# OSSTF-Target 3

## Junctional failure prevention

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# Adjacent level failure

01

**Proximal junctional kyphosis (PJK)**

Is characterized by increased kyphosis at the upper instrumented vertebra segment

(Glatter Spine 2005)

02

**Proximal junctional failure (PJF)**

Is the next step that usually requires surgery

# Proximal junctional kyphosis

- Radiographic finding with >10º increase of vertebral body kyphosis
- Short-term complication of adult spinal deformity (ASD) surgery
- Not always symptomatic and does not always require additional surgery

# Proximal junctional failure

- Clinical presentation with pain, deterioration of balance, and neurological impairment
- Short- to mid-term complication after ASD surgery
- More surgery frequently necessary

# Risk factors

| | | | | |
|---|---|---|---|---|
| Fixation length | Sagittal alignment | Poor bone health | High BMI | Age |

# Fixation length

Proximal junctional kyphosis and proximal junctional failure are common problems after long-segment (>5 levels) thoracolumbar instrumented fusions in the treatment of ASD.

# Sagittal alignment

Multifactorial issue, but

Flatback with decrease of **pelvic incidence minus lumbar lordosis (PI-LL) and pelvic tilt (PT)**

→ significantly higher risk of PJK

Flatback with increase of **thoracic kyphosis (TK)**

→ significantly higher risk of PJK

# Preventing PJK and PJF

Evaluation of stresses in the upper adjacent levels by preoperative finite element analysis of the future instrumentation

