Medtronic

Importance of modeling in the process of development of biomedical implants

THERAPIES

SERVICES & SUPPORT

ENABLING TECHNOLOGIES

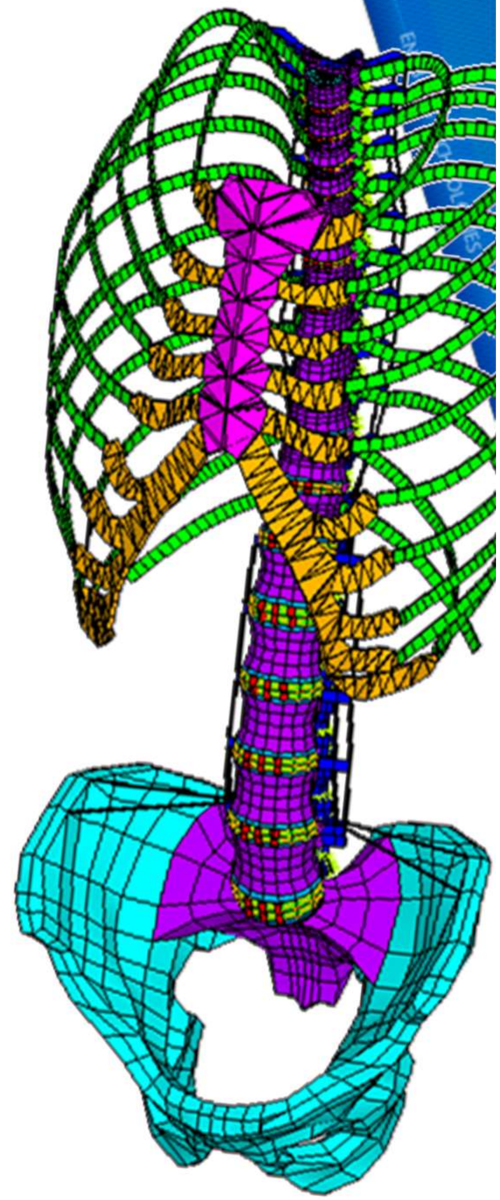
Philippe Maxy

Principal Scientist, Technical Fellow

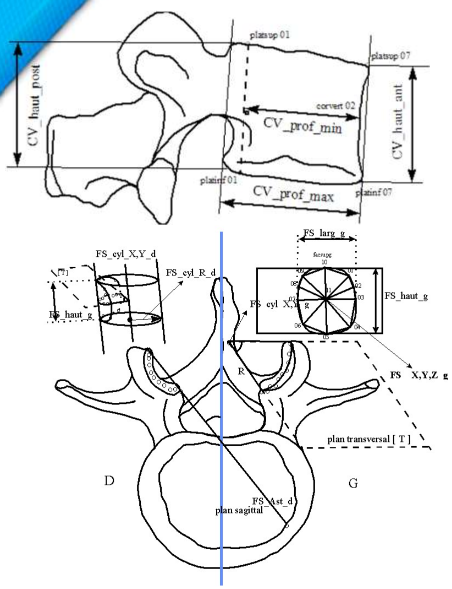
INTEGRATED
SPINE SOLUTIONS

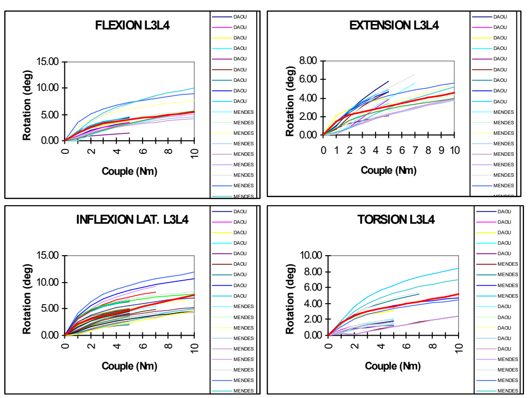
Importance of modeling
in the process of development
of biomedical implants

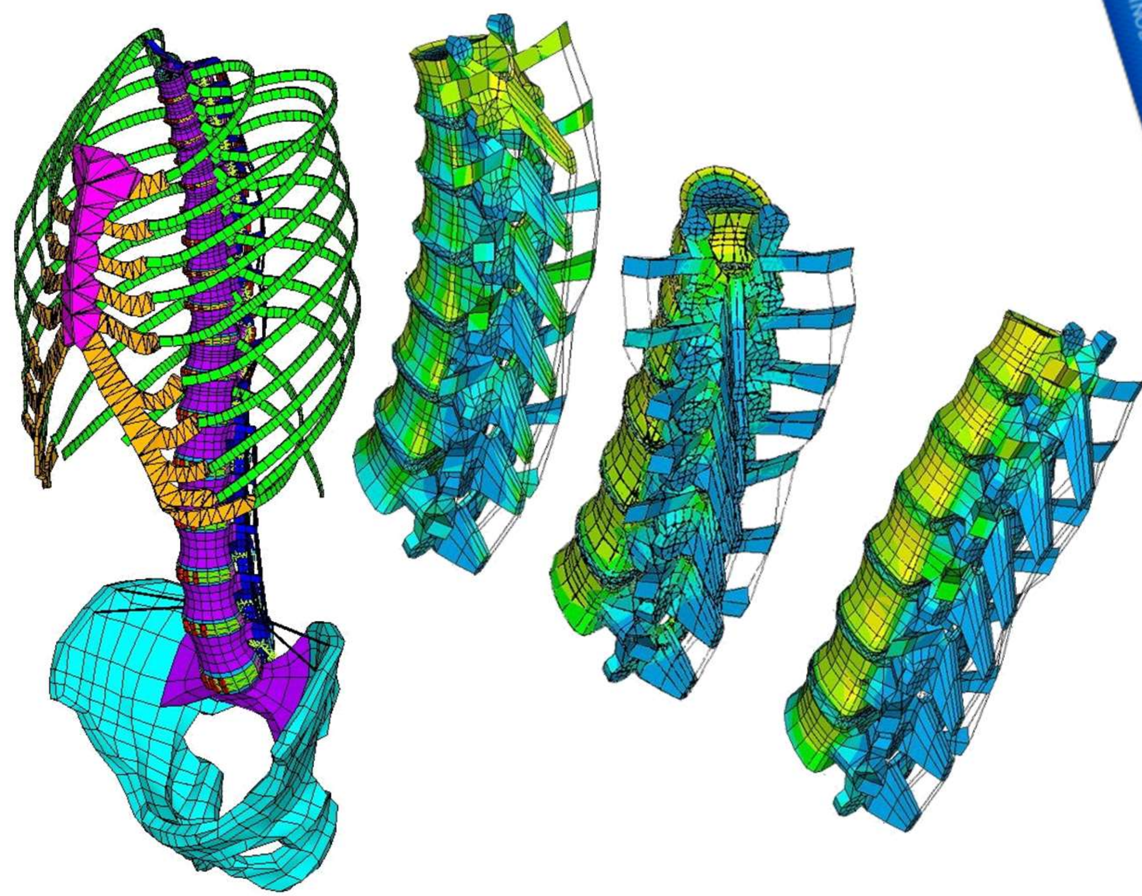
INTRODUCTION



Foundations







Fully Validated Geometrical & Mechanical Model

Why use FEA?

- Fundamental Research
  - For a Better Knowledge
- From Fundamental to Applied Research
  - For a Better Concept
- Development & Design Optimization
  - For a Better Design
- Malfunction Analysis & Understanding
  - For a Better Prevention of Risks

Importance of modeling
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FUNDAMENTAL RESEARCH

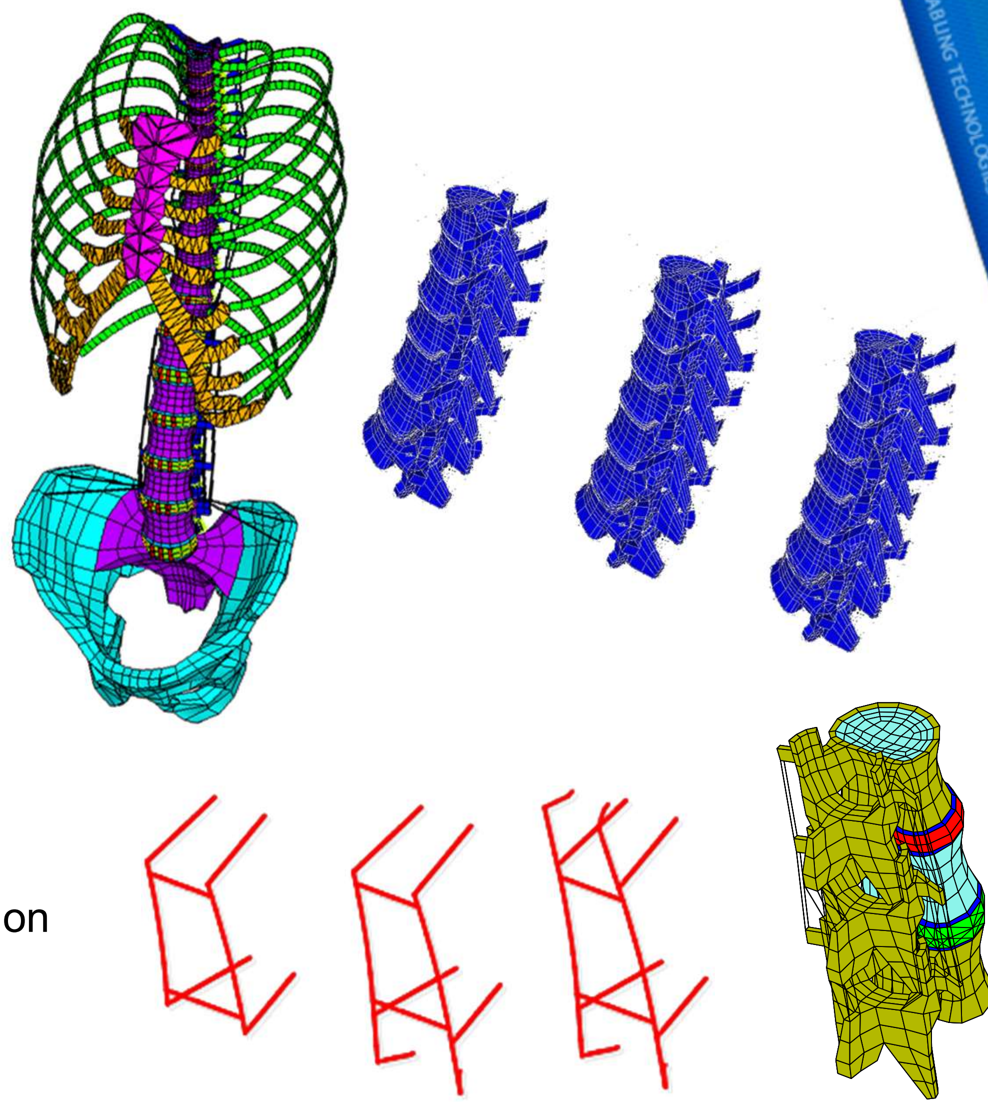
Fundamental Research

Exemple:
Burst-Fracture Instrumentations

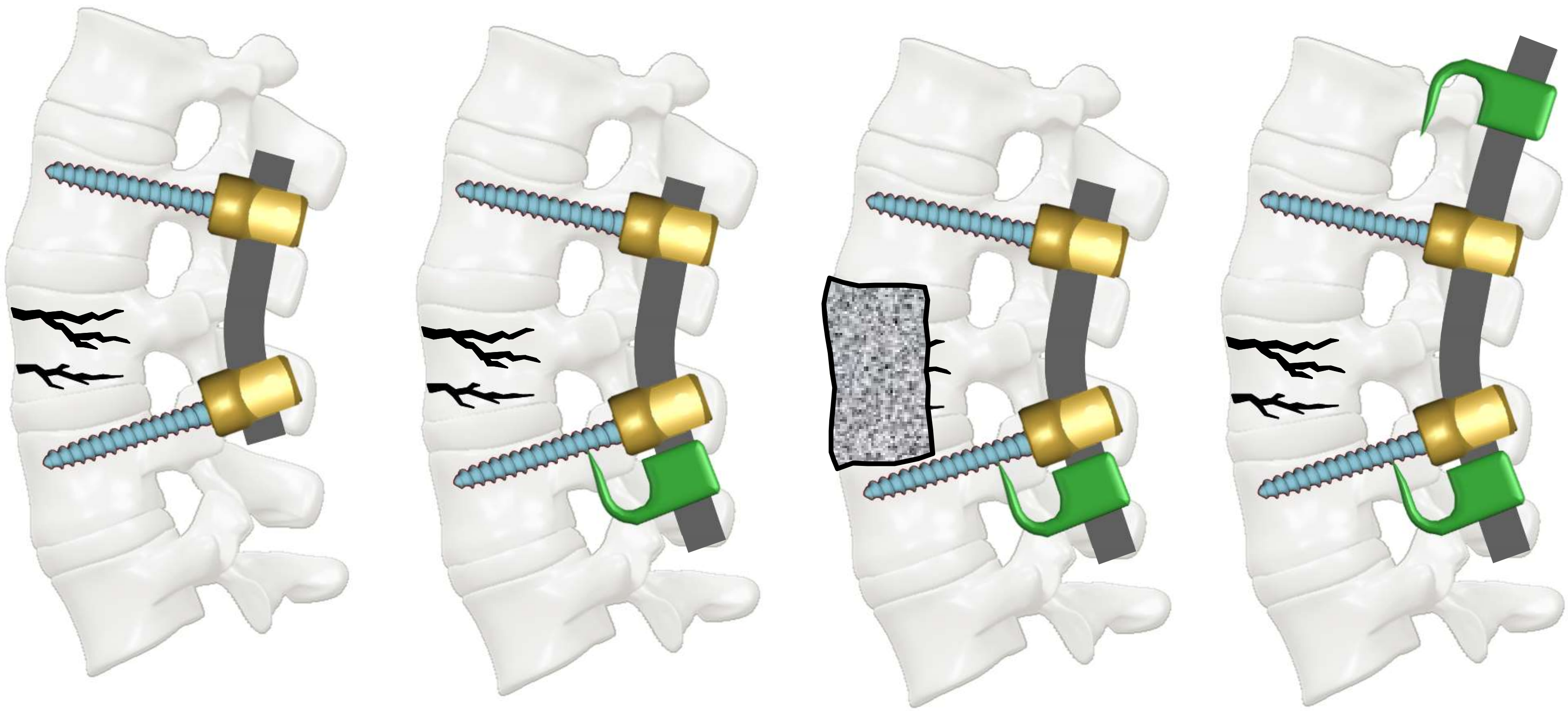
A fully validated 3D FEA model of the spine can be a powerfull tool to obtain the mechanical environment of the fixation device (forces & moments distribution along the pedicle screws, etc.)

A Burst Fracture can be used as a clinical case to compare different posterior fixation techniques.

Optimize implants with the knowledge of forces and moments that are acting on the device.



Fundamental Research



SHORT D

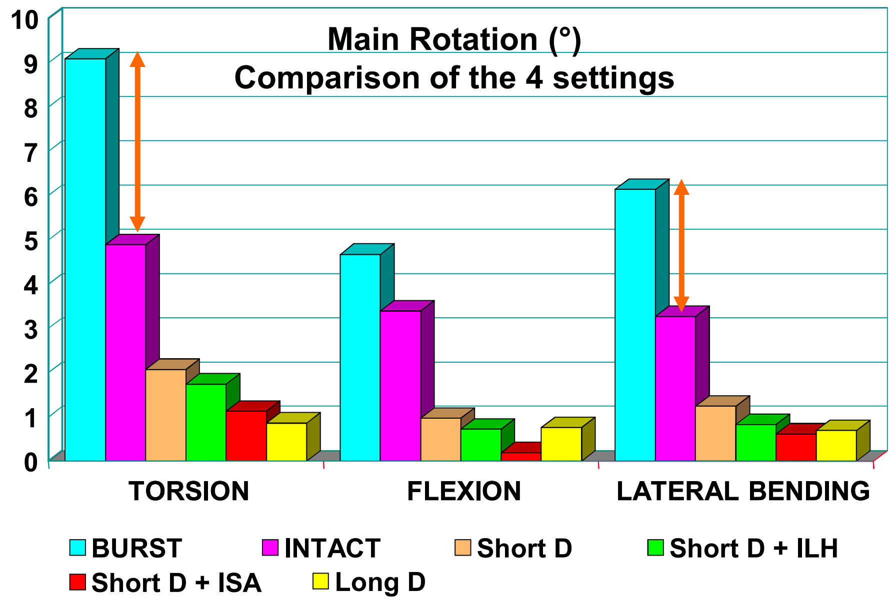
SHORT D
+ ILH

SHORT D
+ ILH + ISA

LONG D

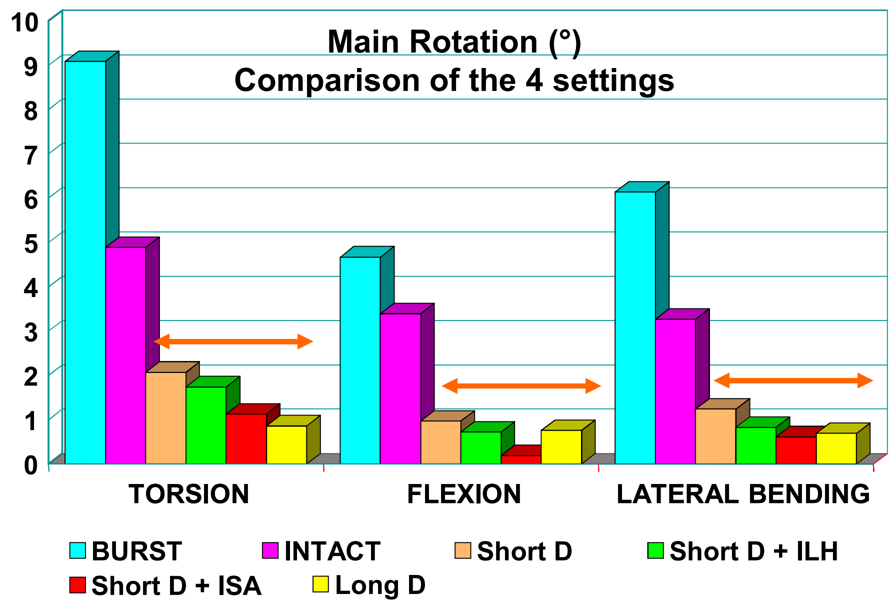
Fundamental Research

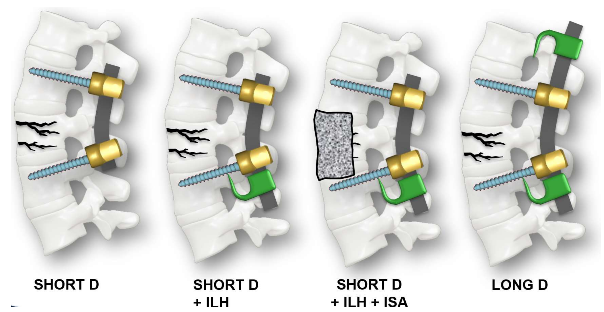
- Increase rotation of the injured segment, mainly in torsion



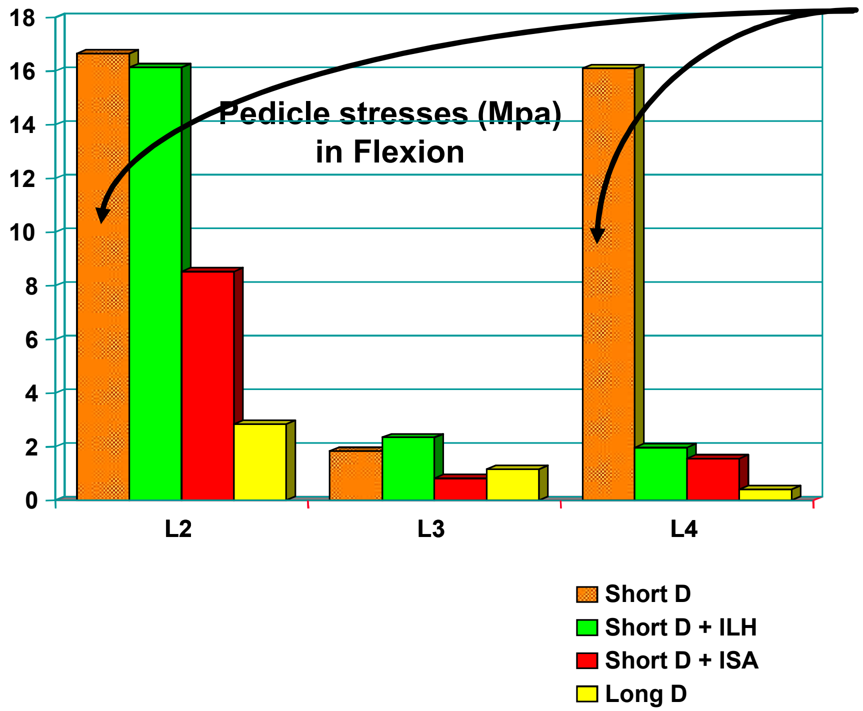
Fundamental Research

- Increase rotation of the injured segment, mainly in torsion
- No significant difference in mobilities between the 4 devices

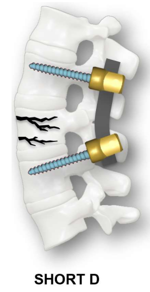




Fundamental Research

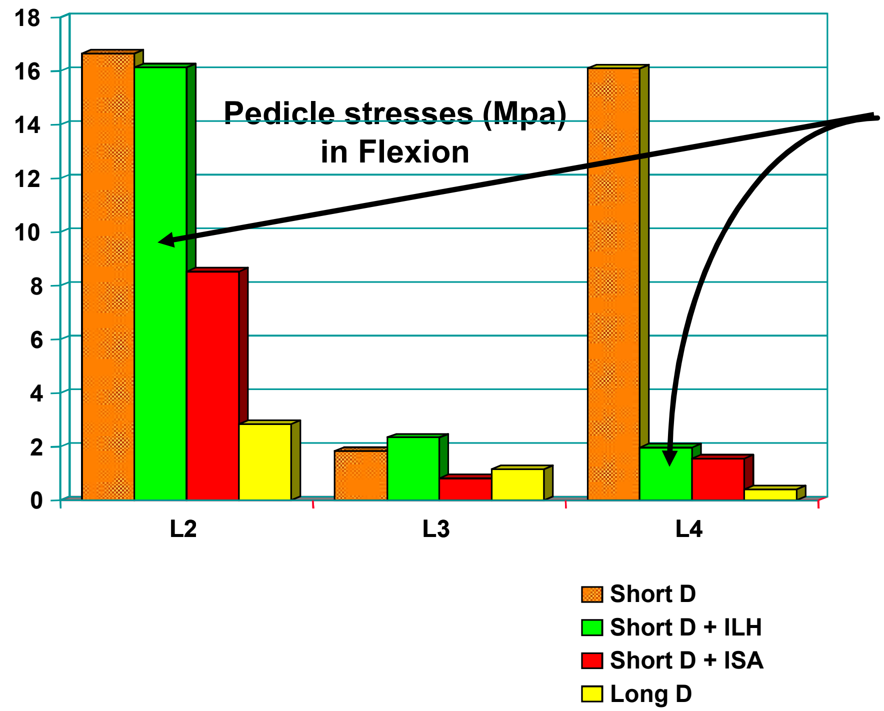


- High stresses were found in the pedicle screw for the Short Device

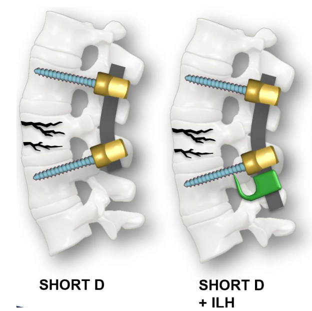


Fundamental Research

Results



- High stresses were found in the pedicle screw for the Short Device
- The infralaminar hook unloaded the lower pedicle screw and did not change the stress distribution in the upper pedicle screw



