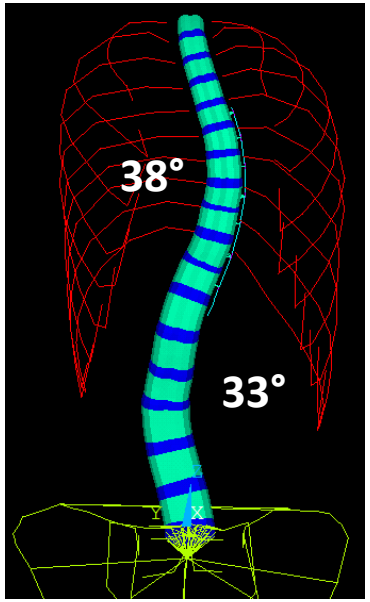
- MT and TL/L Cobb angles ± 5°
- Kyphosis and lordosis angles ± 5°
- Apical axial rotation ± 3°

❑ **1 year follow-up:**

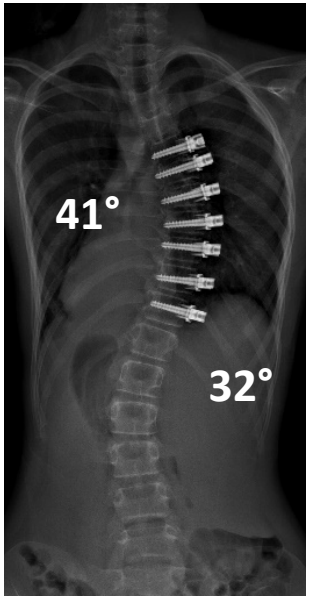
- Cobb angles ± 4°
- Spinal growth (T1-L5 height) ± 3%
- Vertebral and discal wedging ± 3°



Pre-op

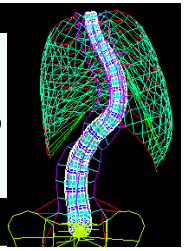


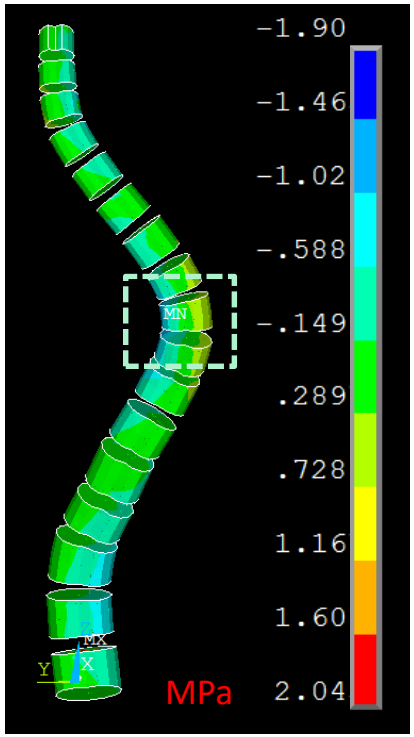
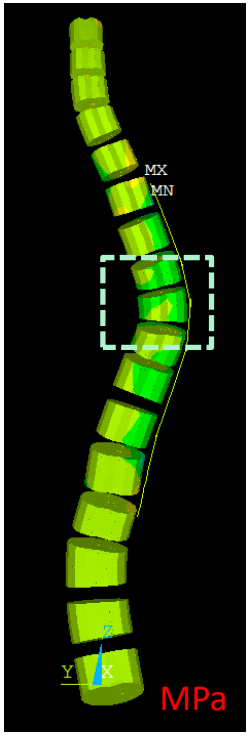
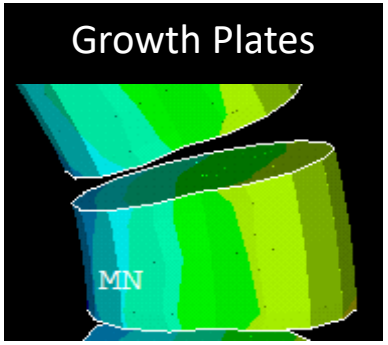
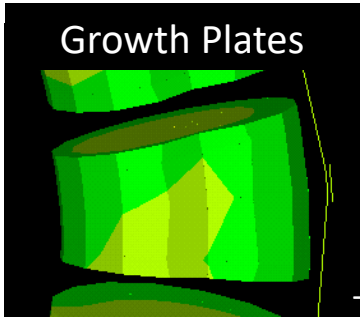
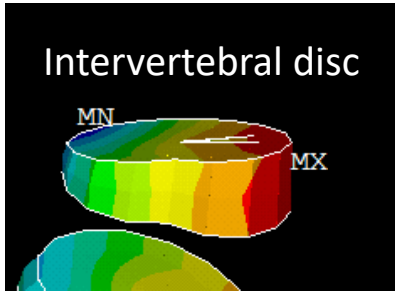
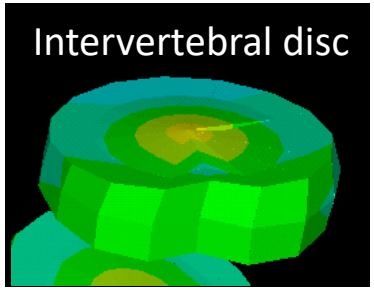
Simulation