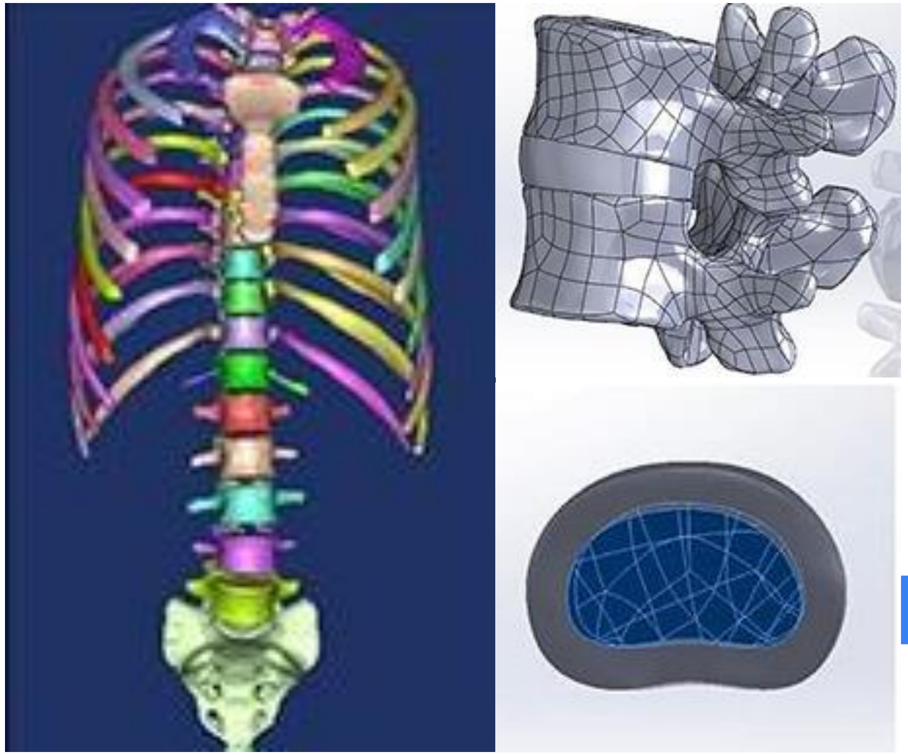
**Initial set-up and experience by**

**Osmar JS de Moraes (Sao Paulo)**

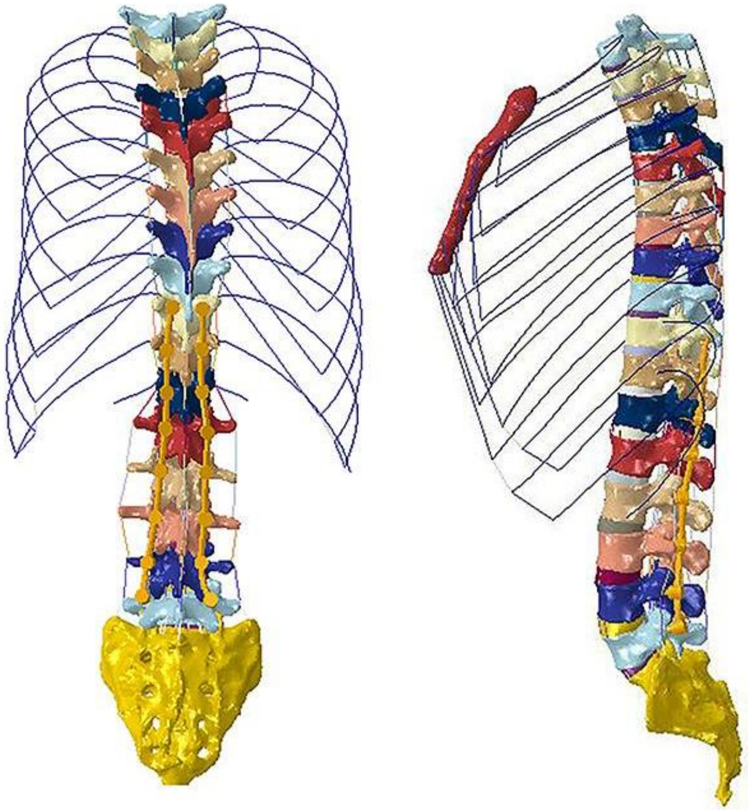
# Construction of geometric models

- Computed tomography images imported into Mimics software (Materialise, Belgium)
- Vertebral bodies segmented according to the different gray-scale values of the vertebral bone and surrounding tissue
- 3D reconstruction using 2D imaging data of the segmented vertebral bodies to produce T1-S1 3D geometric models

