Adult deformity and sagittal balance

Definition

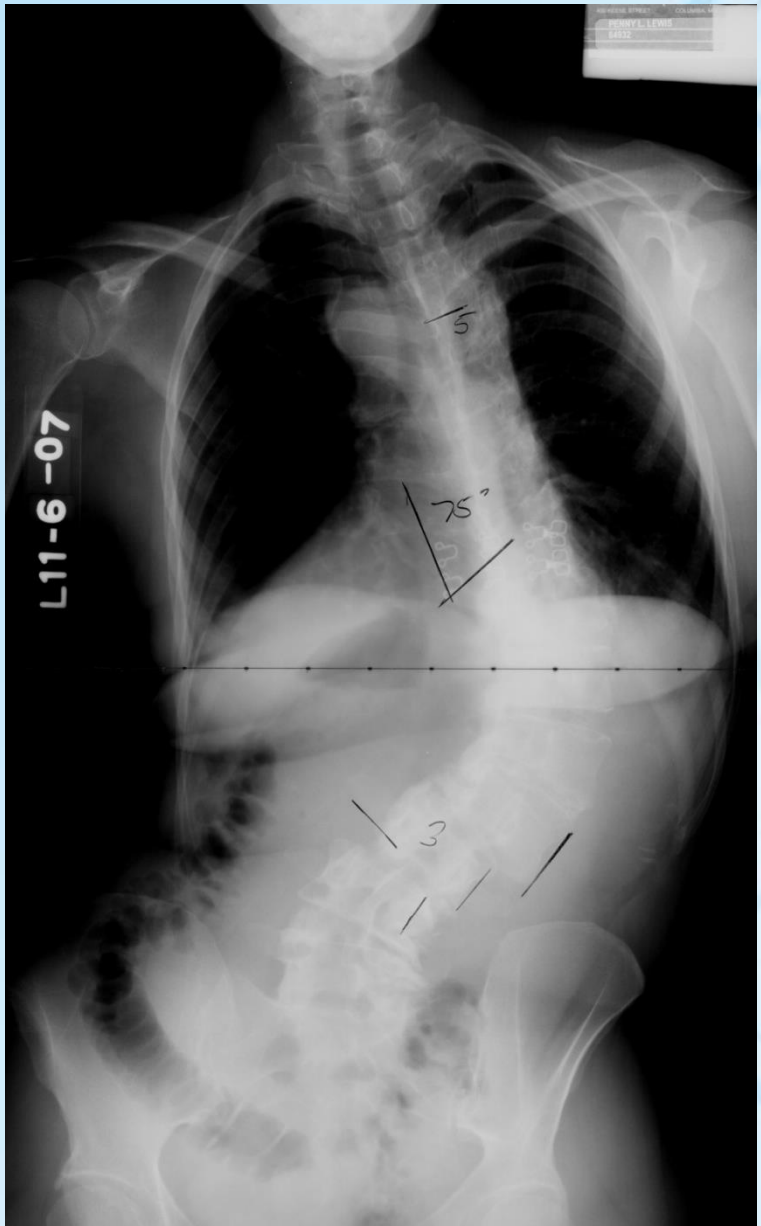
A spinal deformity with a Cobb angle > 10^0

in a patient > 20 yrs

1. **Onset of deformity in pre skeletally maturity patients with progression after age of 20 yrs**

2. **Previously straight spine with onset of de novo scoliosis after age of 20 yrs**

Degenerative changes in a pre-existing deformity



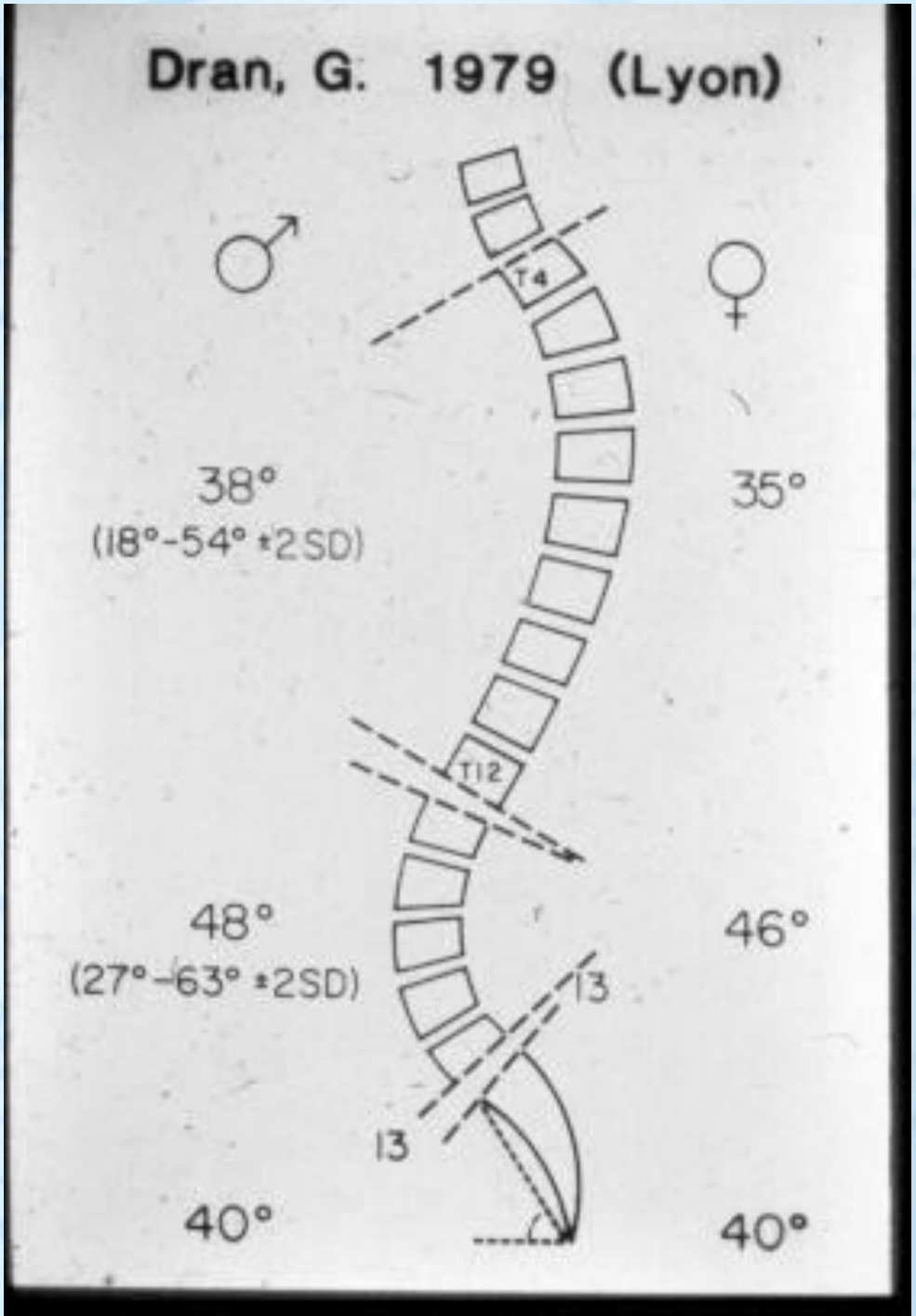
De novo scoliosis: Progressive asymmetric degeneration

Thoracic kyphosis:

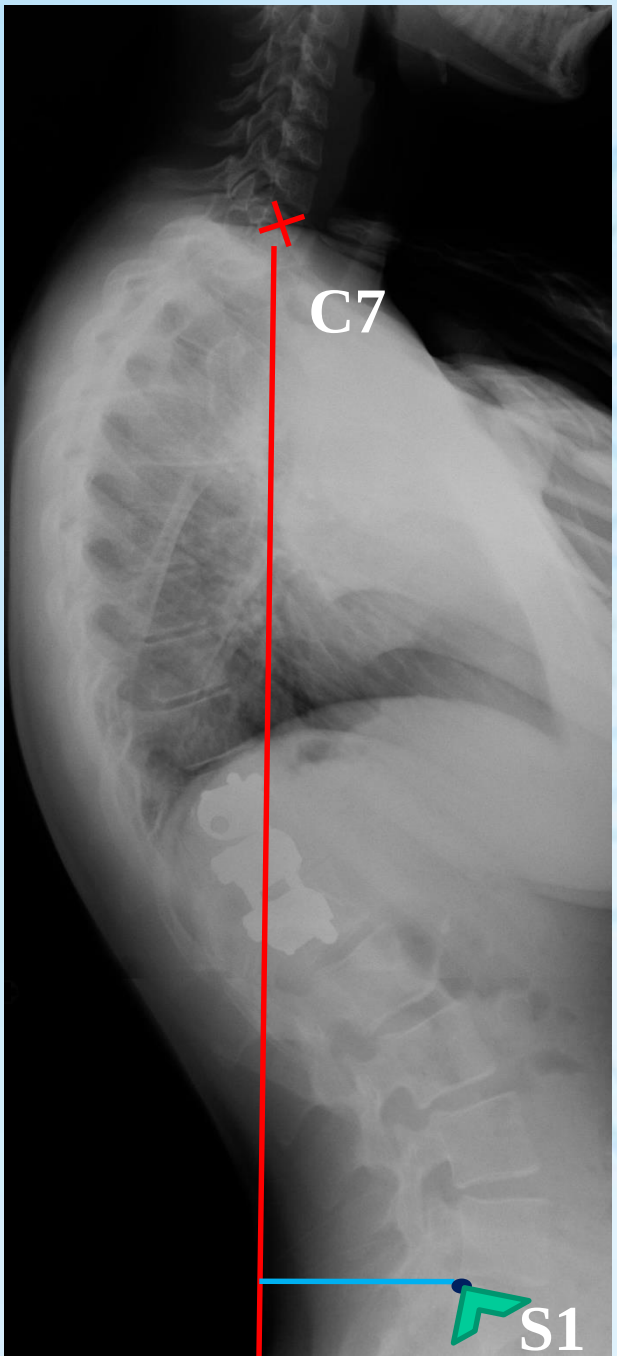
38° ± 18°

Lumbar lordosis:

48° ± 18°



Sagittal vertical axis



Plumb-line shifts:

- Front Positive
- Back Negative
- S1 corner Neutral

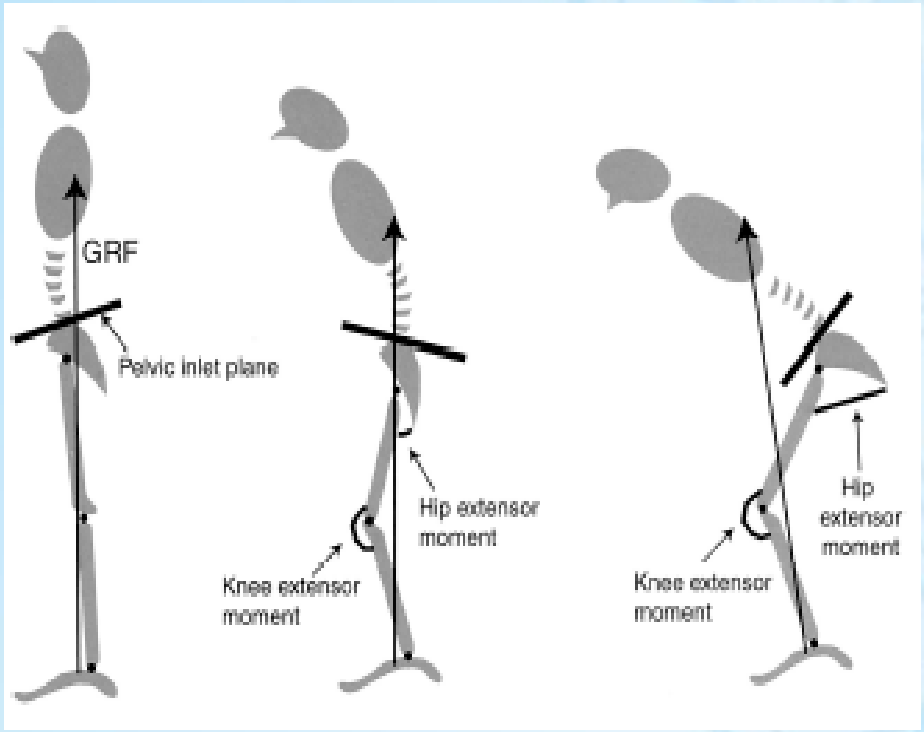
Clinical effects of plumb-line shifts

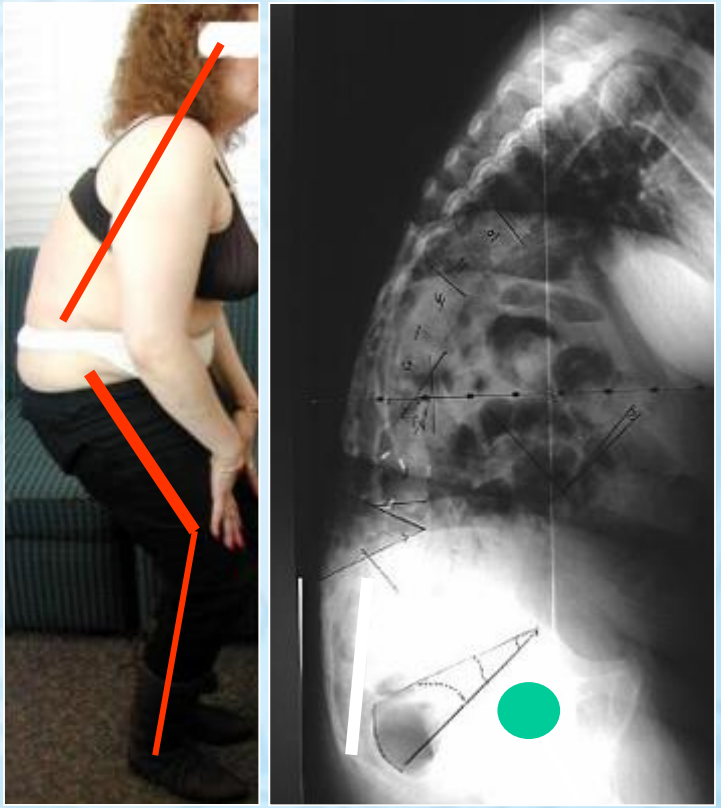
Glassman, Bridwell et al. Spine 2005

Lumbar kyphosis marked disability

SRS-29, ODI ($p<0.05$)