Post-op

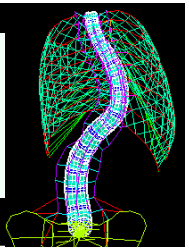
Local forces on growth plates and intervertebral discs



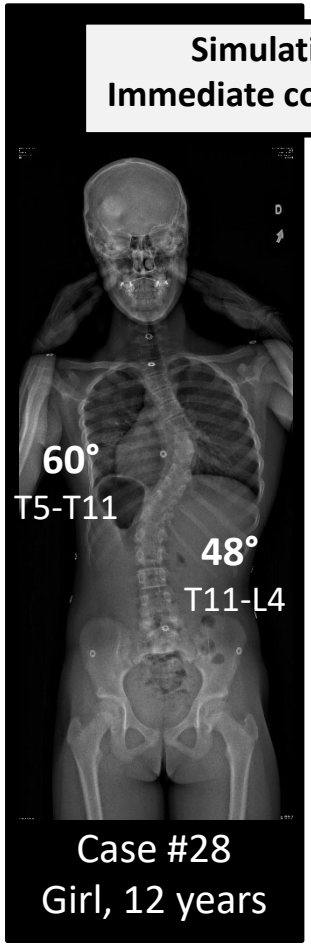
Pre-operative loads	Post-operative loads
	
	
Concave/Convex Asymmetrical pressures	**Balanced pressures on concave/convex sides**
	

Balance of loads applied on growth plates and intervertebral discs

Pre-op surgical planning



Pre-op

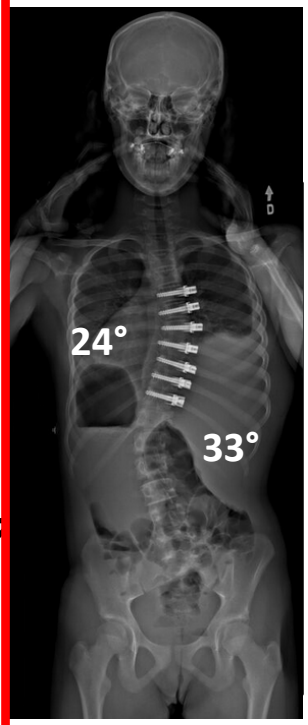


Case #28
Girl, 12 years

Simulation
Immediate correction

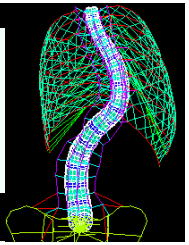
T4-T10	T4-T11	T5-T11	T5-T11
25°	24°	22°	28°
33°	32°	32°	32°
300 N	300 N	300 N	200 N
2 years	2 years	2 years	2 years
-12°	-17°	-19°	-4°
17°			18°