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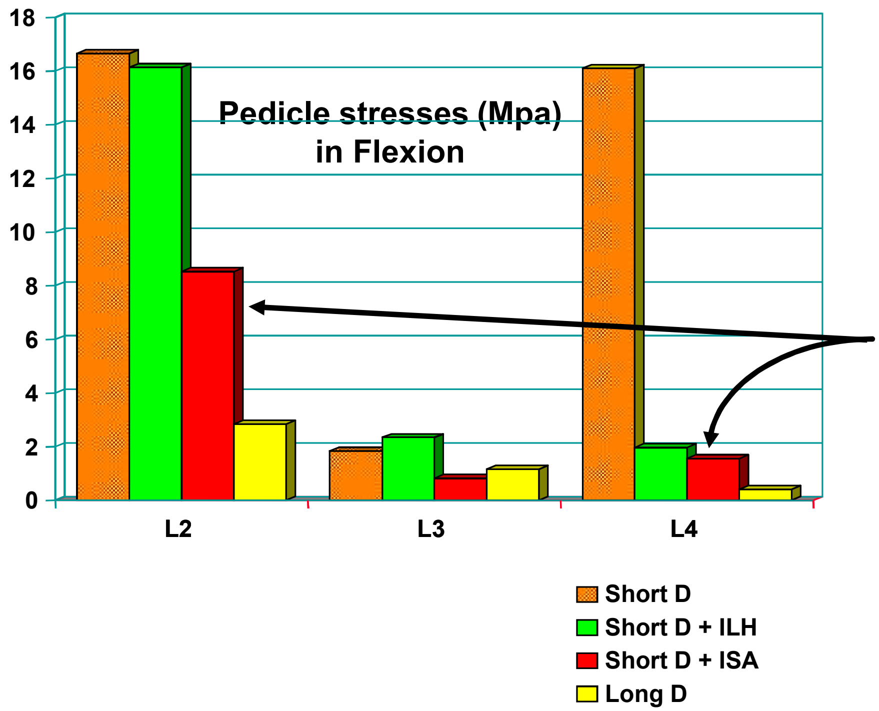
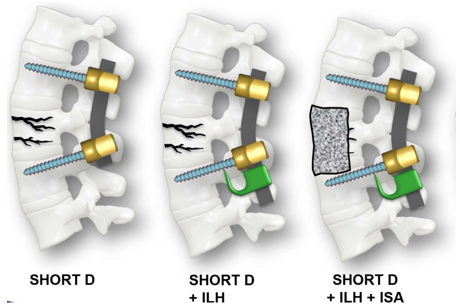
Fundamental Research

Results

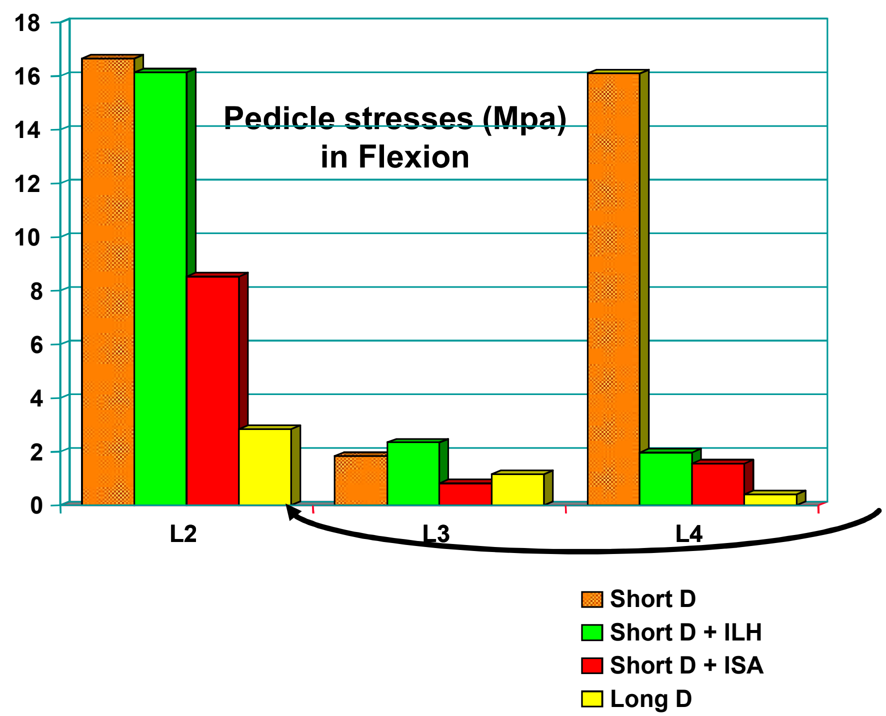


- High stresses were found in the pedicle screw for the Short Device
- The infralaminar hook unloaded the lower pedicle screw and did not change the stress distribution in the upper pedicle screw
- The bone graft also yielded a decrease of stresses both in lower and upper screws



Fundamental Research

Results



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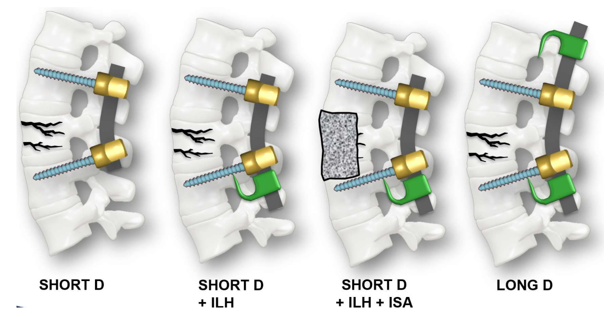
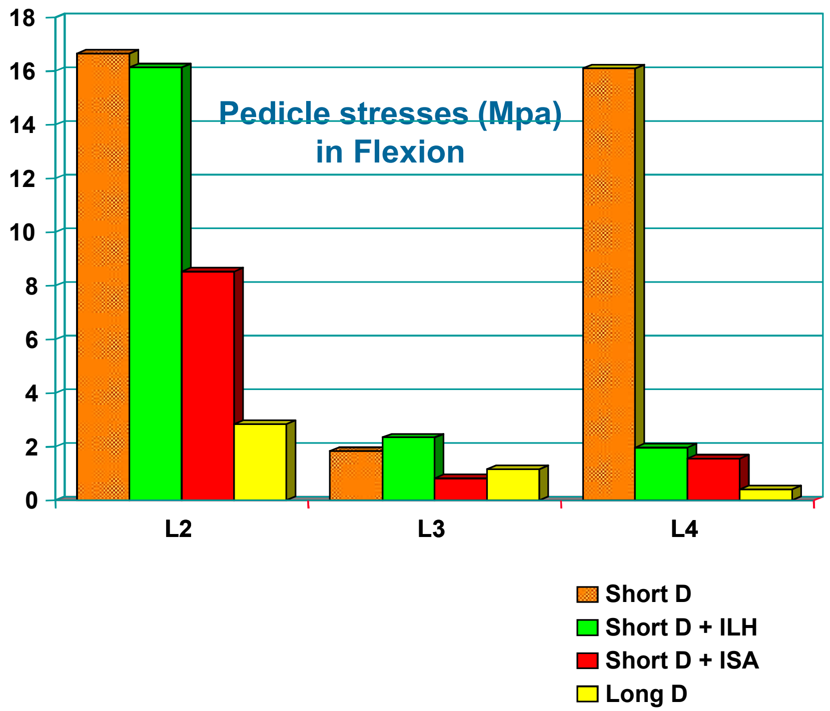
- Pedicle stresses disappeared with the long device



Fundamental Research

Results



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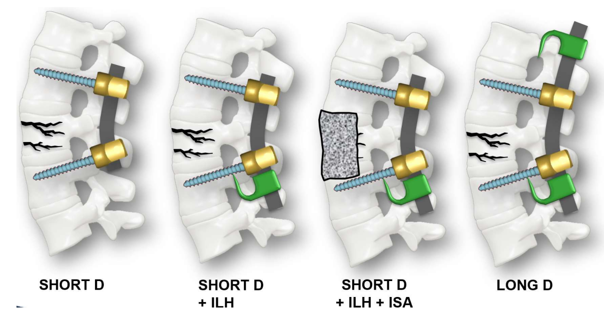


Medtronic

Fundamental Research

- Spinal Finite Element model allows us to analyze not only the segmental mobility, but also the stress distribution in the vertebral segment for various constructs.

- It emphasizes the role of hooks or of bone graft in protecting the pedicle screws from excessive stresses.

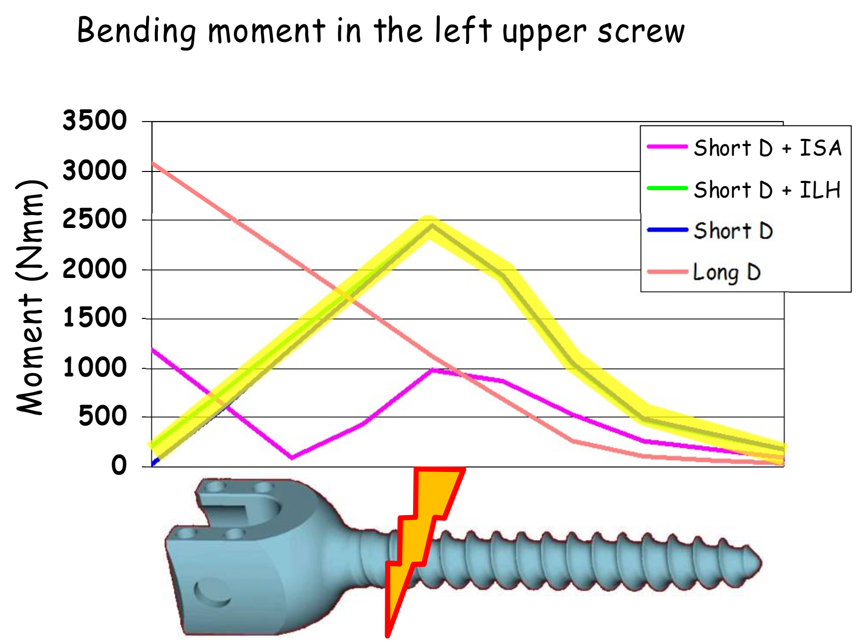
- **Such a Finite Element model of the vertebral spine appears to be a powerful simulation tool which yields new useful information to complement experimental data and can help in answering most conceptual design questions**.

Importance of modeling
in the process of development
of biomedical implants

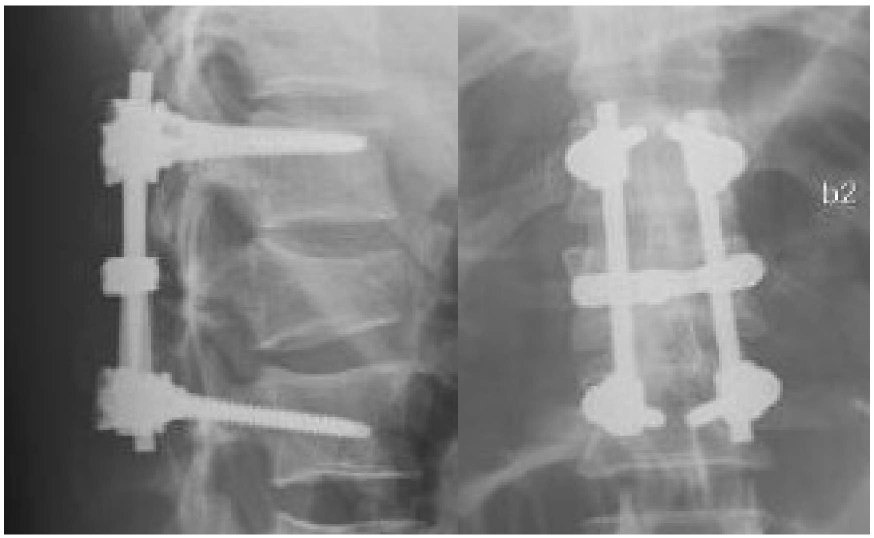
FROM FUNDAMENTAL TO APPLIED RESEARCH

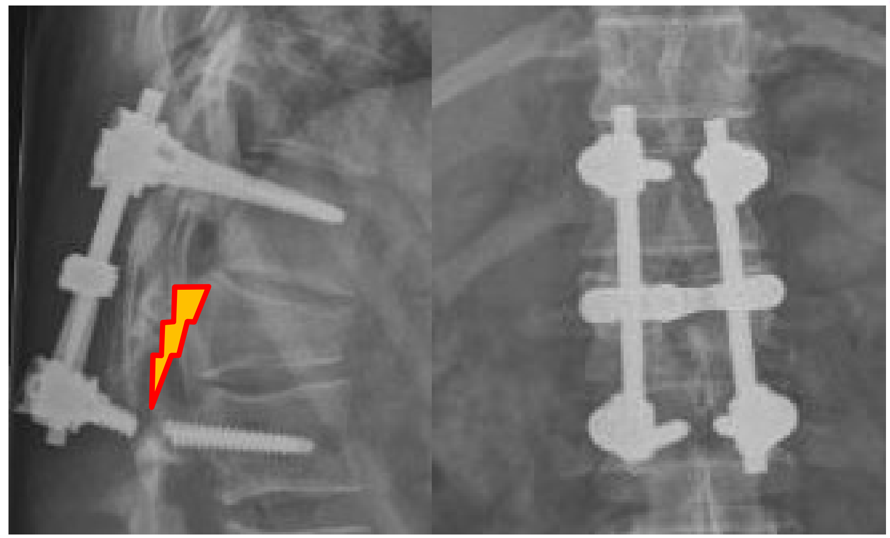
From Fundamental to Applied Research

- Short Devices:
  - Stress peak in pedicle area



From Fundamental to Applied Research

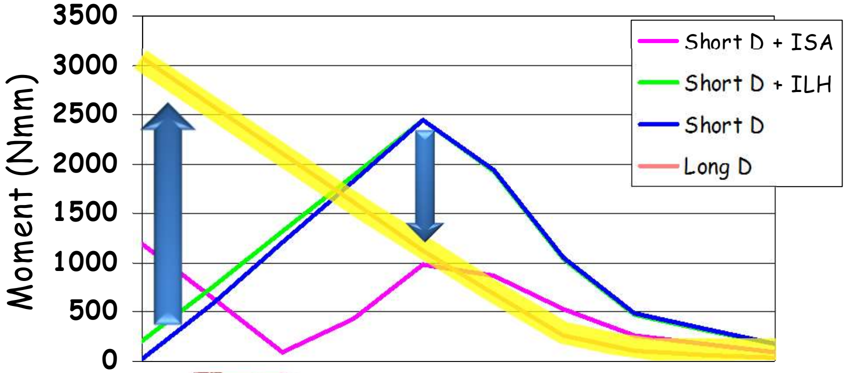


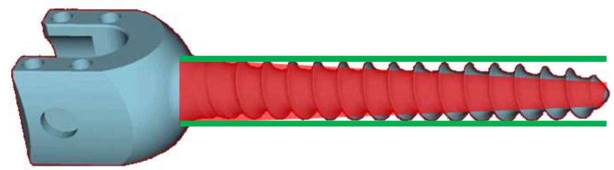


From Fundamental to Applied Research

- Long Device
  - Lowering and moving of stress peak from pedicle area to screw head junction

Bending moment in the left upper screw



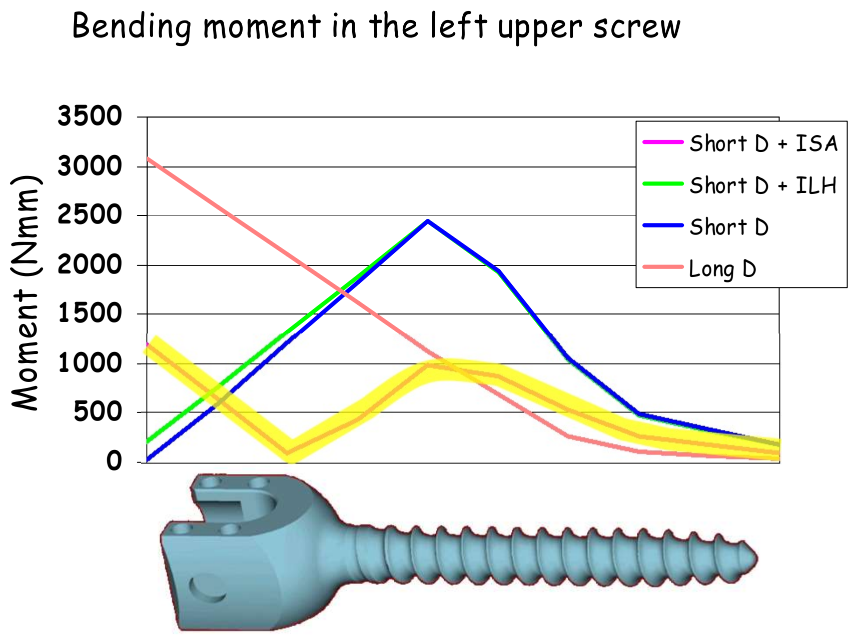


Conical Core for Bending Strength

Cylindrical Thread for Pull-out Strength

From Fundamental to Applied Research

- Long Device
  - Lowering and moving of stress peak from pedicle area to screw head junction
- Intersomatic arthrodesis:
  - Intermediate solution between short device and long device in terms of implant forces



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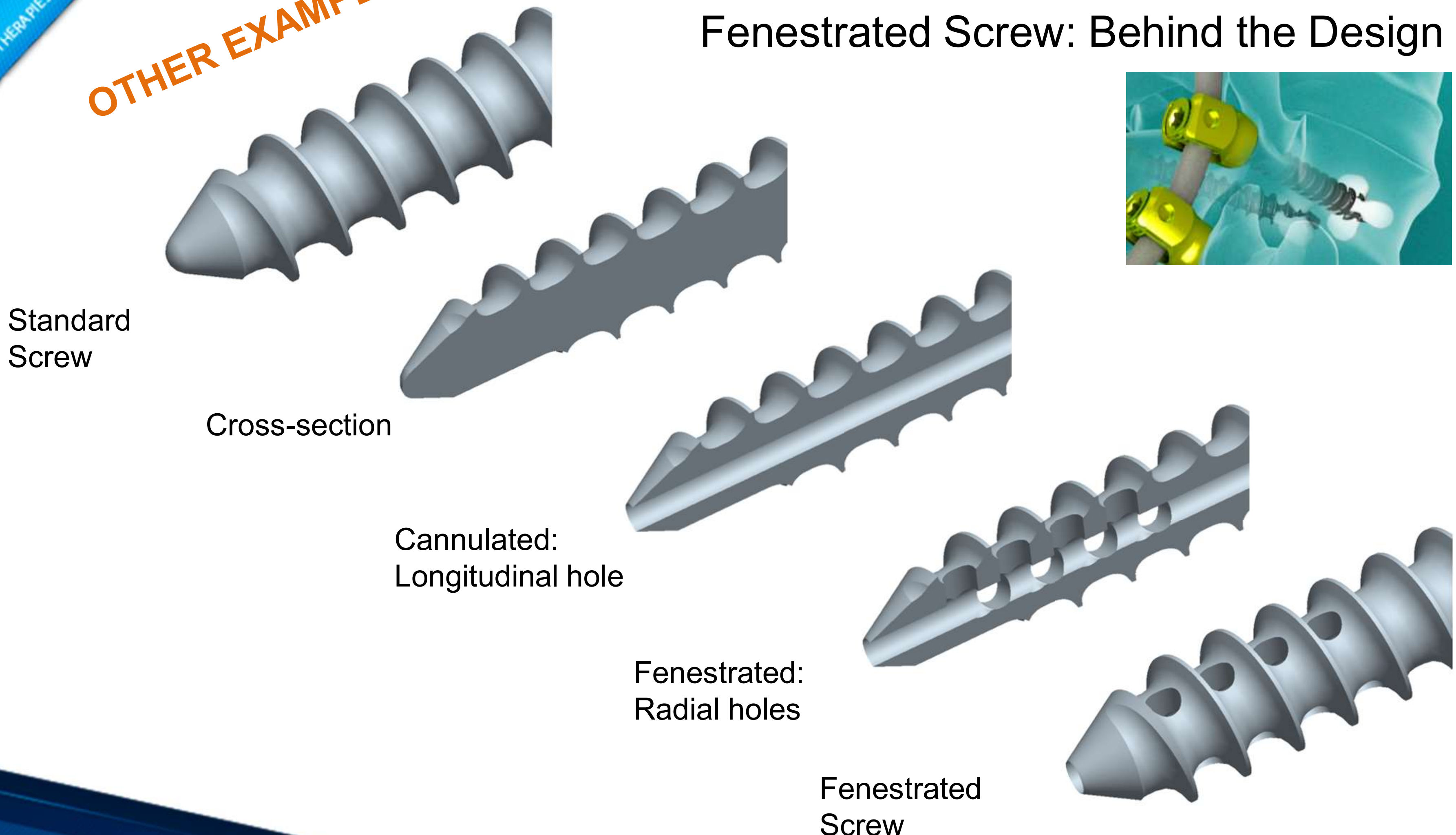
DEVELOPMENT & DESIGN OPTIMIZATION