# Reconstructed Model of T1-S1



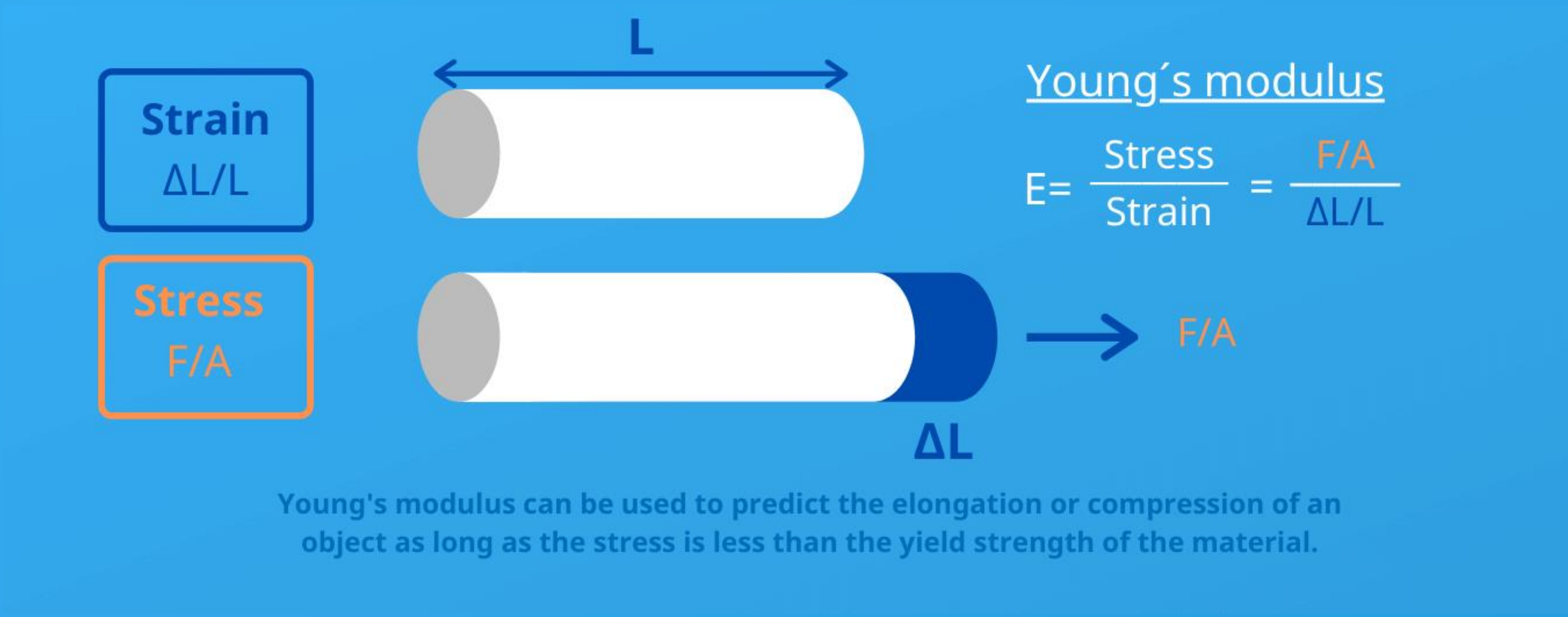
+ Ribcage, ligaments, and discs

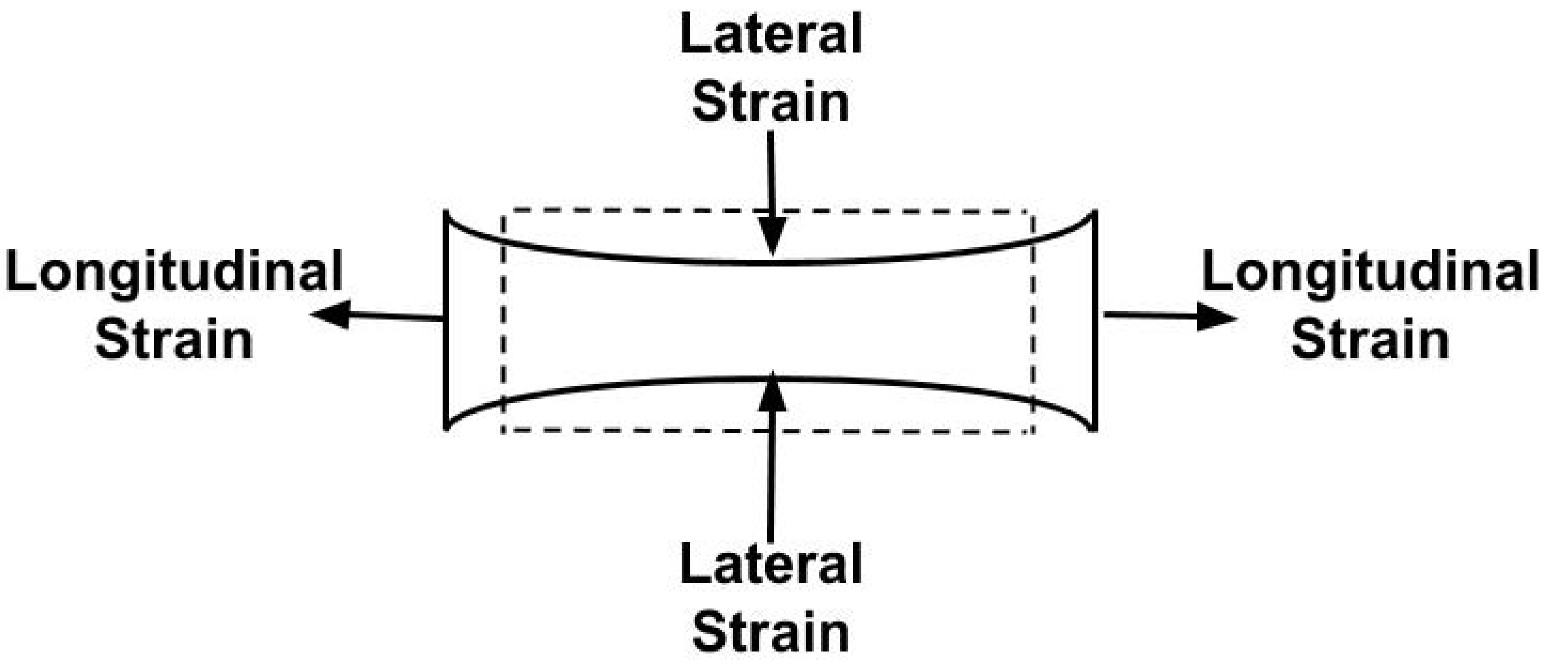


# Material properties used in the model

| Component | Young's modulus, MPa | Poisson's ratio | Cross-section, mm$^2$ |
|---|---|---|---|
| Cortical bone | 12,000 | 0.3 | |
| Cancellous bone | 100 | 0.2 | |
| End plate | 3,000 | 0.25 | |
| Anterior longitudinal | 15 | | 40 |
| Posterior longitudinal | 10 | | 20 |
| Ligamentum flavum | 8 | | 30 |
| Interspinous | 10 | | 40 |
| Ligamentum flavum | 15 | | 40 |
| Intertransverse | 10 | | 1.8 |
| Capsular | 7.5 | | 30 |
| Nucleus pulposus | 1.0 | 0.499 | |
| Annulus fiber | 4.2 | 0.45 | |
| Fusion mass (Ti) | 110,000 | 0.28 | |