Compensatory mechanisms

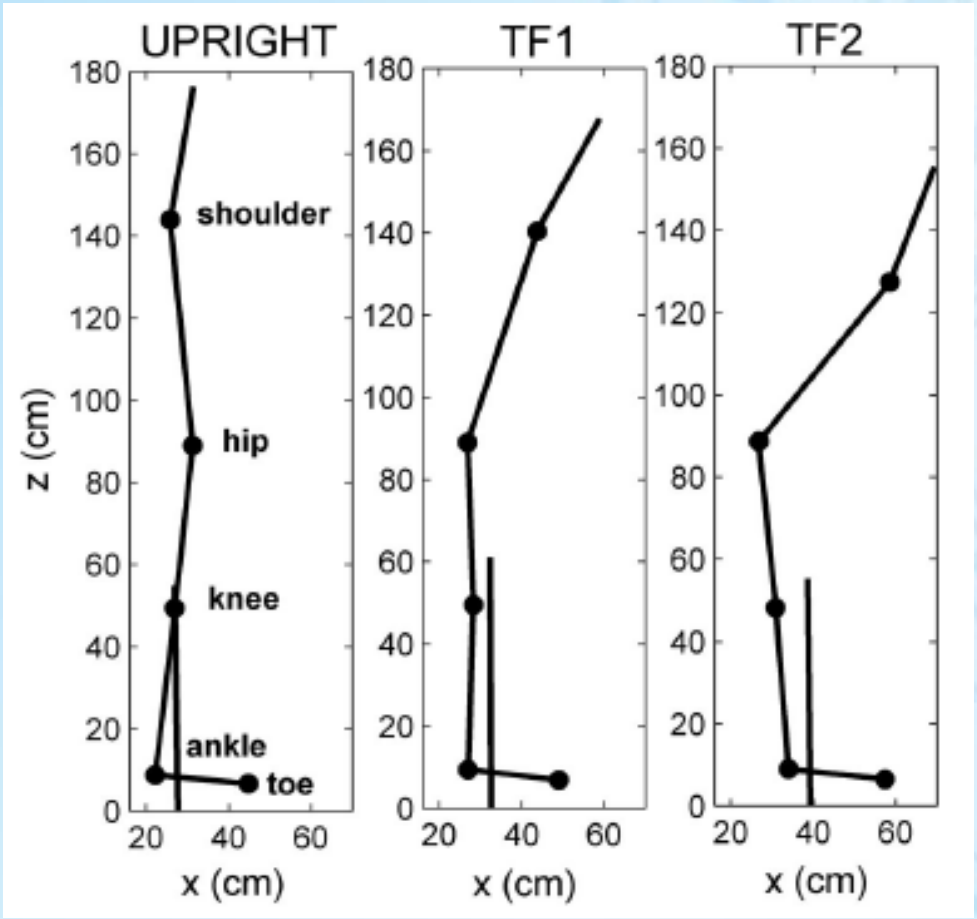


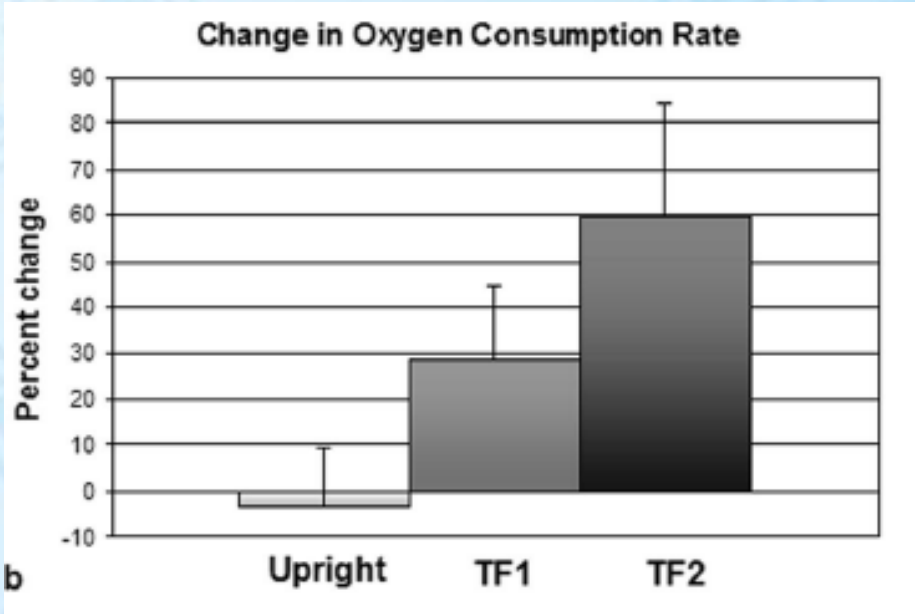


SPINE Volume 32, Number 15, pp 1605–1611

The Effect of Trunk-Flexed Postures on Balance and Metabolic Energy Expenditure During Standing

Devjani Saha, MS,*† Steven Gard, PhD,*†‡ Stefania Fatone, PhD, BPO(Hons),*‡ and Stephen Ondra, MD§