Development & Design Optimization

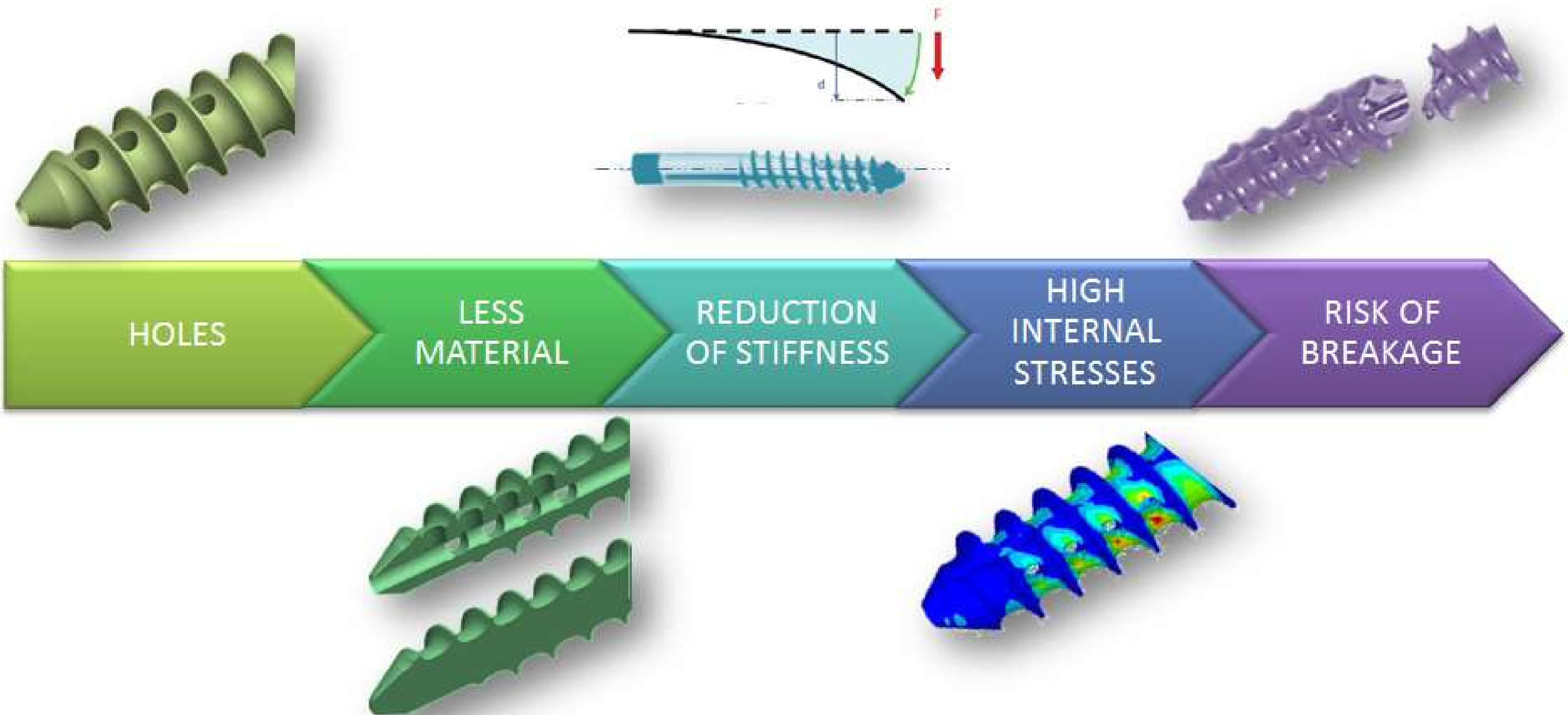
OTHER EXAMPLE

Fenestrated Screw: Behind the Design

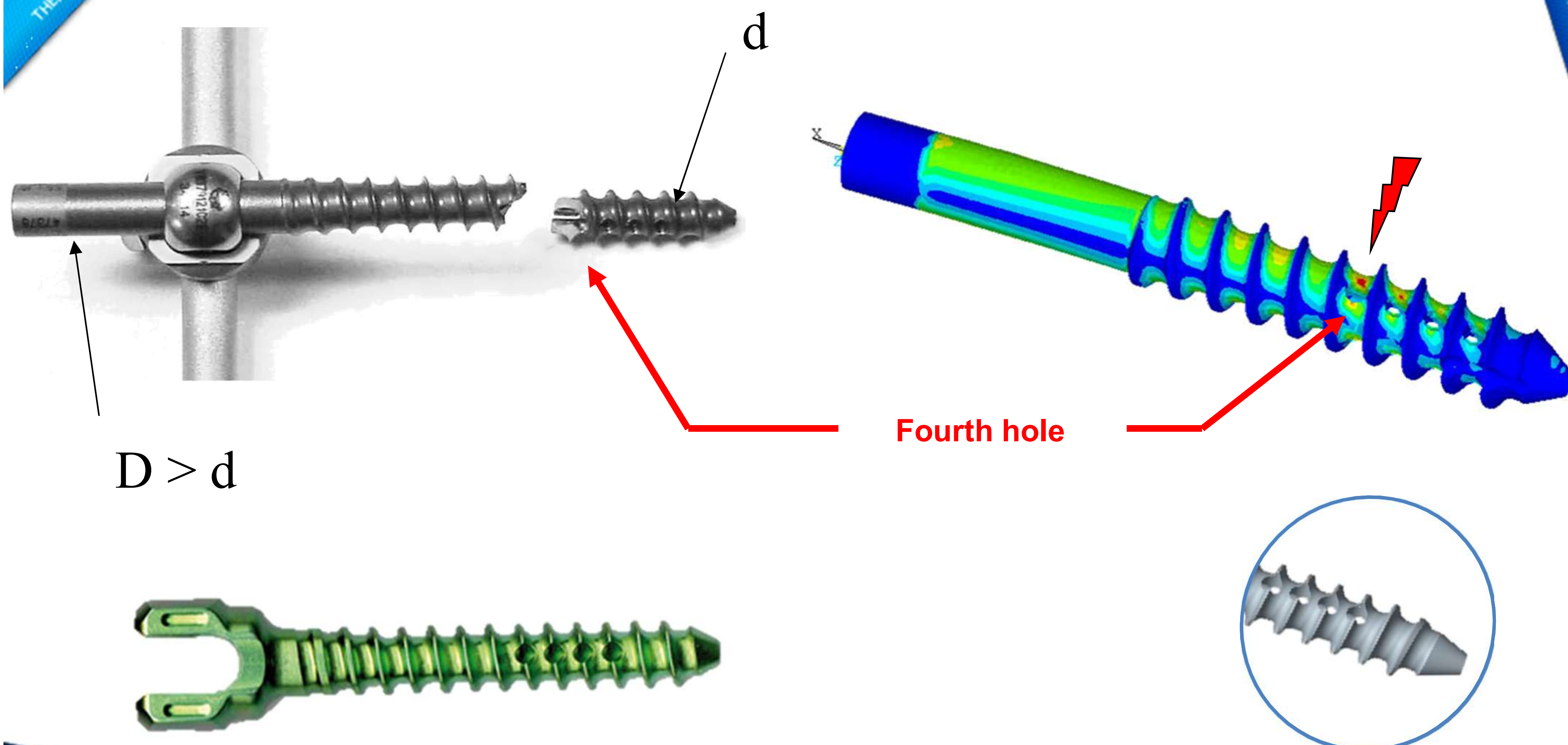


Development & Design Optimization

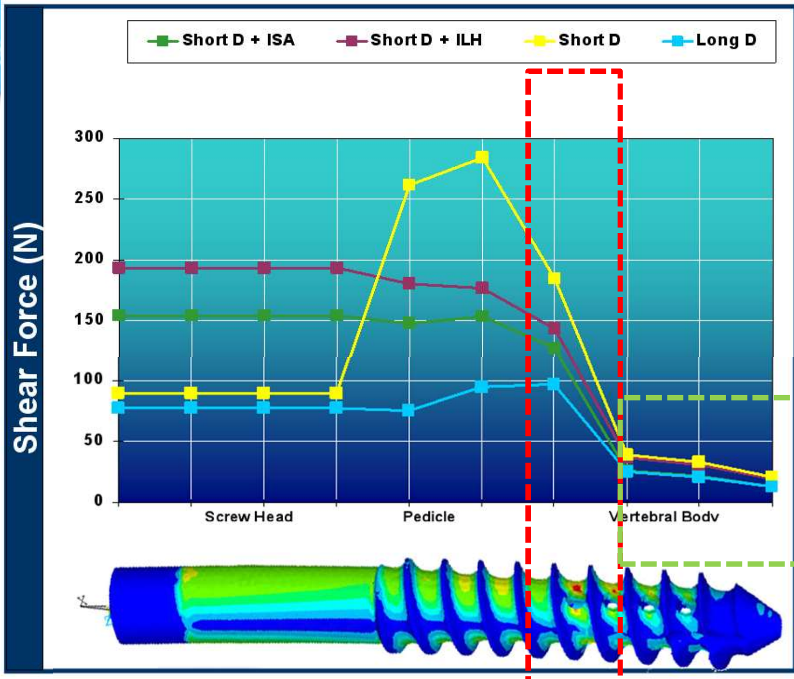
Consequences on Design Performance

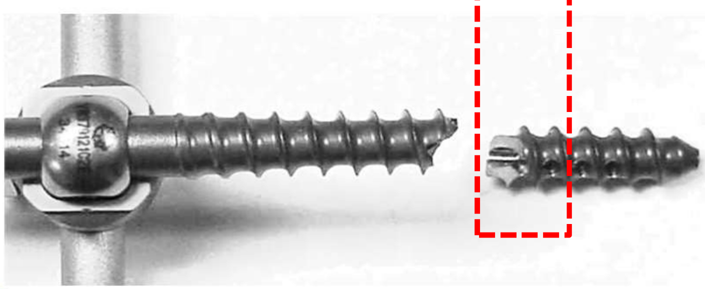


Development & Design Optimization
Malfunction Analysis & Understanding

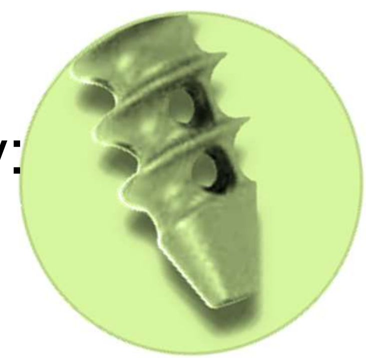


Development & Design Optimization
Malfunction Analysis & Understanding



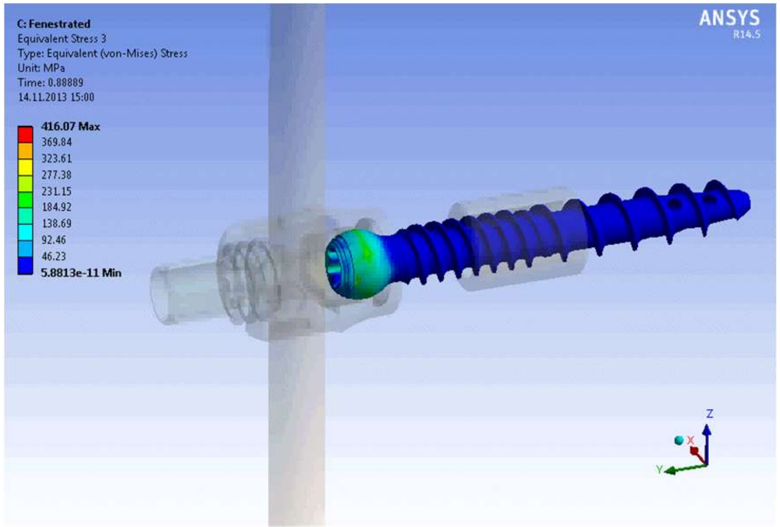


Two holes on Valley:
Seems better !

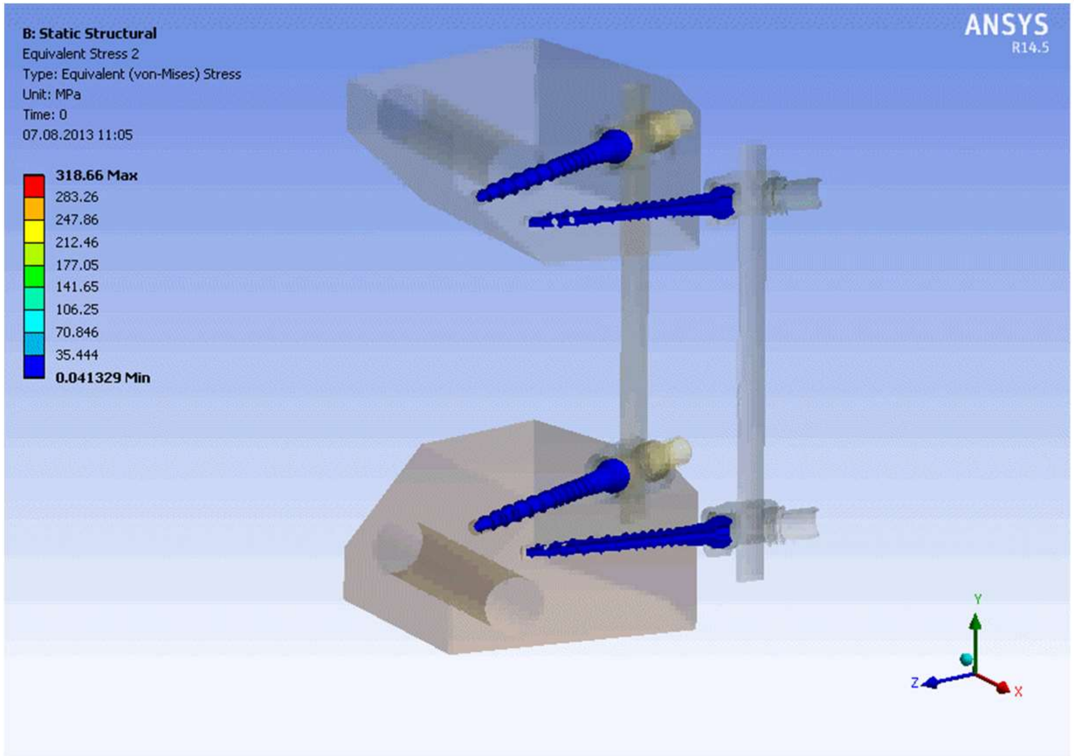


Development & Design Optimization

Static & dynamic (fatigue) tests



ASTM F-1798

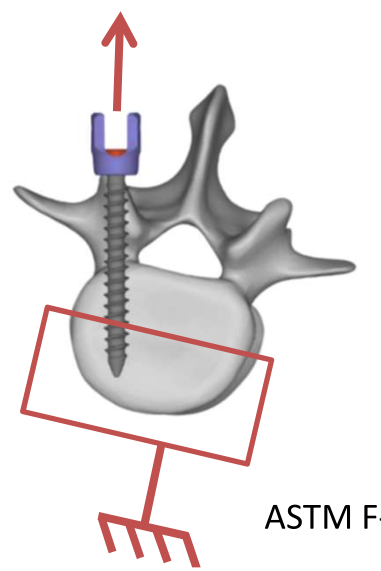


ASTM F-1717

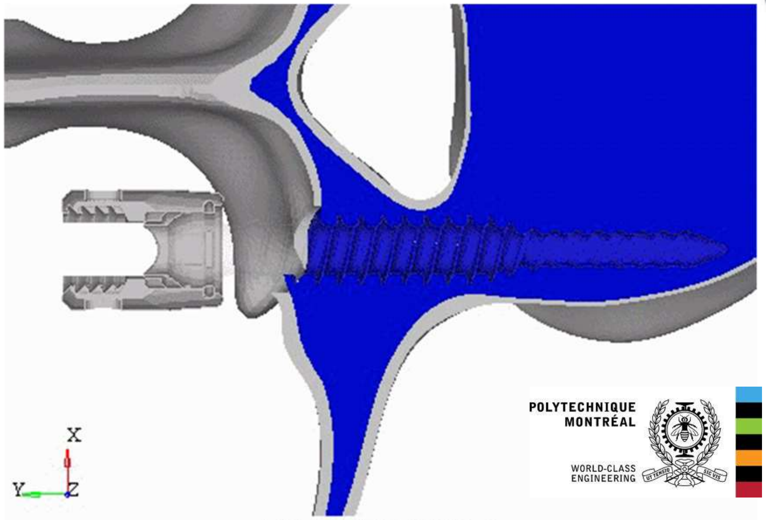
Development & Design Optimization

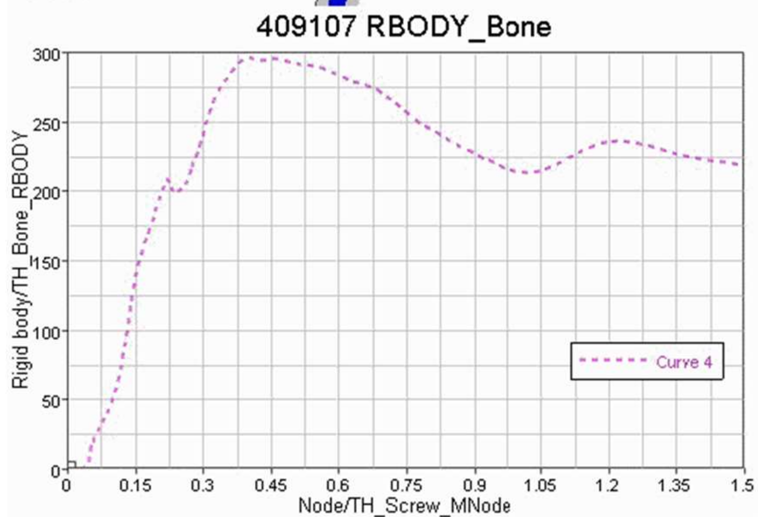
Axial pull-out following ASTM-F543 standard

- Anterior part of vertebral body rigidly clamped
- Axial ramped load on the screw until total pull-out
- Measurement of screw displacement and resulting forces



ASTM F-543

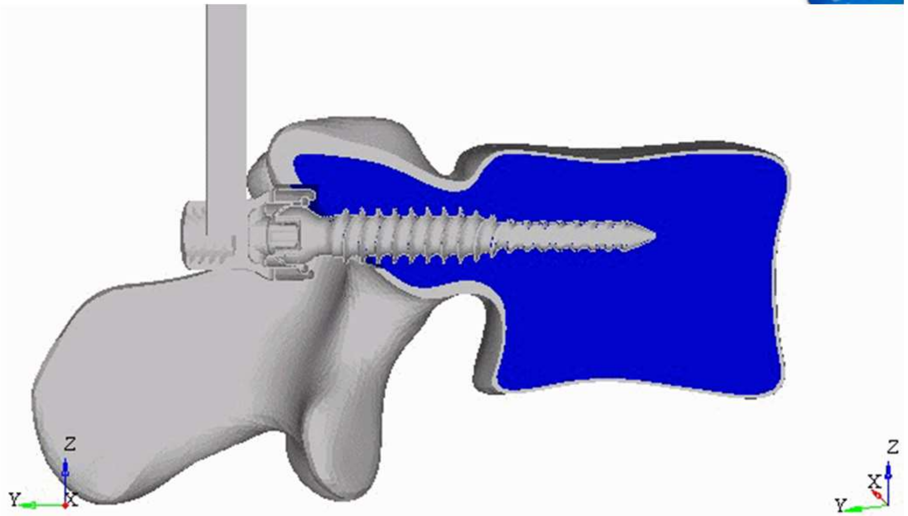


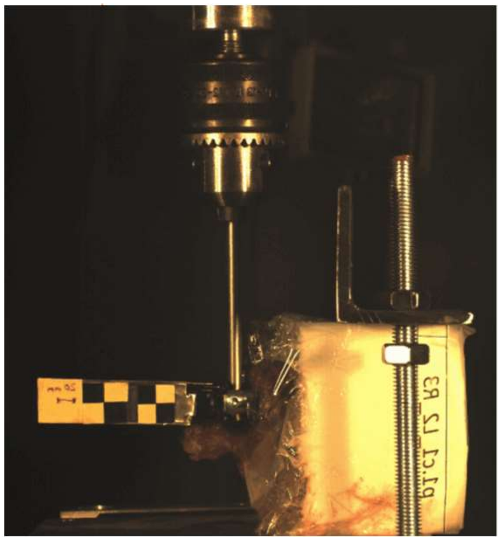


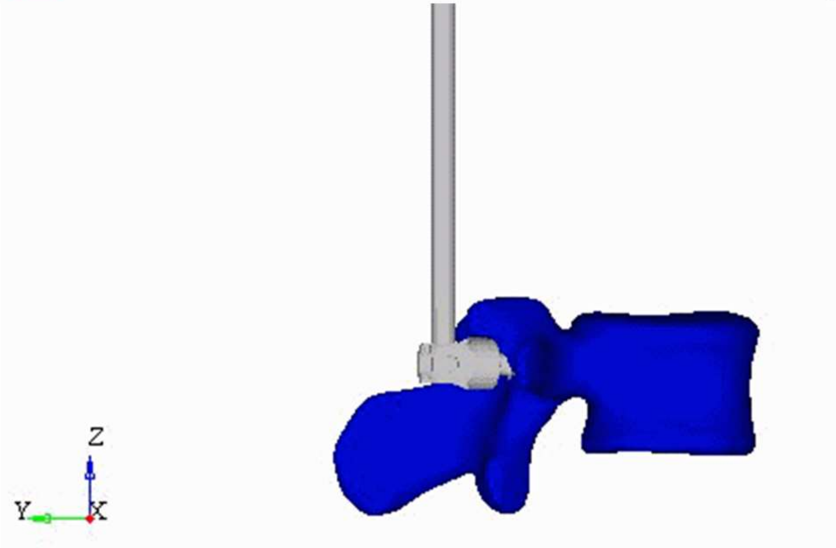
Development & Design Optimization

Caudo-cranial toggling

- Anterior part of vertebral body rigidly clamped
- Caudo-cranial sinusoidal load on the screw head
- Measurement of screw displacement and resulting forces
- Force to failure and fracture pattern was analyzed.