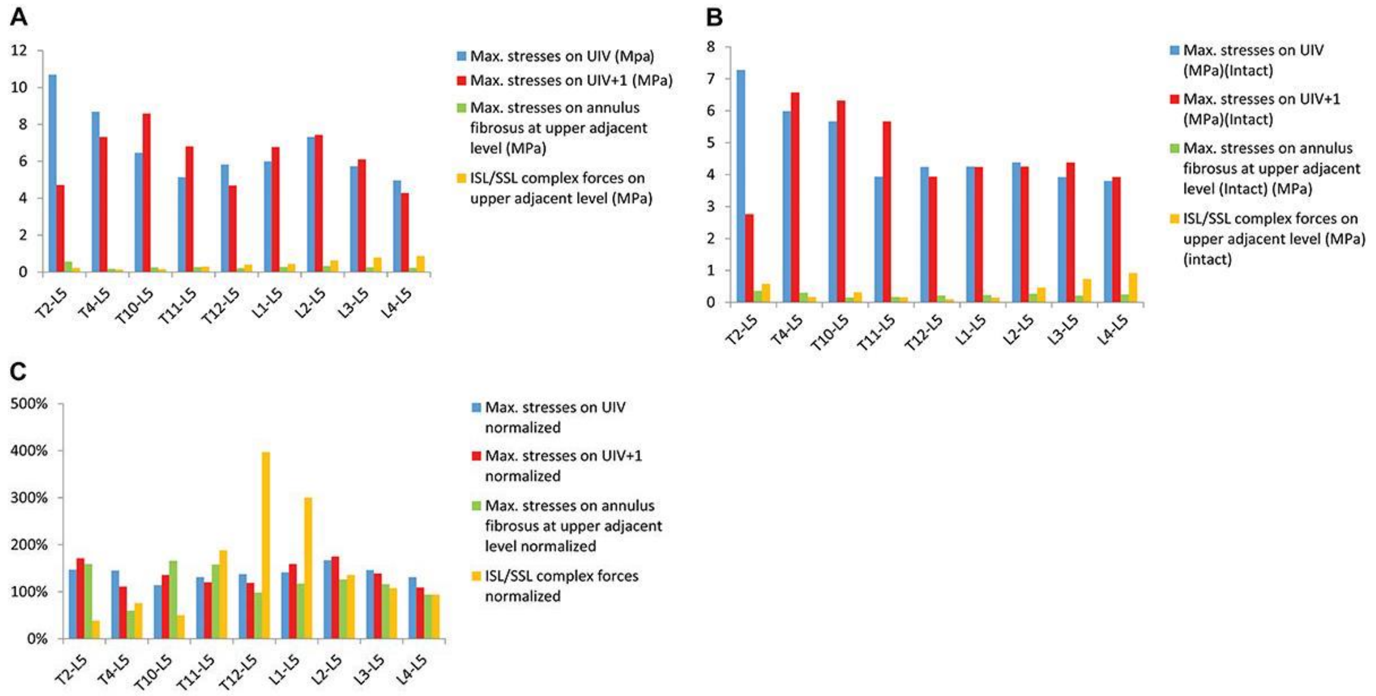
# Young’s modulus

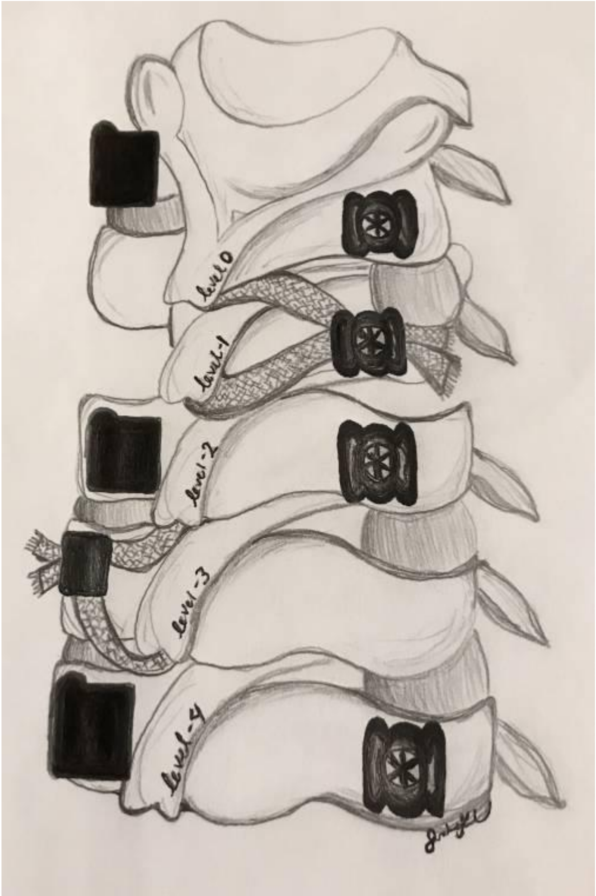





$$\text{Poisson's Ratio} = \frac{\text{Lateral Strain}}{\text{Longitudinal Strain}}$$

# Stresses at upper end of different constructs




Example of top ending of construct

# Selection of nine fusion models and comparison of the maximum von Mises stresses on the pedicle screw

| Fusion model | Max. screw stress, MPa |
|---|---|
| T2-L5 fusion | 106.50 |
| T4-L5 fusion | 48.14 |
| T10-L5 fusion | 45.50 |
| T11-L5 fusion | 44.68 |
| T12-L5 fusion | 42.66 |
| L1-L5 fusion | 49.97 |
| L2-L5 fusion | 48.71 |
| L3-L5 fusion | 47.59 |

# Opportunities using construction of geometric models

New materials for reinforcement

Expandable screws

**Local measure of pressure/axial load using cheap chips**

**Mechanical models suitable for clinical practice**

# Next steps

Proposal by Osmar de Moraes