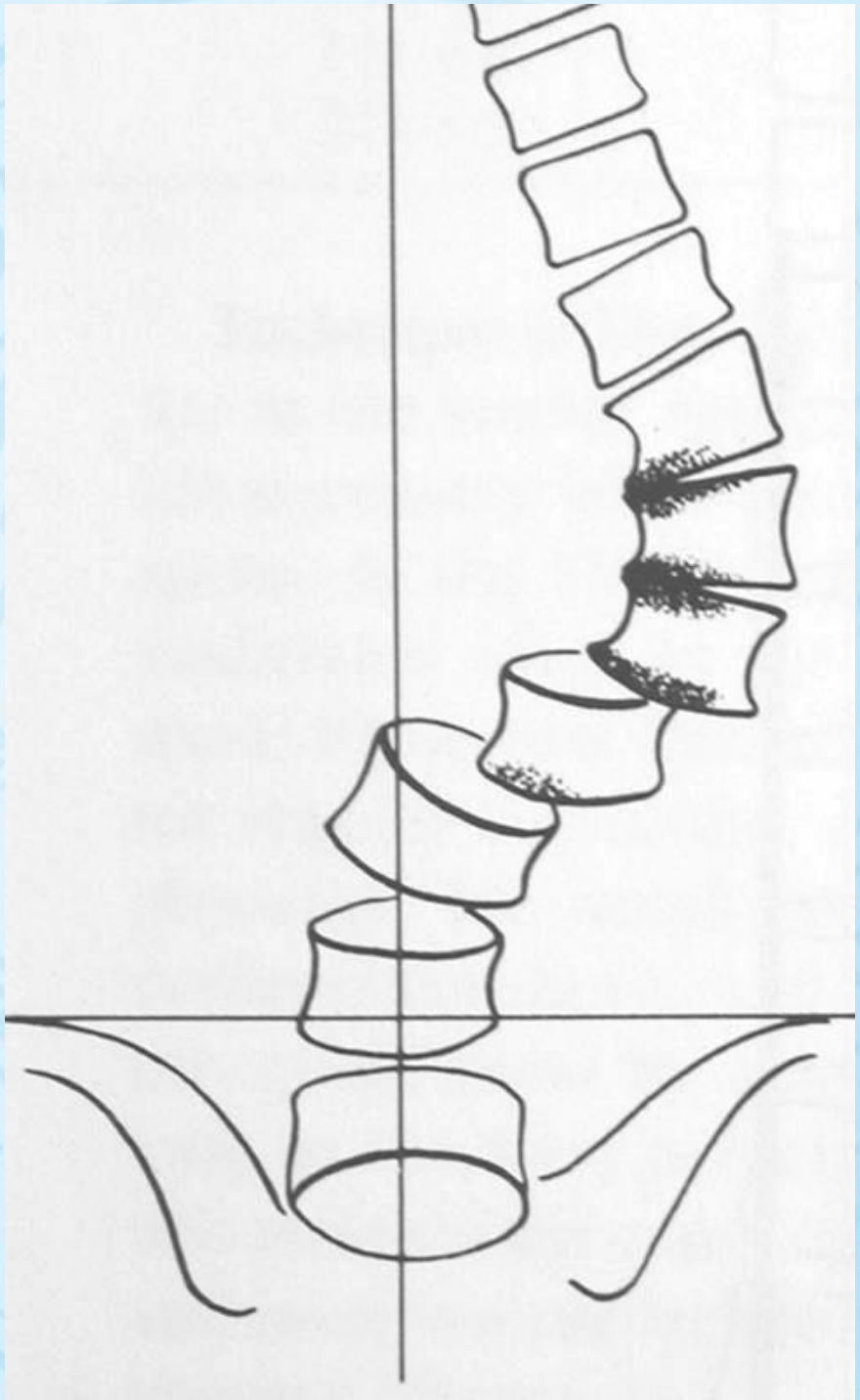
Clinical findings

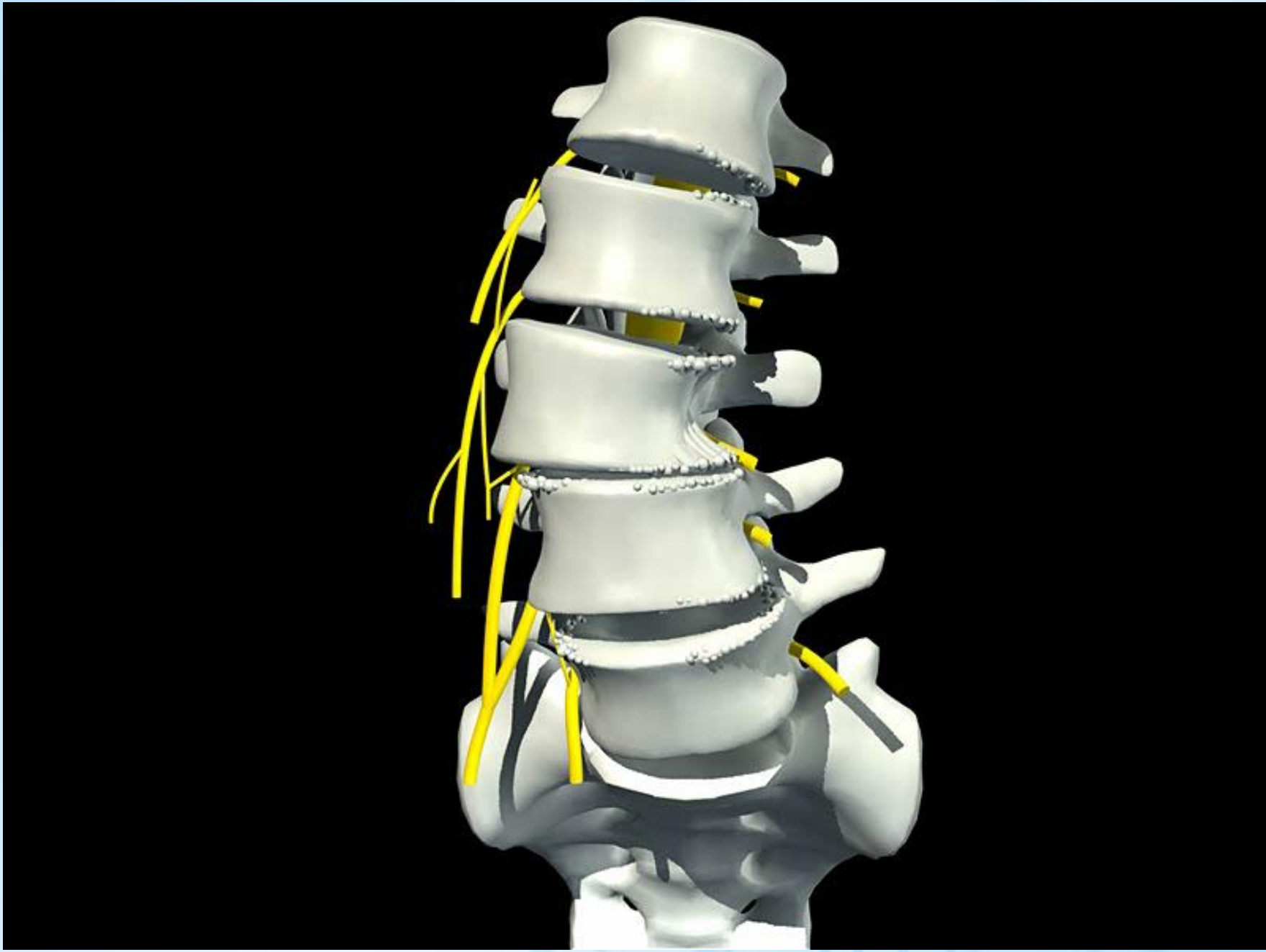
- Pain
- Deformity
- Balance

Pain patterns

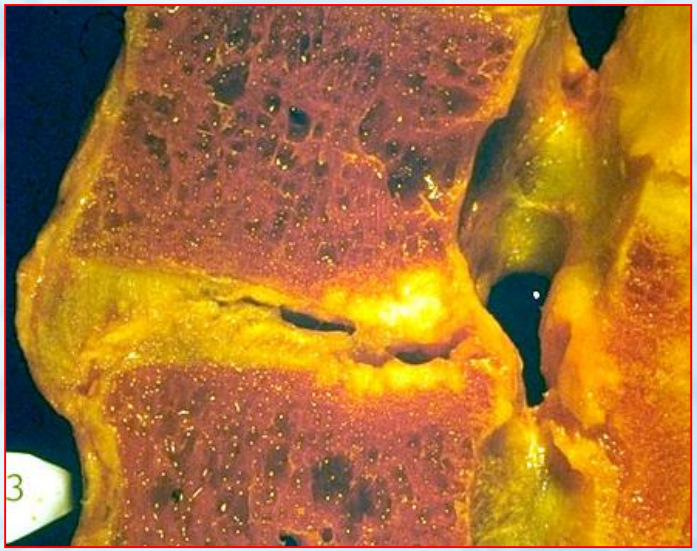
- Back pain
- Radicular pain
- Claudication