Importance of modeling
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of biomedical implants

VALIDATION

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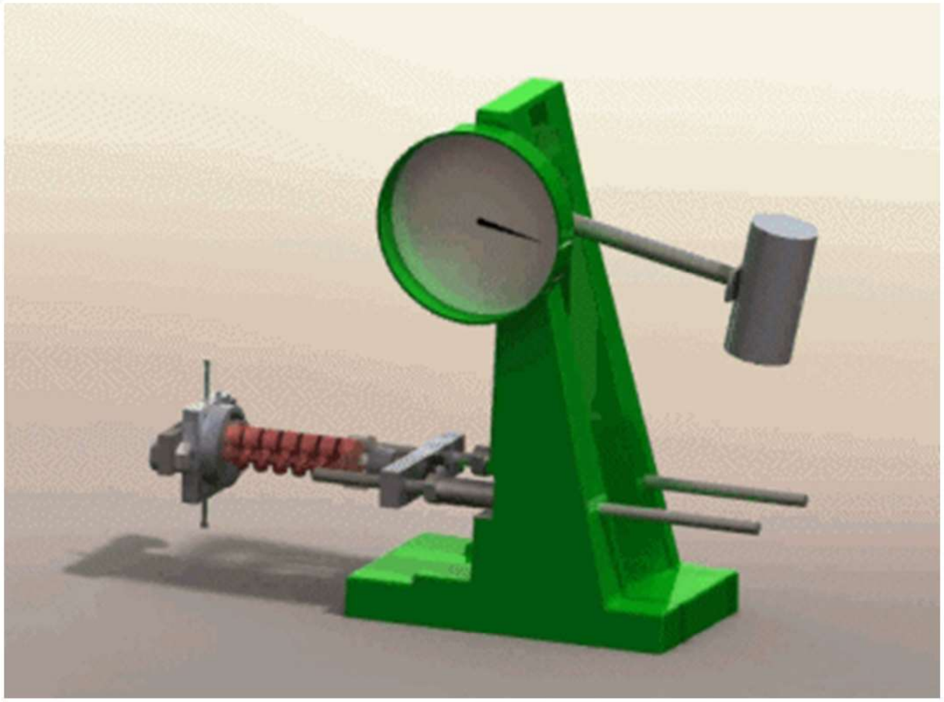
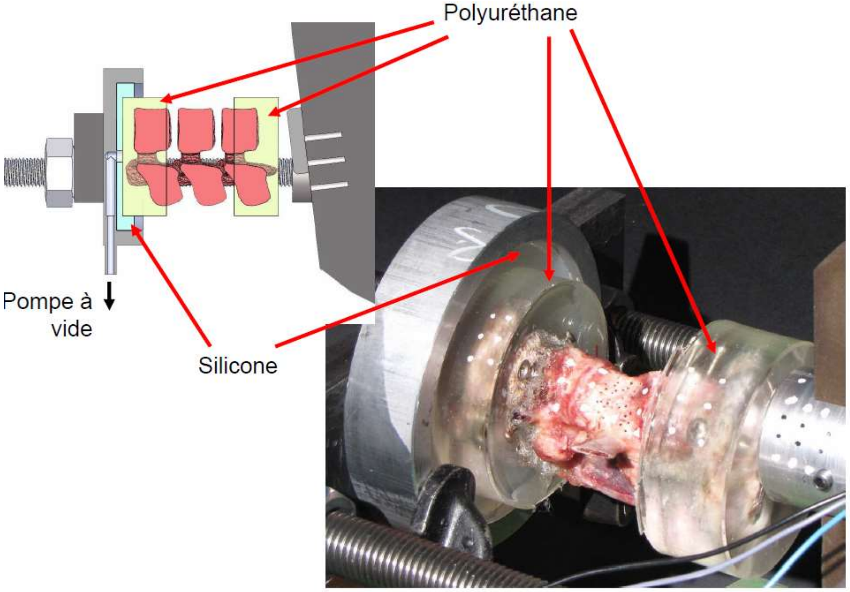
THERAPIES

ENABLING TECHNOLOGIES

Validation





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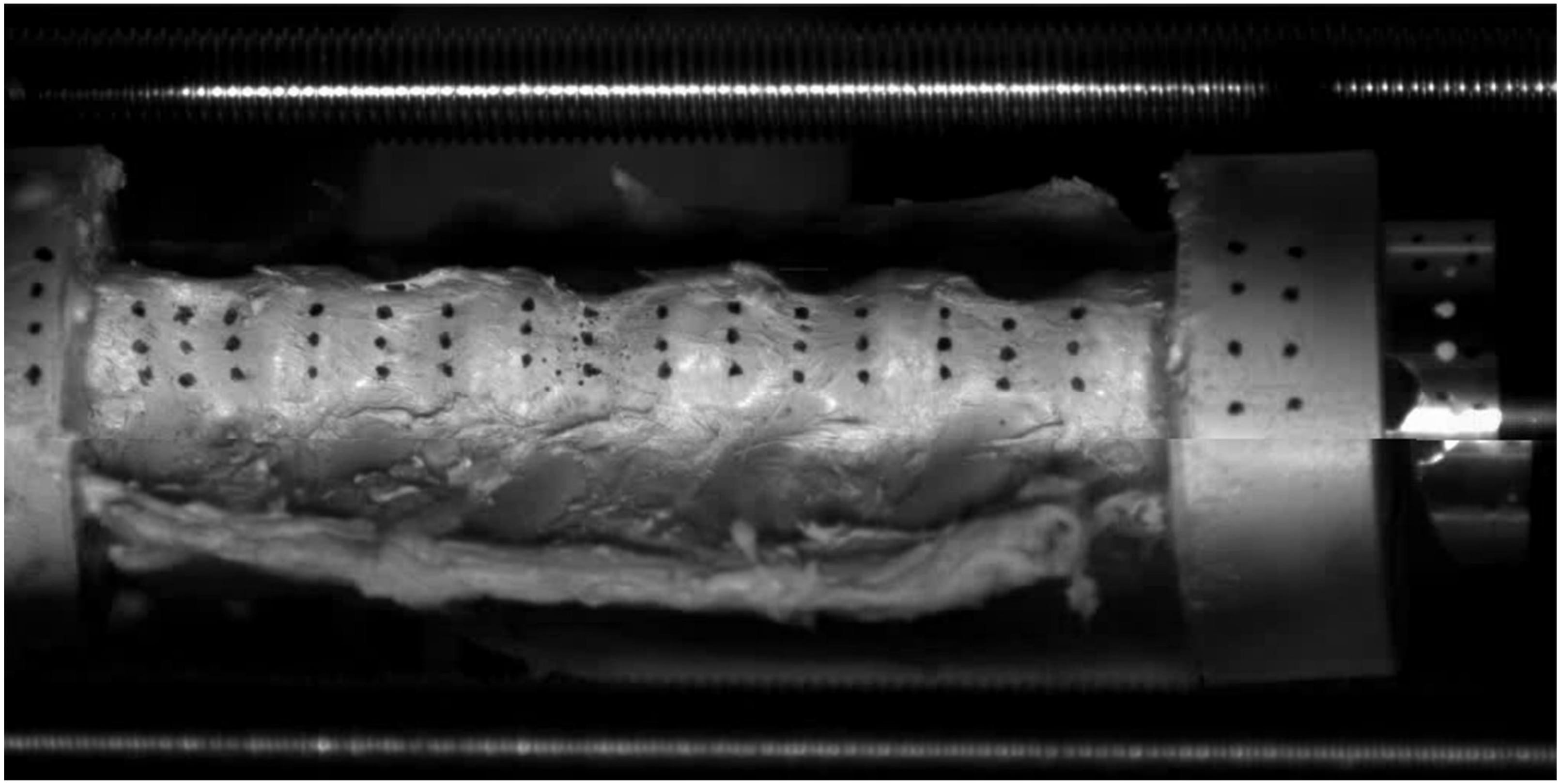
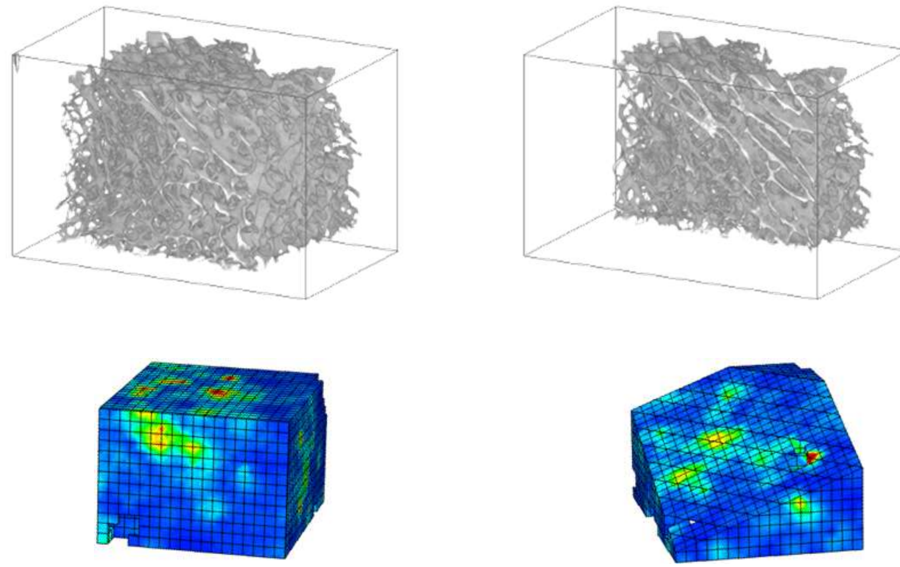
INTEGRATED SPINE SOLUTIONS

SERVICES & SUPPORT

Validation



Validation



Field of 3D deformations of a spongy bone cube in compression

Importance of modeling
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OTHER EXAMPLES

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TOTAL DISC REPLACEMENT

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SPINE SOLUTIONS

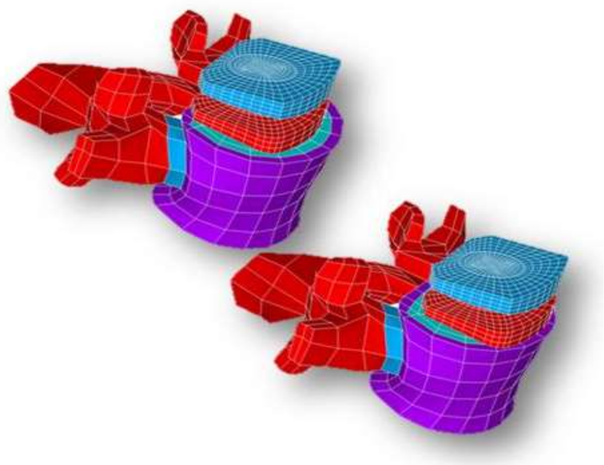
Total Disc Replacement

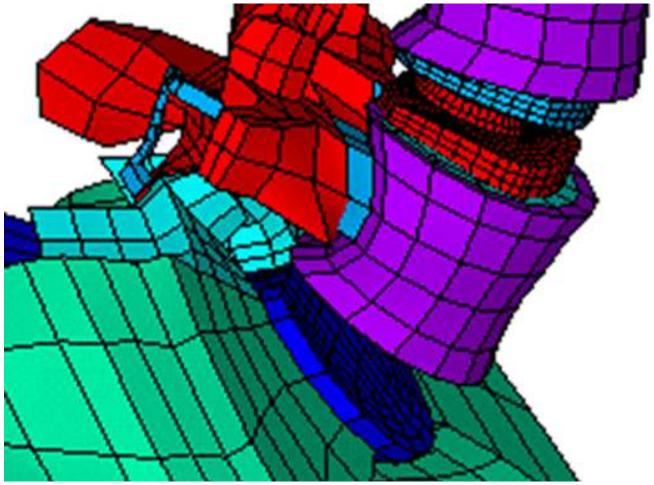
THERAPIES

ENABLING TECHNOLOGIES

Understand the effect of the TDR on the physiologic motion behavior of the spine segment

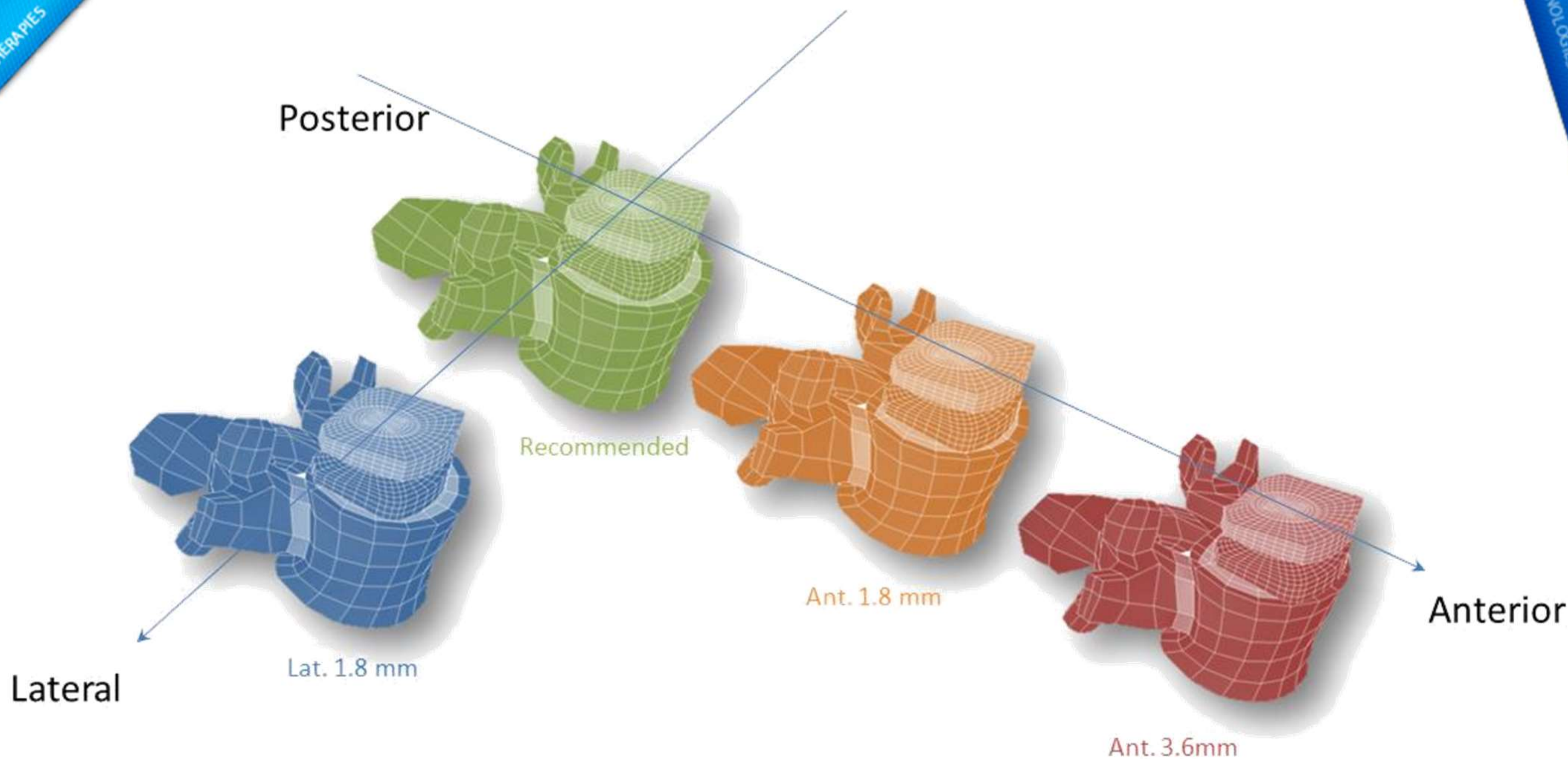
1. Effect of disc prosthesis positioning



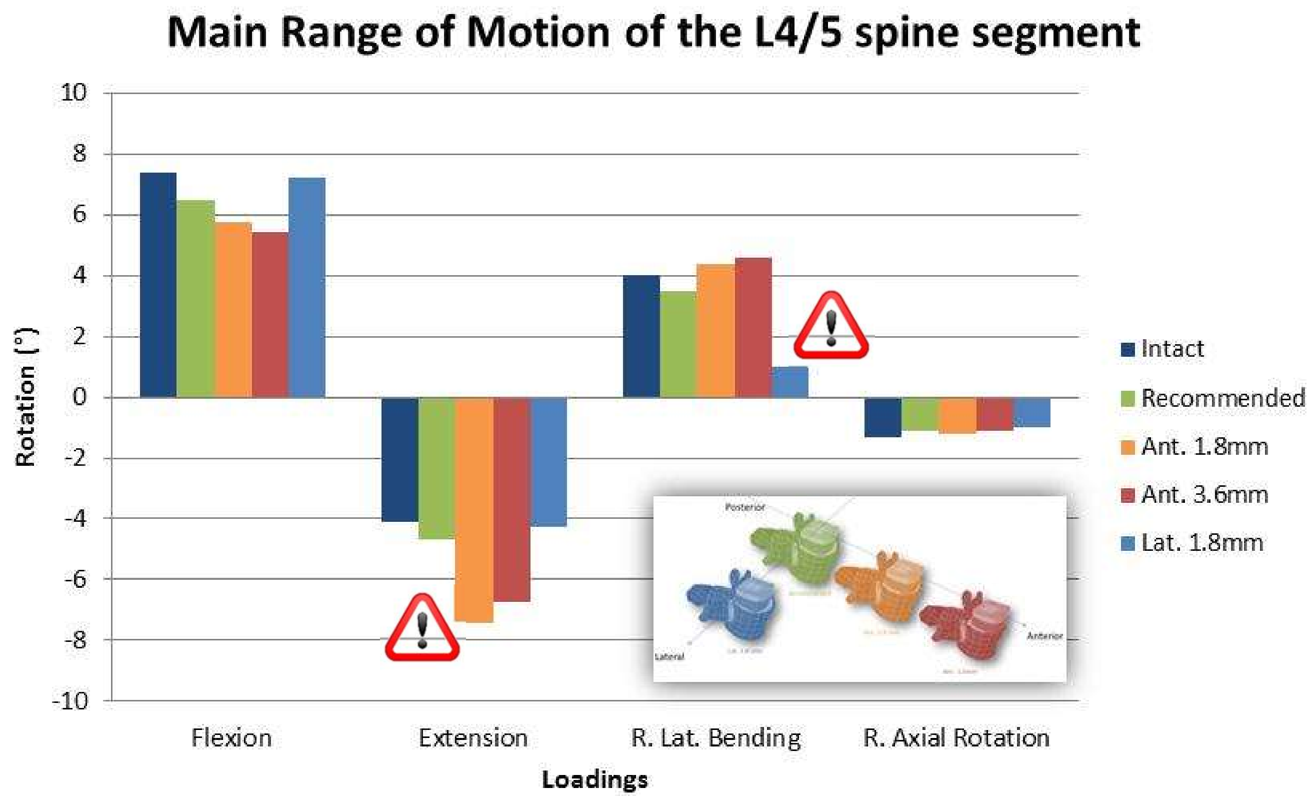


2. Effect of the disc prosthesis on adjacent levels – Comparison with a rigid posterior fixation device

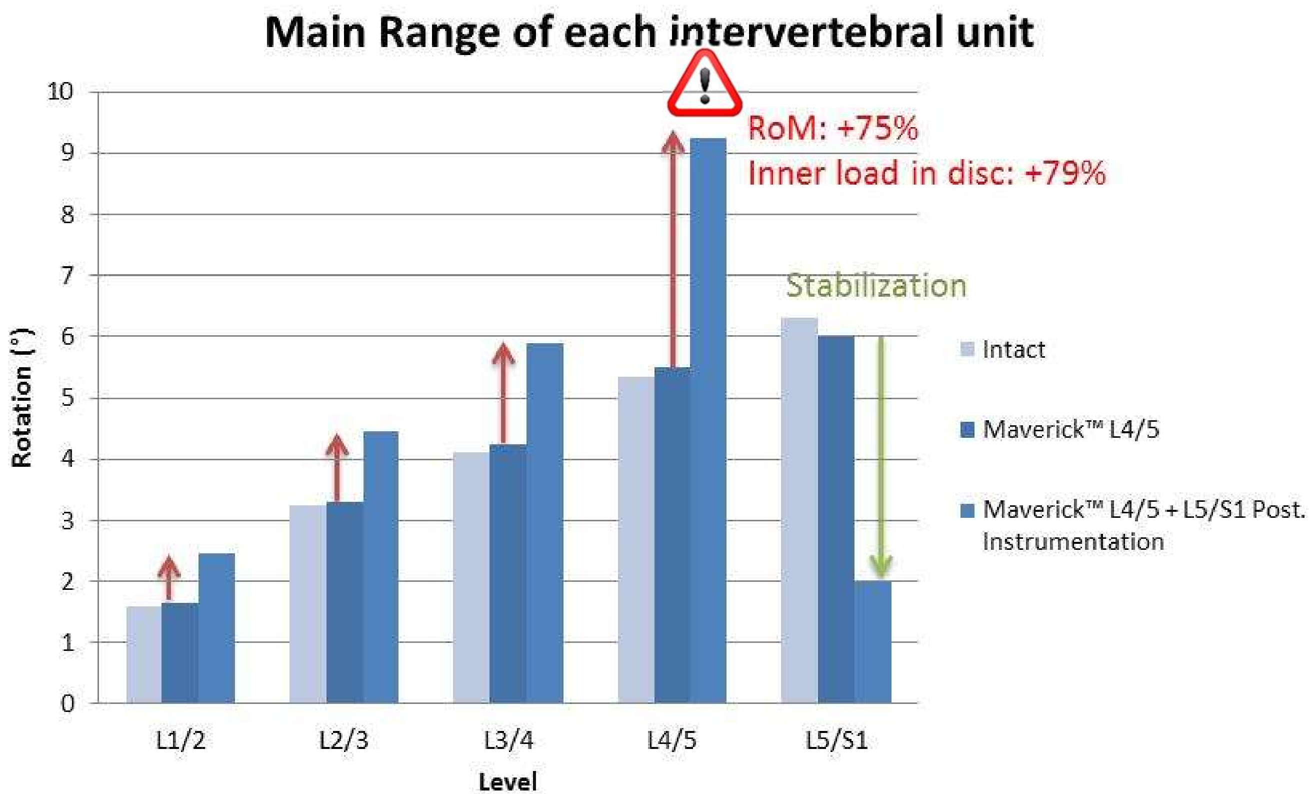
Total Disc Replacement



Total Disc Replacement



Total Disc Replacement



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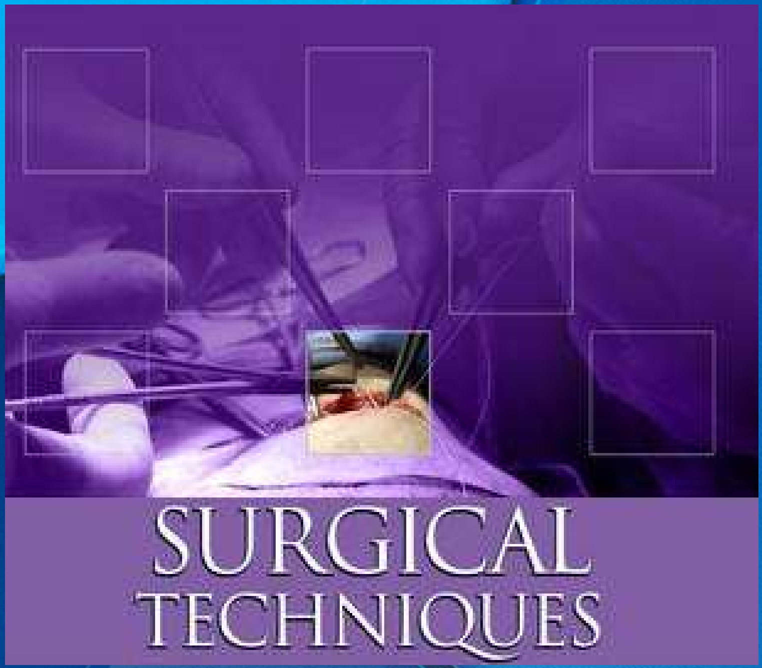