Post-op



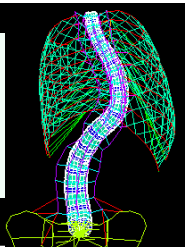
T5-T11

Conclusion



Feasibility and clinical utility of the planning tool to reasonably predict the short and long term correction of various configurations of Anterior Vertebral Body Tethering

LIMITATIONS AND PERSPECTIVES

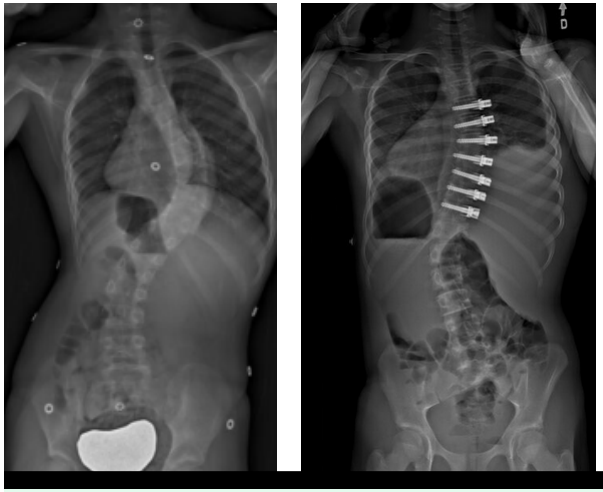


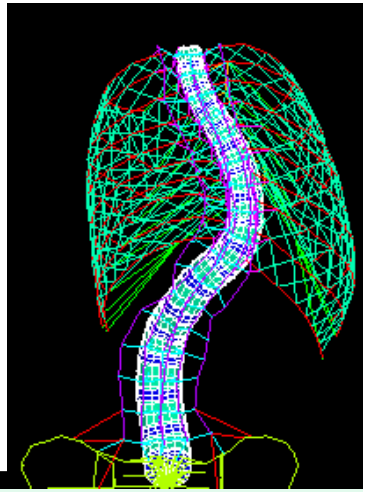
Limitations

- Rib cage growth not modeled
- Muscles not modeled

Perspectives

- On going study for validation by including every new tethered cases
- Personalized surgical planning method enabling to improve current techniques and eventually study other compression-based fusionless approaches





Thank you for your attention !

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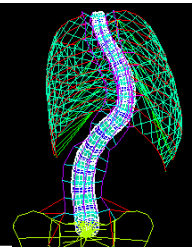
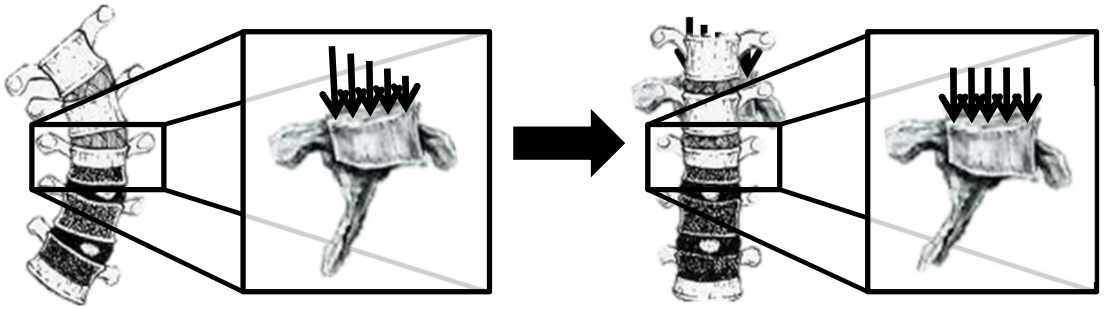
Pediatric Scoliosis with Remaining Growth Potential
Fusionless Approaches