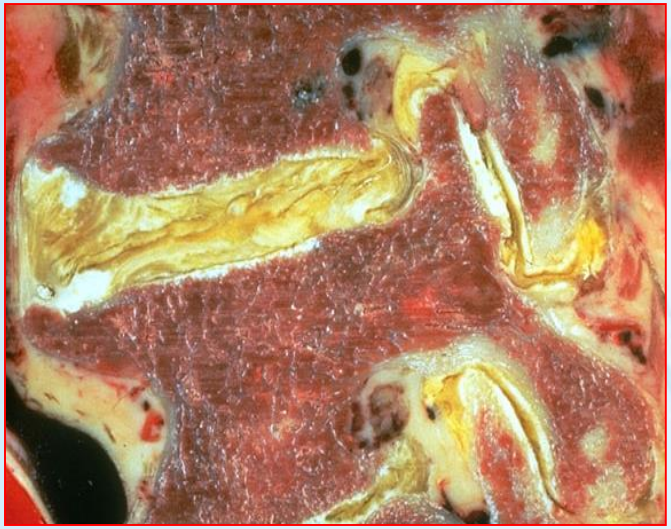

Erect
2
3
A
A

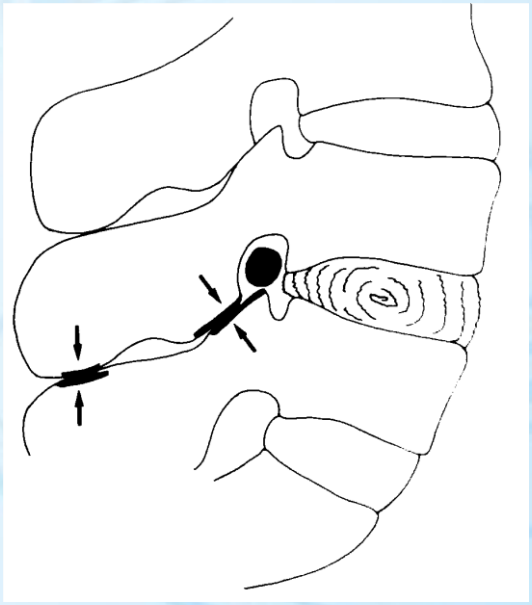


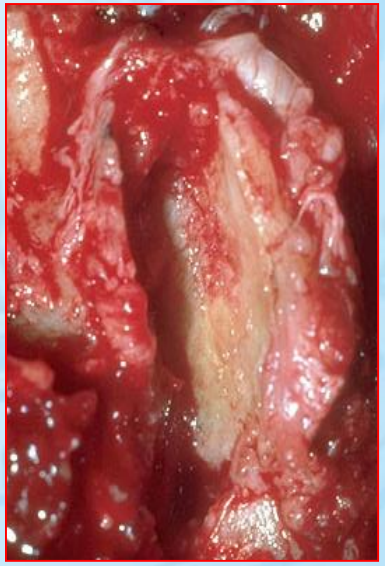


Pain generators



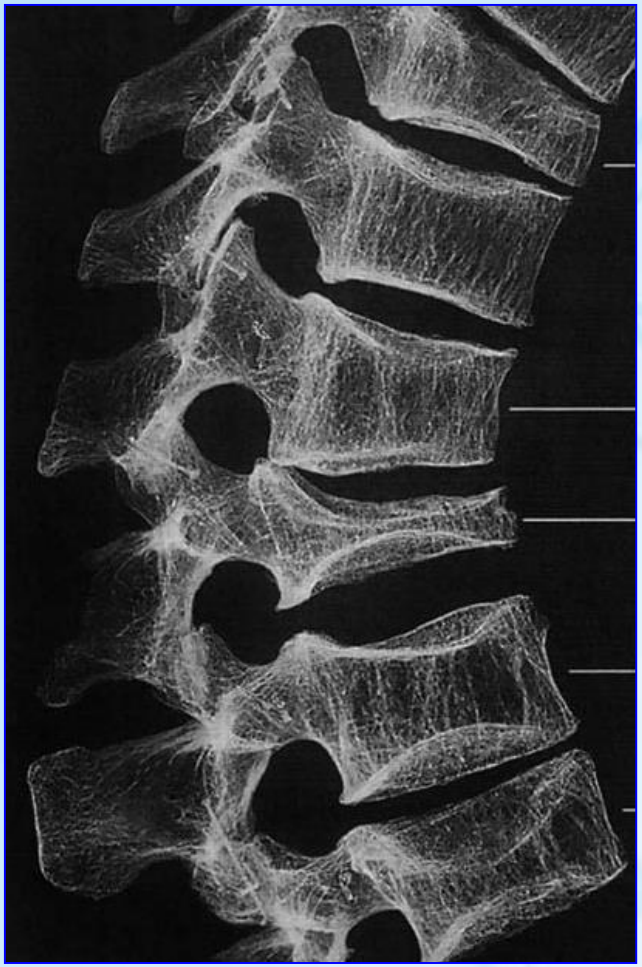


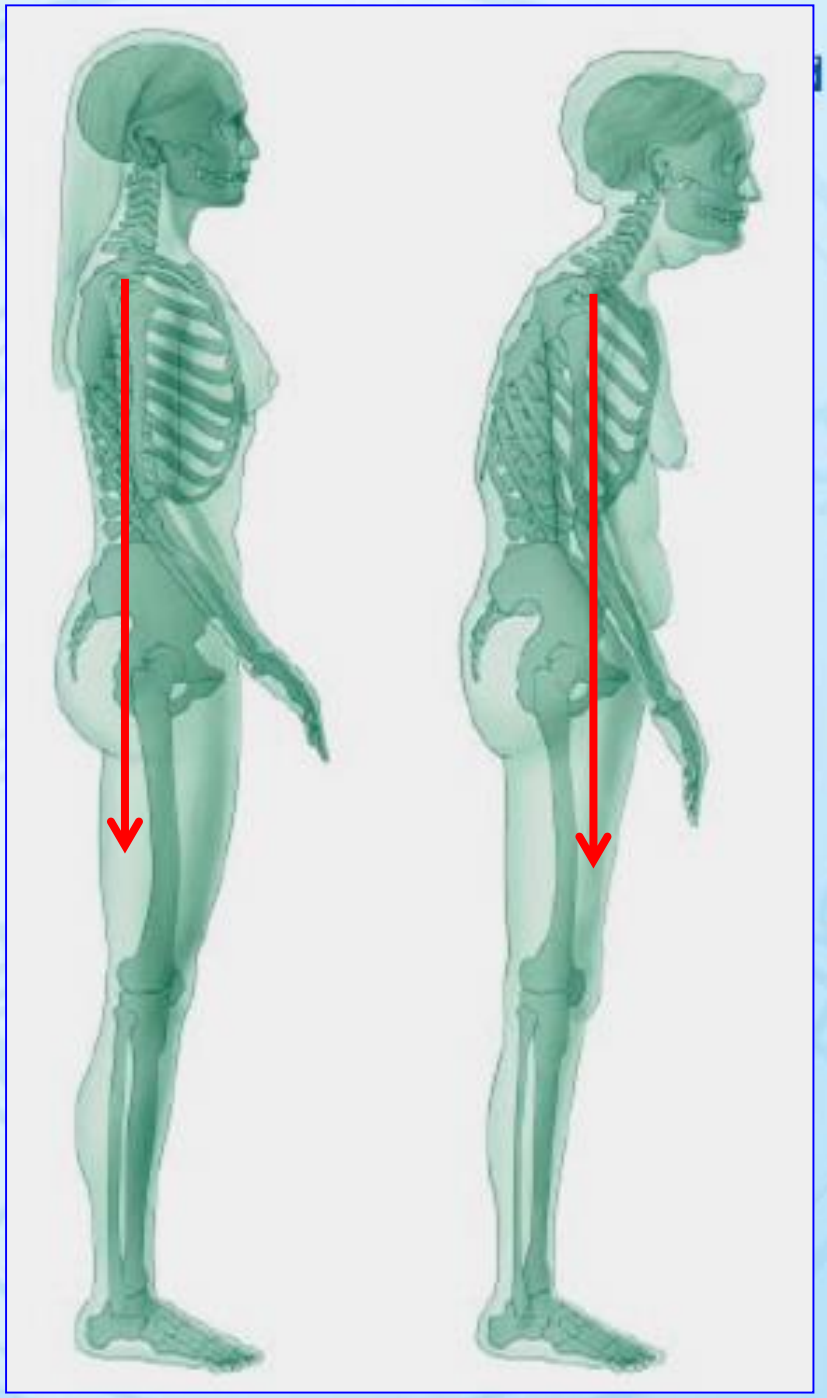




Deformity

- Magnitude of the underlying deformity
- Progression
- Costo-pelvic impingement
- Balance

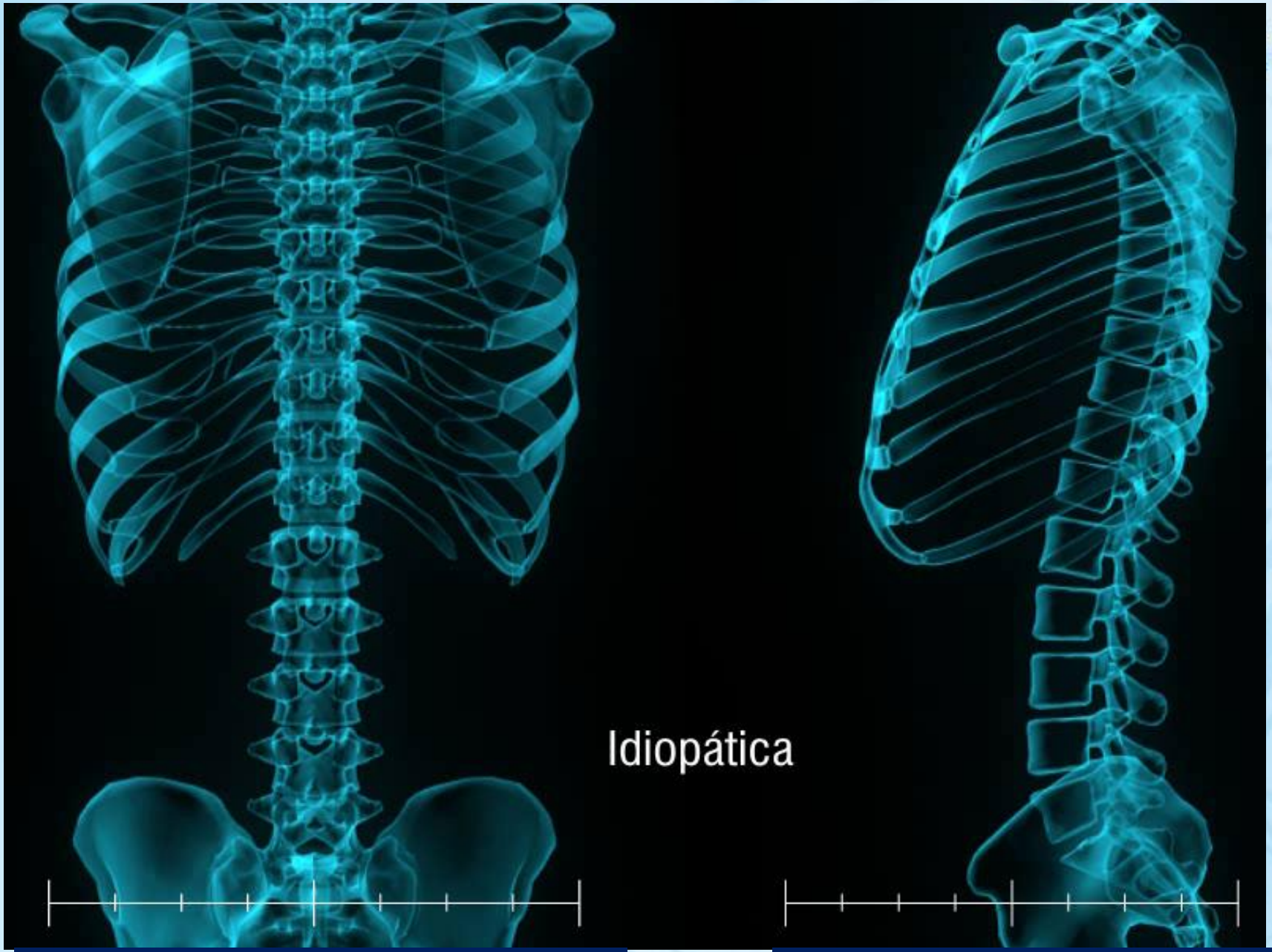




Loss of sagittal alignment

increases fracture risk x 8

Kobayashi et al. Osteoporos Int 2008

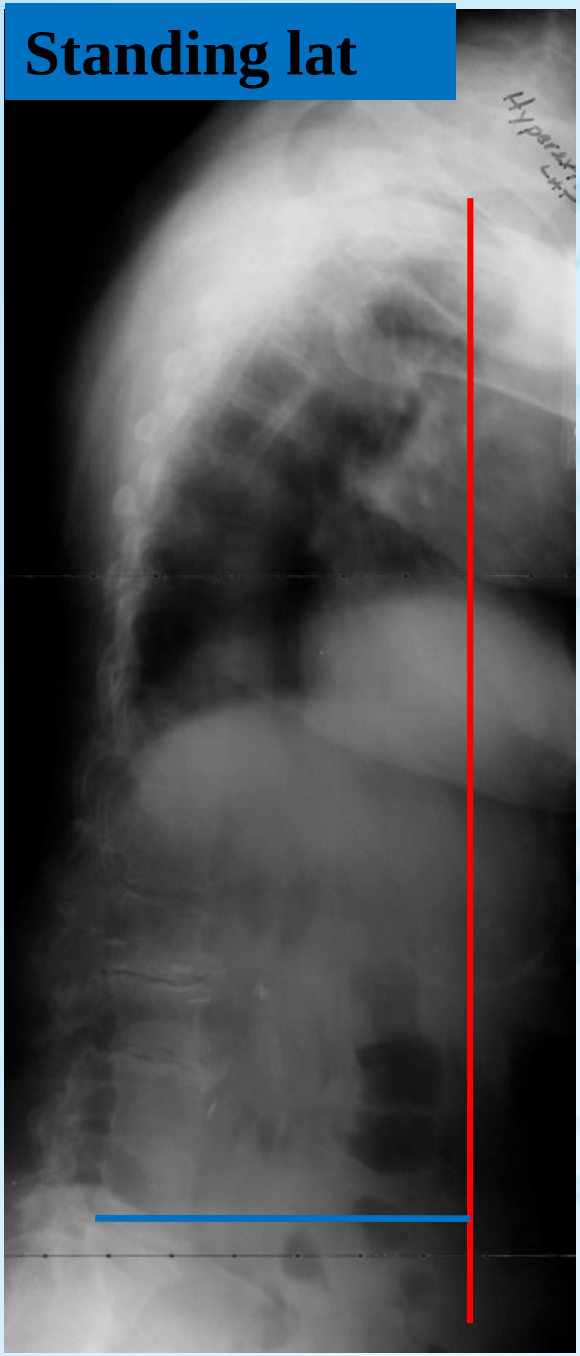


Coronal imbalance

Sagittal imbalance


Hyper-extension lateral
9:45AM

Standing lat



Hyperext lat

Management options

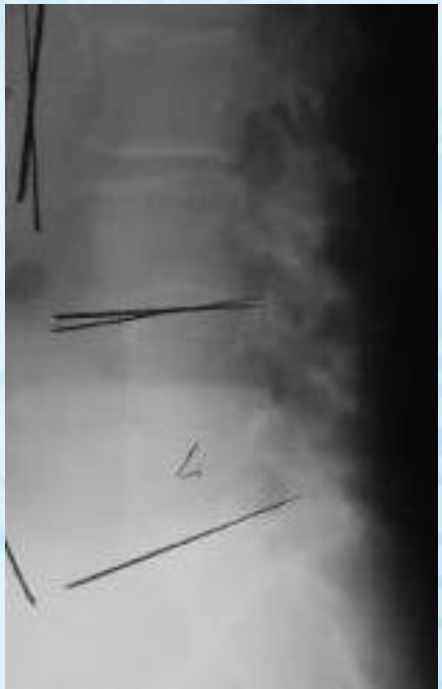
- Option 1: The conservative 'bundle'
- 1 + levels decompression
- Fusion
- Advanced strategies: releases, osteotomies, interbody fusion