THERAPY STRATEGIES
&
SURGICAL TECHNIQUES

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SPINE SOLUTIONS

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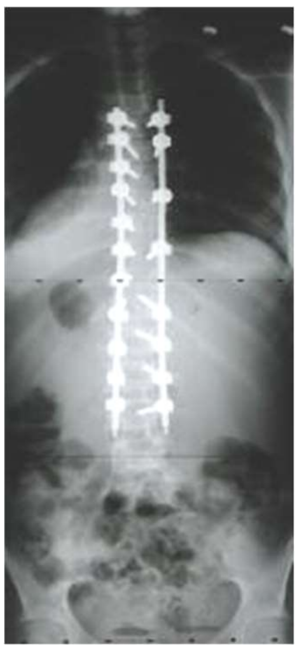
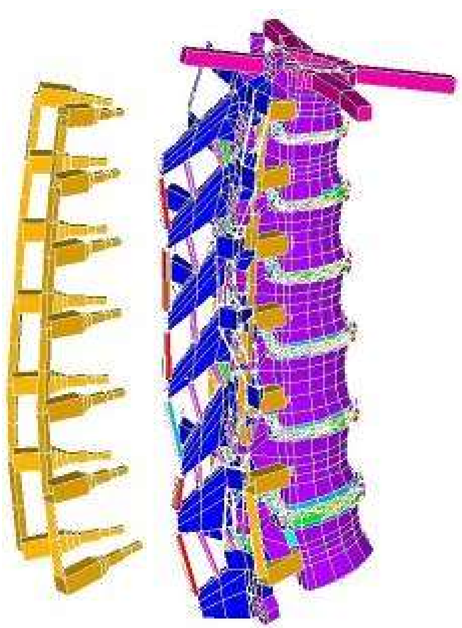
THERAPIES

ENABLING TECHNOLOGIES

Therapy Strategy

- Pedicle Screw Placement Strategy





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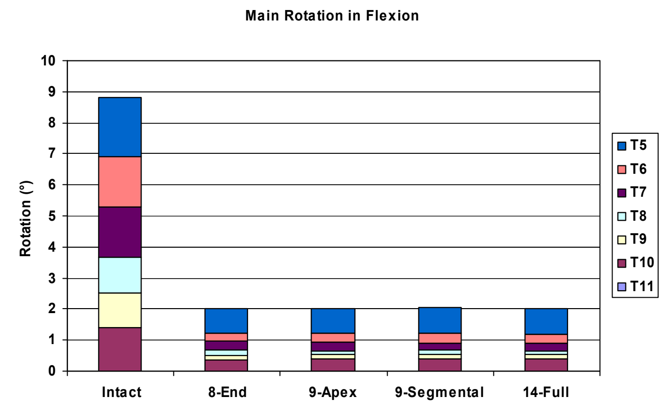
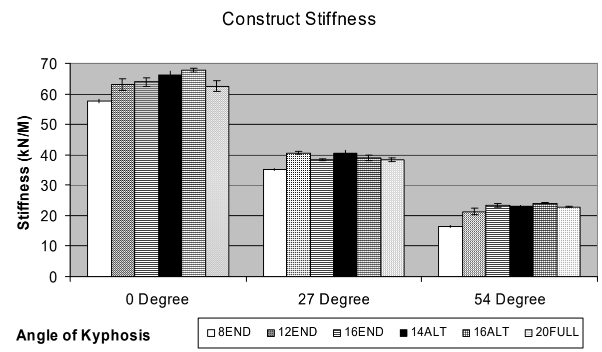
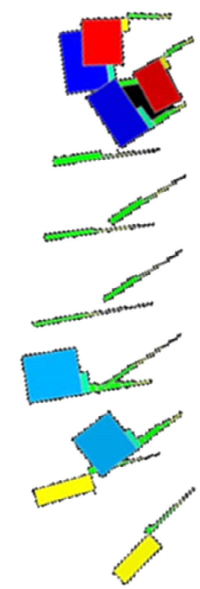
Michael F. O'Brien, MD, Denver, CO

FEA



EXPERIMENTAL TESTS





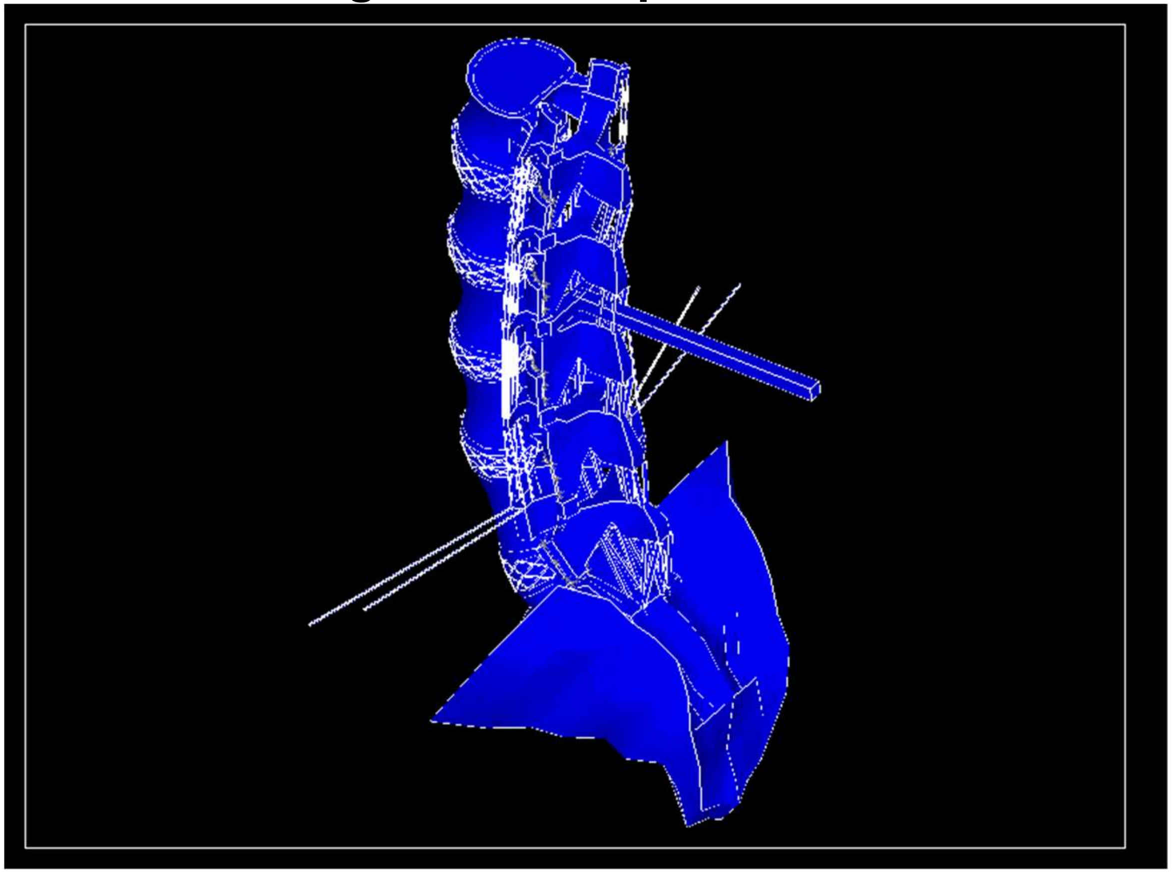
Forces & Moments
In The Construct

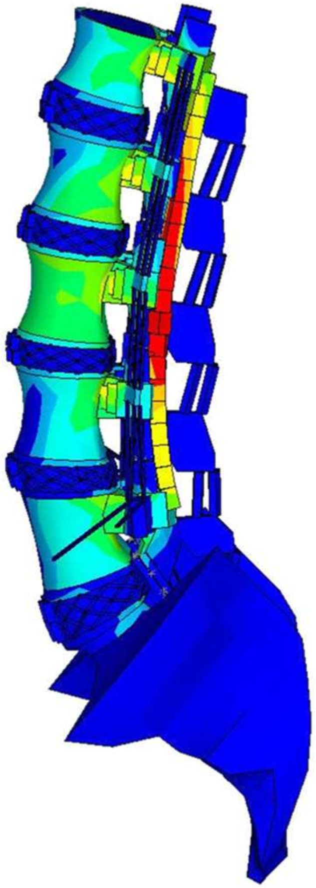
INTEGRATED
SPINE SOLUTIONS

SERVICES & SUPPORT

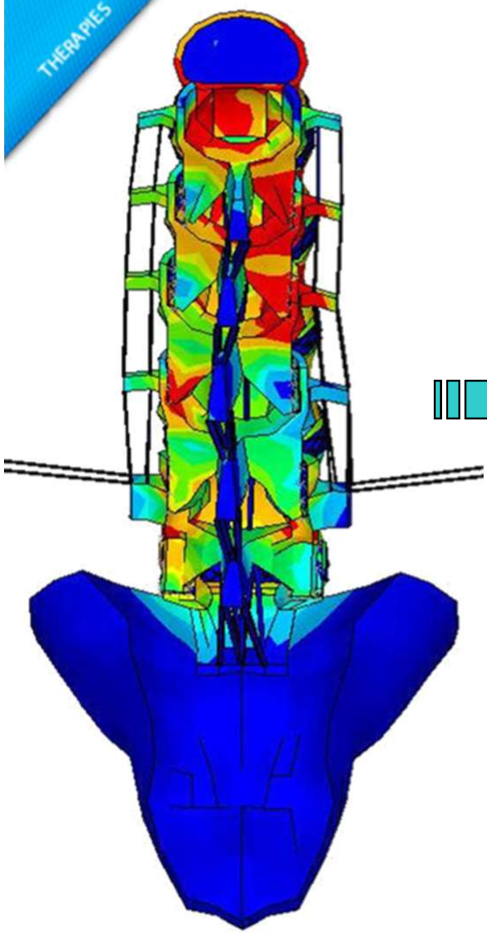
Surgical Technique Evaluation

VCM Surgical Technique Modelization

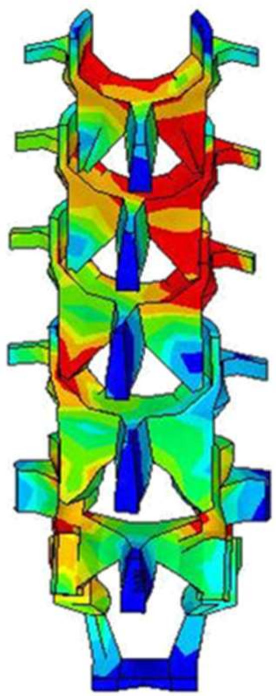




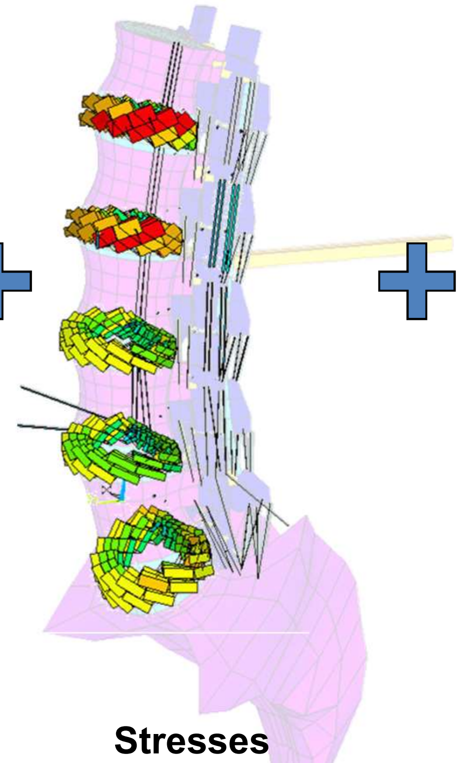
Surgical Technique Evaluation



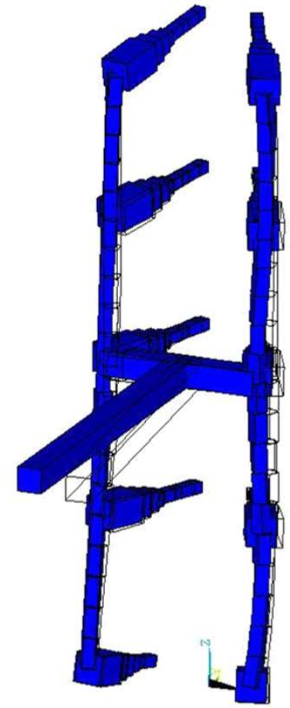
Fundamental Results



Stresses
in facet-joints



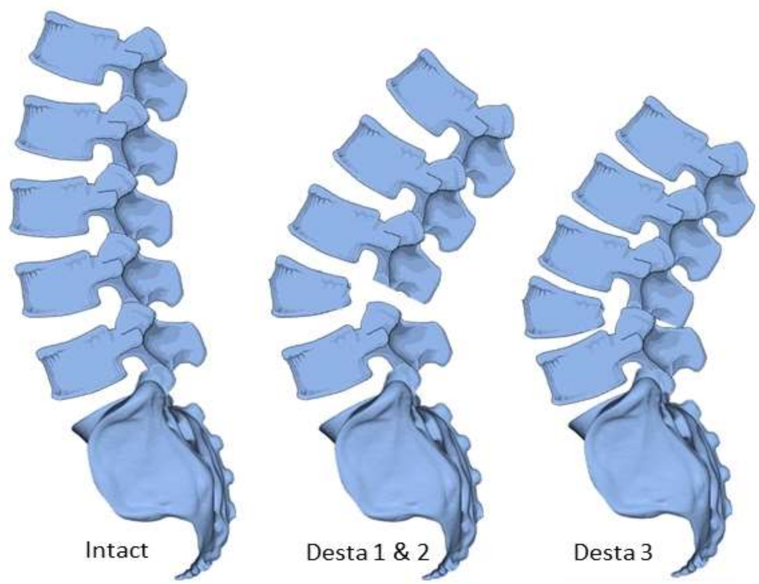
Stresses
in discal fibers

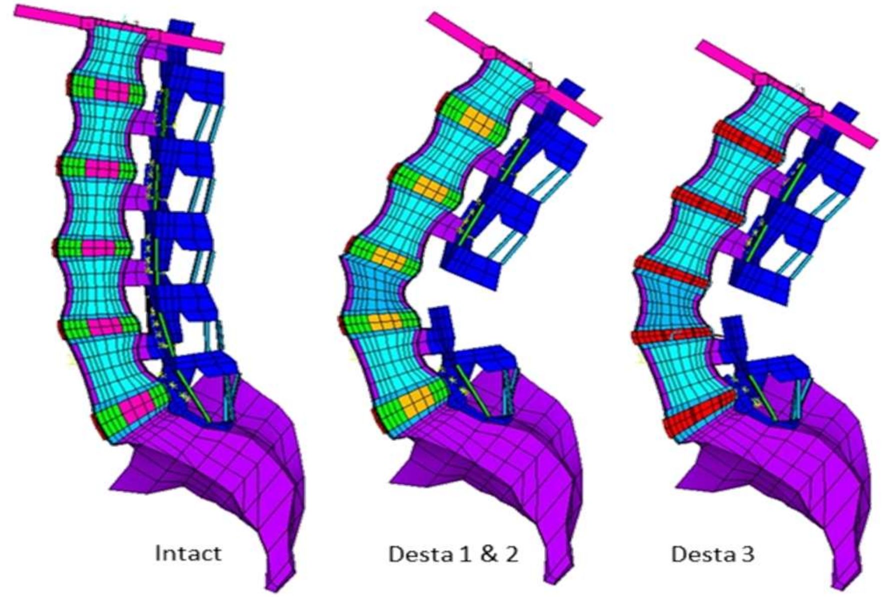


Construct
Deformation

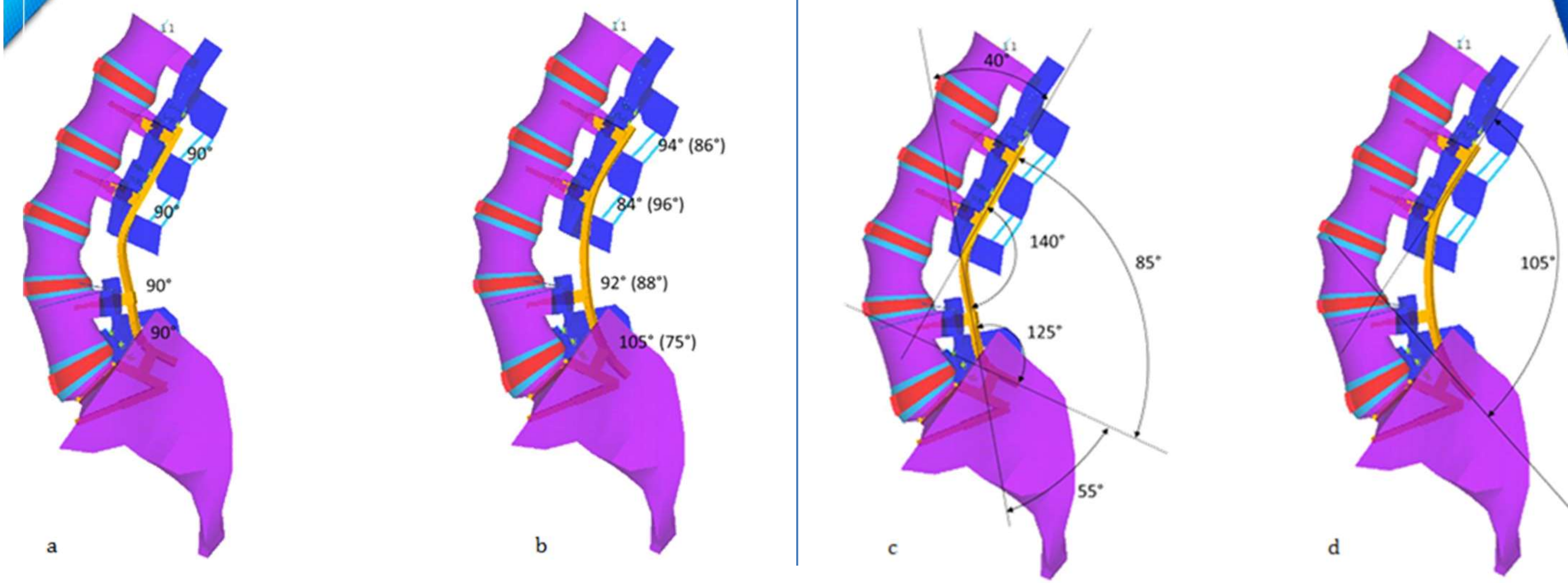
Surgical Technique Evaluation

Pedicle Subtraction Osteotomies



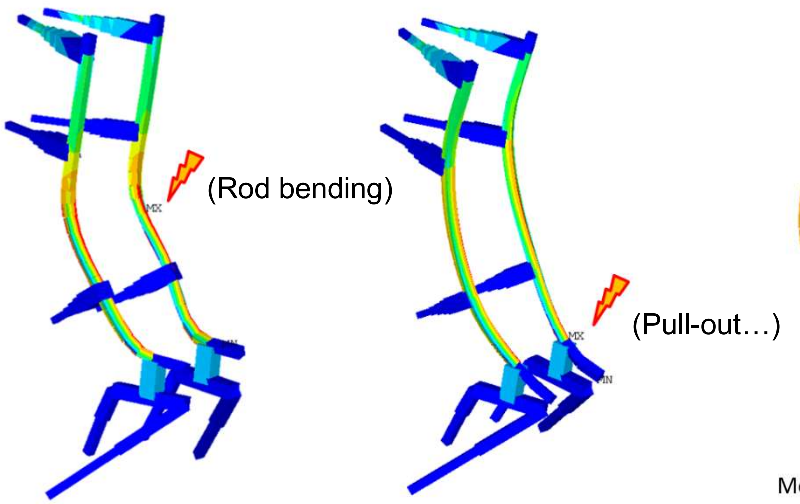


Surgical Technique Evaluation



- Screw shaft / rod angle for Mono (a) and Poly-axial (b) constructs.
- Rod contour for Mono (c) and Poly-axial (d) constructs

