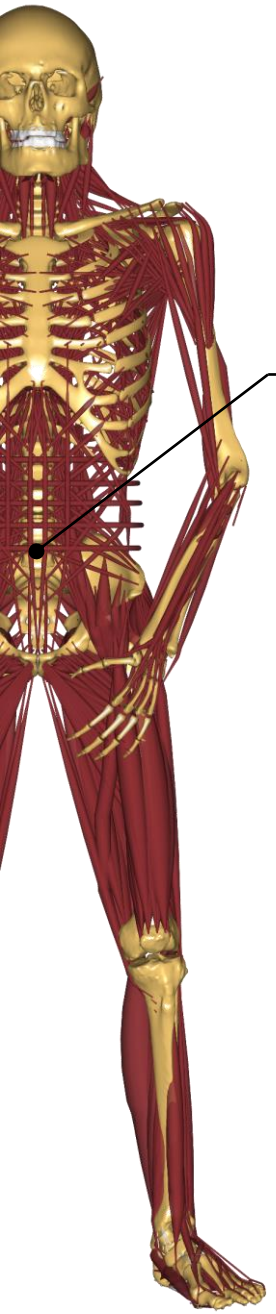
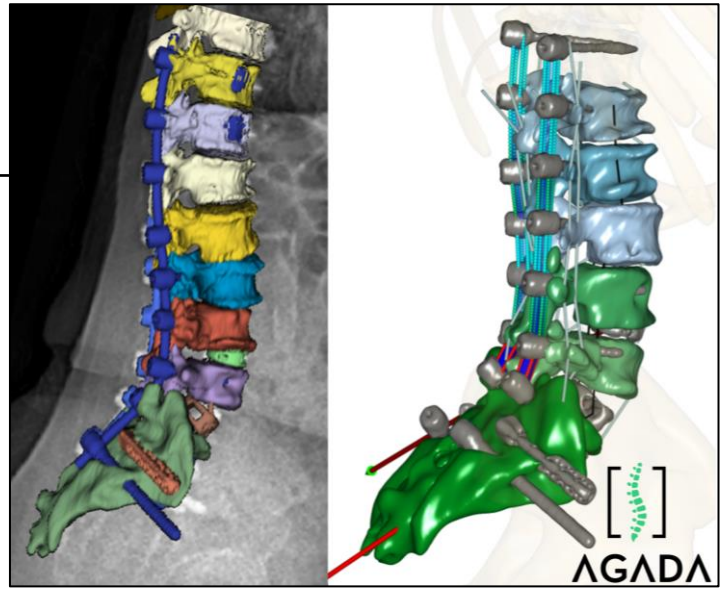





# Patient-Specific Spine Analytics

March 2nd 2023

The webinar will begin shortly…

# Outline

- Introduction
- Presentation: Patient-Specific Spine Analytics
- Let’s meet at AAOS 2023
- Q&A session

**Host**:

- Kristoffer Iversen, Technical Sales Executive, AnyBody Technology




**Presenters**:

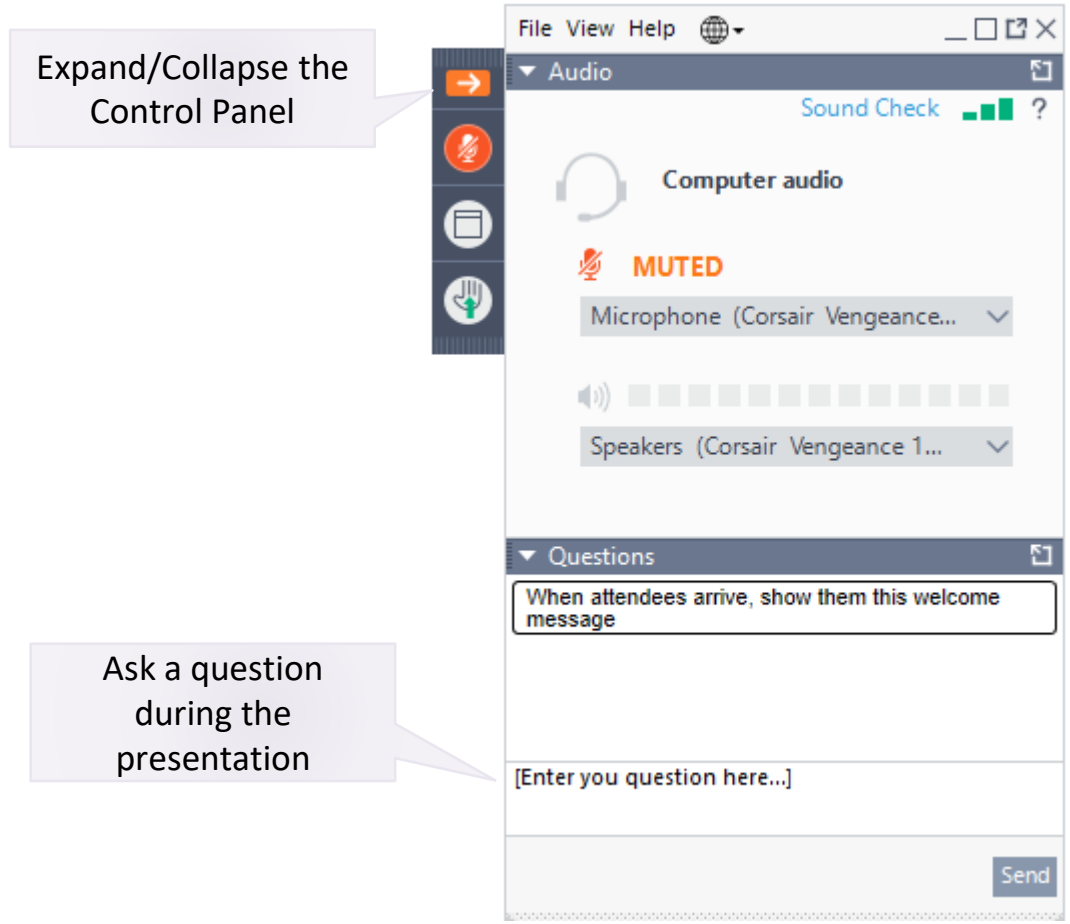
- Dr. Isador Lieberman, Chief Medical Officer, Agada Medical
- Kobi Blank, VP R&D, Agada Medical
- Samuel Shannon, Ph.D, Sr. Algorithm Engineer, Agada Medical
- Pavel Galibarov, Ph.D, Sr. Consultant, AnyBody Technology

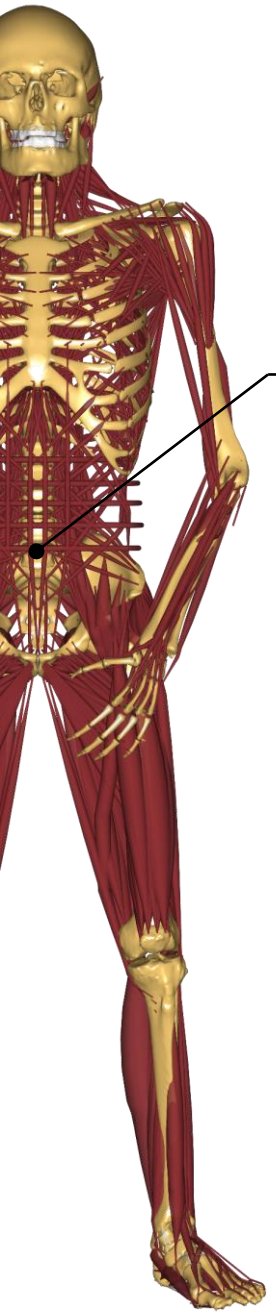
# Control Panel

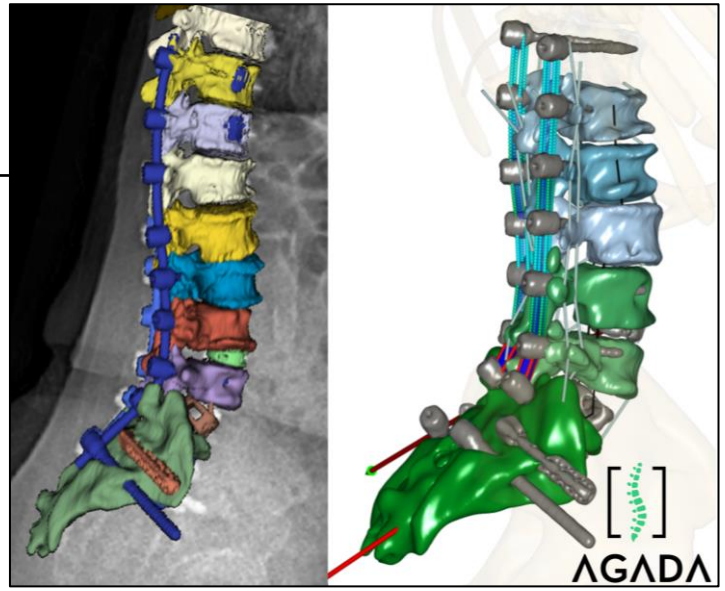
The Control Panel appears on the right side of your screen.

Submit questions and comments via the Questions panel.

*Questions will be addressed at the end of the presentation. If your question is not addressed, we will do so by email.*

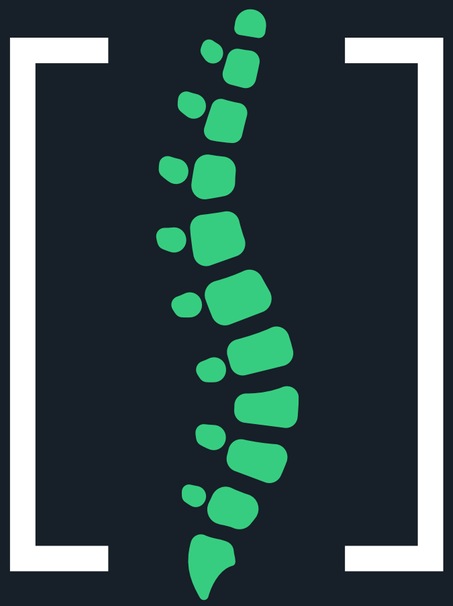







# Patient-Specific Spine Analytics

March 2nd 2023



# AGADA

## Defining the Future of Spine Surgery

# WHO WE ARE


## Dr. Isador Lieberman

**Founder, President, Chairman of The Board, Chief Medical Officer**

Orthopedic & Spine Surgeon,  Former President of the Texas Back Institute. Leadership & clinical roles at the University of Toronto and the Cleveland Clinic. 40+ U.S. patents for spinal surgery instruments and implants. Author of industry-defining medical literature. Consultant to companies like Kyphon, SIBone, J&J DePuy Synthes and Mazor Robotics.

## Mr. Kobi Blank

**VP Research & Development**

Kobi is a graduate of the MSM-Polytechnic University NY. He holds a B.Sc. in Mechanical Engineering, TAU. He has over 20 years' experience in medical devices, imaging systems, active implants, and manufacturing technologies (TopSpin Medical, SuperDimension, Medtronic, Sync-Rx, Philips). He has been a consultant to multiple medical device companies in the Cardiology and Orthopedics space.

## Mr. Samuel Shannon

**Senior Algorithm Engineer**

Samuel holds a PhD. in computational mechanics. He specializes in algorithm development, including finite element analysis, machine learning & signal processing. He has over 12 years experience in the medical device industry.

THE PROBLEM

# Nearly 1/3 of Spinal Surgeries FAIL

**$10B**
Total Addressable Market

→

**$5.6B**
Yearly Revision Burden (US)

| Spinal Deformity | Spinal Degeneration |
|---|---|
| 100k surgeries yearly | 500k surgeries yearly |
| **20%-36% FAIL** | **12%-40% FAIL** |
| Cost of revision surgery: $130k | Cost of revision surgery: $30k |
| **Total revision burden: $2.6B** | **Total revision burden: $3B** |

THE NEED

# Quantify the Forces & Predict the Clinical Outcomes

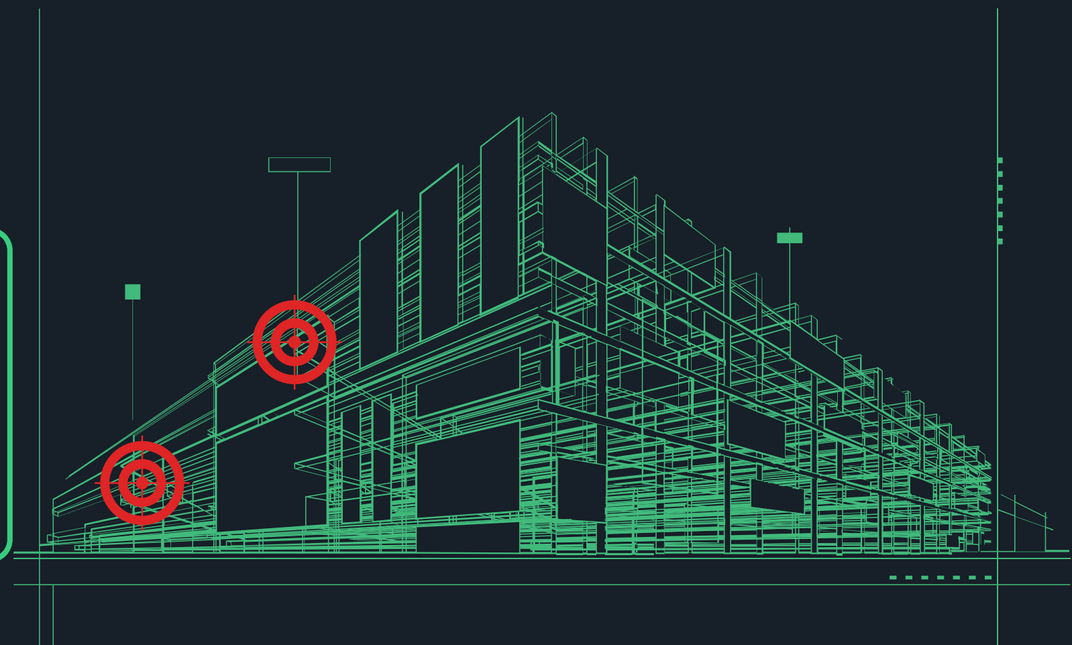
## ART

To date, surgeons do not have the tools to analyze the forces on the spine, or to predict the outcome of surgery