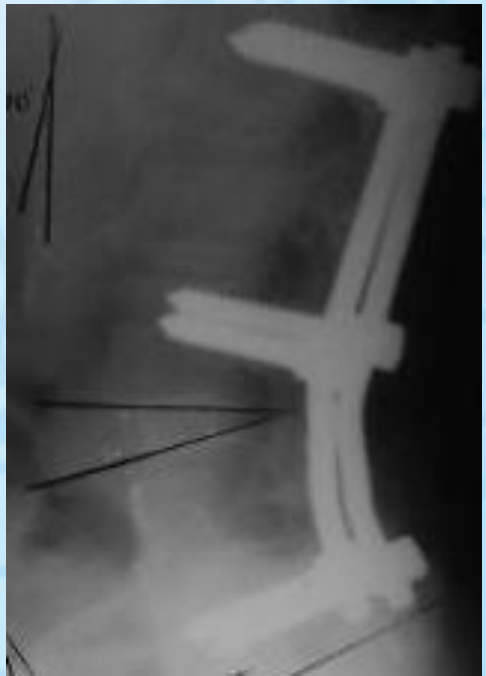
Rationale for fusion

- Good pain relief; 69 – 87%

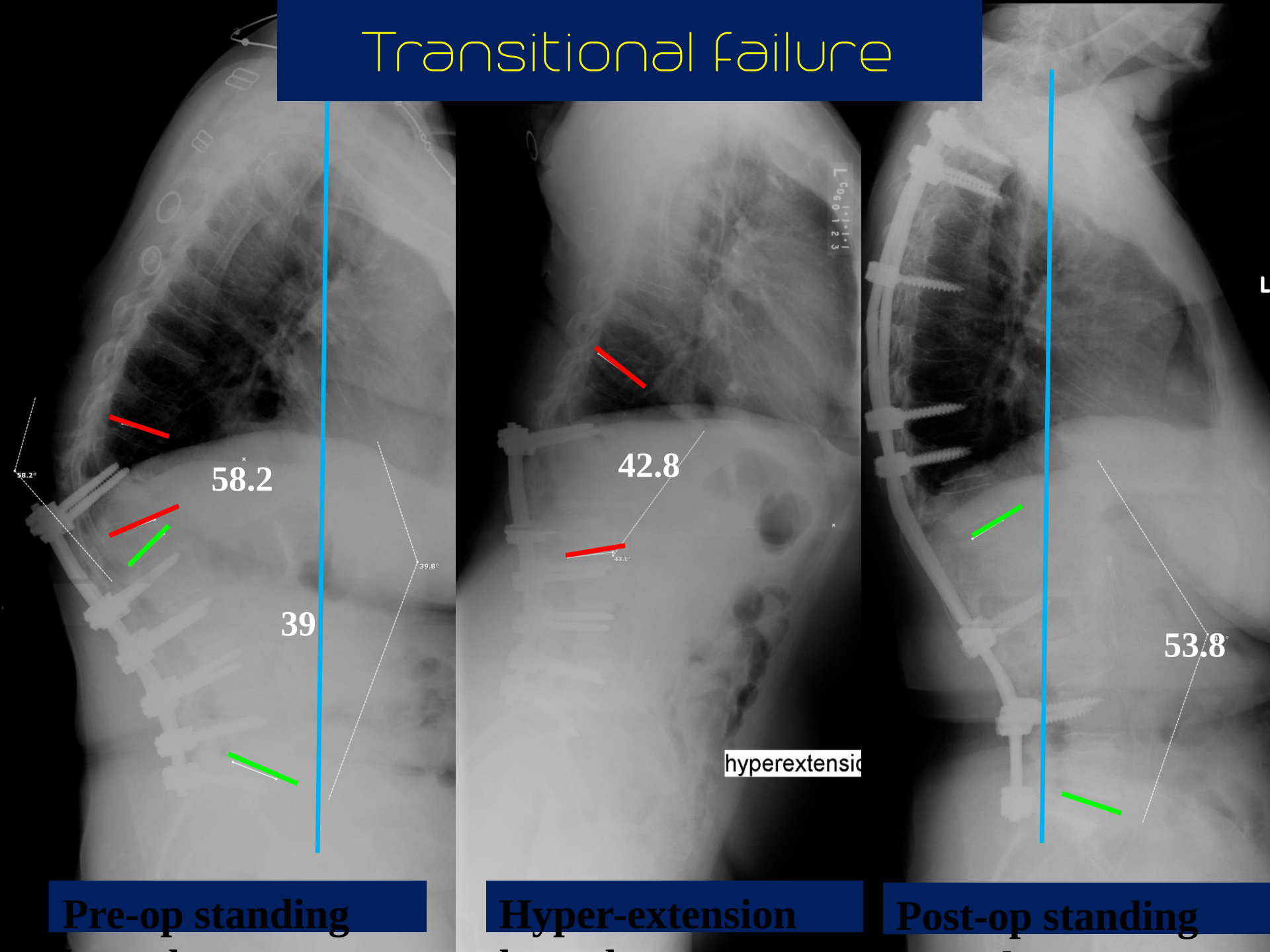
  Kostuik Clin Orthop 1973
  Swank JBJS Am 1981

- Improvement in the lumbar lordosis :
  - Anterior
  - Posterior
  - Releases
  - Osteotomies



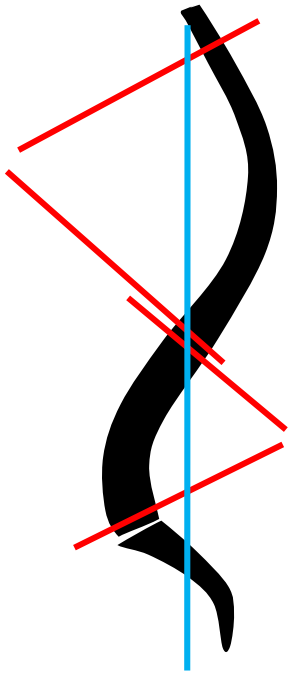


Transitional failure



Aims of intervention

- Restore balance without stressing junction
- Adaptation of the lordosis
- Restore plumb line



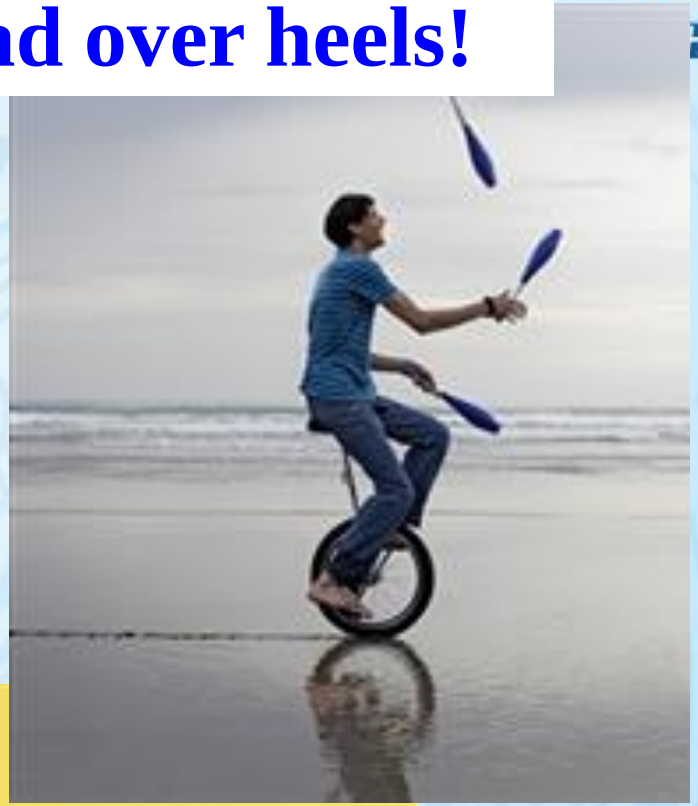

Spinal problems.....
.....not too hot to handle !