Surgical Technique Evaluation

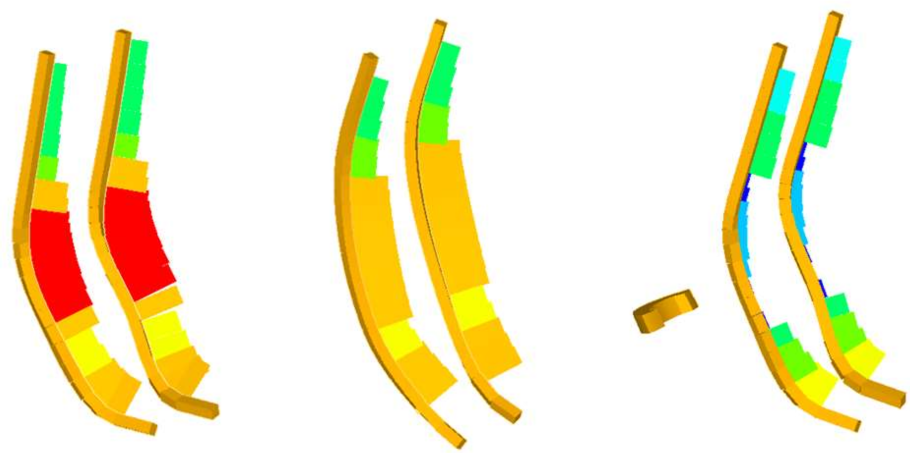


Mono-axial connections

Multi-axial connections

.637E-05 10 20 30 40 50 60 75 100

Von Mises Stresses



Mono-axial connection

Multi-axial connection

Mono-axial connection
+ TLIF 45

.568E-09 500 750 1000 1250 1500 1750 2000 2250

Bending Moments

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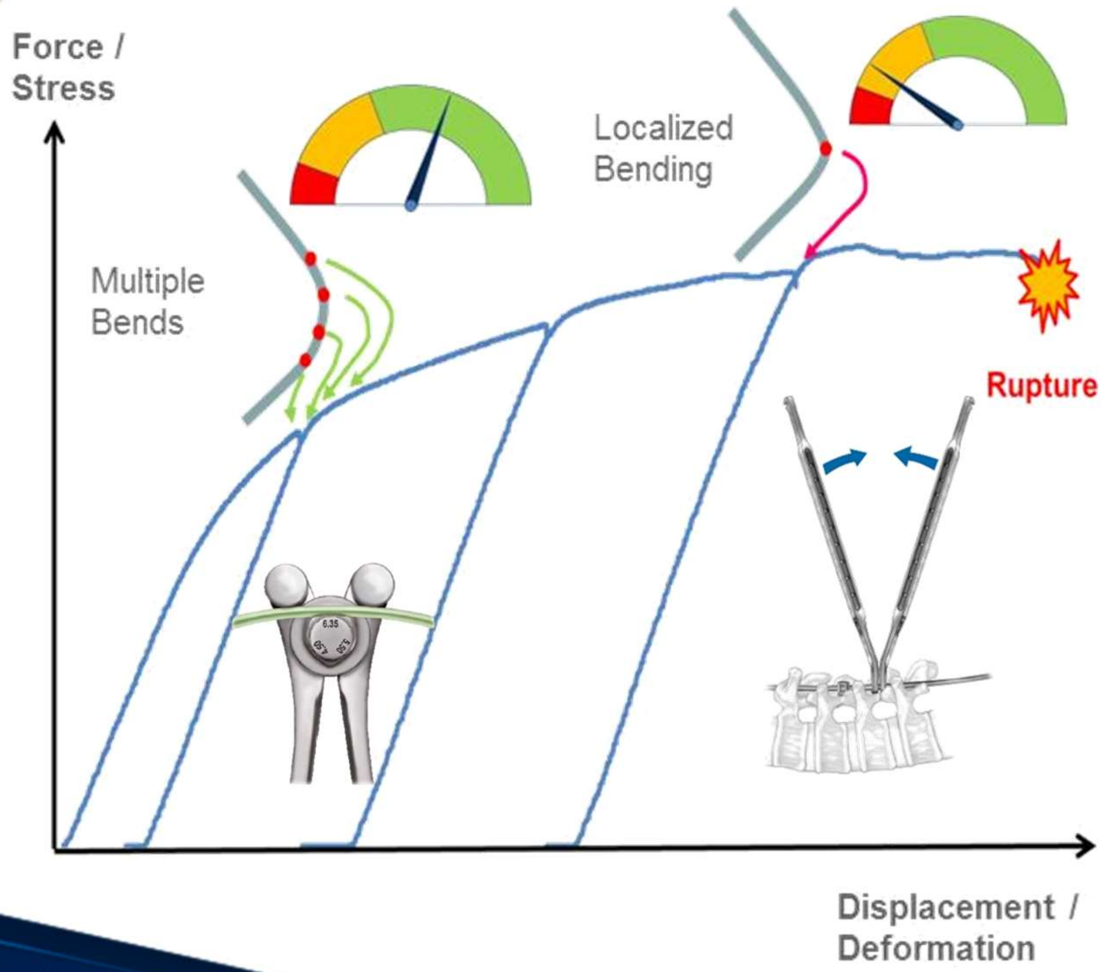
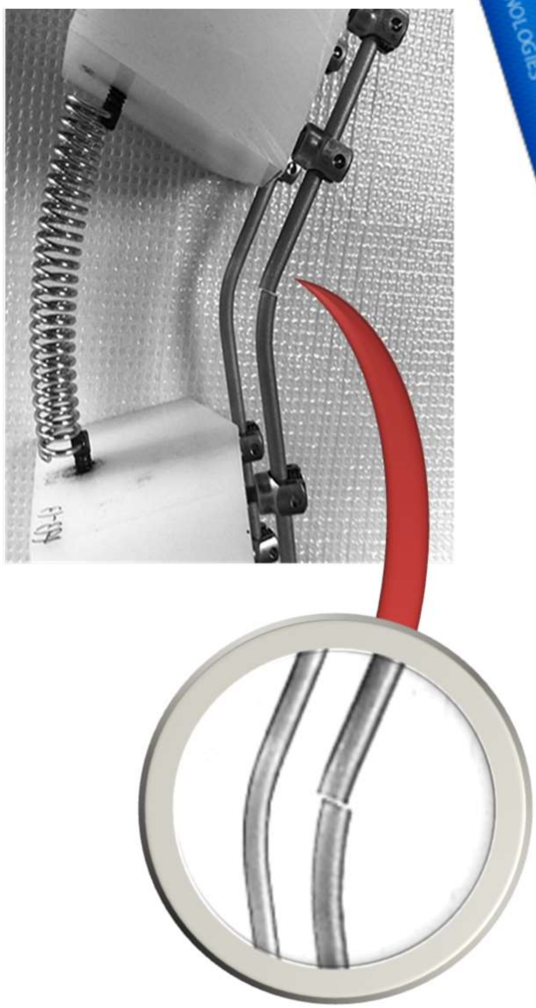
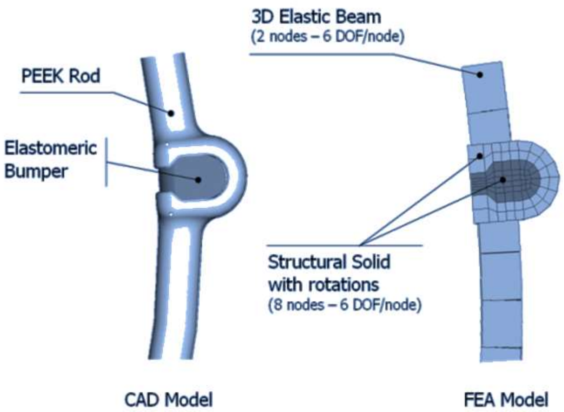
Surgical Technique Evaluation Education

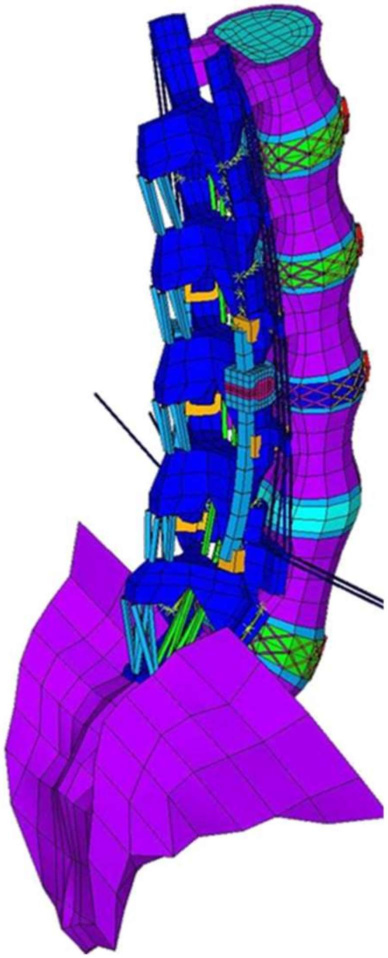
Rod Bending

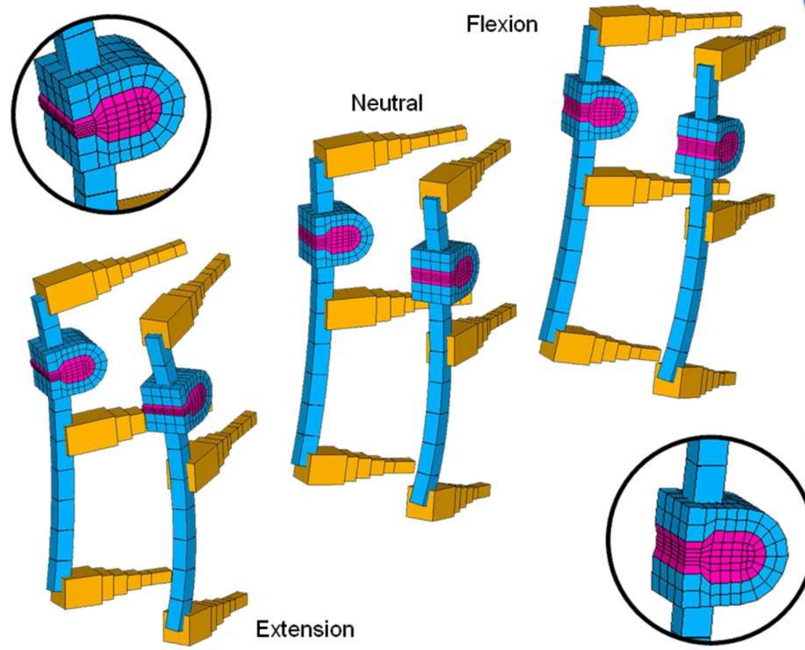




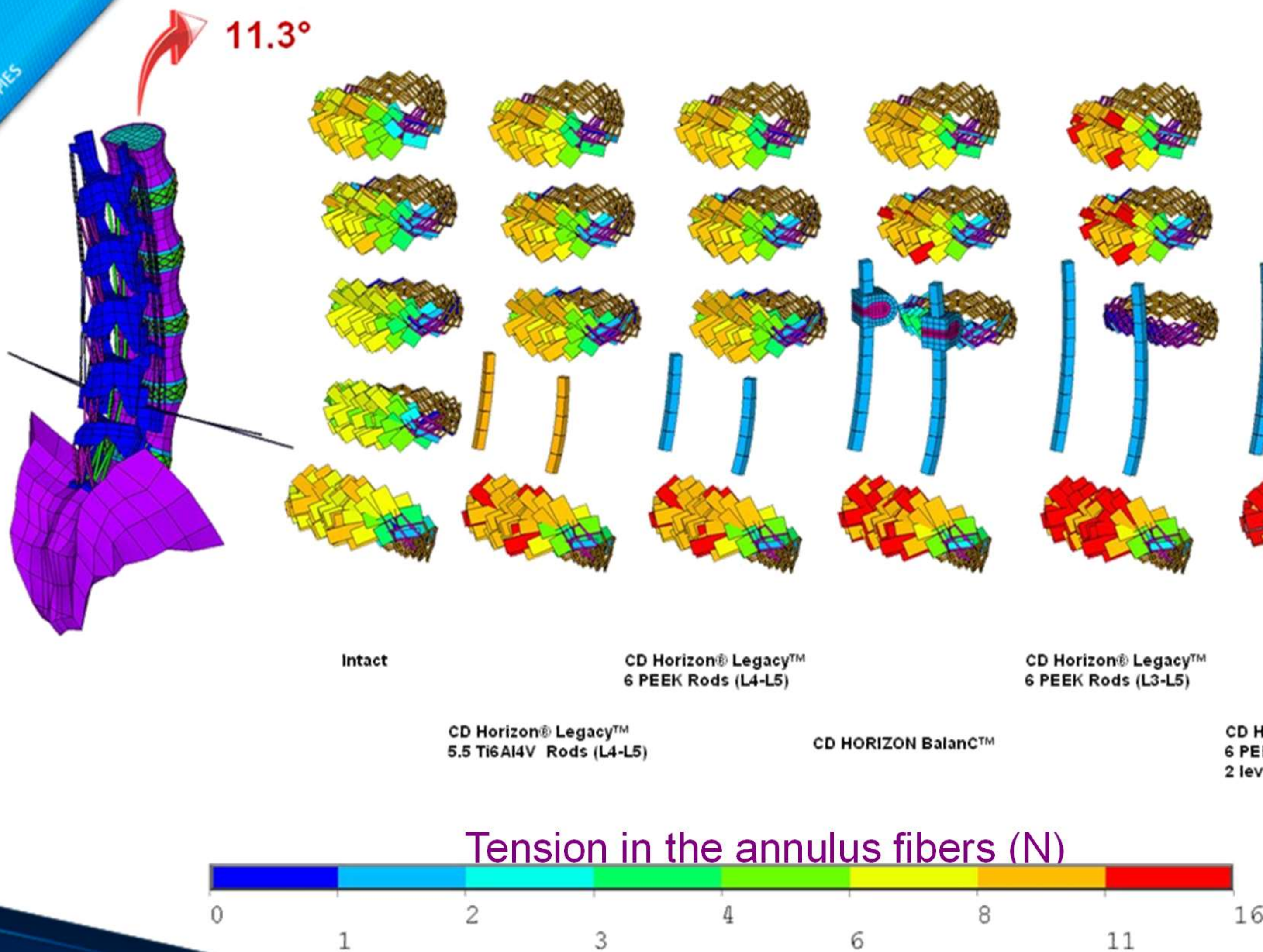
Design Verification







Design Verification / Adjacent Segment Desease



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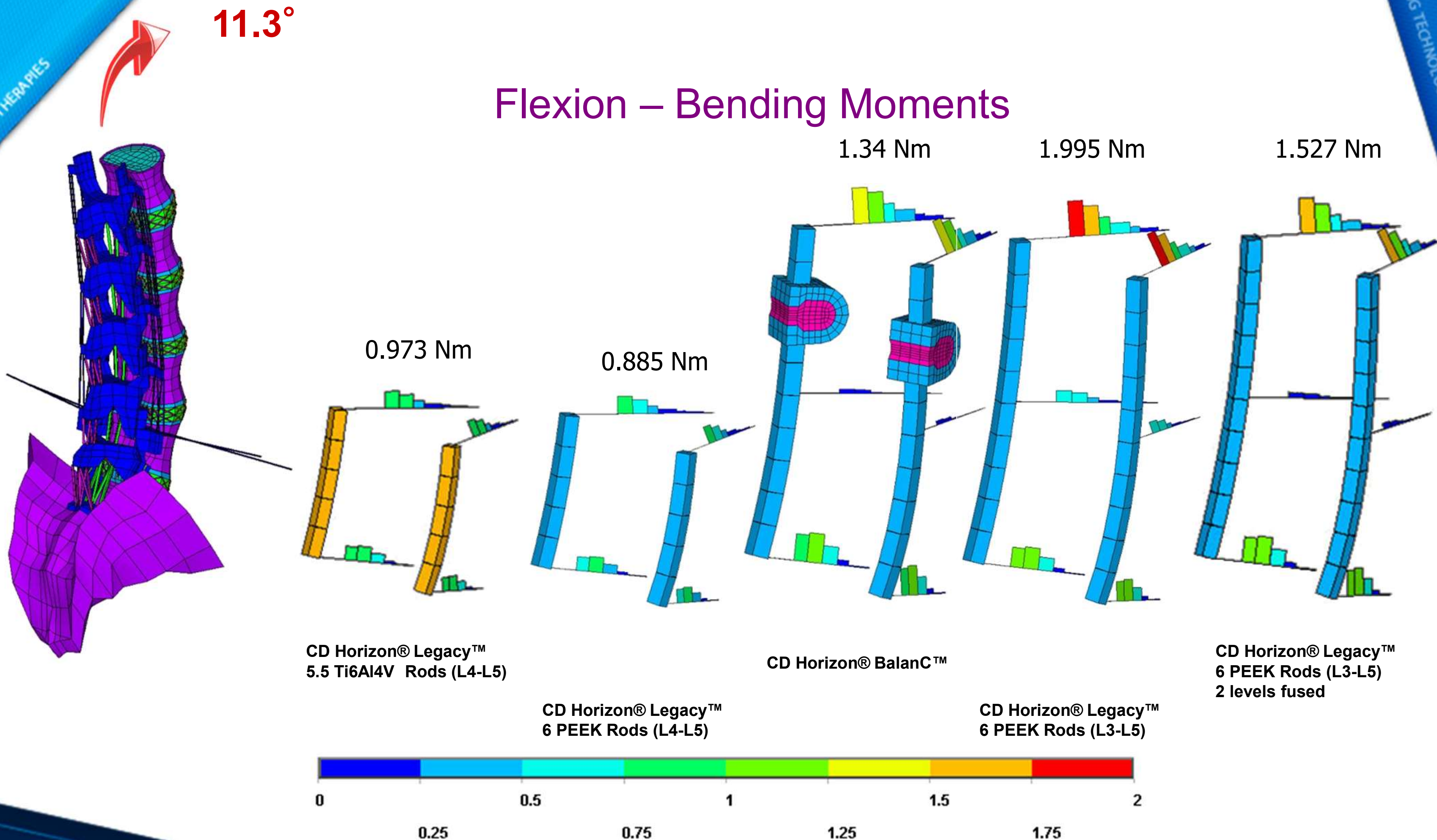
Design Verification

Flexion – Bending Moments



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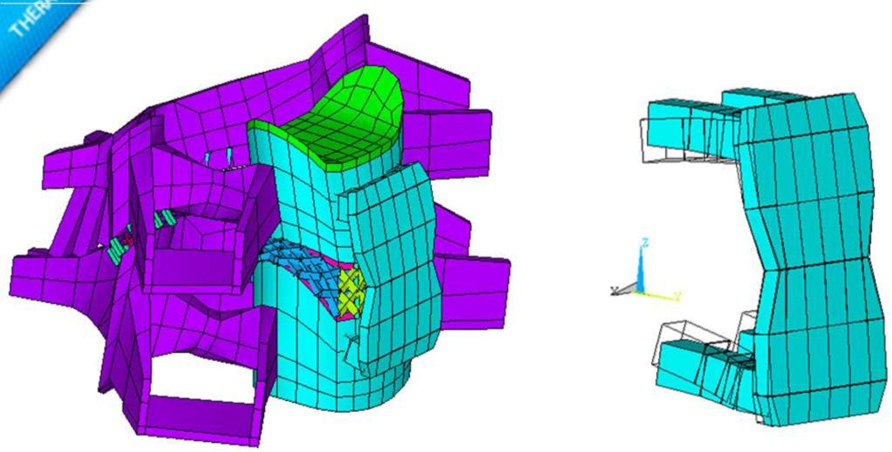
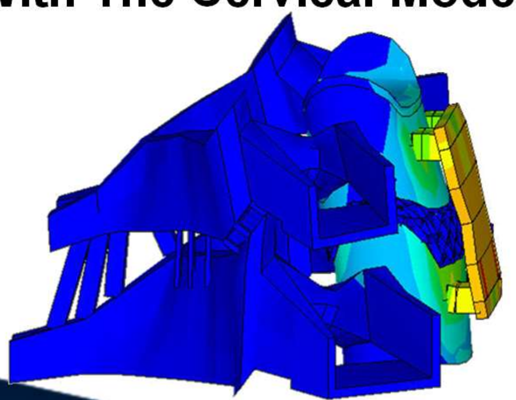
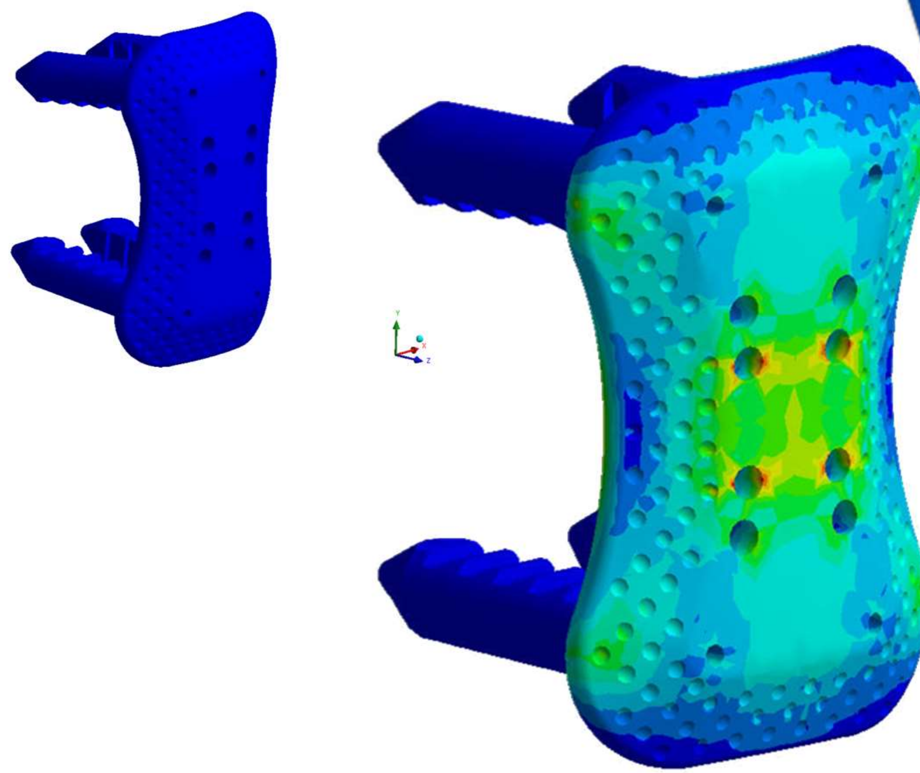
MISCELLANEOUS

GRAFT COMPRESSION CERVICAL PLATE



Concept Evaluation
With The Cervical Model





Stresses Evaluation
During The Development Process

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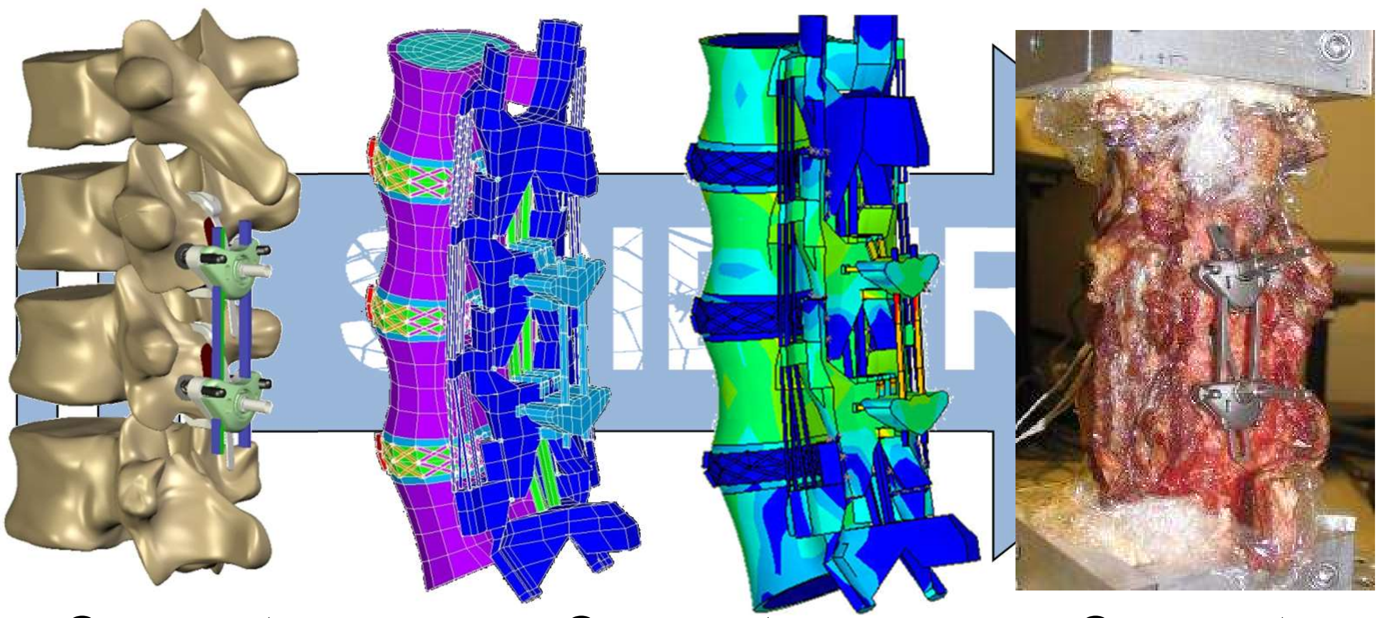
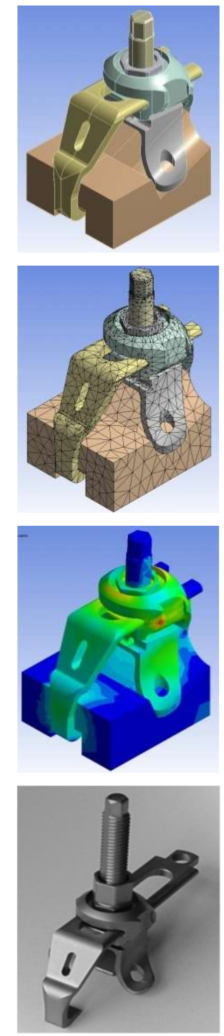
SPIDER FIXATION SYSTEM