## Apply the Science to the Art

## SCIENCE

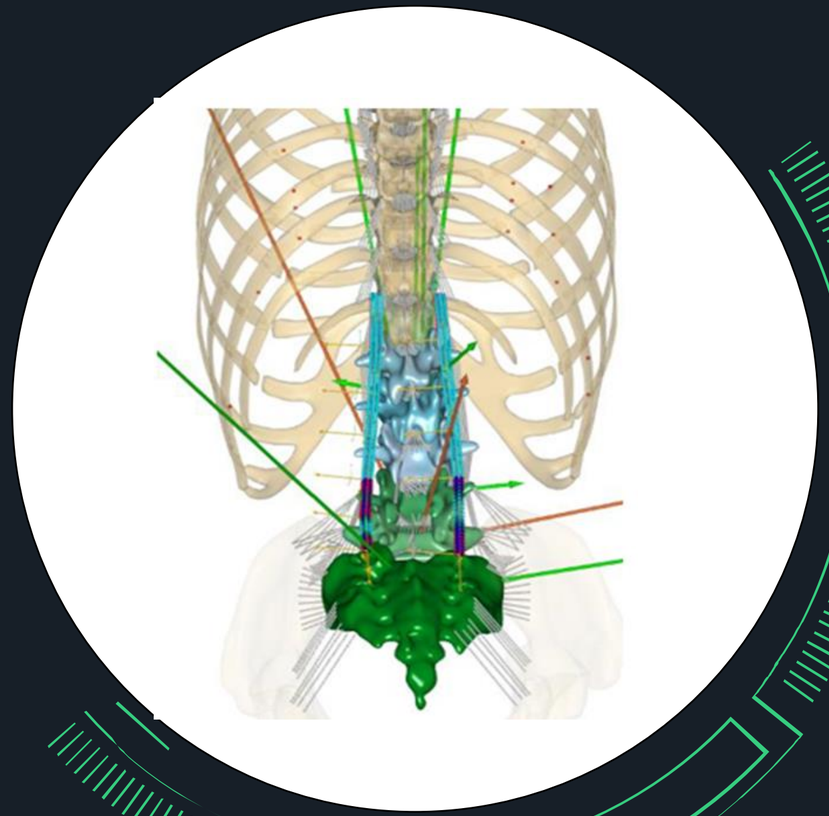
Structural engineers must consider how a structure will support the forces acting on it



THE SOLUTION

# THE SPINE ORACLE™

By calculating the forces acting on the patient's spine, **THE SPINE ORACLE™** transforms the art of surgery from descriptive analytics to the science of surgery with prescriptive AI providing surgeons with the most appropriate least invasive surgical strategy and ensure an optimal outcome.
.

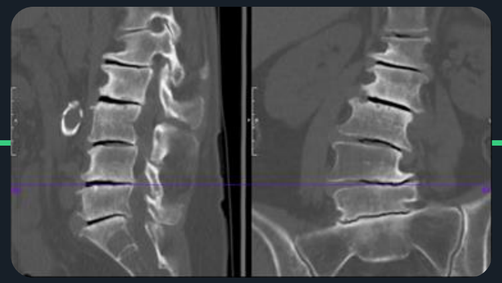


**Human Modeling SW**

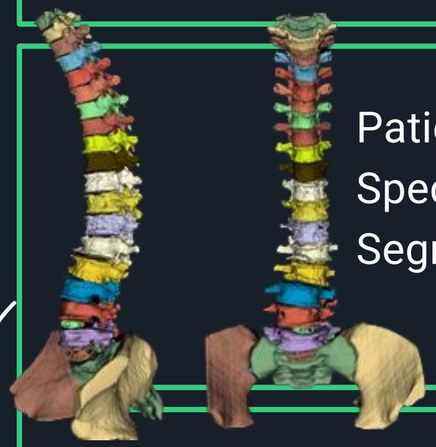
**Biomechanical Simulation SW**

**Artificial intelligence**

# AGADA
THE SPINE ORACLE™



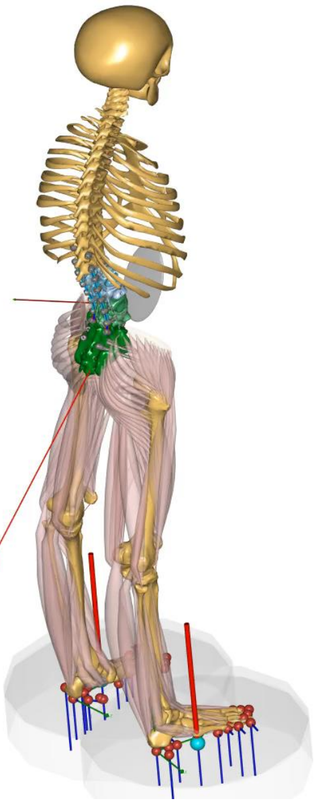
Imaging studies &
anthropometric data



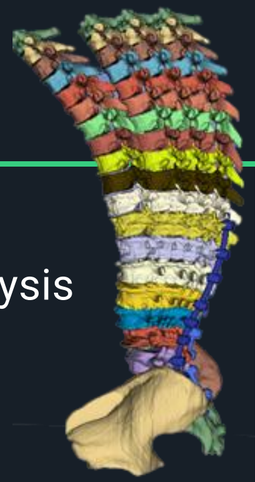
Patient
Specific
Segmentation

Patient
Specific
Digital twin

**Dynamic force analysis pretreatment native state**

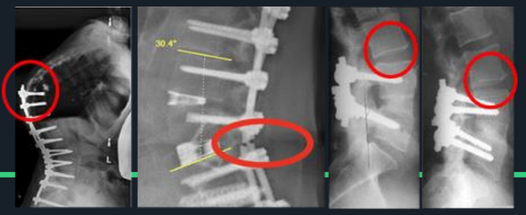


Dynamic force analysis
comparing surgical
strategies



Artificial Intelligence
Machine learning
Predictive analytics
Big Data Analysis

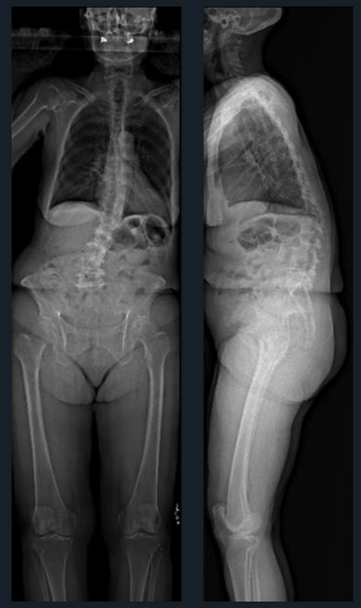
Optimized surgical solution to
prevent poor outcome

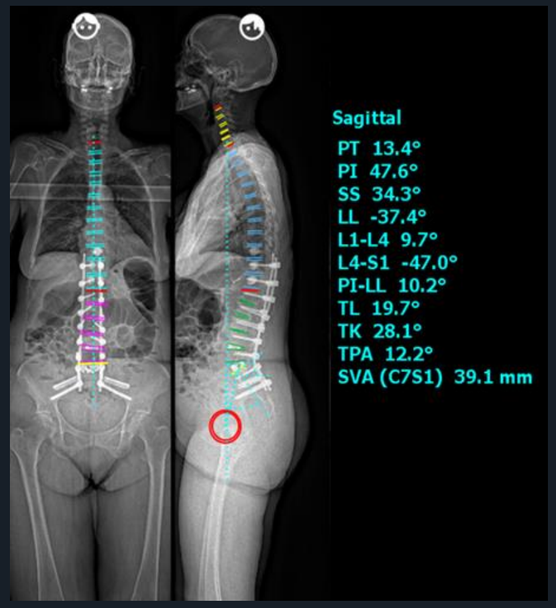


THE SPINE ORACLE™

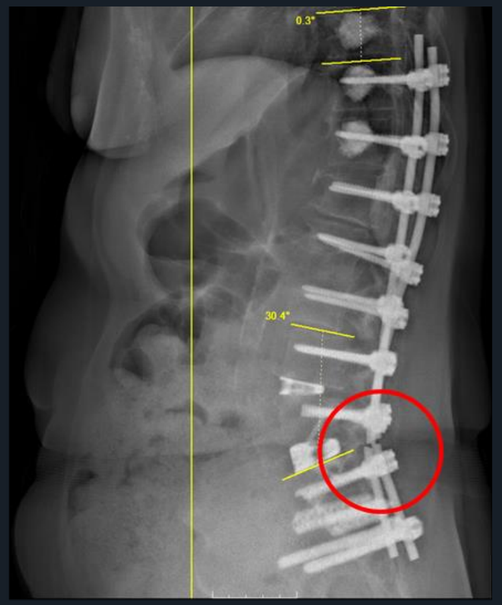
# Case Demonstration

Preoperative CT → Preoperative Plan → Follow Up Result → THE SPINE ORACLE™

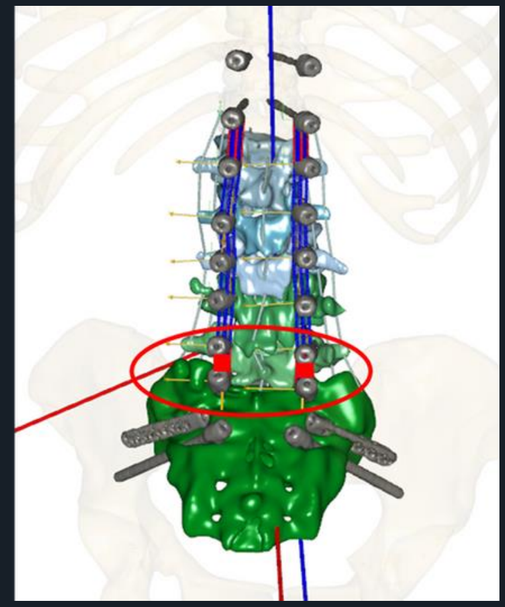





Current planning software based on geometric alignment failed to predict the rod fracture



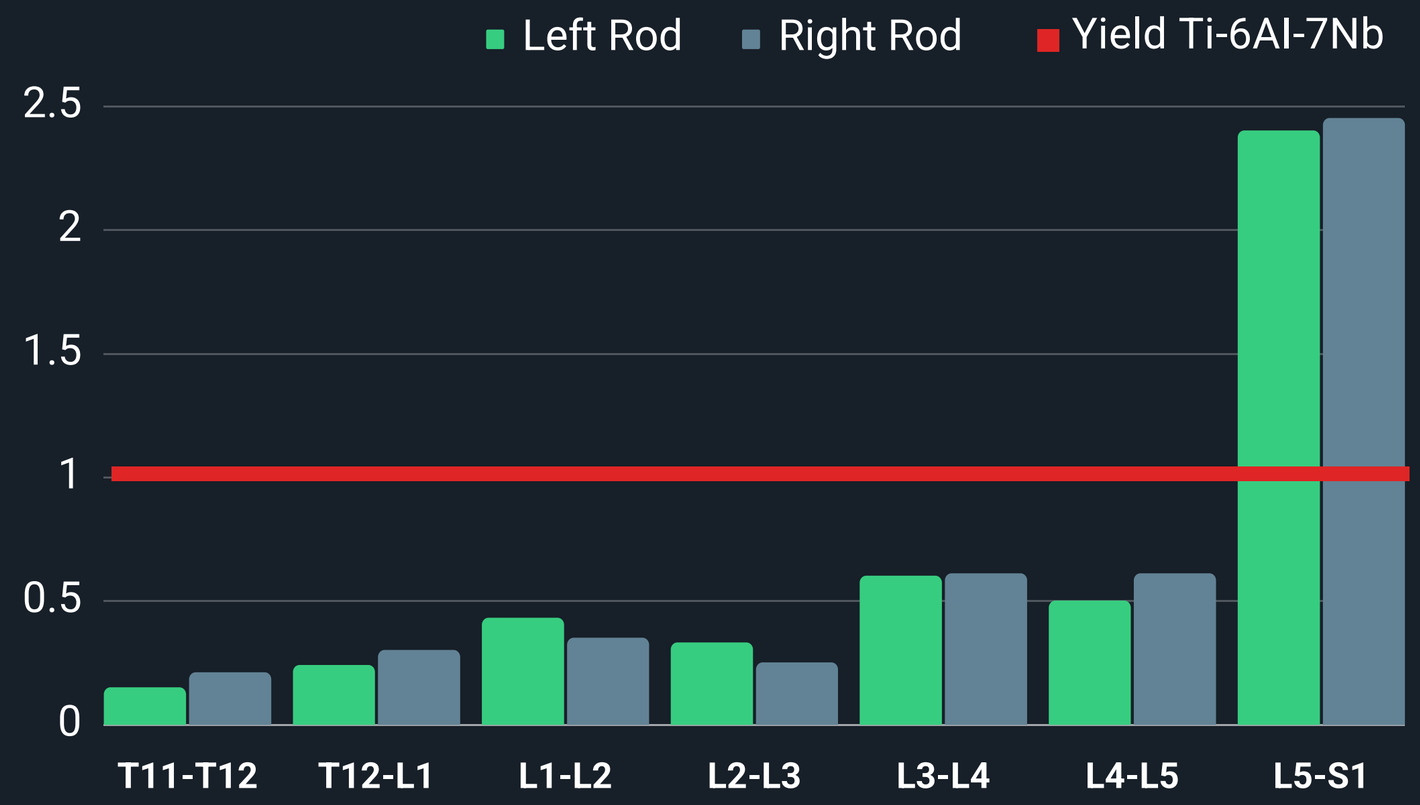

Rod fracture at 6 months



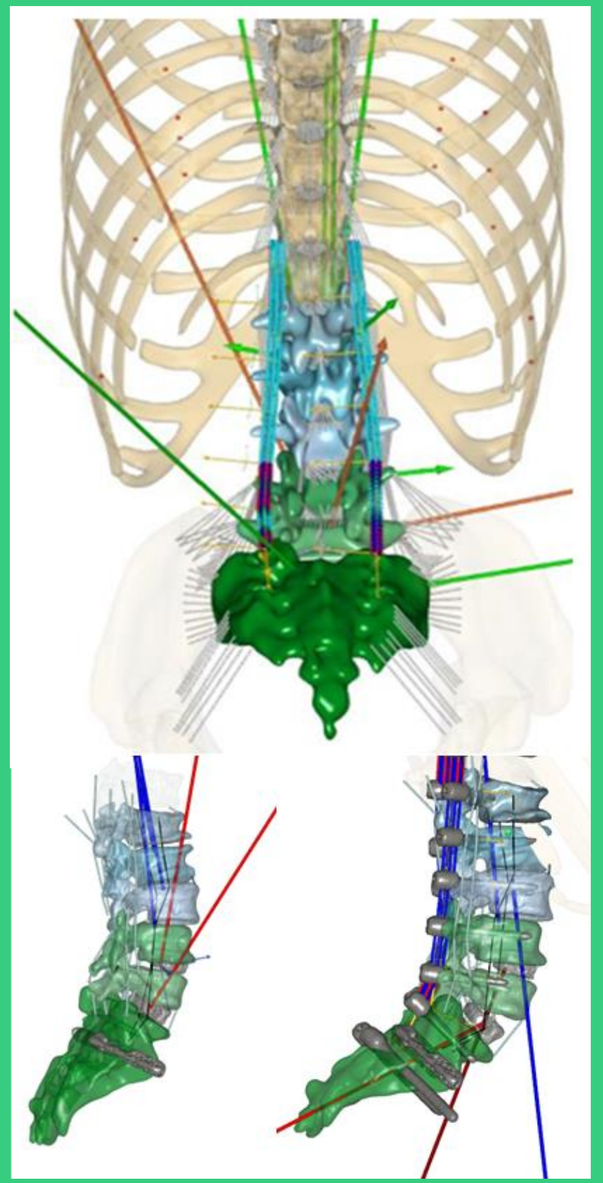
Retrospective analysis predicted the rod fracture