Outline

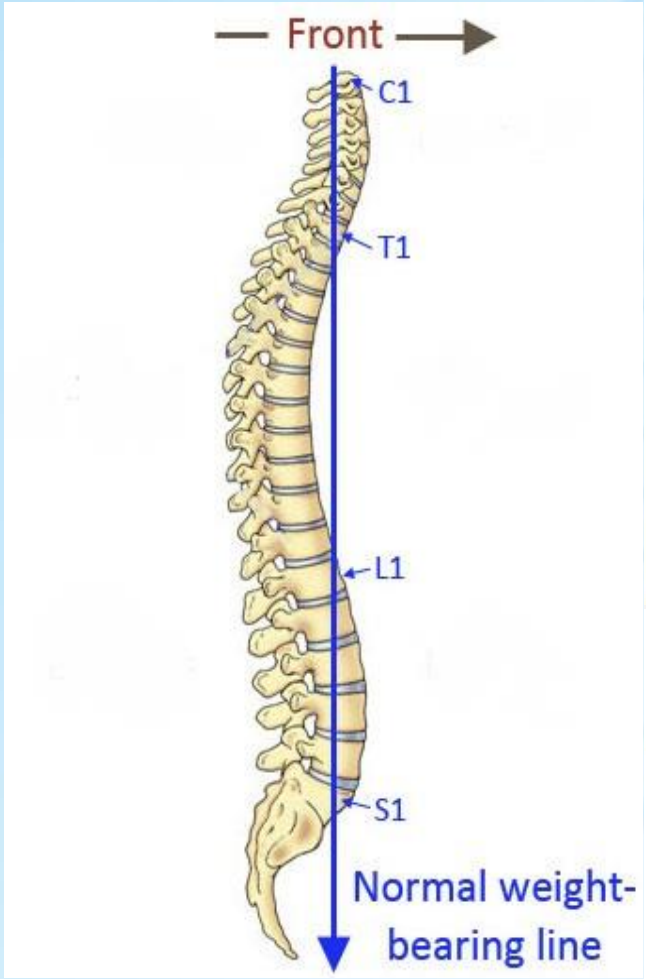
- Understanding & measuring the sagittal profile
- Pathological changes in sagittal profile
- Surgical reconstruction options
- Clinical evidence / cases

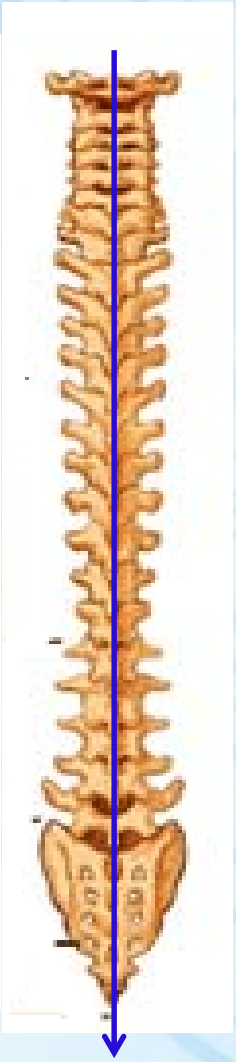
Sagittal plane: divides into right & left halves

Balance: Head over heels!



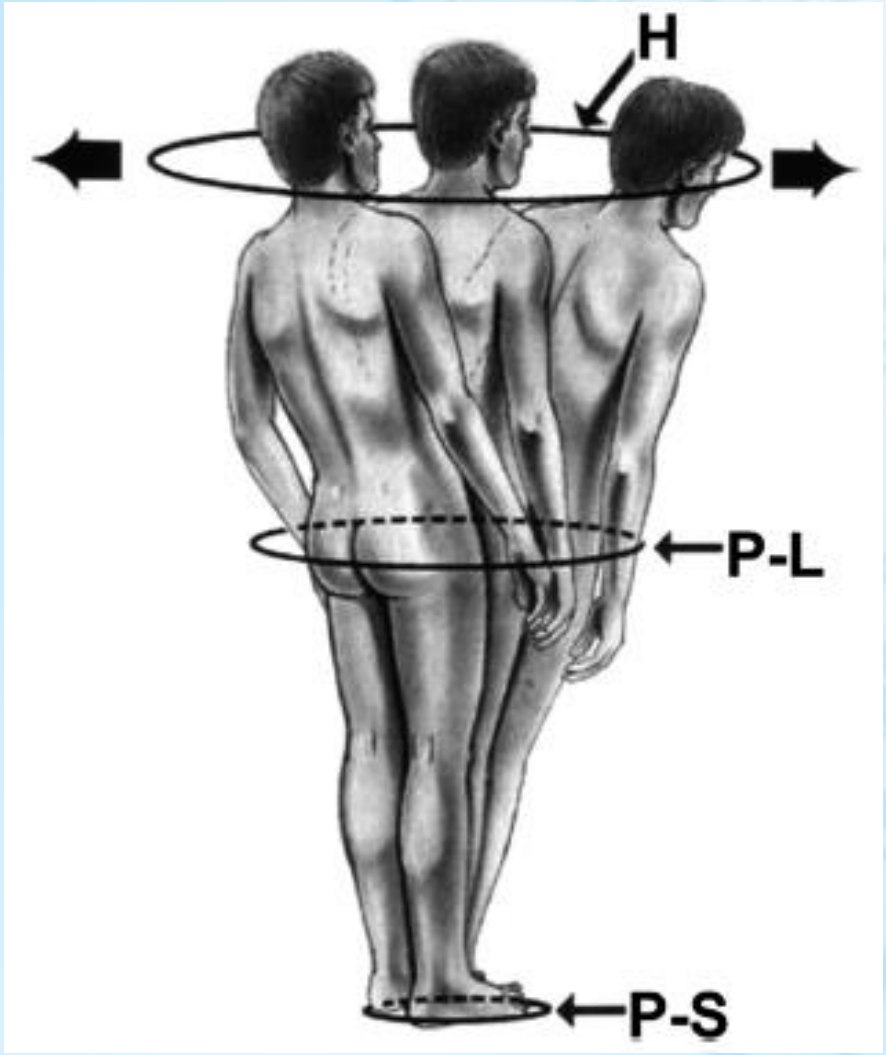
The spinal 'fingerprint'