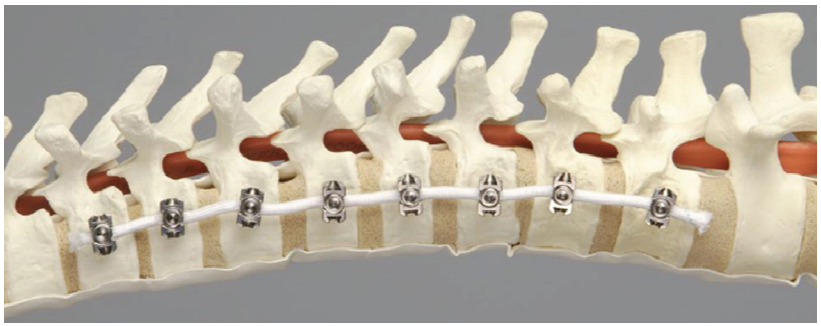
Principles *(Tis 2012, El-Hawary 2013, Matsumoto 2013)*

- Curve stabilisation during growth to delay/avoid vertebral fusion
- Based on Hueter-Volkmann law:
  - Growth modulation
  - Rebalance loads on growth plates



Anterior Vertebral Body Tethering *(compression based fusionless approach)*

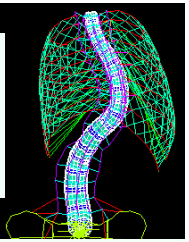
(Lenke 2011, Crawford 2010, Skaggs 2014, Driscoll 2011)



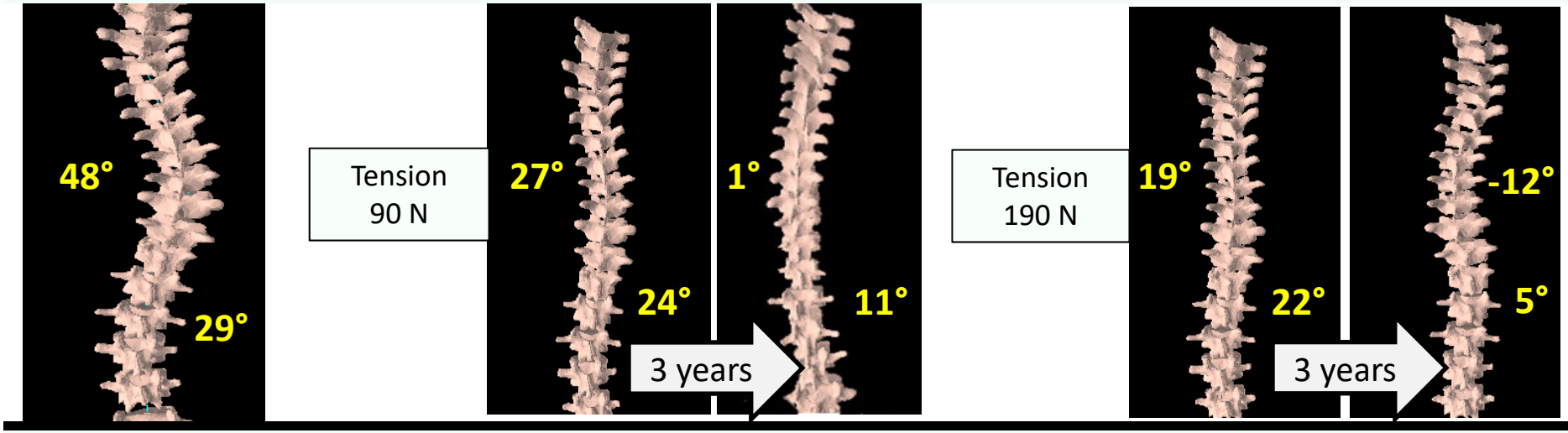
- Bone screws + flexible cable
- Compressive loads on curve convexity
- Allows spine flexibility