Feasible technique, not expensive and reproducible in ASD surgery group

- Build a tool to prevent PJF?
  Customized? Algorithm planning?
  Better construction/screws/anterior support size?

# Surgical strategy

No specific surgical strategy has definitively shown to lower the risk of PJF as the result of a multifactorial etiology.

Different technical options:

- Rod stiffness
- Prophylactic polymethylmethacrylate (PMMA) augmentation
- Bands, tethers, and ligaments
- Soft-landing solutions

# Rod stiffness

The use of CoCr rods is effective in ensuring stability of the posterior spinal construct and accomplishment of spinal fusion. Furthermore, **results indicate that junctional kyphosis may occur more frequently in CoCr systems than in Ti systems.**

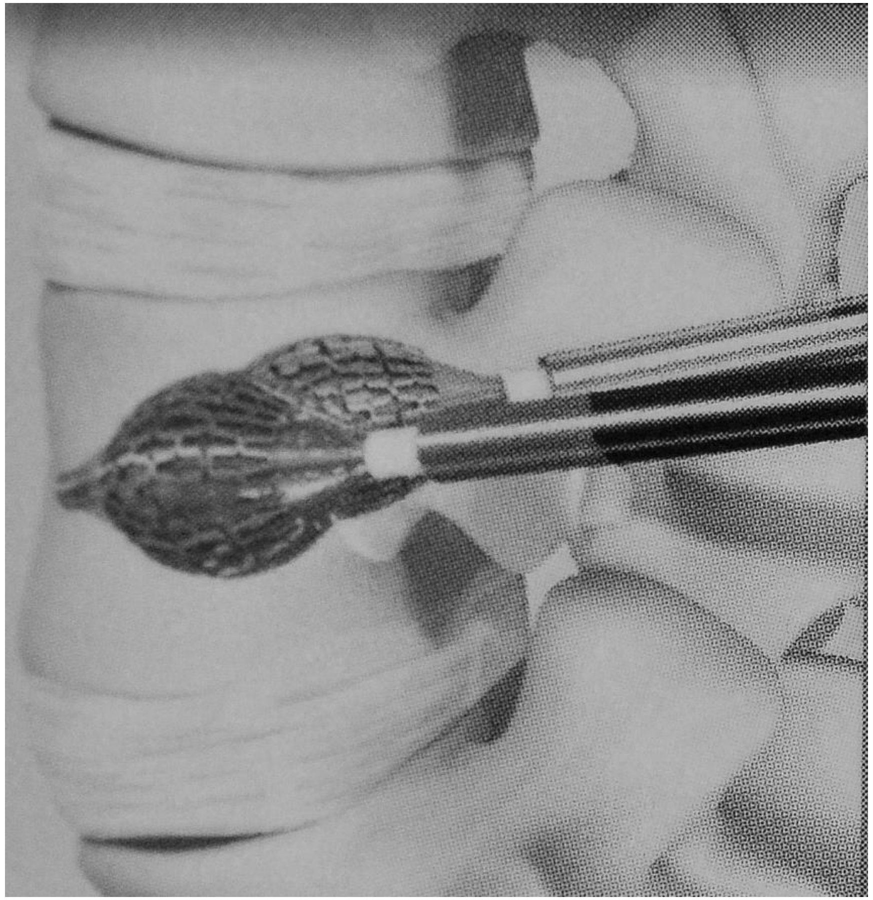
Increasing the rod stiffness by using CoCr rods can prevent **rod breakage** but adversely **affect the occurrence and the time of PJK.**