QUANTIFIED ANALYSIS

# Rod Stress Analysis




VISUAL ANALYSIS

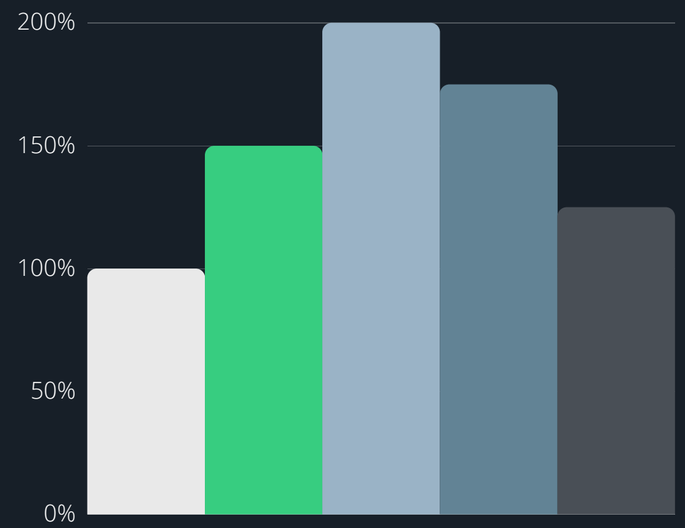


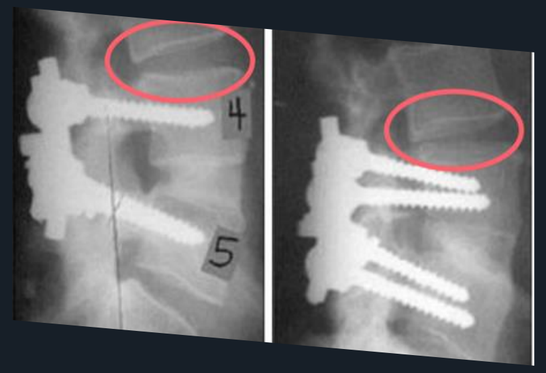
PROXIMAL JUNCTIONAL FAILURE
ADJACENT LEVEL DEGENERATION

# Additional Unmet Clinical Needs

Prevalence of Proximal junction failure (10%-30%)

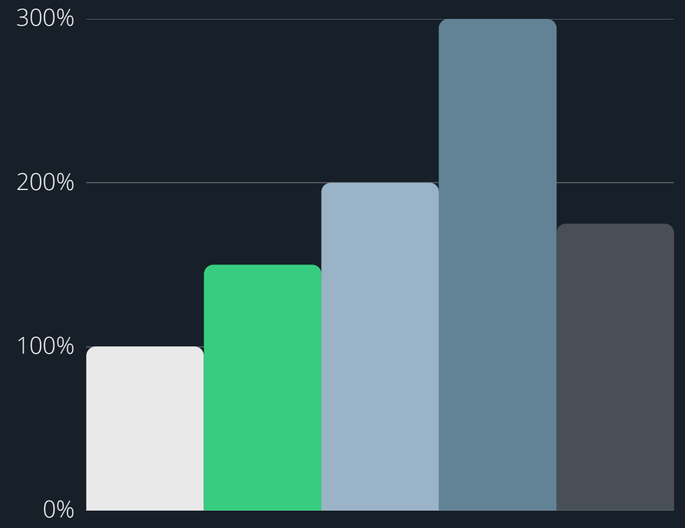
UPPER VERTEBRA STRESS




Prevalence of Adjacent level degeneration (20%-40%)

INTRA-DISCAL PRESSURE



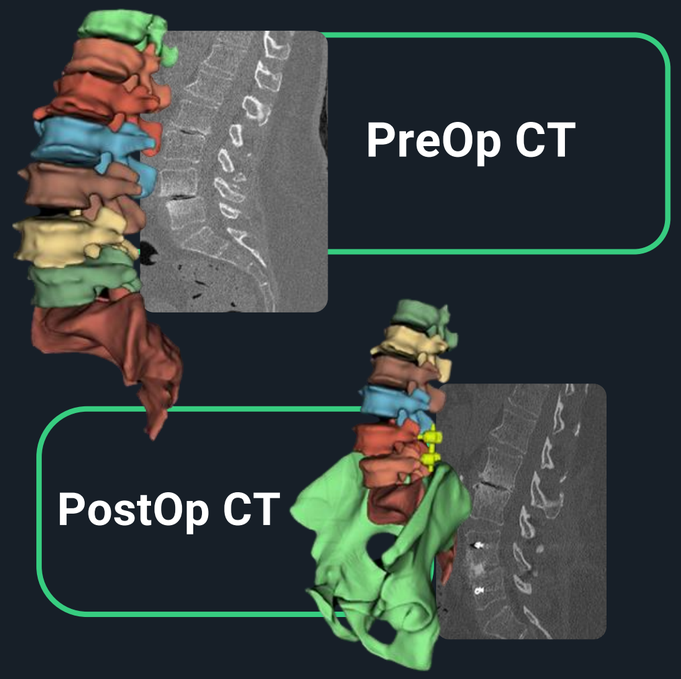
STATUS

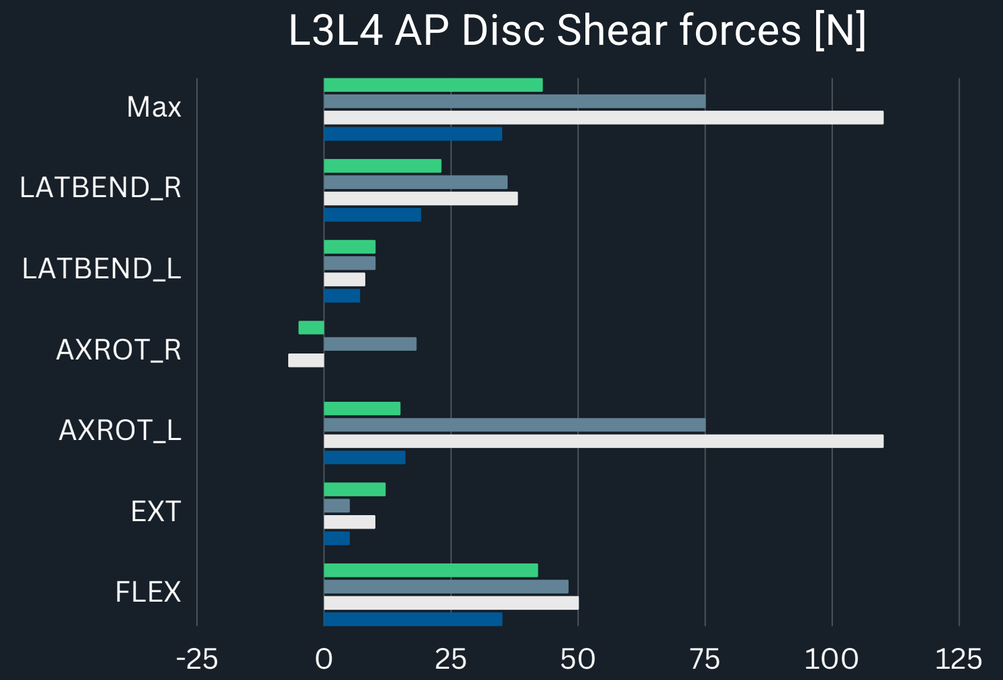
# Where We Are Today

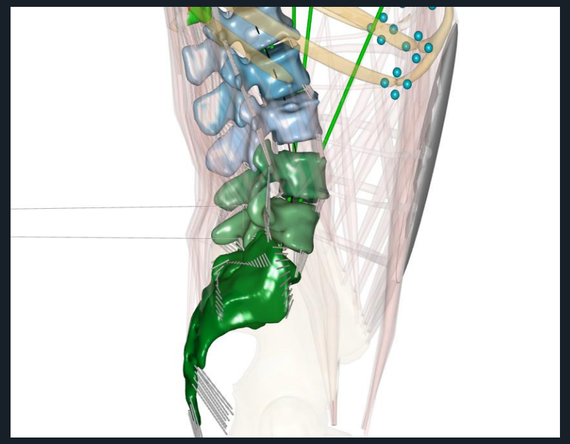
| Technology | Function | Current Status |
|---|---|---|
| **THE SPINE ORACLE™**<br>Automatic Spine Segmentation Algorithm<br>ASSA | Using patient CT scan a fully segmented spine model is created that includes the entire spine and pelvis. | Working prototype complete |
| **THE SPINE ORACLE™**<br>Lumbar Spine Simulation Module<br>LSSM | The segmented spine model is morphed into the simulation module to analyze the forces at the treated level(s) and above and below a one or two-level lumbar fusion or total disc replacement. The module also analyzes the volumetric assessment of spinal stenosis. | Working prototype complete |
| **THE SPINE ORACLE™**<br>Thoracic Spine Simulation Module<br>TSSM | The segmented spine model is morphed into the simulation module to analyze the forces at the upper instrumented level and adjacent level during deformity surgery to predict and prevent PJK and PJF. | Working prototype functional |