CA20
CA21

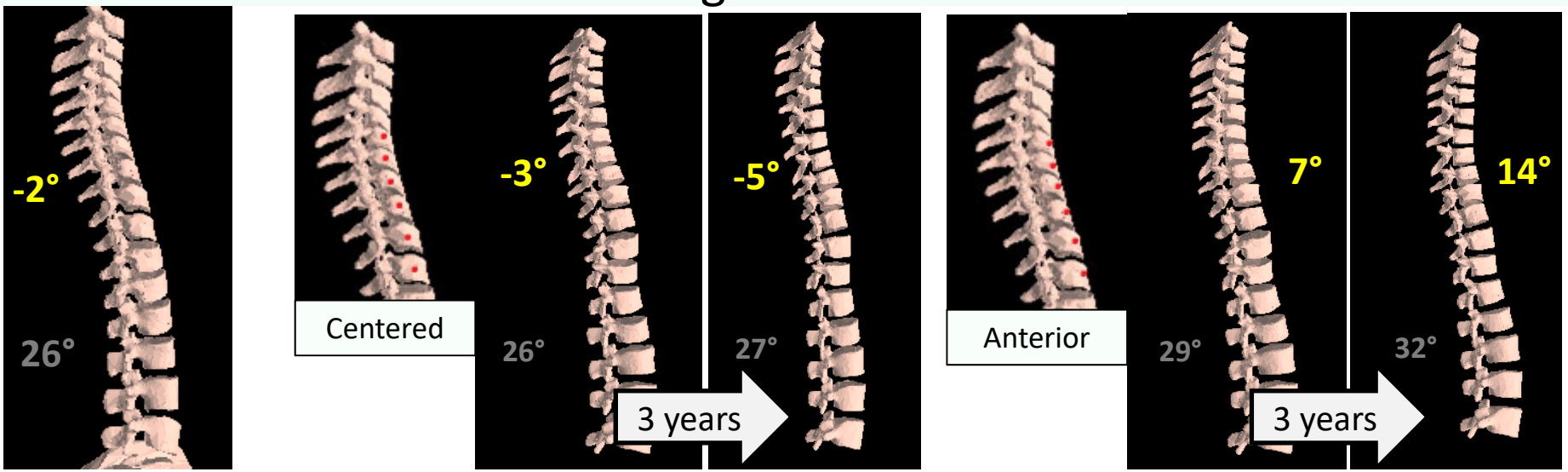
Tested configurations and tensions



Coronal Plane



Sagittal Plane



Slide 16

CA20 je suggère d'enlever cette diapo.
Carl-Eric Aubin, 11/12/2015

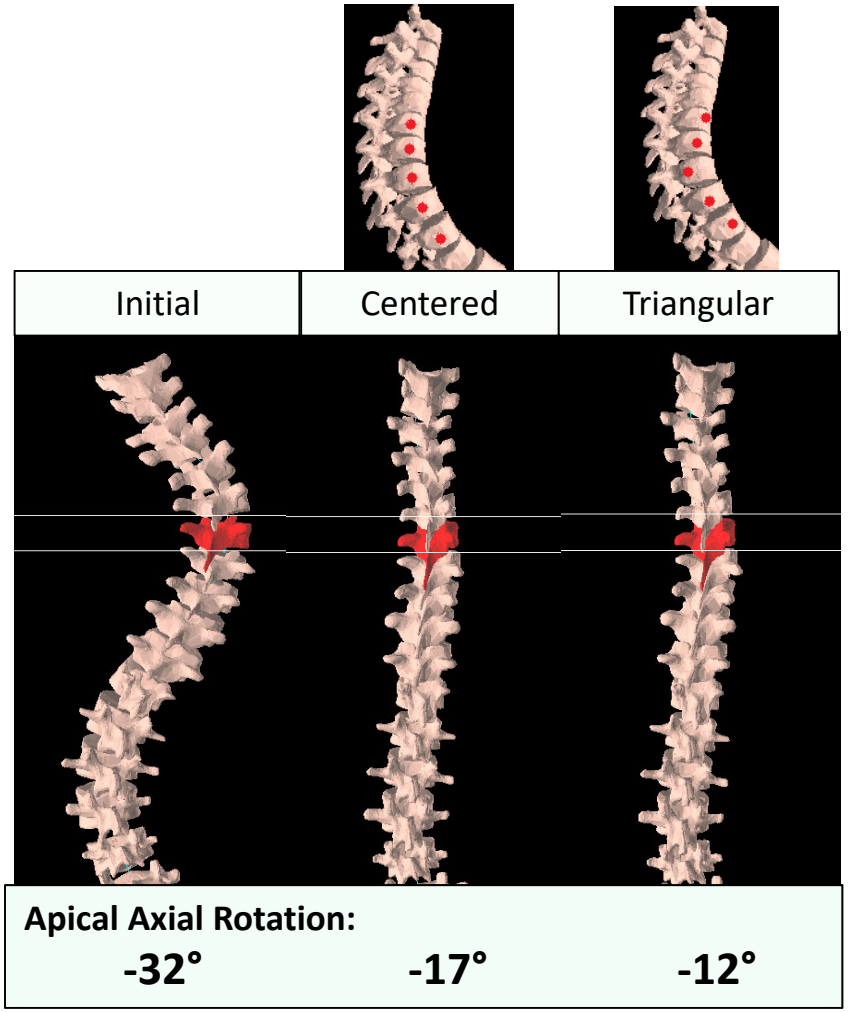
CA21 à laplace,mettre un exemple de 2 tensions à la diapo précédente
Carl-Eric Aubin, 11/12/2015