# Prophylactic PMMA cement augmentation

- Aim is to decrease the incidence of PJK and PJF in patients treated with prophylactic PMMA cement augmentation at the uppermost instrumented vertebrae (UIV) and rostral adjacent vertebrae (UIV+1)
- Is one of the most popular solutions today
- Needs cannulated and perforated screws
- Drawback—PMMA leaks

# Upper level PMMA supplementation

- Stent
- Vertebroplasty
- Kyphoplasty



# Bands tethers ligaments

Sublaminar band placement has been suggested as a possible technique to prevent PJK and PJF but carries the theoretical possibility of a paradoxical increase in these complications as a result of the required muscle dissection and posterior ligamentous disruption.

# Soft-landing solutions

**Aim**

Avoid excessive stress at the instrumentation level upper part of the construct and at the non-instrumented upper levels

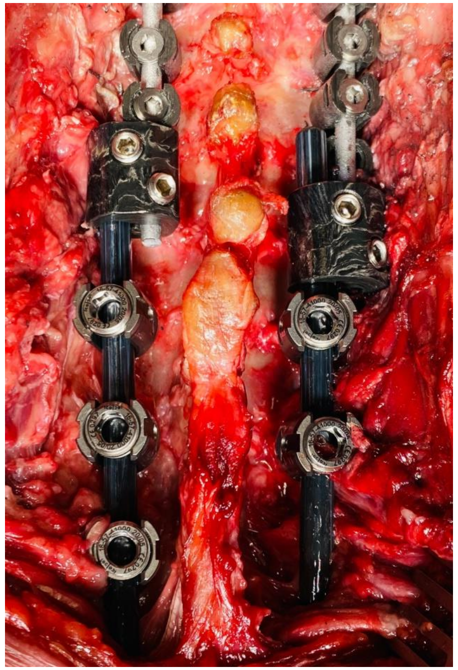
**Solutions**

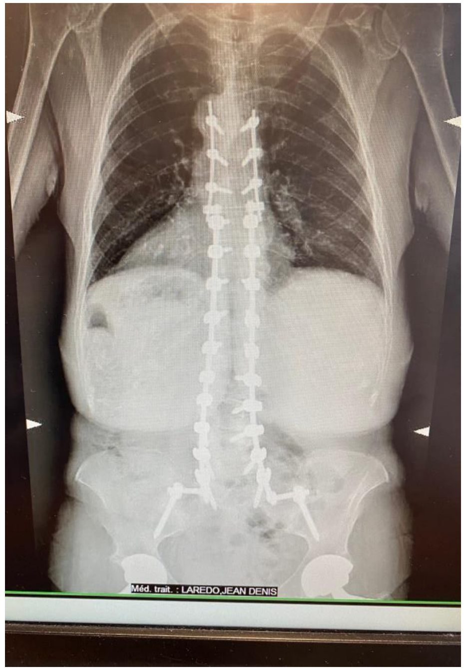
- Less rigid rods
- Change of rod diameter at upper part of instrumentation
- Flexible device at upper part of instrumentation

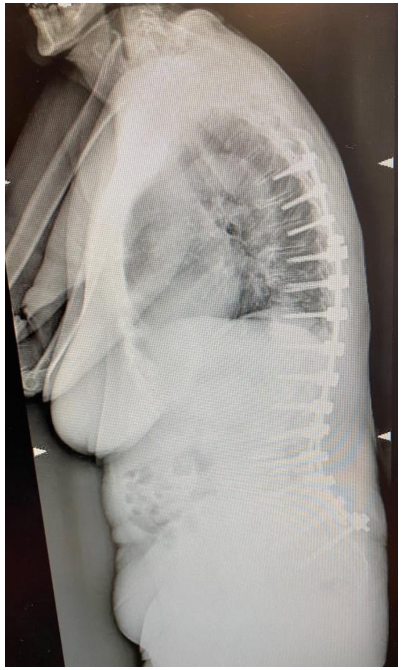
# Two different diameter rods at the upper level