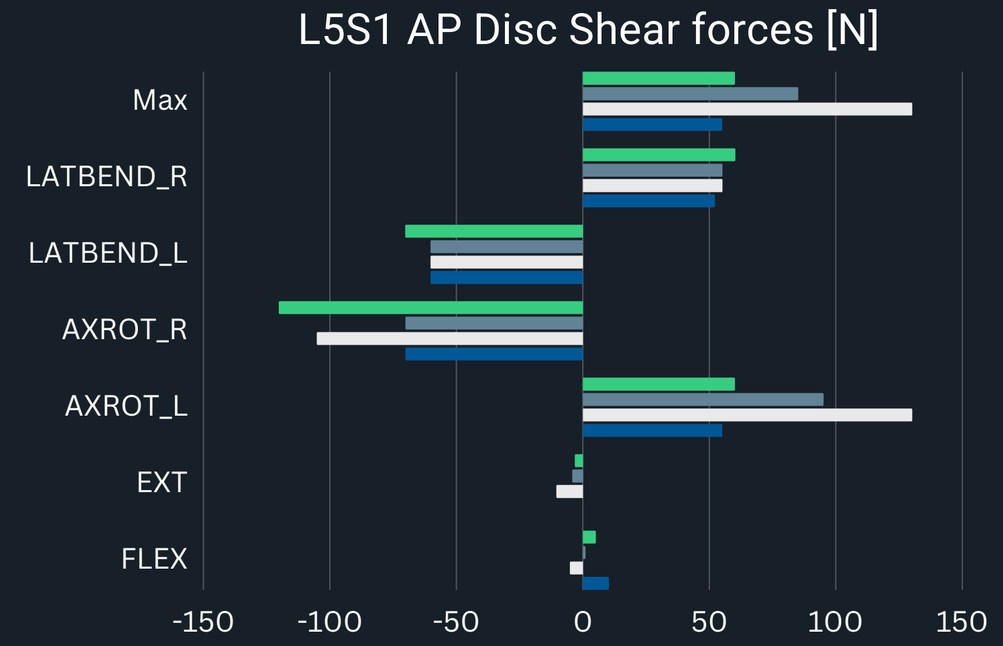
AUTOMATED ADJACENT SEGMENT

# Force Simulation & Analysis

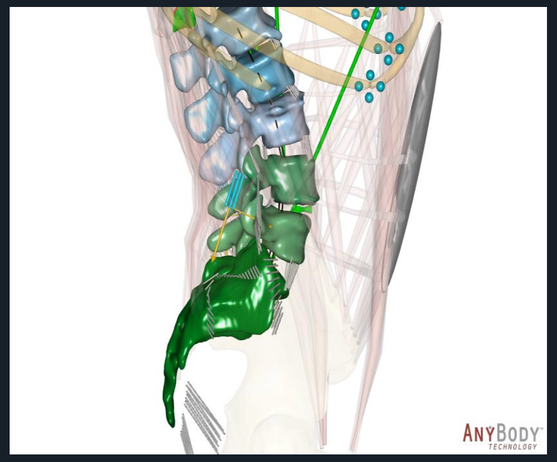


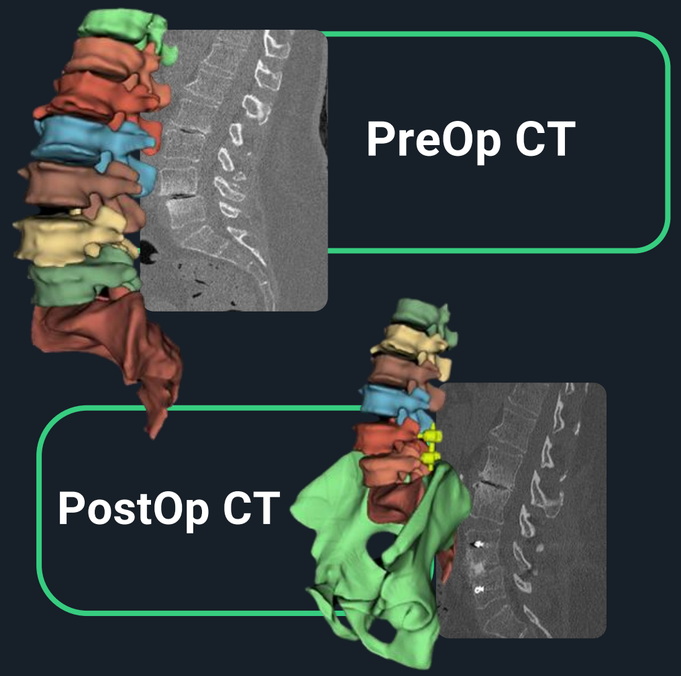


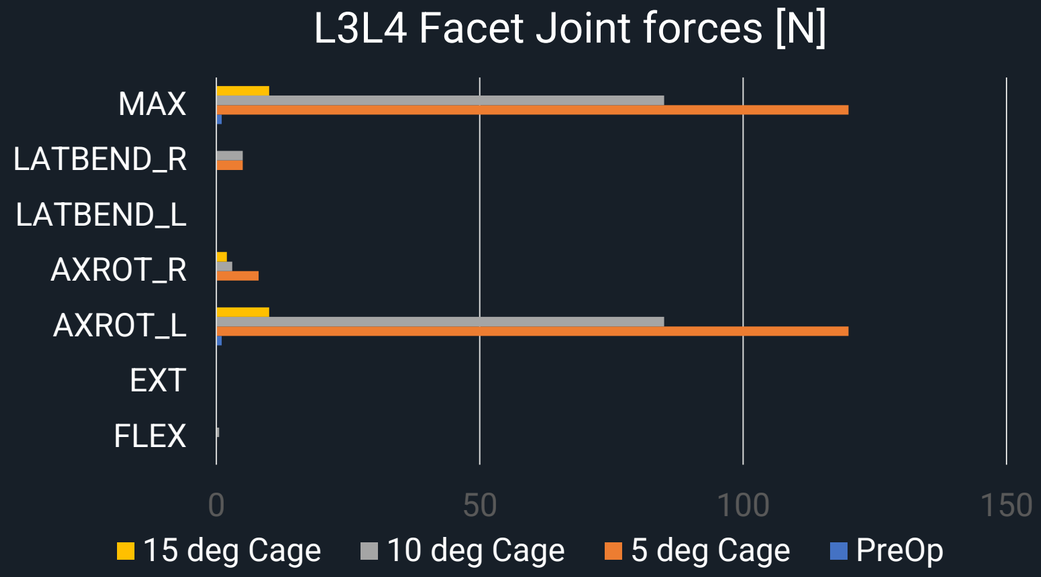

- Pre-op
- 5 deg cage
- 10 deg cage
- 15 deg cage

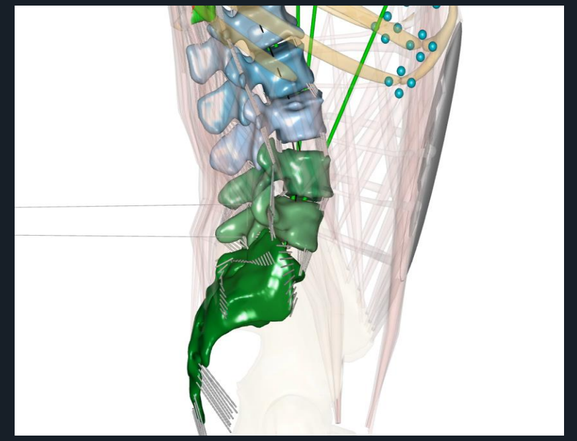


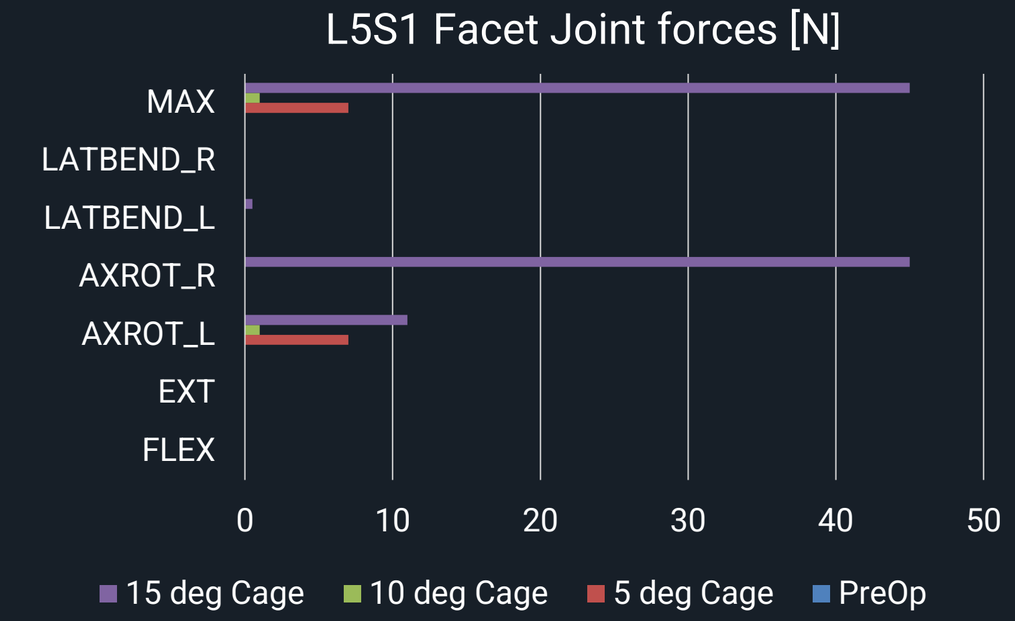
AUTOMATED ADJACENT SEGMENT

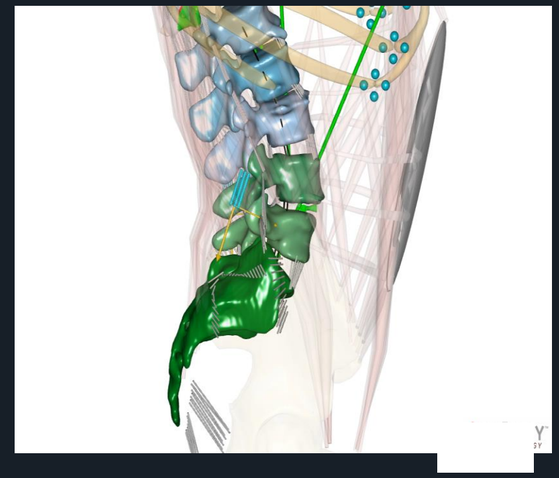
# Force Simulation & Analysis





# AGADA

## Defining the Future of Spine Surgery

**Kobi Blank**
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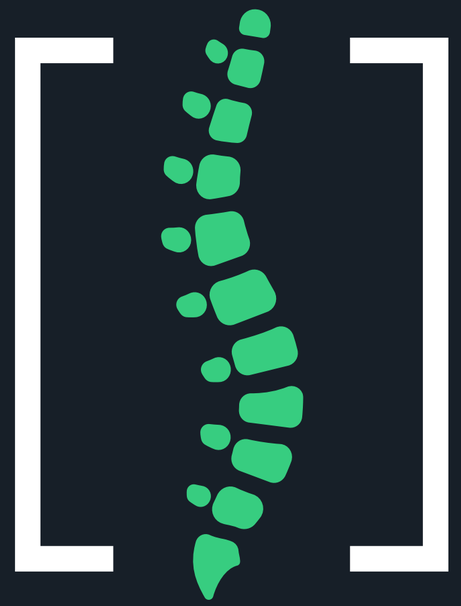
**Isador Lieberman**
izzy@agada-medical.com

**Samuel Shannon**
samuel@agada-medical.com

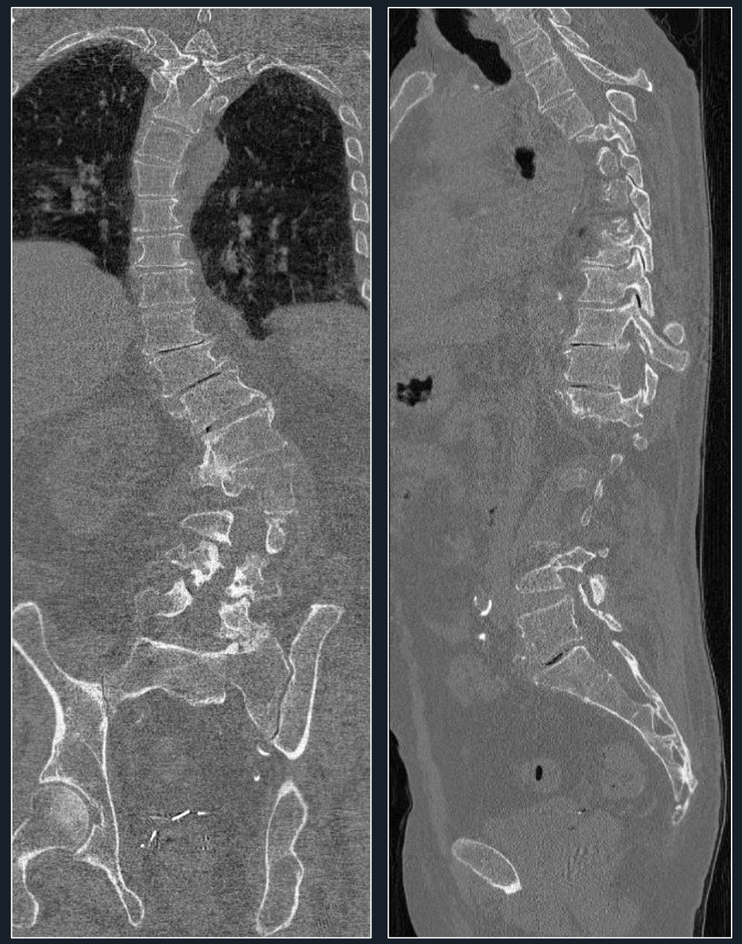


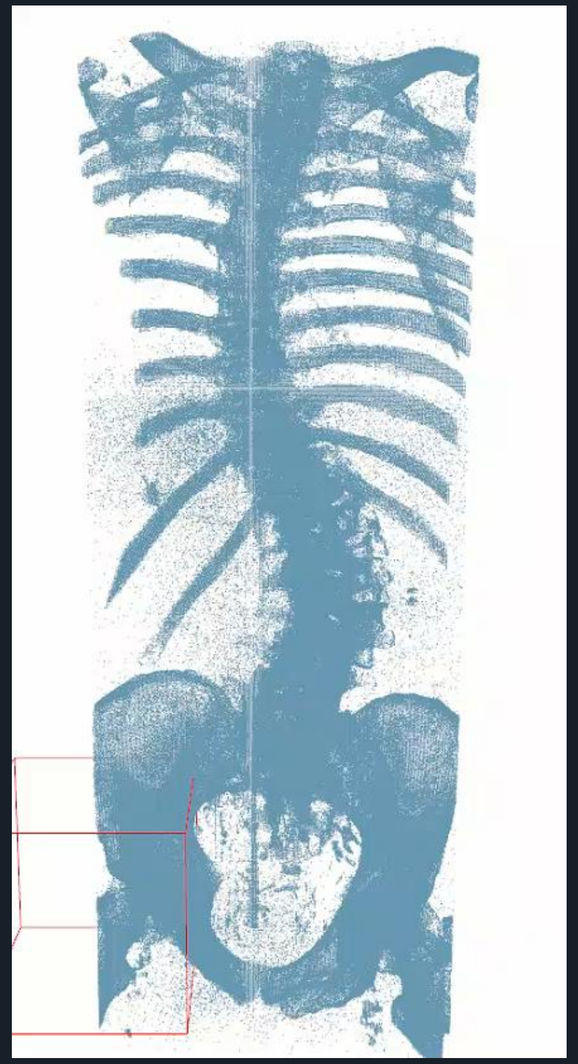
# AGADA

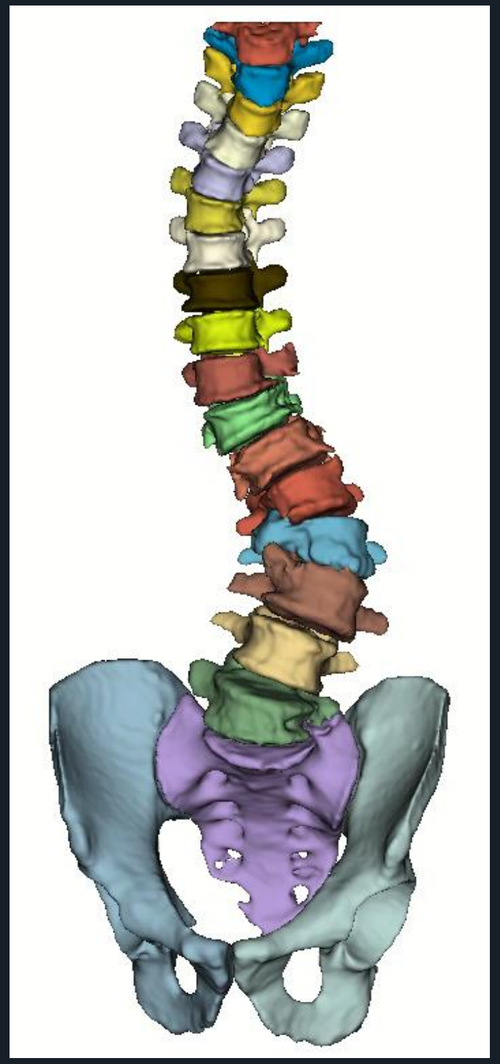
## Automatic Spine Segmentation Module

# AI Automatic Spine Segmentation Algorithm

Automatic segmentation of Pre-operative CTs:





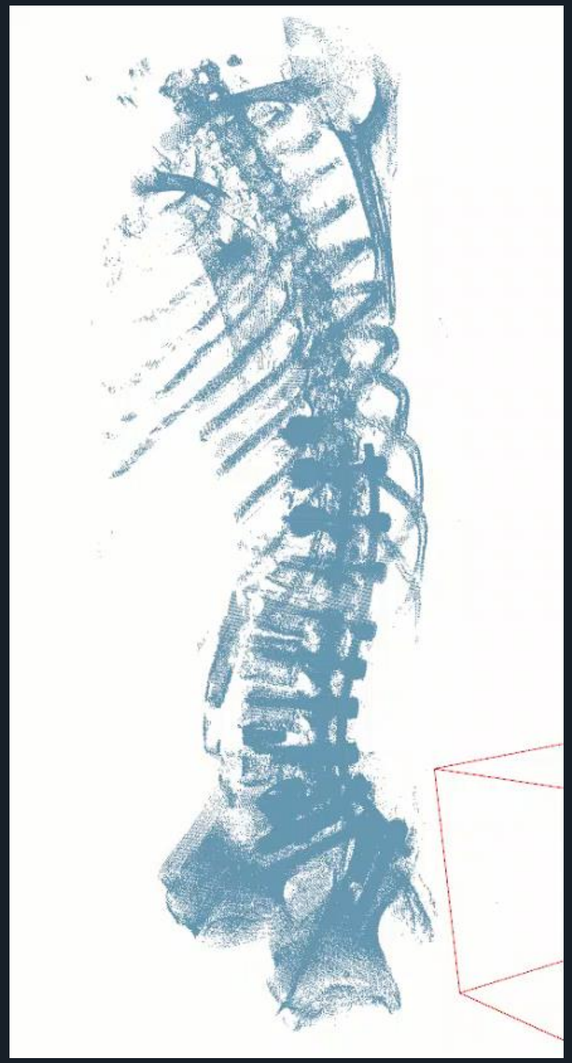


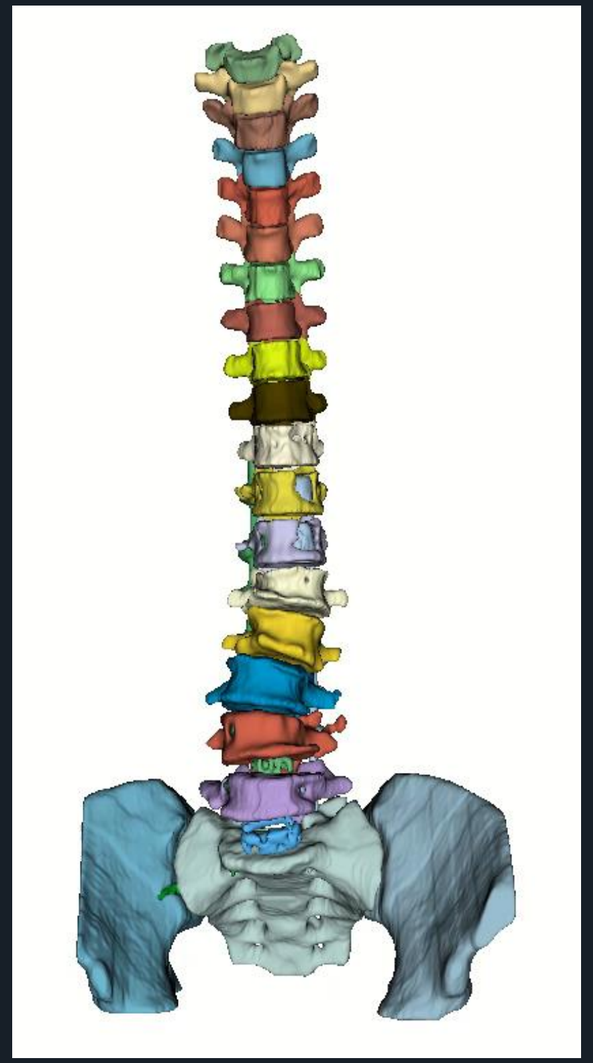
**Segmentation performance:** Dice = 0.965 (std=0.018), Precision = 0.953 (std=0.029) ,Recall = 0.978(std=0.011)

AGADA
THE SPINE ORACLE™

# Automatic Spine Segmentation Algorithm

Automatic segmentation of CTs with implants:



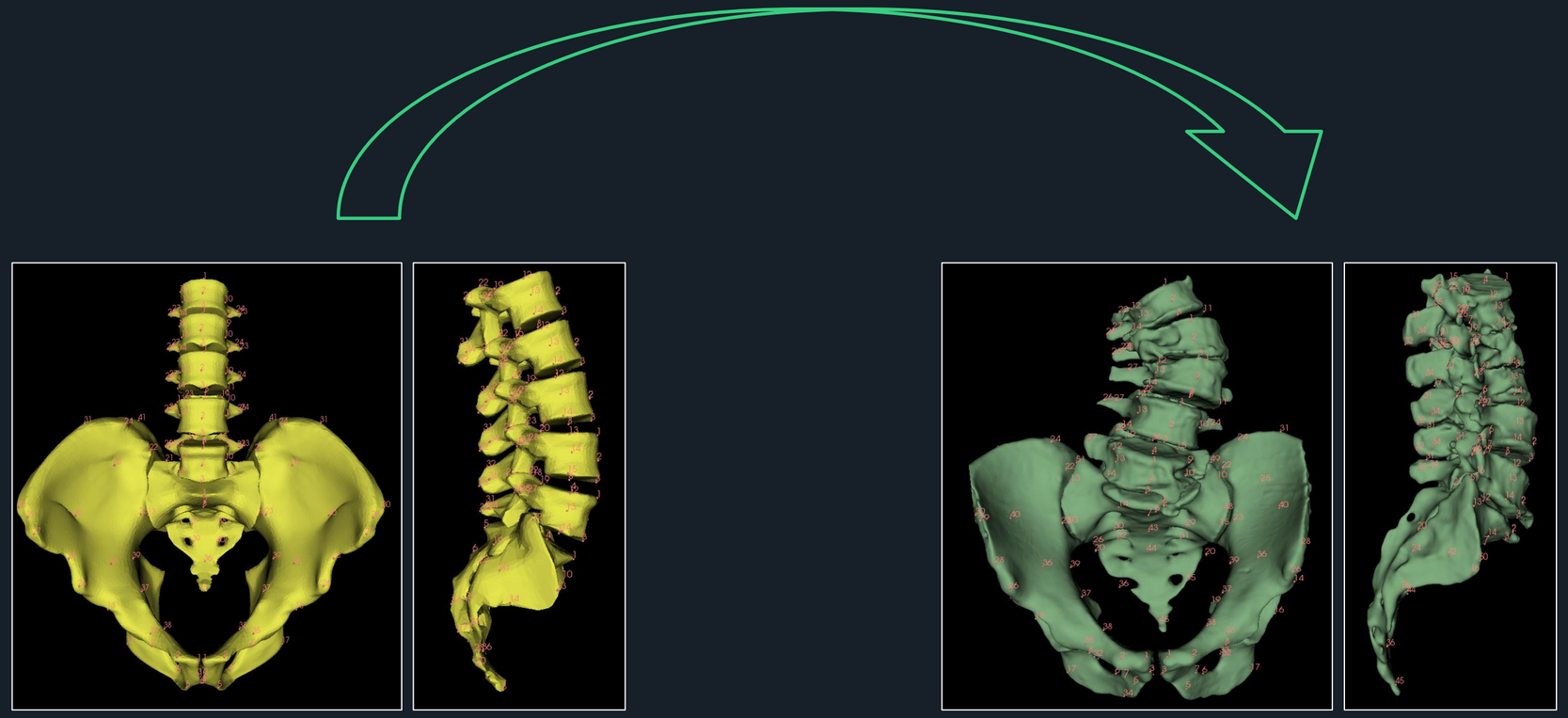


**Segmentation performance:** Dice = 0.965 (std=0.018), Precision = 0.953 (std=0.029) ,Recall = 0.978(std=0.011)

AGADA
THE SPINE ORACLE™

# *Automatic patient-specific spine reconstruction*

Automatic mapping a generic model to the patient-specific segmented model:



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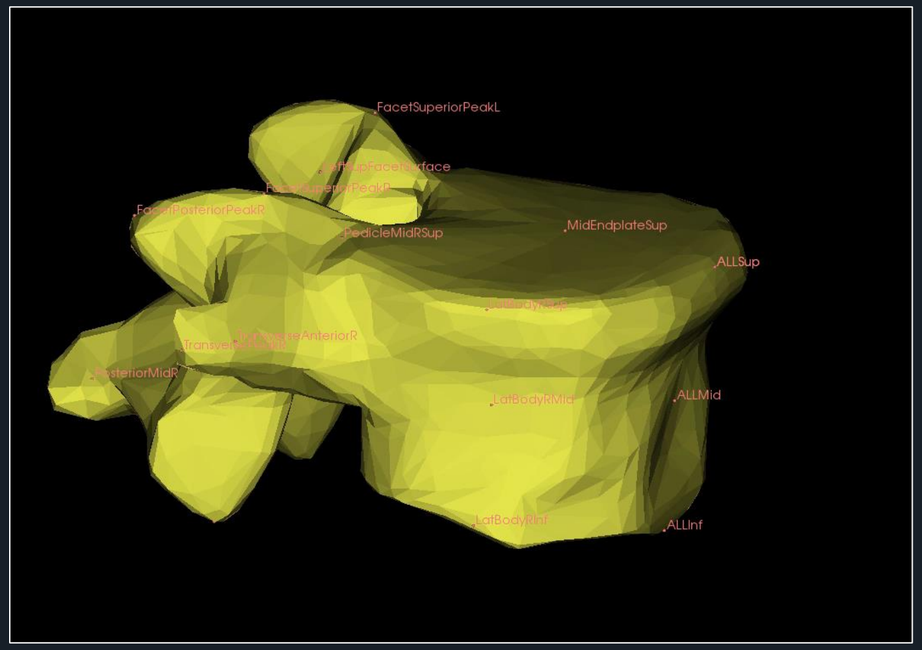
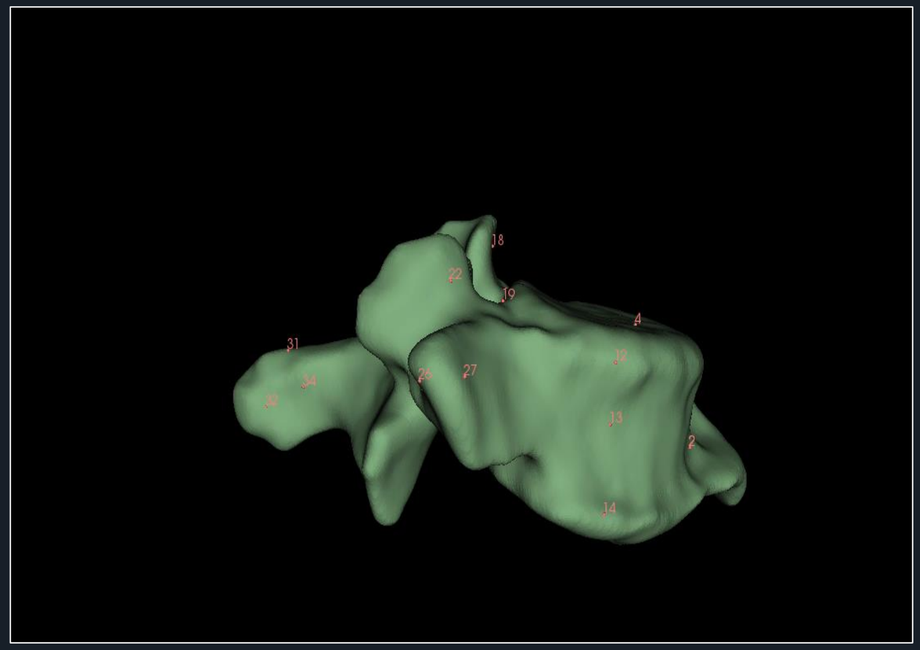
THE SPINE ORACLE™

# *Vertebra mapping*

Automatic Landmarks detection and morphing:

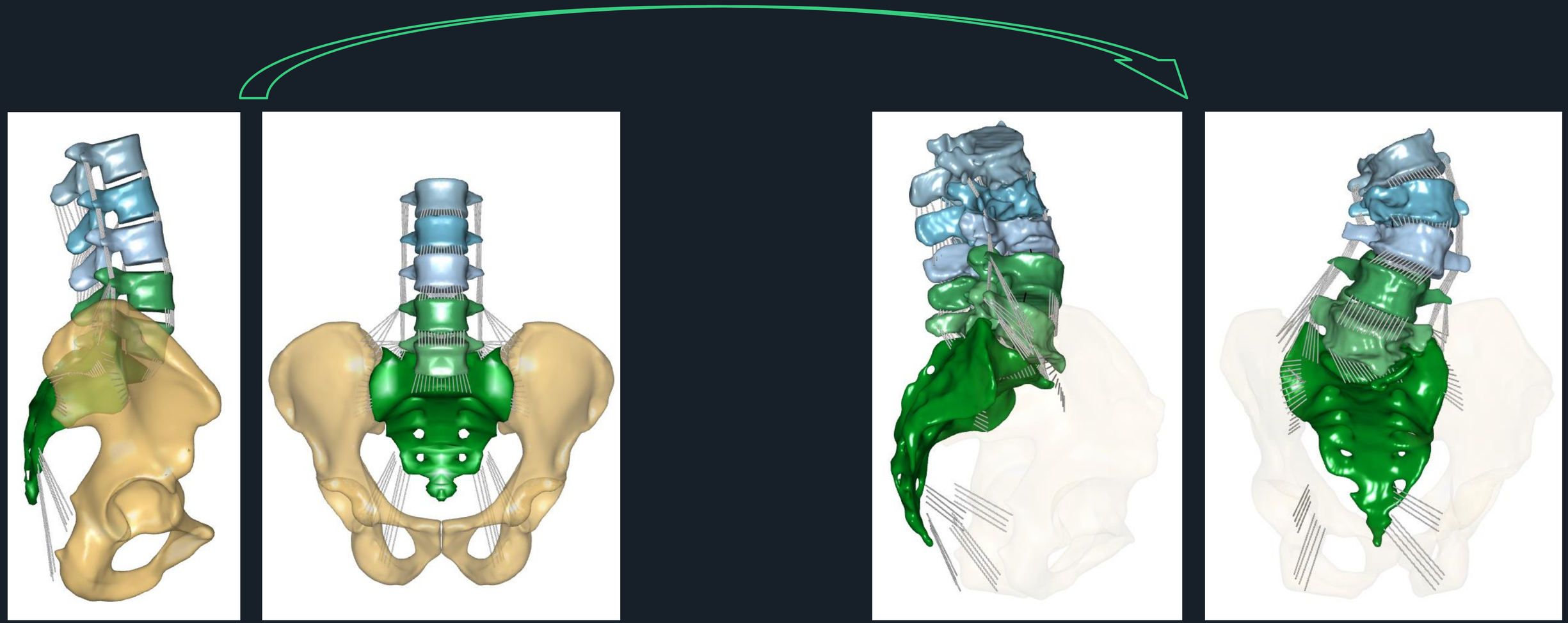



AGADA
THE SPINE ORACLE™

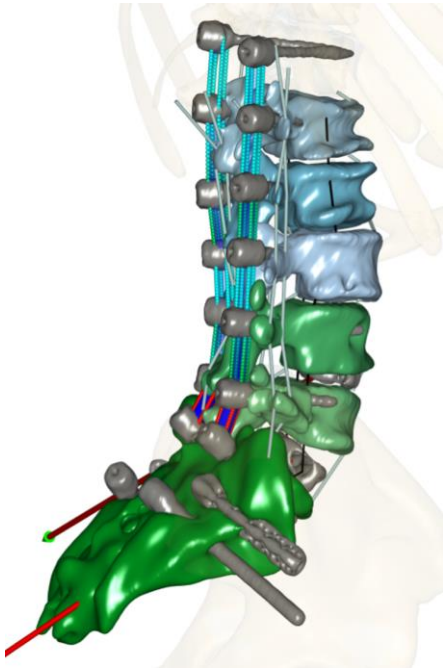
# *Automatic patient-specific spine reconstruction*

Reconstruction of the spine:



AGADA
THE SPINE ORACLE™

ANYBODY TECHNOLOGY



# Simulation module

PATIENT-SPECIFIC MUSCULOSKELETAL TWIN & DYNAMICS ANALYSIS

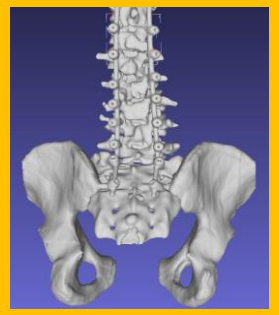
# Background

- AnyBody Technology assists Agada-Medical in developing a musculoskeletal modeling module of the Spine Oracle ™ that creates **a patient-specific musculoskeletal model** and quantifies a surgery-specific state of the patient's spine

- Objectives:
  - **Create a high-fidelity musculoskeletal model accurately representing the patient**
    - Simulate activities of daily living in pre-operative and post-operative states for retrospective studies to enable AI-based solutions
    - Analyze alternative surgical strategies, e.g. different spinal implant placement, soft tissue resection, etc. for pre-operative planning
  - **Establish seamless fully-automated data flow between components of the Spine Oracle ™ and MSM module**

# Patient- and surgery-specific simulation module

**Patient data**
**from the Spine Oracle ™:**
- **Segmentation**
- **Height/Weight**
- **Functional inputs**
- **Pre-op. plan**



**Patient reconstruction:**
- **Geometry**
- **Soft tissue calibration**
- **Spinal implants (if any)**
- **Functional measurements (ongoing)**
- **Motion capture (ongoing)**

**Surgical scenarios:**
- **Preoperative**
- **Post-operative outcome**
- **Alternative surgical strategies**

**Dynamic movement analysis:**
- **Flexion/Extension**
- **Lateral Bending**
- **Axial Rotation**
- **Other movements**

**Report for the Spine Oracle ™**
- **Kinematics of the patient spine**
- **Intradiscal forces and moments**
- **Facet joints contact forces**
- **Loads on the spinal implants**

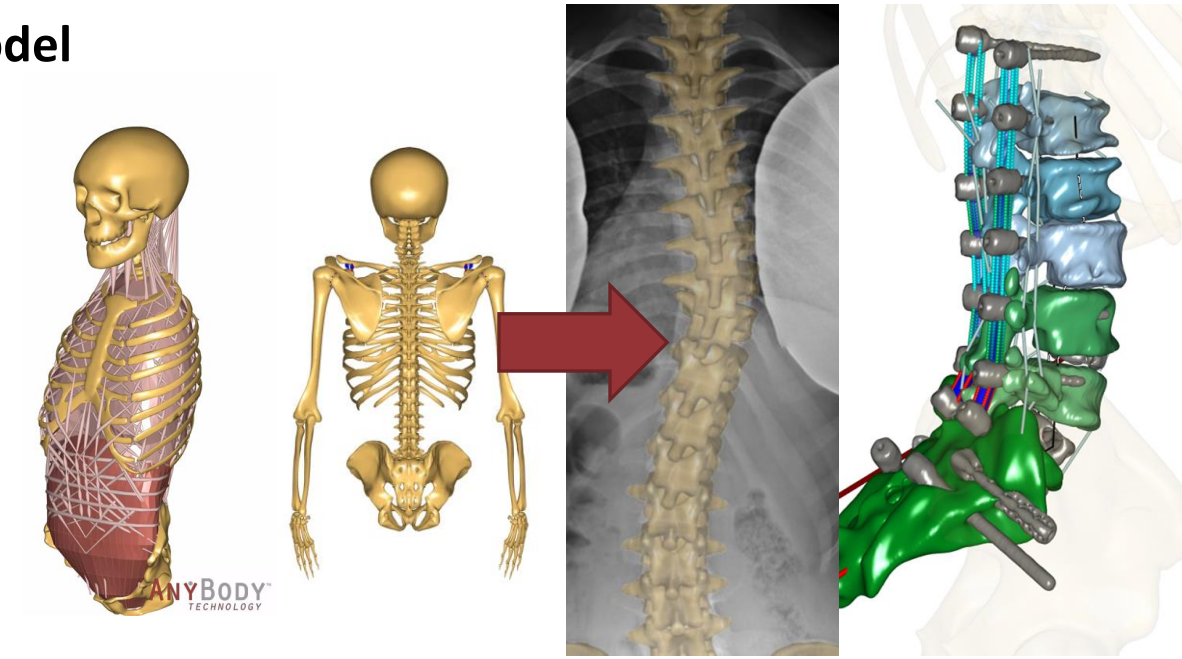
# Patient-specific model

**Objective: Create a high-fidelity musculoskeletal model accurately representing the patient**

Patient reconstruction procedure:

- **Morph generic model into the patient geometry**
- **Construct facet joint contact pairs based on the geometry**
- Calibrate, adjust soft tissues in case-specific configurations
- Add spinal implants from the library according to the retrospective data or surgical plan (if any)
- Apply surgical techniques: facetectomy, ligament resection, etc.

- Functional measurements (ongoing development)
- Motion capture (ongoing development)



**Generic AnyBody model (Incl. ribcage and thoracic column)**

**Patient-specific model reconstructed from patient data**

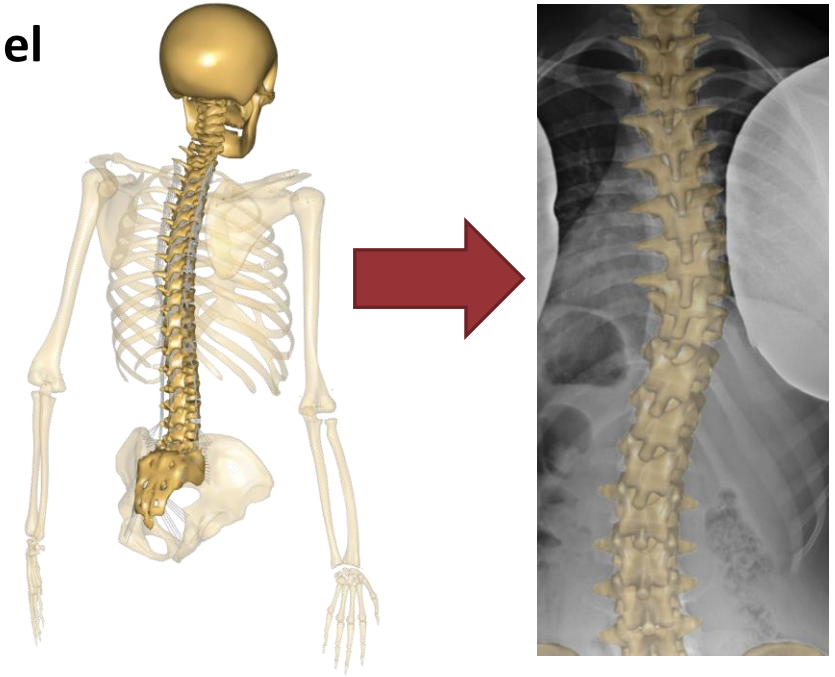
# Intervertebral discs & Ligaments

**Objective: Create a high-fidelity musculoskeletal model accurately representing the patient**

Patient reconstruction procedure:

- Morph generic model into the patient geometry
- Construct facet joint contact pairs based on the geometry
- **Calibrate, adjust soft tissues in case-specific configurations**
- Add spinal implants from the library according to the retrospective data or surgical plan (if any)
- Apply surgical techniques: facetectomy, ligament resection, etc.

- Functional measurements (ongoing development)
- Motion capture (ongoing development)



**Generic AnyBody model (Incl. ribcage and thoracic column)**

**Patient-specific model reconstructed from patient data**

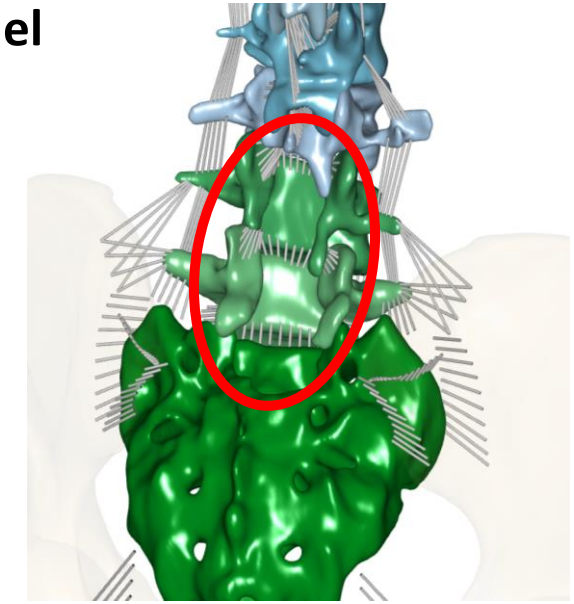
# Surgery-specific model elements

**Objective: Create a high-fidelity musculoskeletal model accurately representing the patient**

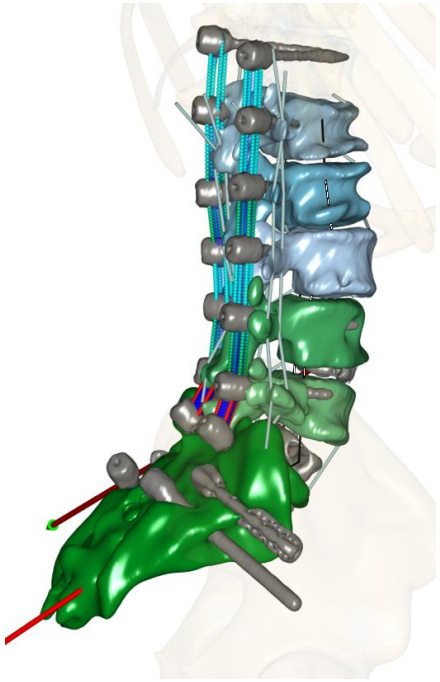
Patient reconstruction procedure:

- Morph generic model into the patient geometry
- Construct facet joint contact pairs based on the geometry
- Calibrate, adjust soft tissues in case-specific configurations
- **Add spinal implants from the library according to the retrospective data or surgical plan (if any)**
- **Apply surgical techniques: facetectomy, ligament resection, etc.**

- Functional measurements (ongoing development)
- Motion capture (ongoing development)



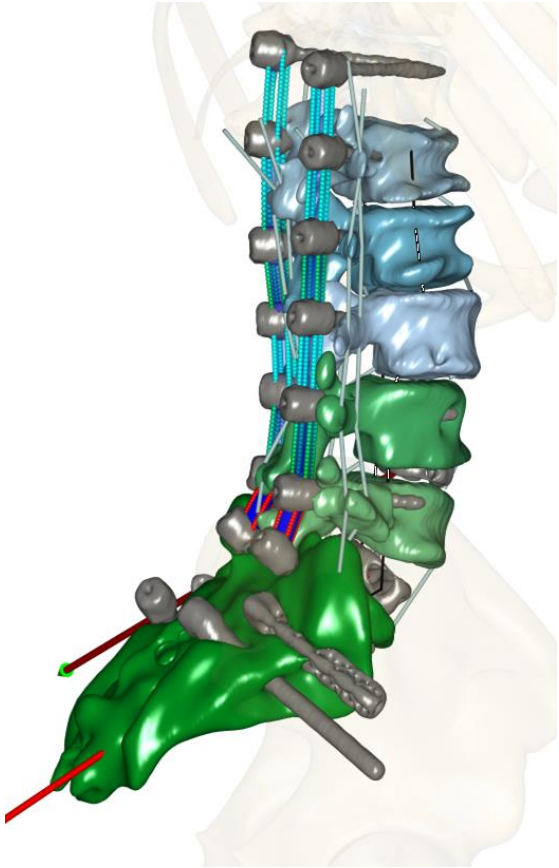
**Facetectomy in a patient-specific model**



**A system of rods, screws, and cages**

# Library of spinal implants

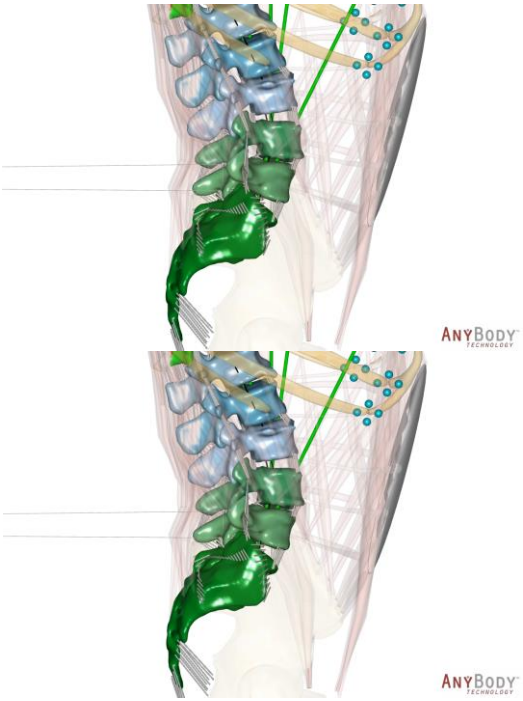
- Commonly used in the industry spinal implants:
  - Rods
  - Cages
  - Intervertebral disc replacements
- Implemented for known geometric dimensions and mechanical properties
- Producer-specific and custom implants (ongoing development)



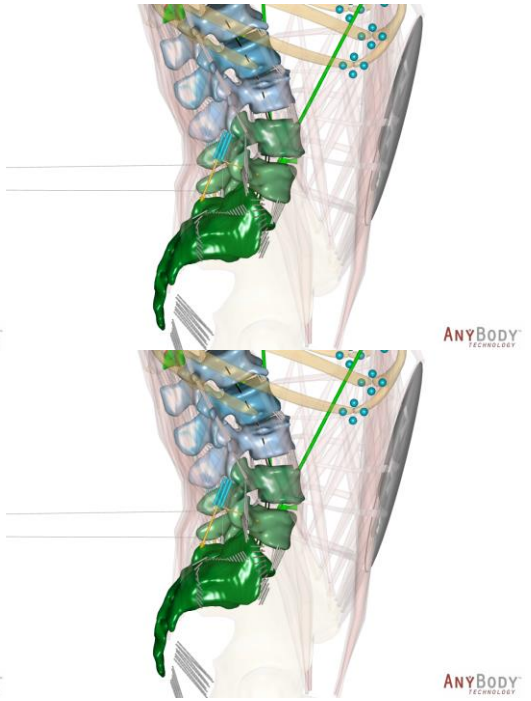
# Simulation

- Analysis strategies
  - Understand biomechanics of primary movements
    - Flexion-Extension
    - Lateral bending
    - Axial rotations
  - Variate loads to assess response of passive structures
    - A torque applied at the cranial end in different planes
    - Follower loads