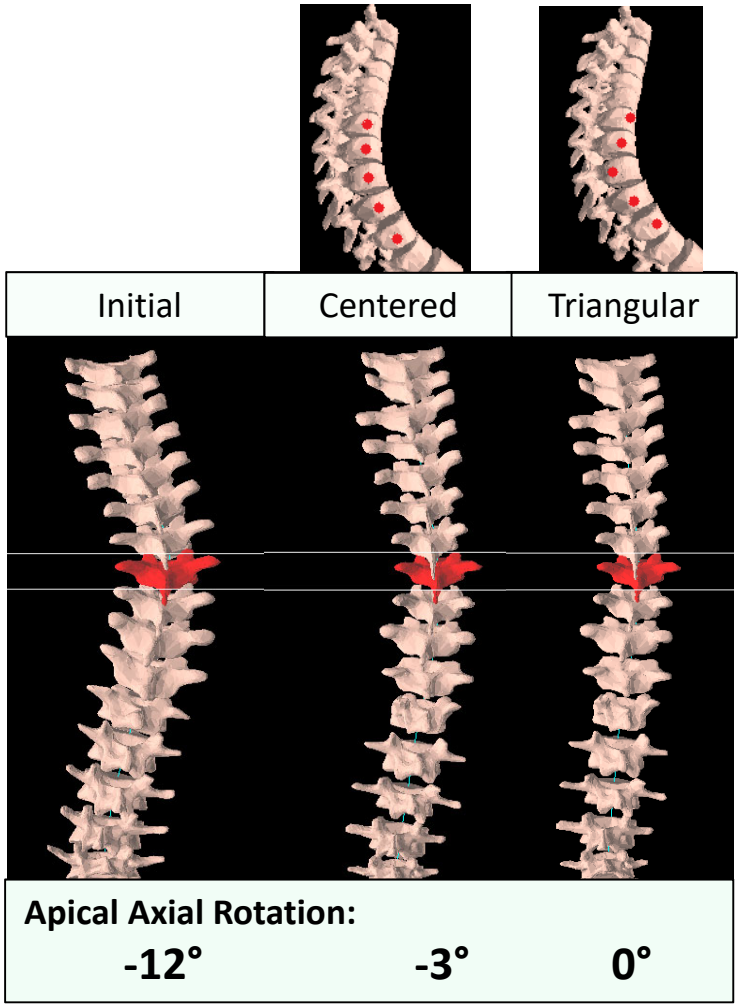
CA23

3D CORRECTION

Transverse Plane

Significant derotation for triangular vs. centered tethers **for cases w/ initial axial rotation ≥ 15°**





Slide 17

CA23 si tu manques de temps, je retirerais cette diapo.
Carl-Eric Aubin, 11/12/2015