**Option 1:**

3.5 mm diameter proximal Ti rod instrumentation and 5.5 mm thoraco lumbar rod instrumentation connected with dominos end-to-end or lateral/lateral



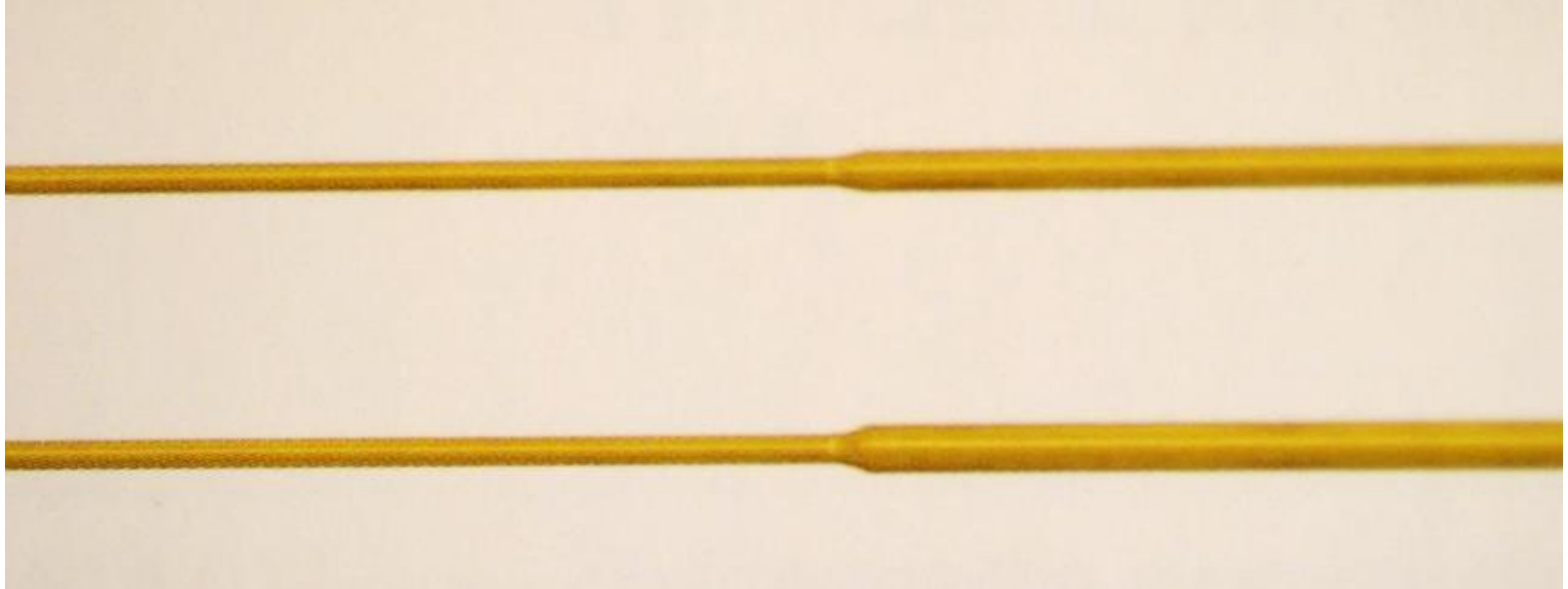


# Two different diameter rods at the upper level

**Option 2:**

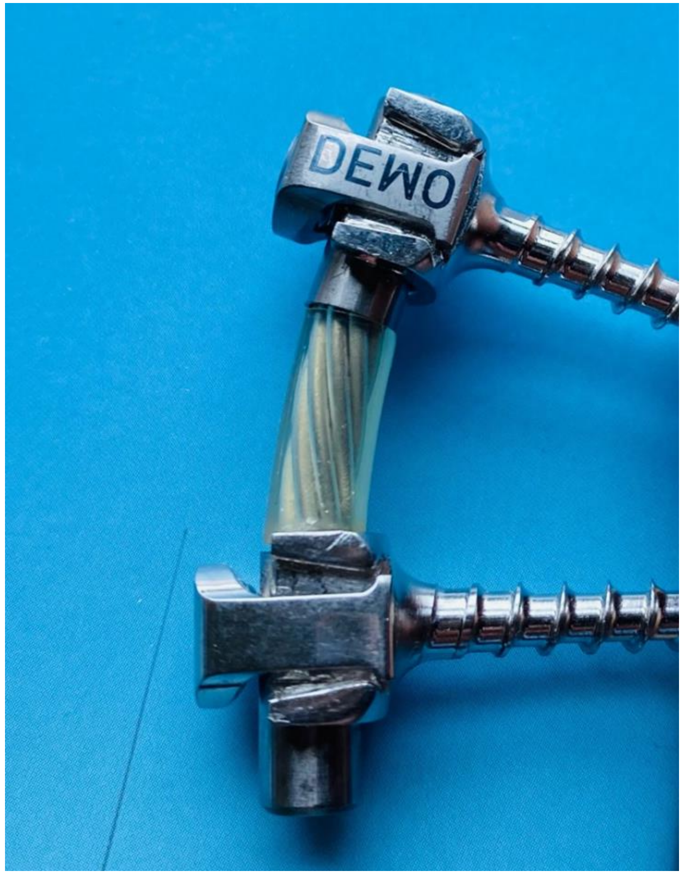
Rod with two different diameters 3.5–5.5 mm