PreOp

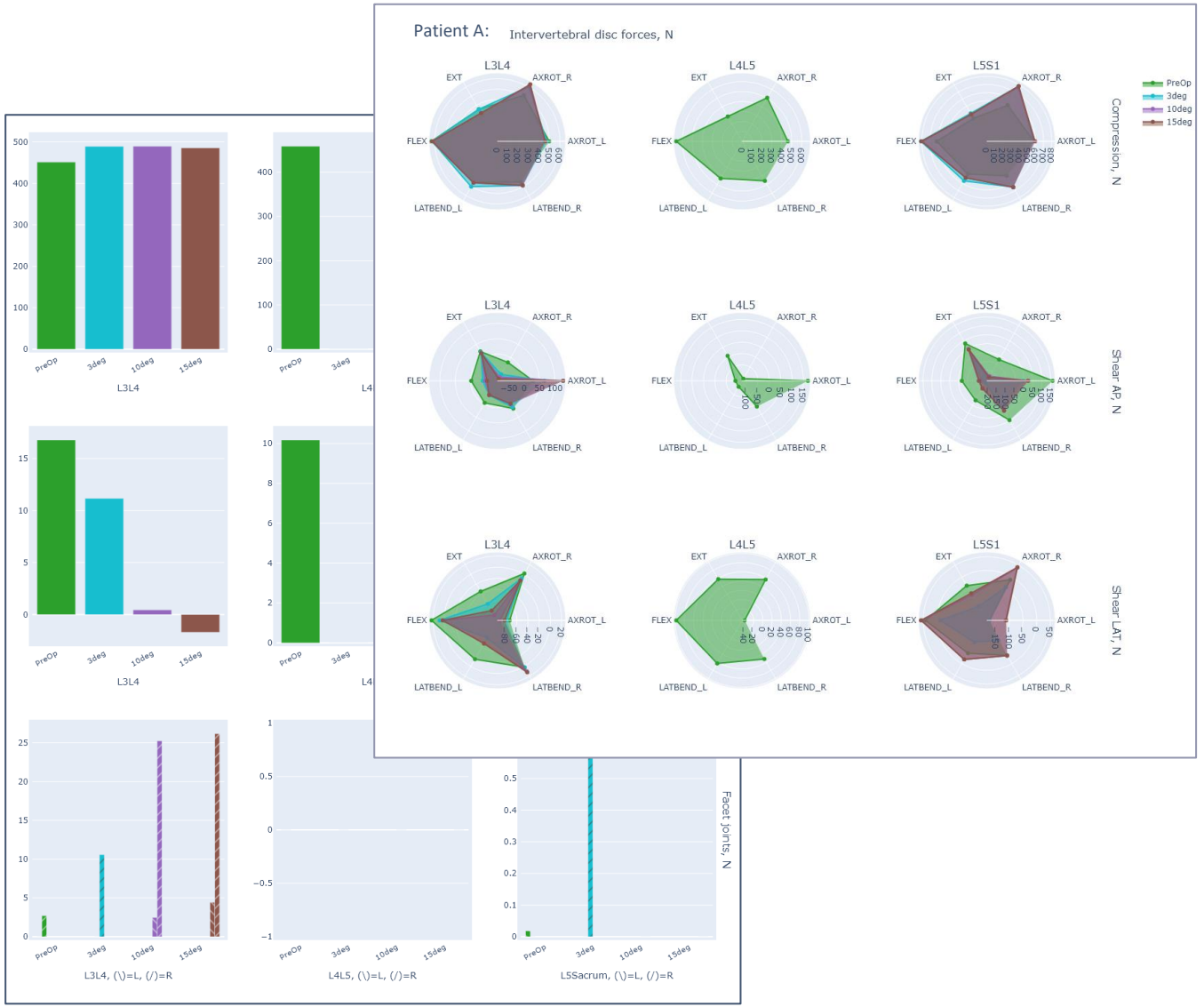


PostOp



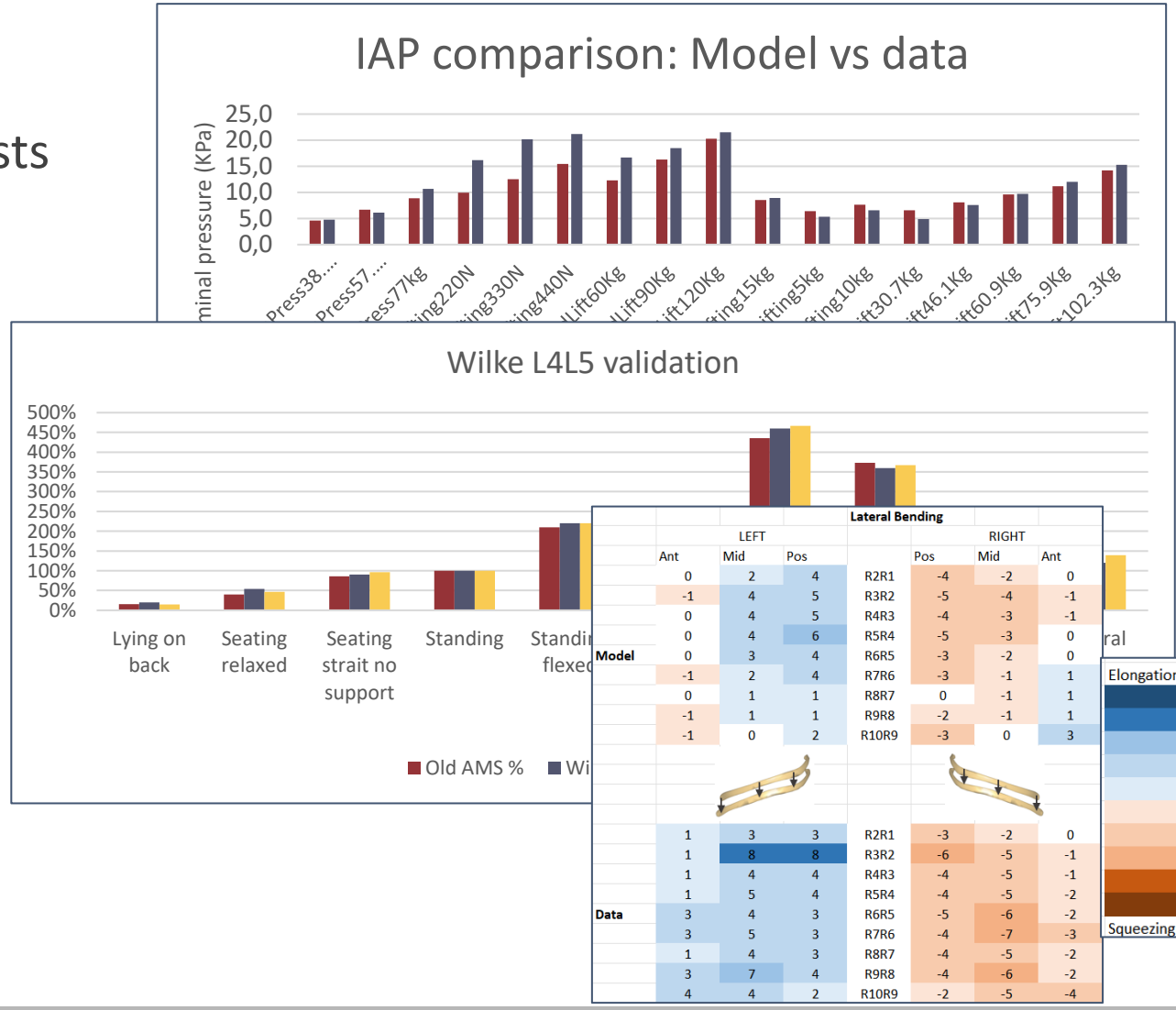
# Output example

- Patient-specific forces
  - Intradiscal forces
  - Facet joint contacts and forces
  - Ligament strain, forces
  - Kinematics
- Spinal implant loads
  - Rod stresses
  - Interface force, i.e. screw pull-out forces
  - Compressive, shear forces
  - Etc.
- Graphical output
  - Video of movement in different planes
  - Screenshots and more



# Validation &Verification

- AMMR is a continuously tested software product using a variety of benchmark tests
- Simulation module development is focused on allowing for:
  - verification & validation
  - uncertainty quantification
  - retrospective analyses

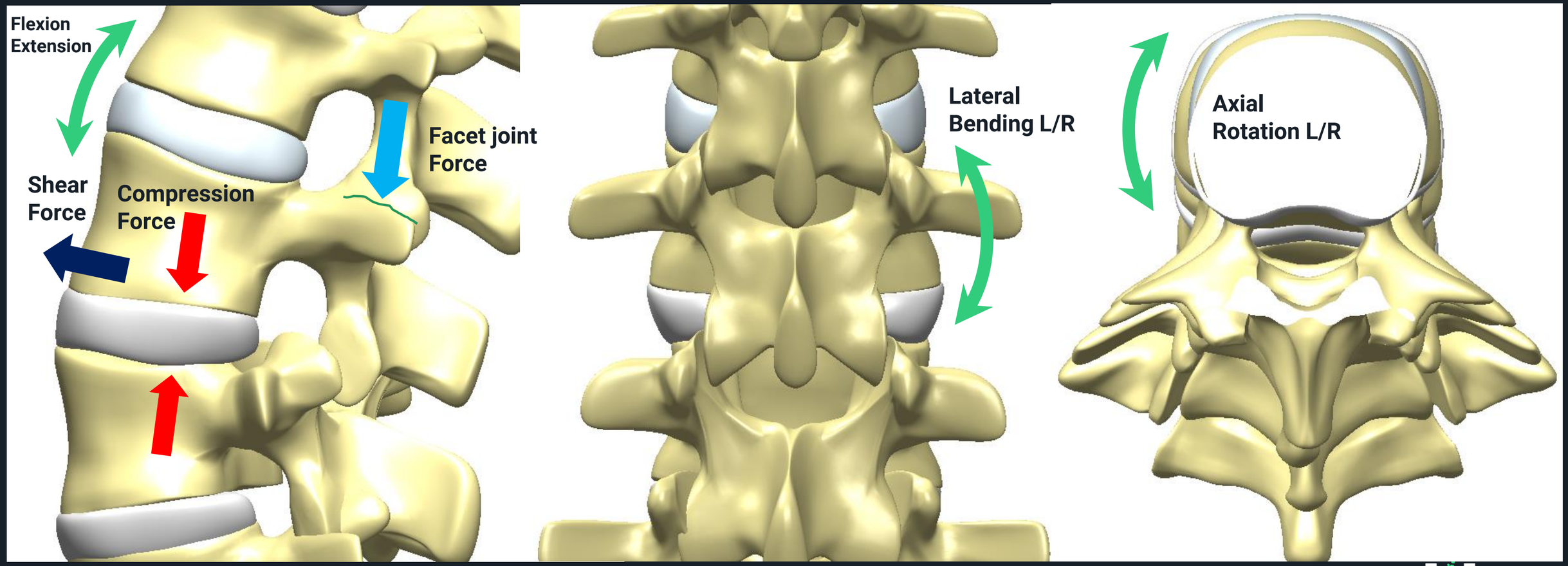


AGADA

# The Spine Oracle™ Validation Methods

# *The Spine Oracle™ Validation Methods*

1. Kinematic validation - ABT simulations compare to gait lab and Standing/flexion-extension X-Ray results
2. Force analysis validation planed to perform on cadaver study

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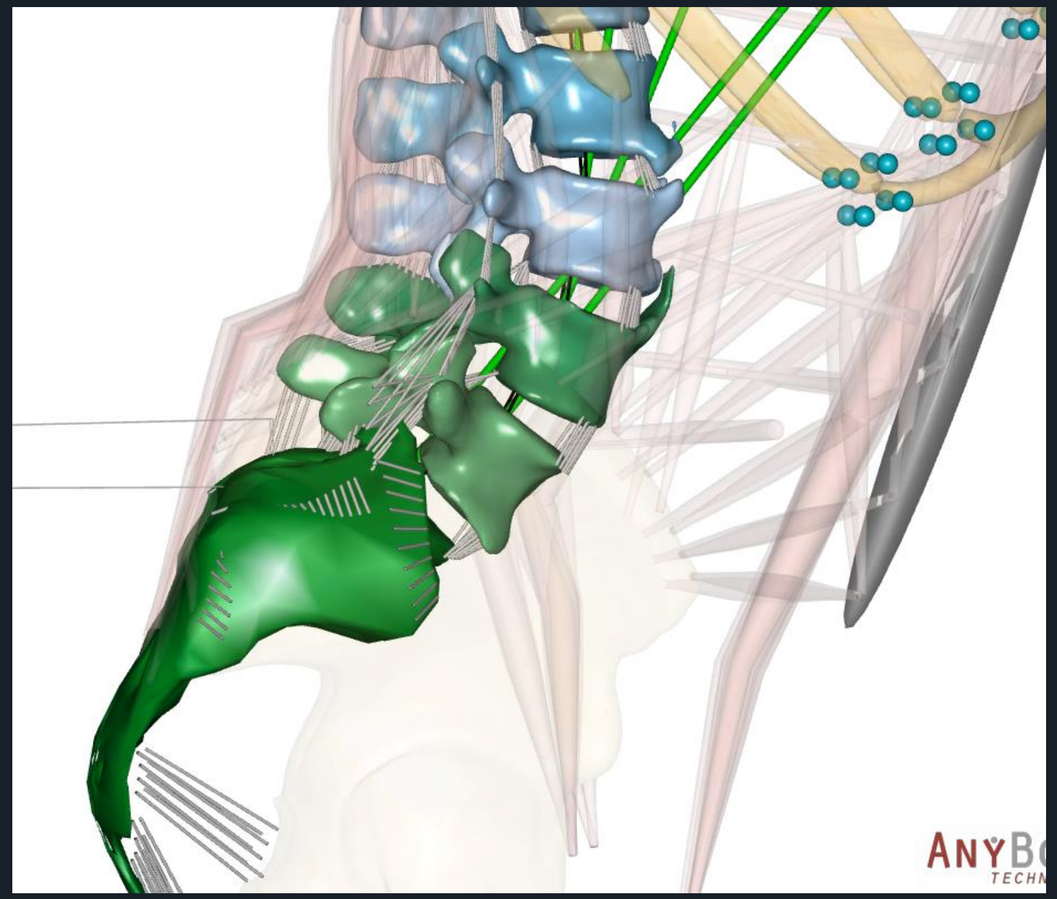
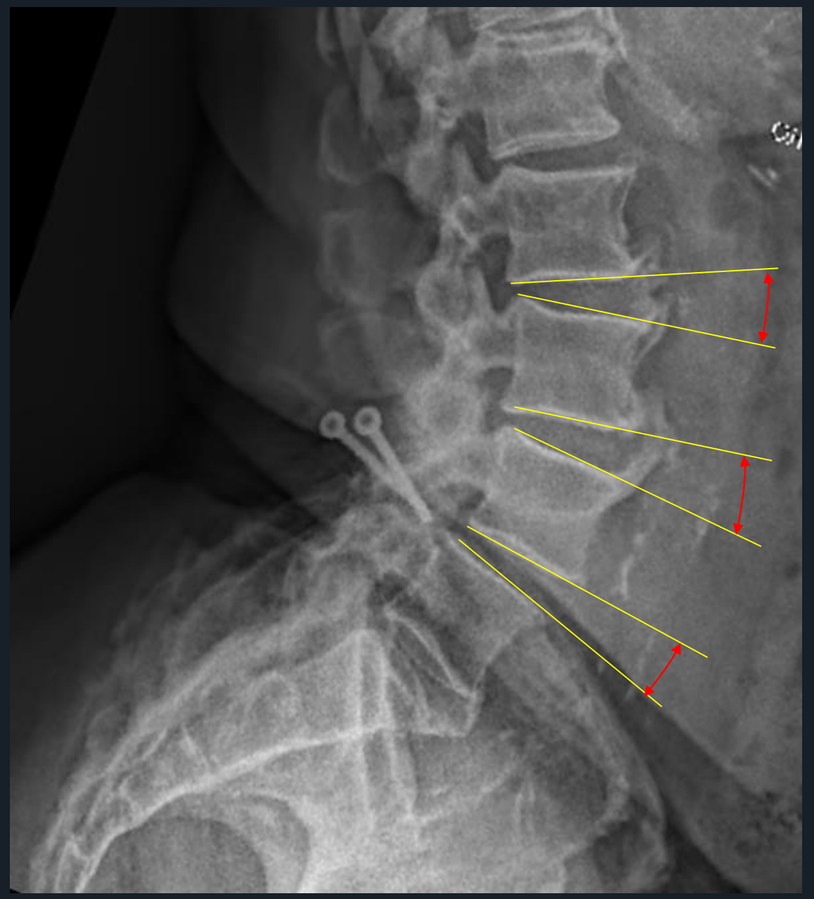
THE SPINE ORACLE™