Concept Design **Concept Evaluation** **Concept Validation**



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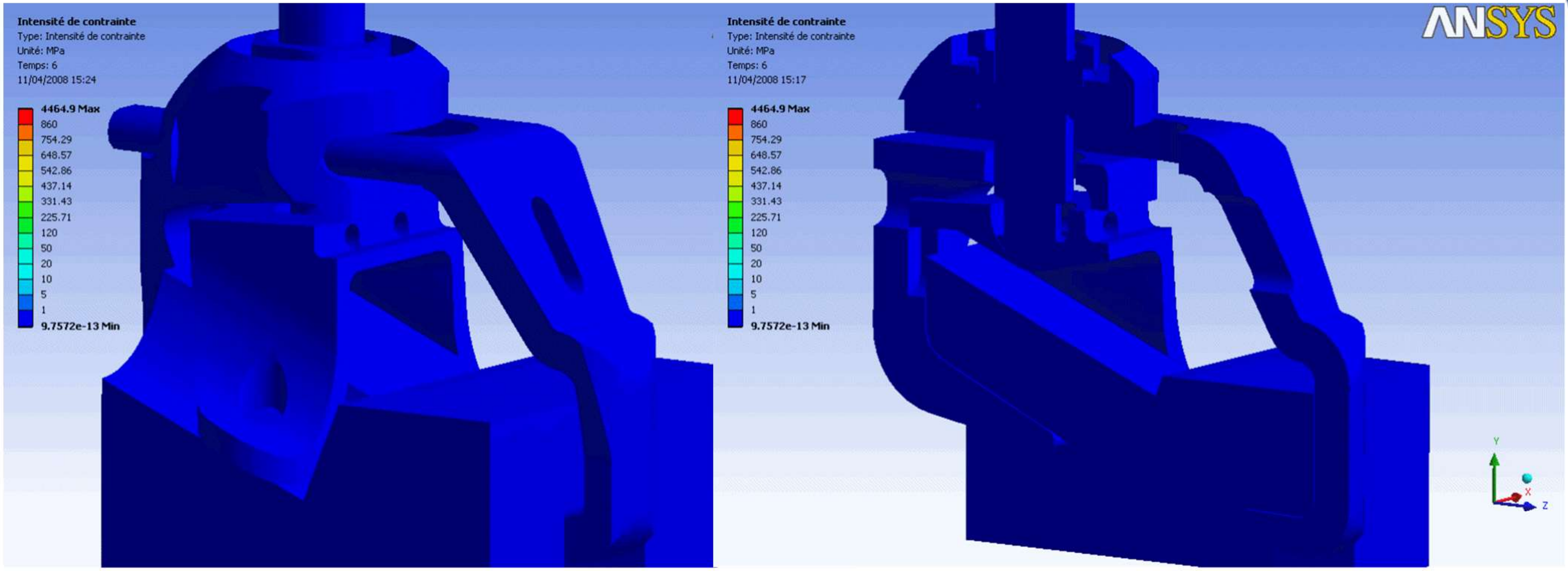
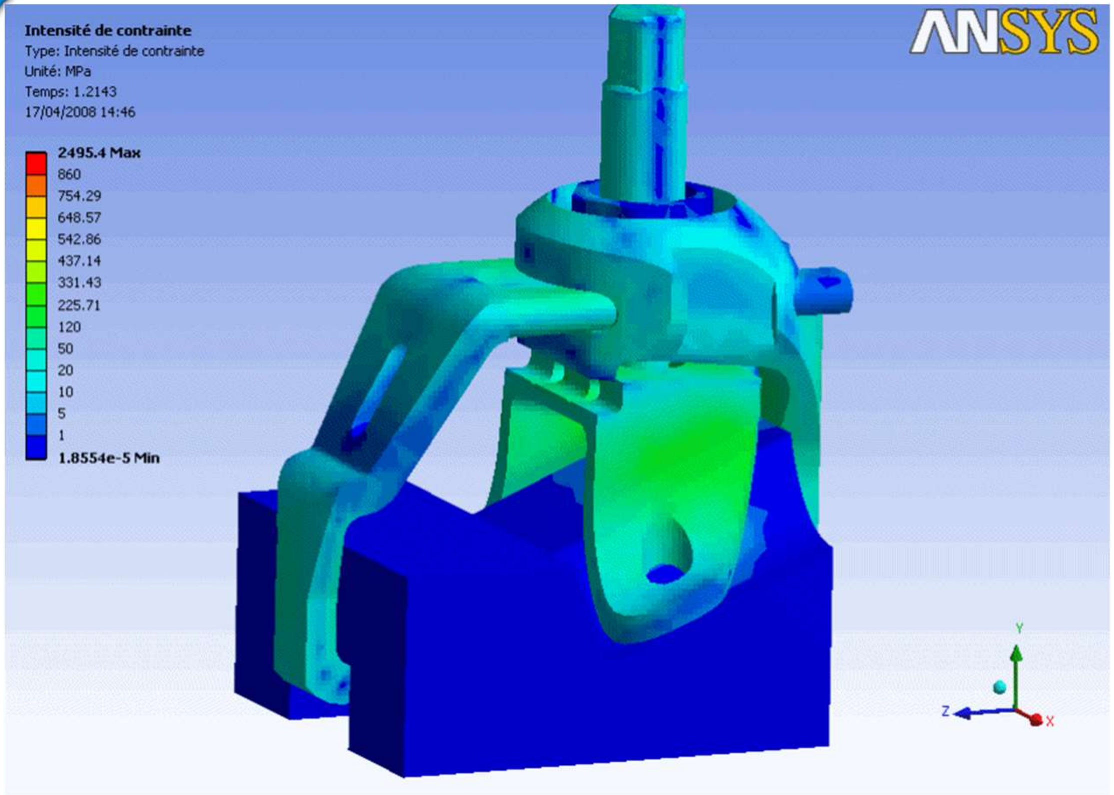
SPIDER FIXATION SYSTEM

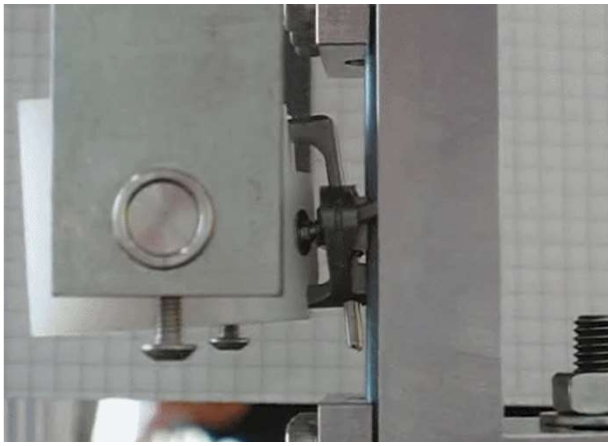
Design Optimization



SPIDER FIXATION SYSTEM

Design Validation

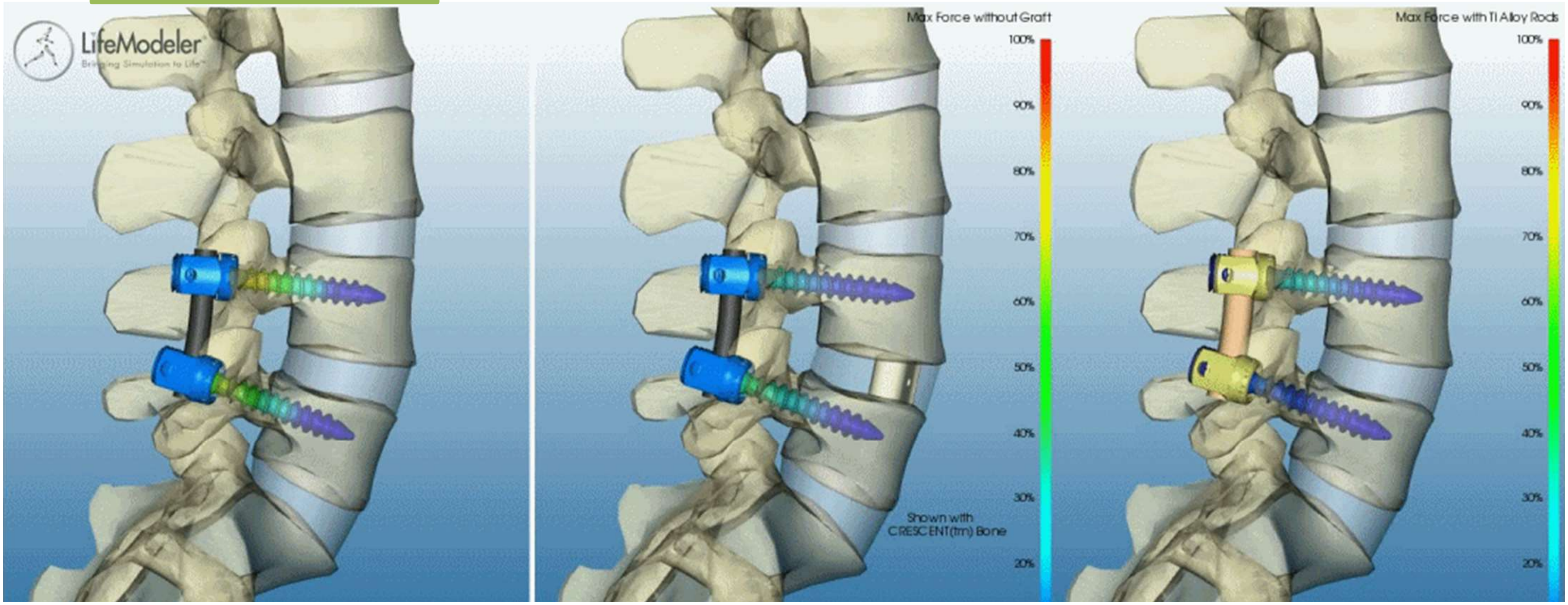




ASTM 1798

Other Numerical Models

Rigid Block Analysis



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« True » corrective forces concept

C.E. Aubin, X. Wang, D. Crandall, S. Parent, H. Labelle

IMAST
18th International Meeting on Advanced Spine Techniques

11. Biomechanical Effectiveness of Three Types of Pedicle Screws for the Spinal Instrumentation of Adolescent Idiopathic Scoliosis

Xiaoyu Wang, PhD; Carl-Eric Aubin, PhD, PEng; Hubert Labelle, MD; Dennis Crandall, MD; Stefan Parent, MD, PhD

Spine

SPINE Volume xx, Number
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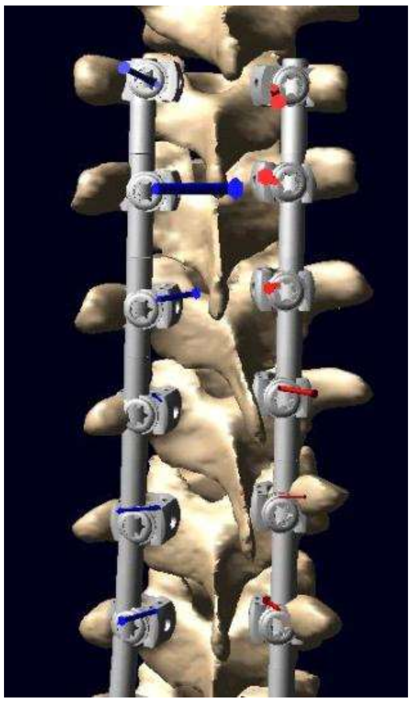
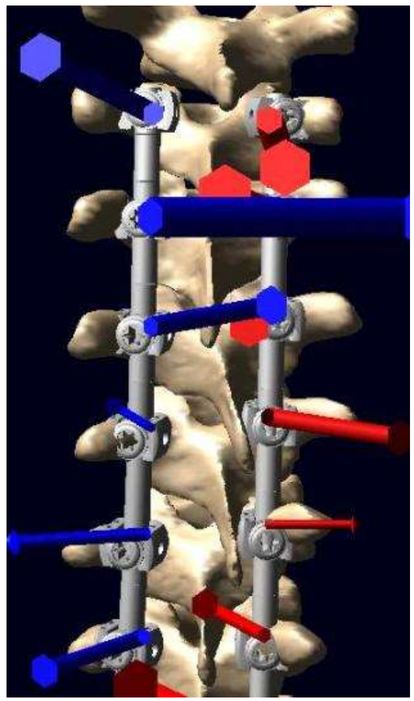
BIOMECHANICS

Biomechanical Analysis of Corrective Forces in Spinal Instrumentation for Scoliosis Treatment

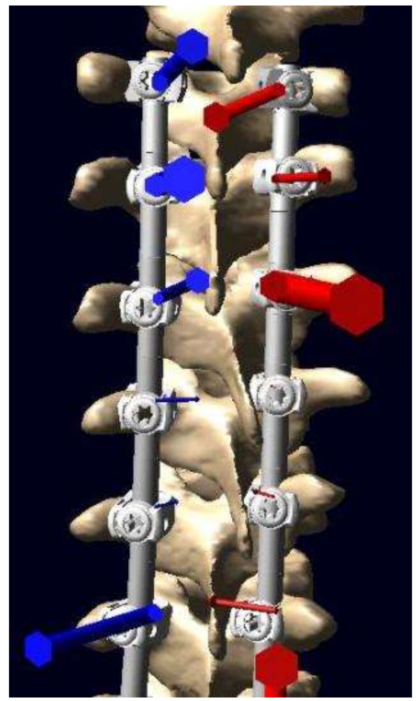
Xiaoyu Wang, PhD,* Carl-Eric Aubin, PhD, PEng,*† Hubert Labelle, MD,† Stefan Parent, MD, PhD,† and Dennis Crandall, MD,‡



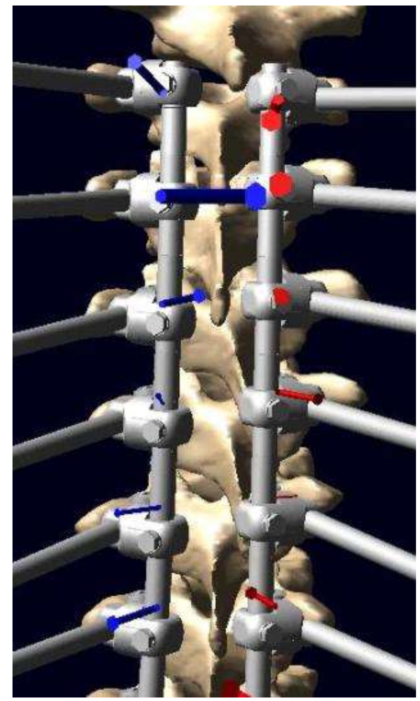
LOWEST forces



FAS



MAS



Dorso-axial

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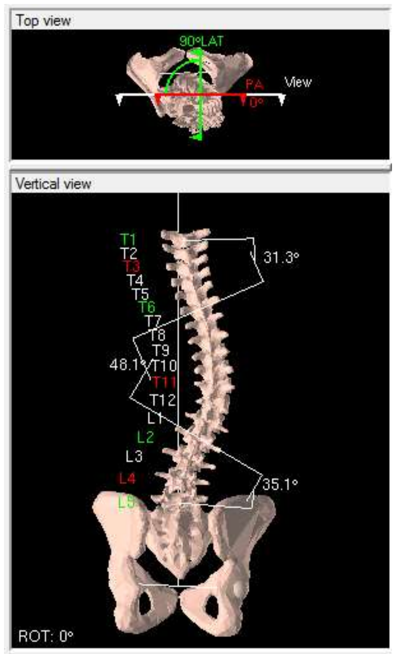

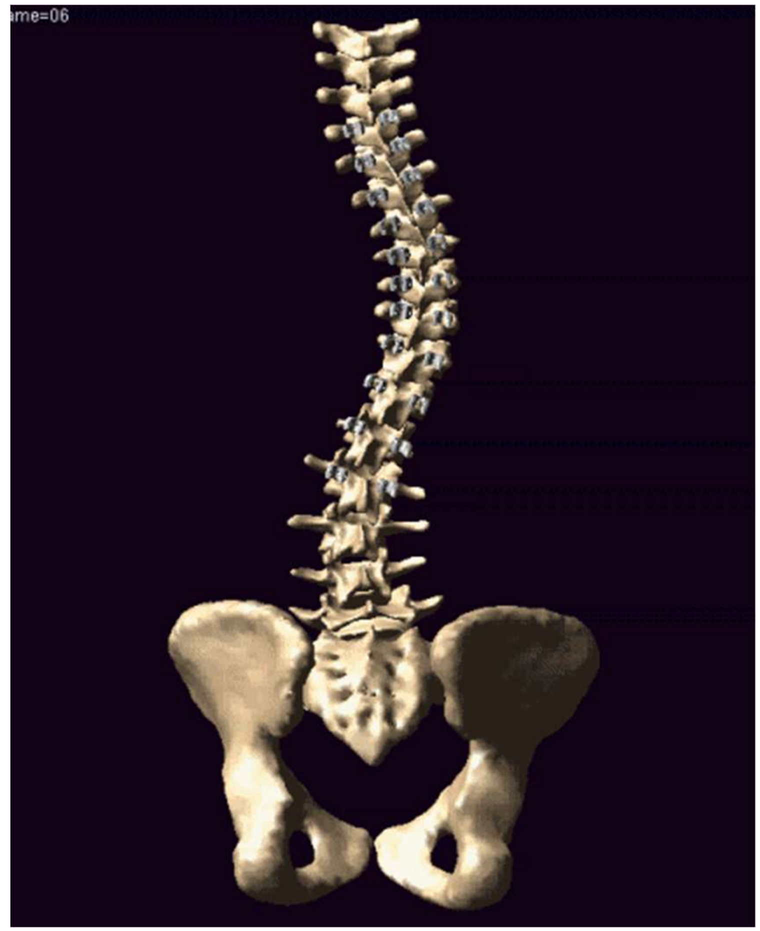

Numerical Simulations

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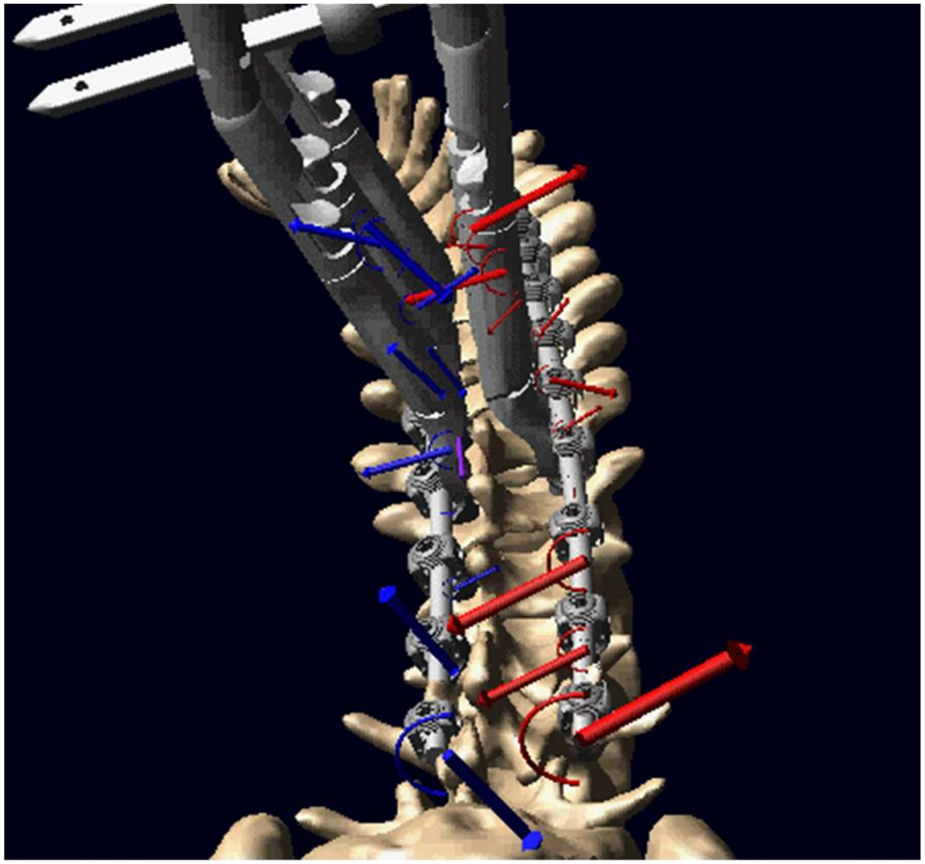
« True » corrective forces concept

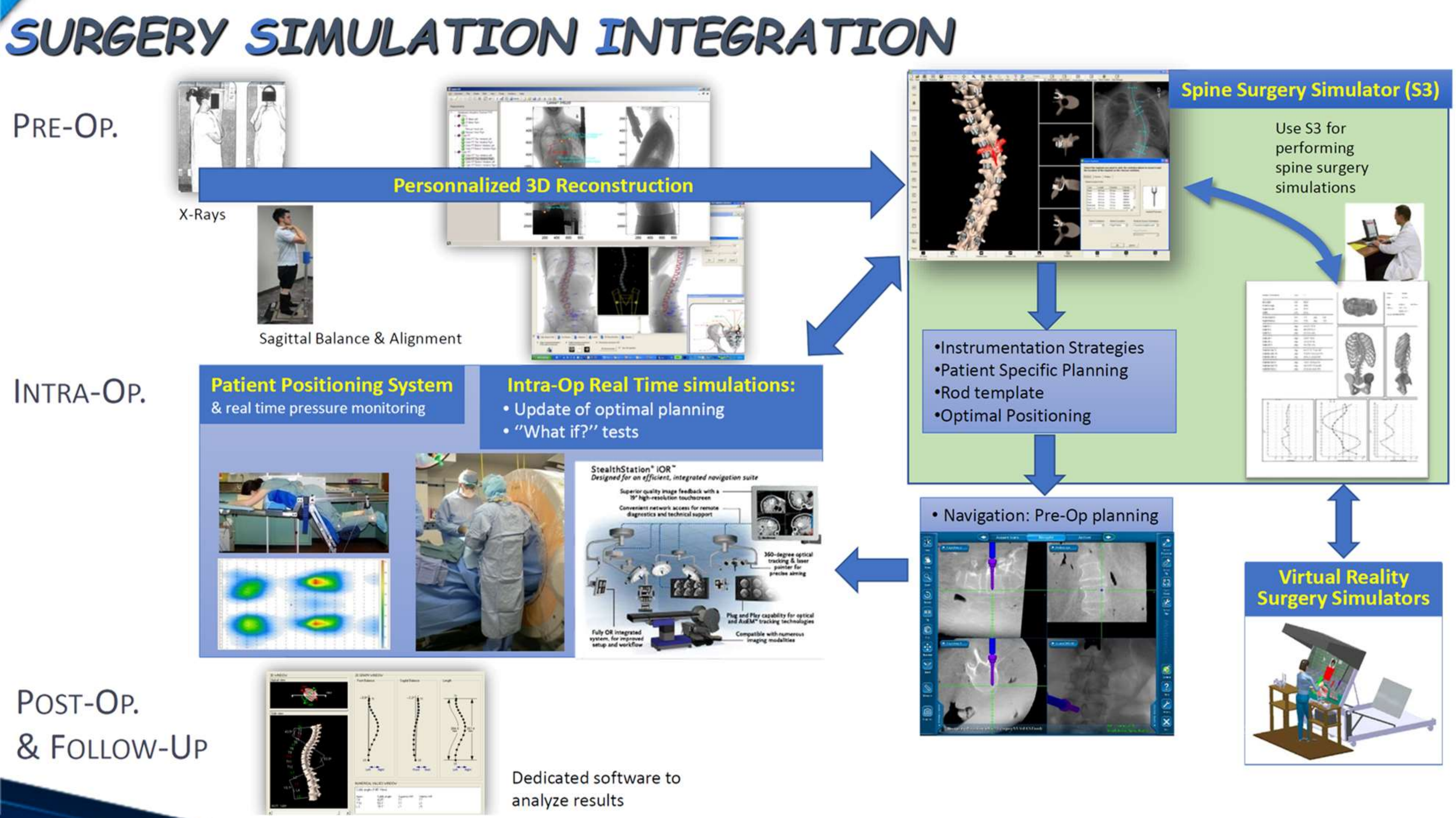
C.E. Aubin, X. Wang, D. Crandall, S. Parent, H. Labelle