# Upper levels flexible devices

**Option 1:**

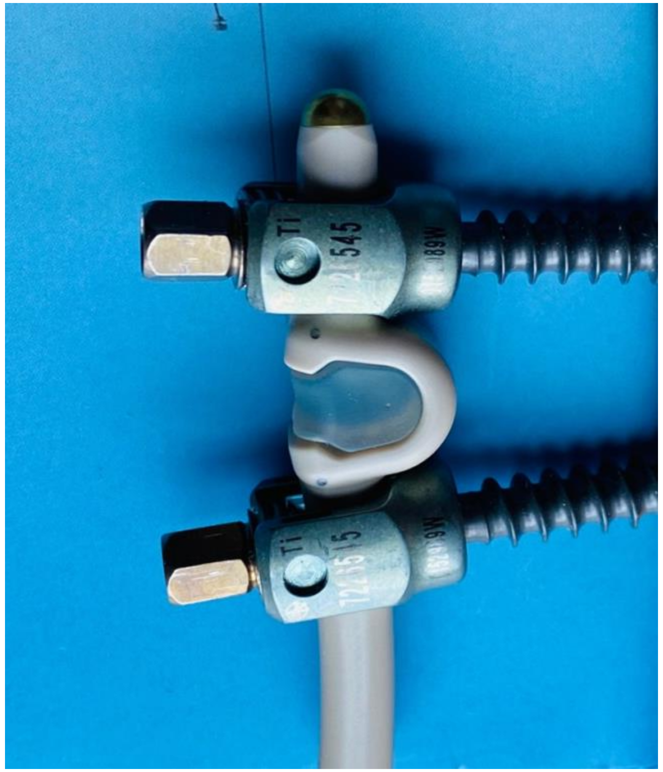
Cable

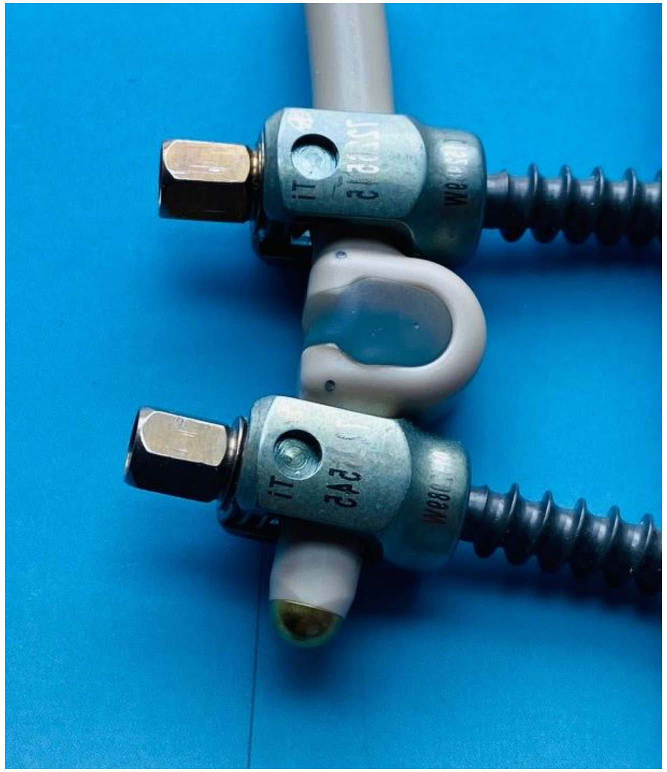



# Upper levels flexible devices

**Option 2:**

Bumper







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# Other flexible devices