# *The Spine Oracle™ Validation Methods*

Kinematic validation - ABT simulations compare to gait lab and Standing/flexion-extension X-Ray results





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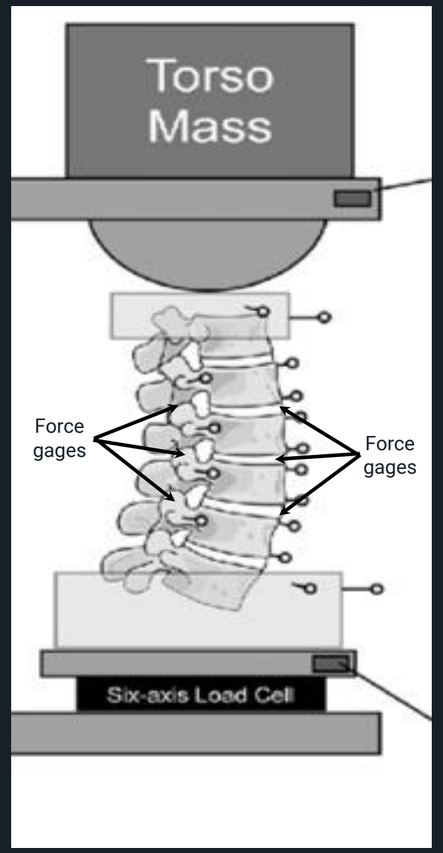
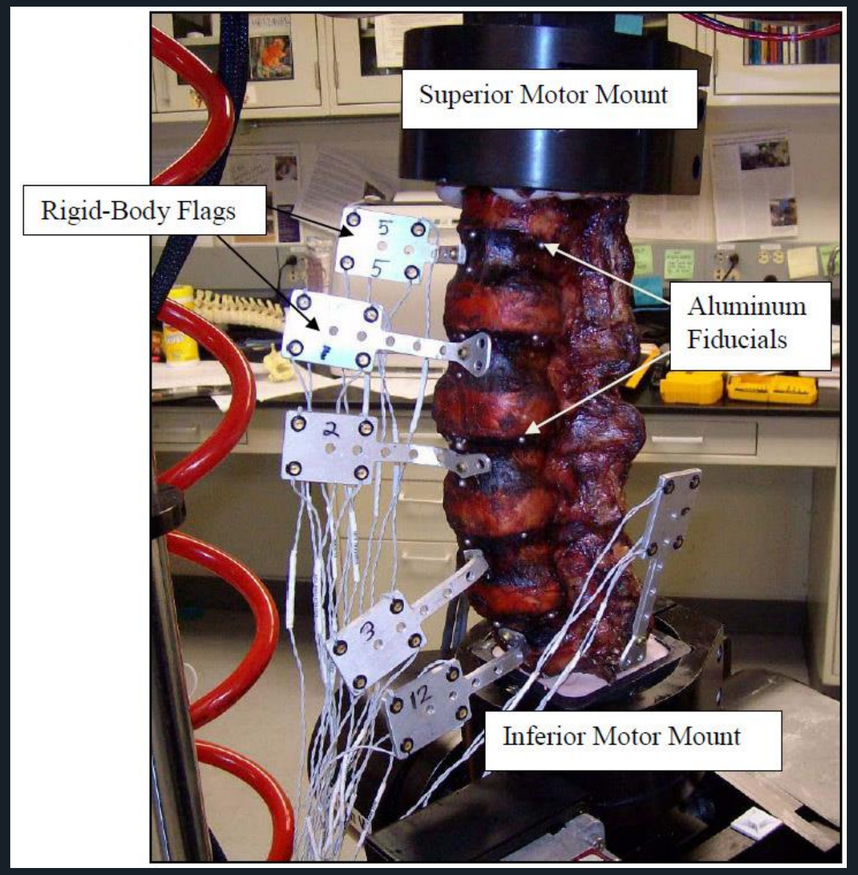
THE SPINE ORACLE™

# *The Spine Oracle™ Validation Methods*

Challenge: In-Vivo spine forces measurements is problematic.
Force analysis validation planed to perform cadaver study in one of the Biomechanics labs
Mainly use of *Spine Oracle™* is to compare between surgery planning configurations, the Absolut values and accuracy in the first phase need to be define.




Example for Test setup from University of Pittsburgh

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- +900 Publications
  - Filter by:
    - Industry
    - Research area
    - Body part
- +100 Webcasts
  - Filter by
    - Industry

## Publication list

Industry

sports | exoskeleton | work place ergonomics | orthopedics | defense | aerospace | automotive | consumer products | furniture

Research area

gait | methods | validation | animal | sensitivity analysis | rehab | seating | fea | occupational health

Body part

knee | lower extremity | foot | spine | upper extremity | hand | shoulder | hip | mandible | wrist | trunk | elbow | ankle | leg

NEW

Year 957 Publications

| | | |
|---|---|---|
| 2023 | Li H, Peng F, Lyu S, Ji Z, Li Y, (2023), **"Study on Two Typical Progressive Motions in Tai Chi (Bafa Wubu) Promoting Lower Extremity Exercise"**. vol. 20, pp. 2264. [ DOI, WWW ] | NEW sports lower extremity |
| 2023 | Zhu Y, Li H, Lyu S, Shan X, Jan YK, Ma F, (2023), **"Stair-climbing wheelchair proven to maintain user's body stability based on AnyBody musculoskeletal model and finite element analysis"**. vol. 18, pp. e0279478. [ DOI, WWW ] | NEW consumer products lower extremity fea |
| 2023 | Madinei S, Nussbaum MA, (2023), **"Estimating Lumbar Spine Loading When Using Back-Support Exoskeletons in Lifting Tasks"**. pp. 111439. [ DOI, WWW ] | NEW exoskeleton spine |
| 2023 | Bayoglu R, Witt JP, Chatain GP, Okonkwo DO, Ignasiak D, (2023), **"Clinical Validation of a Novel Musculoskeletal Modeling Framework to Predict Postoperative Sagittal Alignment"**. vol. Publish Ahead of Print, [ DOI, WWW ] | NEW orthopedics spine validation |
| 2023 | Scherb D, Wartzack S, Miehling J, (2023), **"Modelling the interaction between wearable assistive devices and digital human models—A systematic review"**. vol. 10, [ DOI, WWW ] | NEW exoskeleton |
| 2023 | Telfer S, (2023), **"Chapter 24 - Musculoskeletal Modeling of the Foot and Ankle"**. Book Chapter, In: Ledoux WR, Telfer S, (Ed), Foot and Ankle Biomechanics, pp. 387-396. [ DOI, WWW ] | NEW ankle foot |
| 2022 | Harada T, Hamai S, Okazawa K, Fujita T, Hara D, Kozono N, Kawahara S, Yamaguchi R, Fujii M, Ikemura S, Motomura G, Nakashima Y, (2022), **"Reverse dynamics analysis of contact force and muscle activities during the golf swing after total hip arthroplasty"**. [ DOI, WWW ] | NEW orthopedics sports hip |
| 2022 | Ignasiak D, Behm P, Mannion AF, Galbusera F, Kleinstück F, Fekete TF, Haschtmann D, Jeszenszky D, Zimmermann L, Richner-Wunderlin S, Vila-Casademunt A, Pellisé F, Obeid I, Pizones J, Sánchez Pérez-Grueso FJ, Karaman MI, Alanay A, Yilgor Ç, Ferguson SJ, Loibl M, ESSG European Spine Study Group, (2022), **"Association between sagittal alignment and loads at the adjacent segment in the fused spine: a combined clinical and musculoskeletal modeling study of 205 patients with adult spinal deformity"**. [ DOI, WWW ] | NEW orthopedics spine |
| 2022 | Li J, Zhu Y, Guan T, (2022), **"Numerical Simulation Method of Scoliosis Orthosis Considering Muscle Factor"**. [ DOI ] | NEW spine fea methods |
| 2022 | De Pieri E, Cip J, Brunner R, Weidensteiner C, Alexander N, (2022), **"The functional role of hip muscles during gait in patients with increased femoral anteversion"**. [ DOI, WWW ] | NEW orthopedics hip lower extremity gait |
| 2022 | Zhang W, Wang Q, Xu Z, Shang Y, Xu H, (2022), **"Development of a tractor operator-operation environment coupled biomechanical model and analysis of lower limb muscle fatigue"**. vol. 93, pp. 103407. [ DOI, WWW ] | NEW automotive lower extremity |
| 2022 | Miura T, Hongo M, Kasukawa Y, Kijima H, Kudo D, Saito K, Kimura R, Iwami T, Miyakoshi N, (2022), **"Relationship between Intervertebral Disc Compression Force and Sagittal Spinopelvic Lower Limb Alignment in Elderly Women in Standing Position with Patient-Specific Whole Body Musculoskeletal Model"**. vol. 19, [ DOI, WWW ] | NEW orthopedics spine |
| 2022 | Musso M, Oliveira AS, Bai S, (2022), **"Modeling of a Non-Rigid Passive Exoskeleton-Mathematical Description and Musculoskeletal Simulations"**. [ DOI, WWW ] | NEW exoskeleton upper extremity |

https://www.anybodytech.com/resources/anybodypublications

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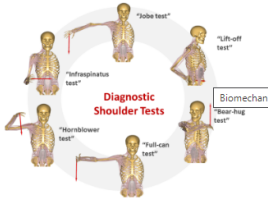
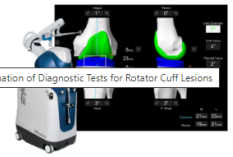



29. November 2022

Biomechanical Evaluation of Diagnostic Tests for Rotator Cuff Lesions

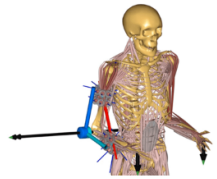
Johanna Menze, PhD Candidate, University of Bern




27. October 2022

The future of personalized orthopedics: Kinematic modeling to restore the premorbid knee functionality through robotic-assisted TKA

Daniele De Massari, Data Science Manager, Stryker & Periklis Tzanetis, PhD Candidate, University of Twente



27. September 2022

An introduction to exoskeleton design using musculoskeletal modeling

Divyaksh S. Chander, Ph.D, Biomechanical Specialist, AnyBody Technology

ANYBODY™ VERSION 7.4

8. June 2022

What's New In The AnyBody Modeling System 7.4

Morten Enemark Lund, Sr. R&D Engineer, AnyBody Technology

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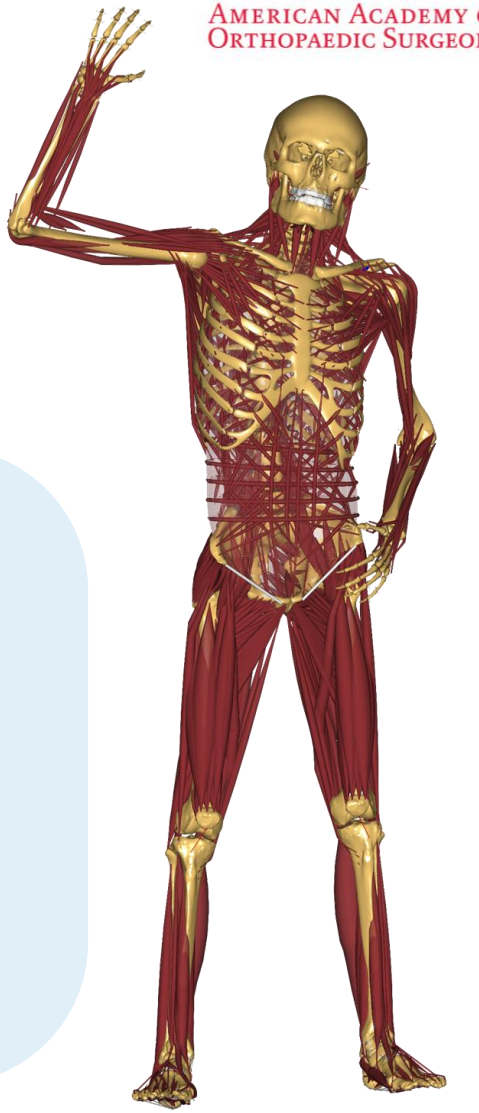
- Be sure to visit us in the Exhibit Hall at the AAOS Annual Meeting
  - Booth 4857
  - March 8 – 10, 2023

Exhibiting at: AAOS American Academy of Orthopaedic Surgeons | 2023 Annual Meeting
March 7 – 11, Las Vegas, Nevada



**Get in contact?**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