EXAMPLE



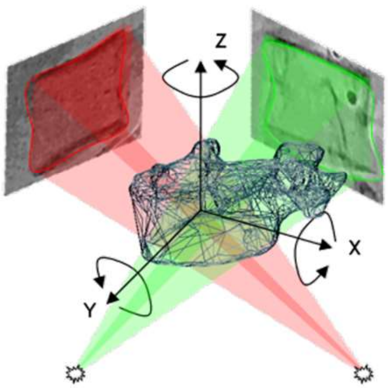
Numerical Simulations

And Tomorrow…

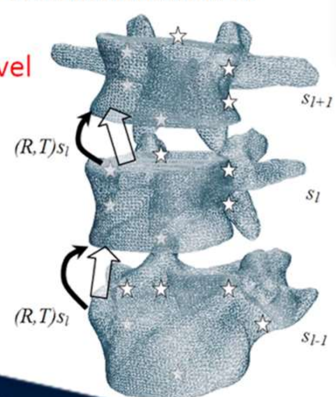


And Tomorrow…

Personalized 3D Reconstruction

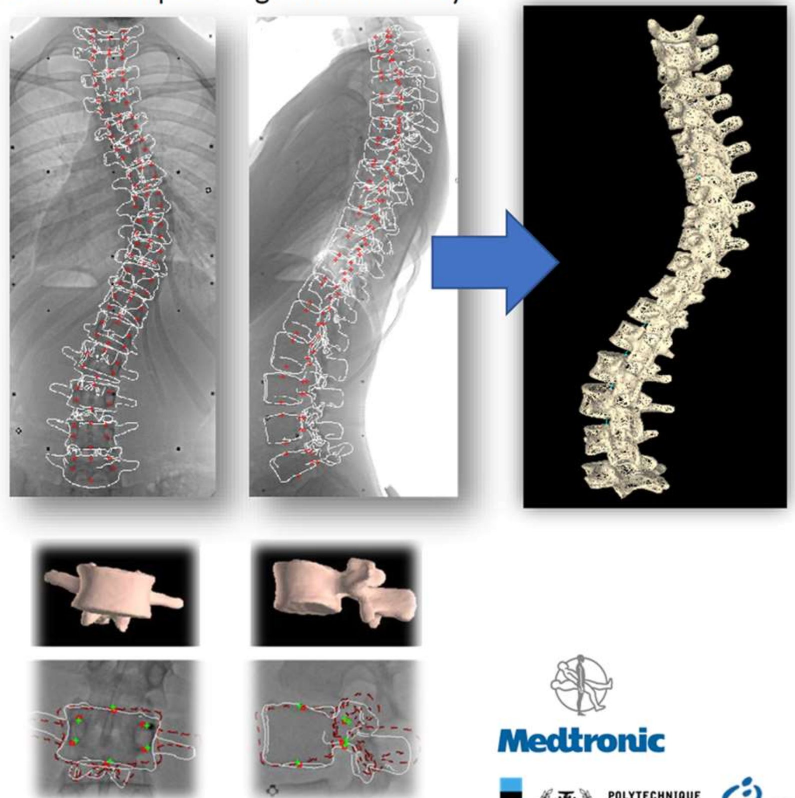


Sequential level-set deformation of prior models
per vertebral level



Vertebra shape recognition on X-rays

3D model



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And Tomorrow…

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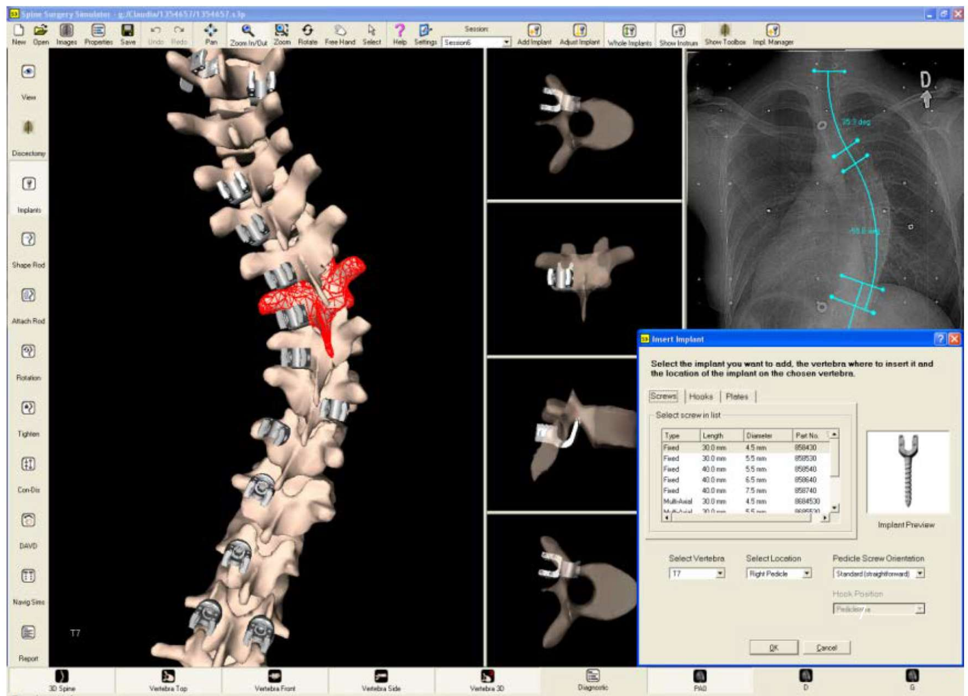
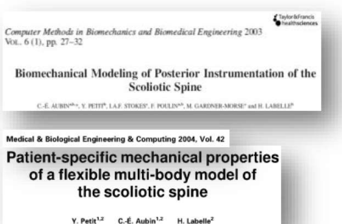
Spine Surgery Simulator

Personalized Biomechanical Model

- Patient's spine stiffness estimated from side bending radiographs



- Spinal elements
- Hooks, screws
- Rods
- …


Computer Methods in Biomechanics and Biomedical Engineering 2003
Vol. 6 (1), pp. 27–32

Biomechanical Modeling of Posterior Instrumentation of the Scoliotic Spine

Medical & Biological Engineering & Computing 2004, Vol. 42

Patient-specific mechanical properties of a flexible multi-body model of the scoliotic spine

Y. Petit[1,2] C.-É. Aubin[1,2] H. Labelle[2]

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And Tomorrow…

Spine Surgery Simulator

Pre-op radiographs

Rods contouring, Implants Maneuvers …

Post-op radiographs

3D reconstruction and model

Surgery Simulation

3D reconstruction and model

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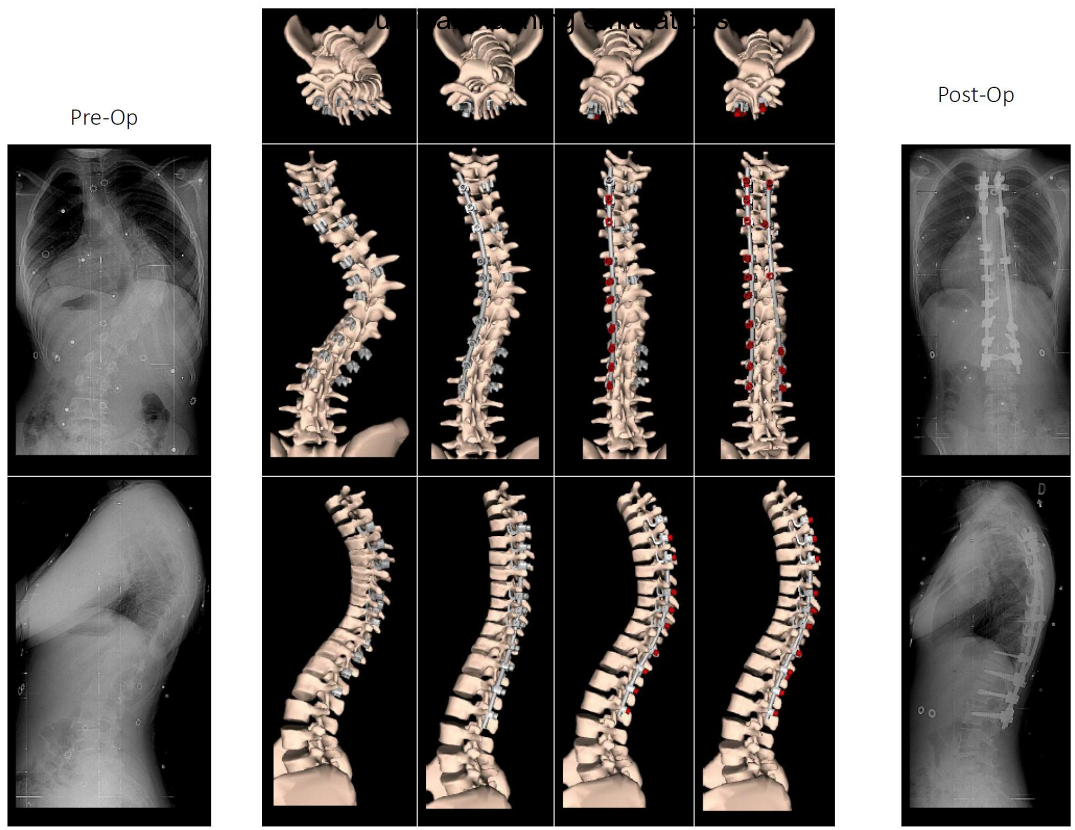
Spine Surgery Simulator



Preoperative Planning Simulator for Spinal Deformity Surgeries

C. E. Aubin, PhD,*† H. Labelle, MD,† C. Chevrefils, MASc,*† G. Desroches, MASc,*† J. Clin, MASc,*† and A. Boivin M. Eng*†

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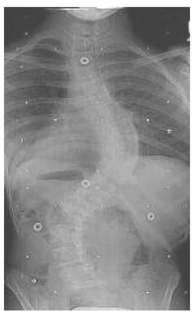
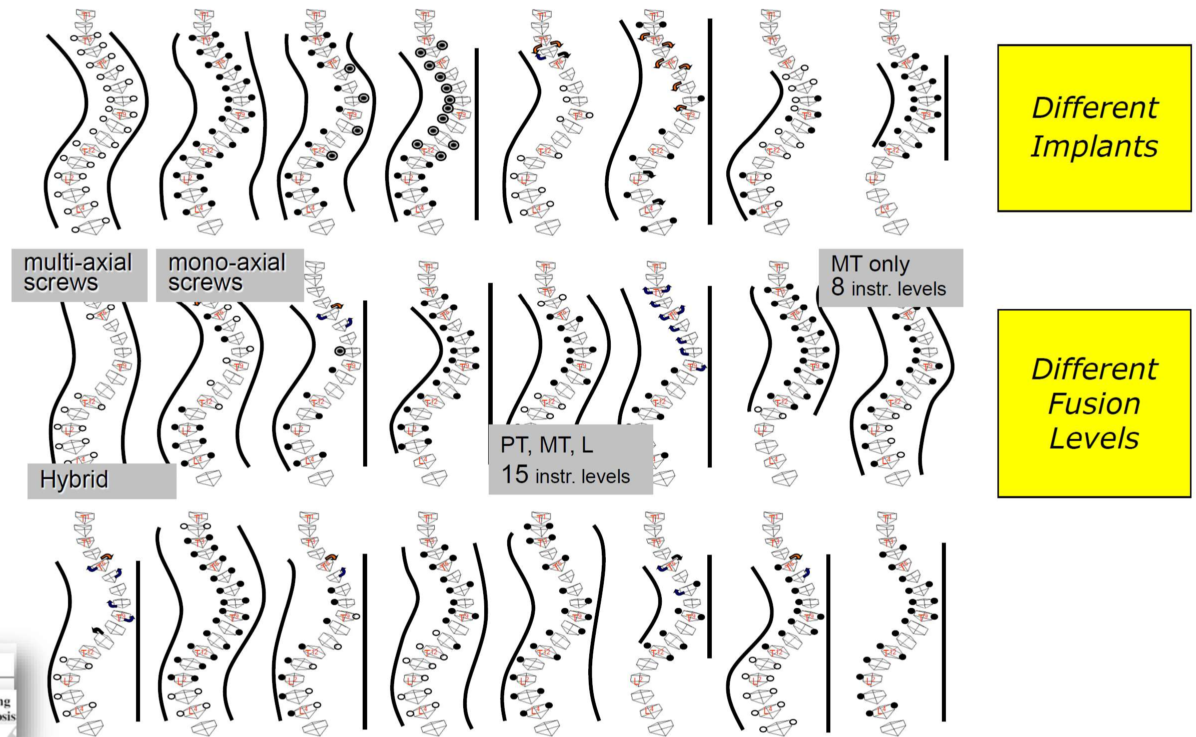
And Tomorrow…

Spine Surgery Simulator

Surgical Strategies: Which is the best?

Patient





Eur Spine J (2007) 16:1604–1614
DOI 10.1007/s00586-007-0431-x

ORIGINAL ARTICLE

Intra and interobserver variability of preoperative planning for surgical instrumentation in adolescent idiopathic scoliosis

M. Robitaille · C. E. Aubin · H. Labelle

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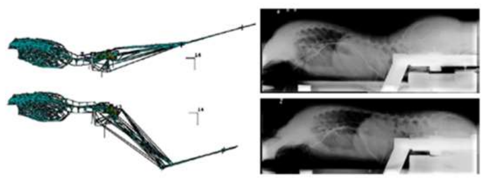
Patient Pozitioning System

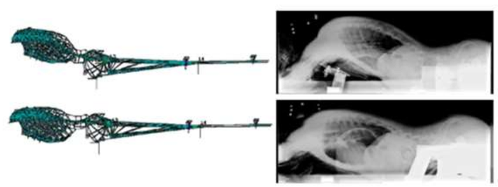
Per-Op Simulations

- Maintain patient (stability), minimize bleeding, minimize chance of damage to vital structures, allow proper ventilation, avoid post-operative morbidity
- Facilitation of instrumentation, procedures (laminectomy, discectomy, decompression), imaging
- Optimize patient positioning (intra-op motion), multifunctional, preservation of natural biomechanics

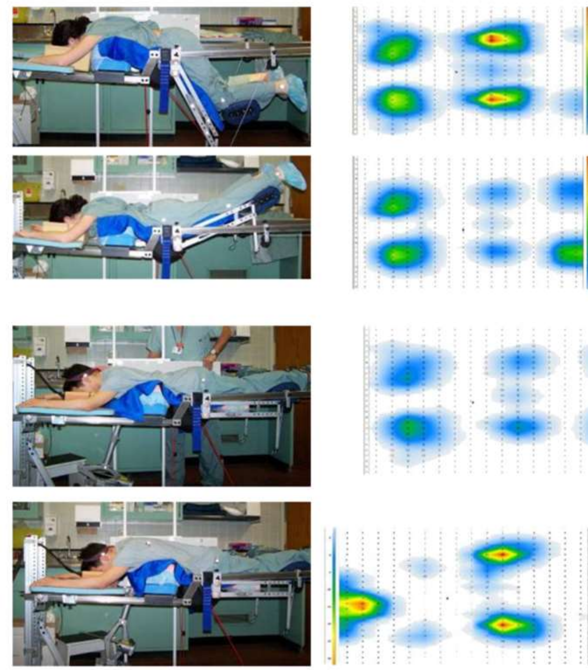
Lower Limb Pozitioning



Sternum Raising



Real Time Pressure Monitoring



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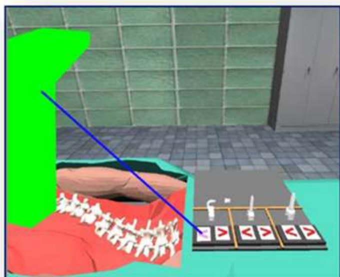
Virtual Reality Surgery Simulators

Implant Insertion



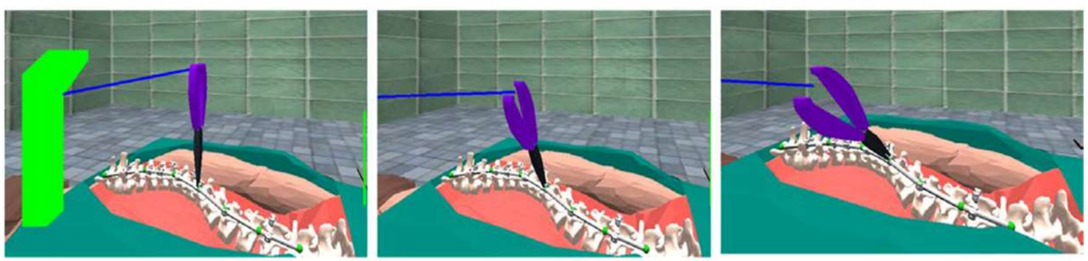
Selection

Approach

Insertion

After Multiple Implant Insertions

Rod Manipulation / Biomechanical Simulations



Force Feedback

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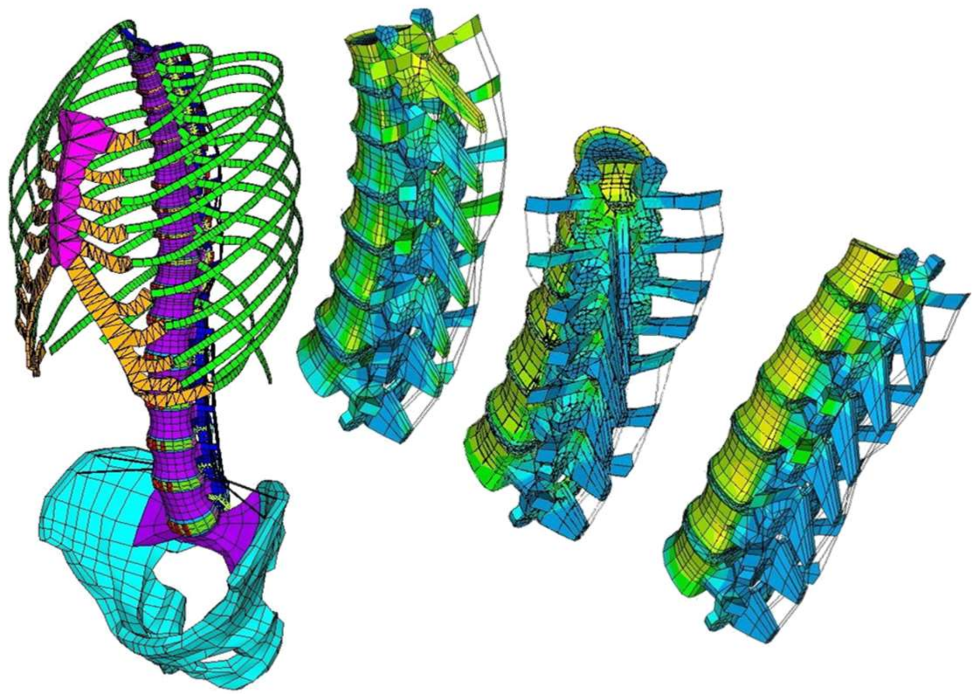
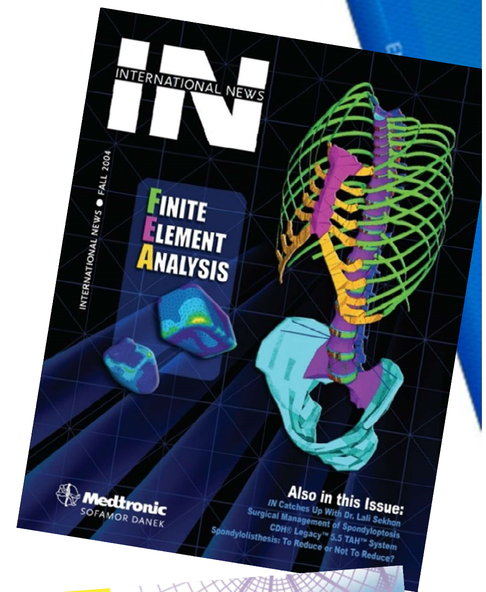
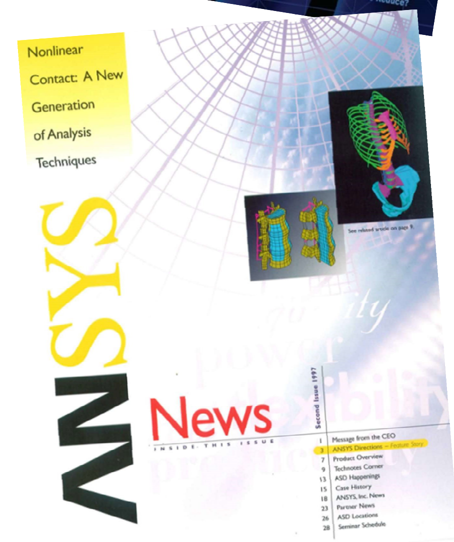
Conclusion







"By using FEA, Medtronic is able to assess the nature of stresses on spinal structures – information that is crucial to designing implants or other devices to treat spinal damages."

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"About Information..."

Philippe MAXY

Principal Scientist

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