Cone of economy

J. Dubousset



Sagittal Plane Alignment…

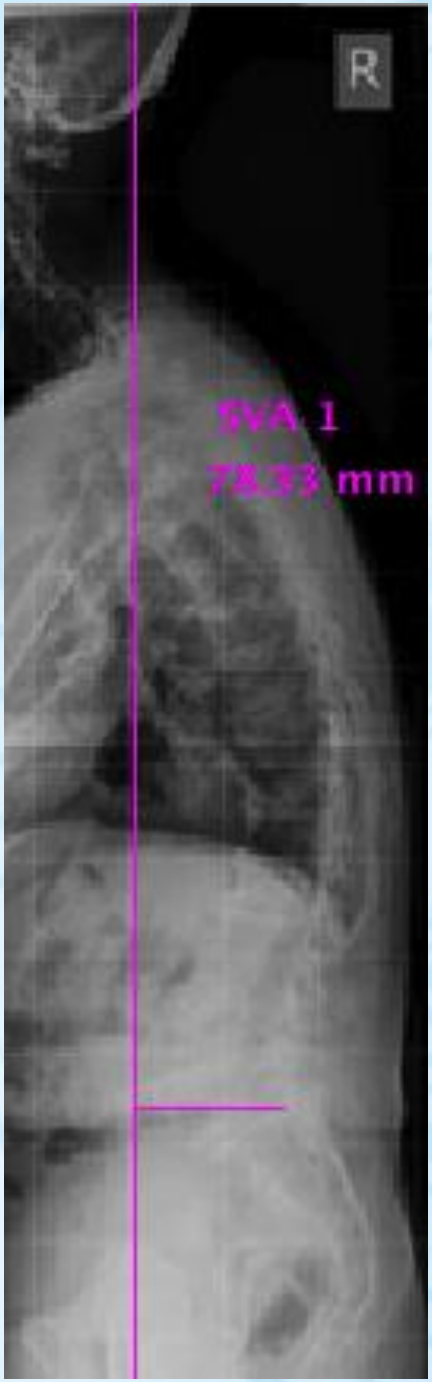
… More Than Just the Spine

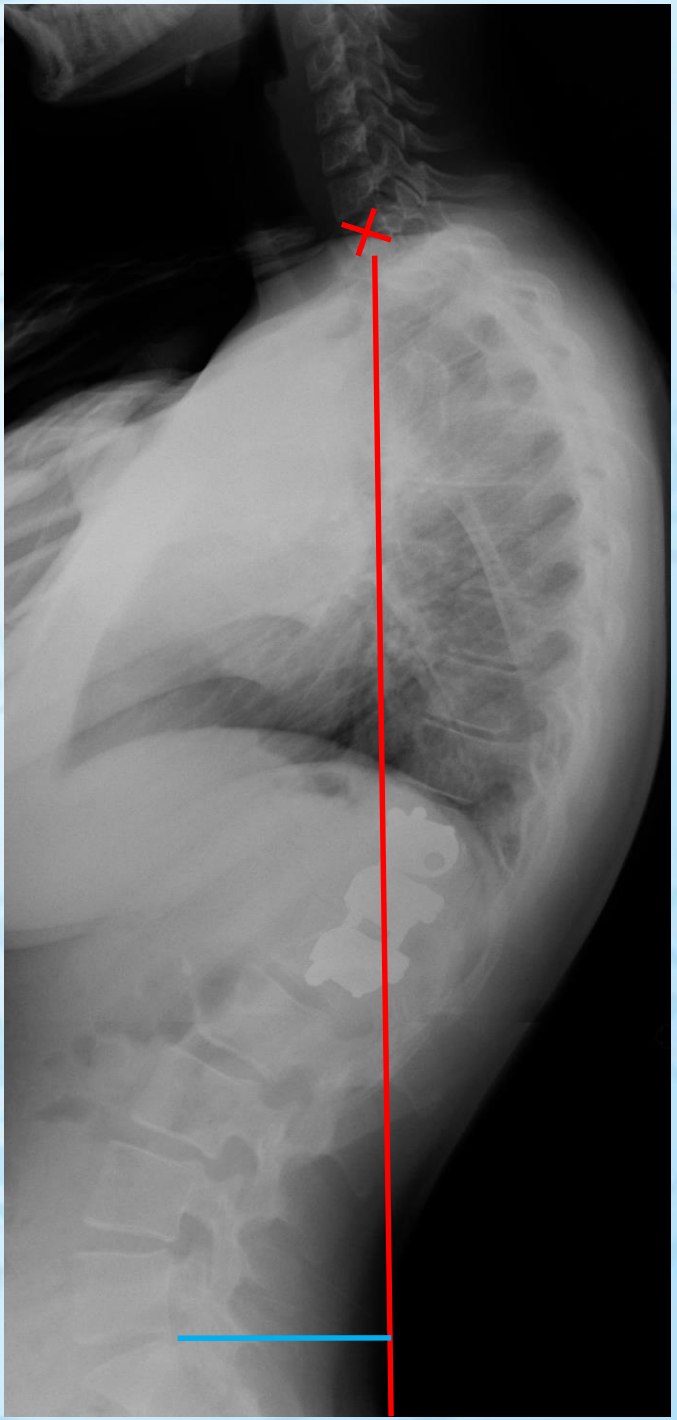
- Thoracic kyphosis
- Lumbar lordosis
- Pelvic morphology/ version
- Lower extremity

Global Alignment

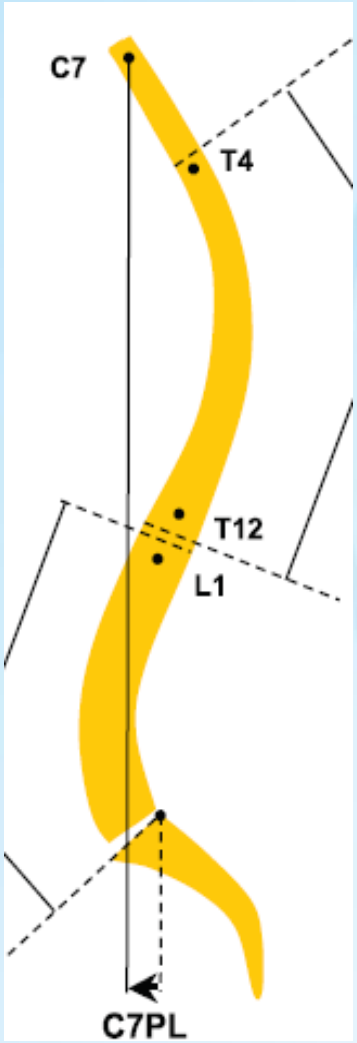
Sagittal vertical axis


SVA 1
151.63 mm
L Lordo 1
35°


SVA 1
mm



Radiographic measures



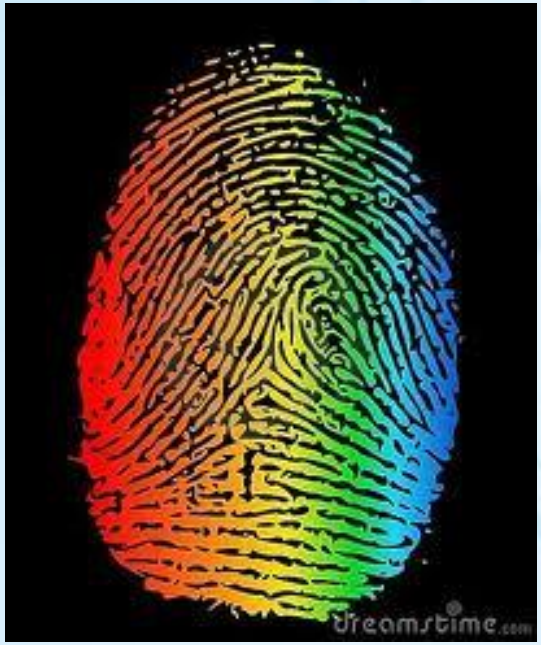
- Lumbar lordosis L1 S1
- TL junction T10 L2
- Thoracic kyphosis T4 T12

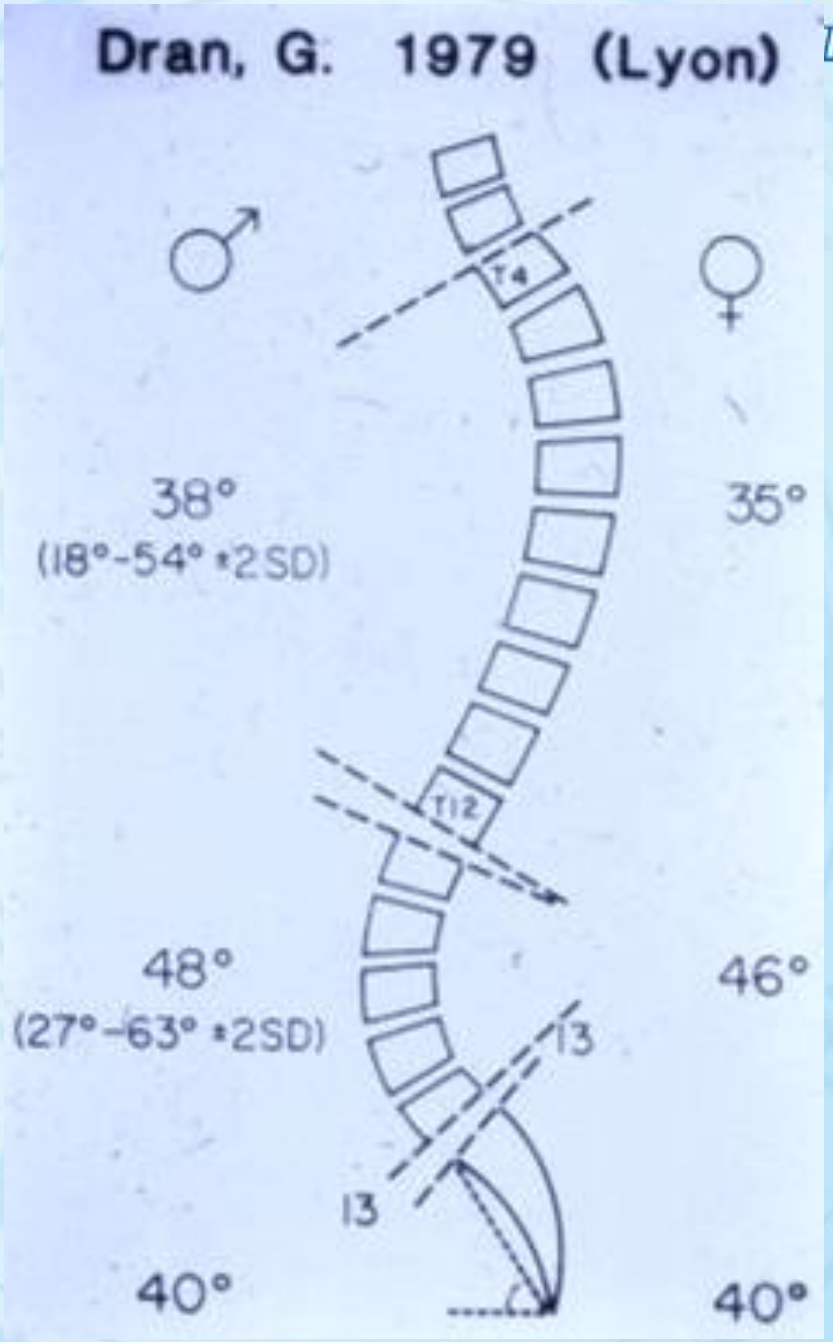
Thoracic kyphosis:

38° ± 18

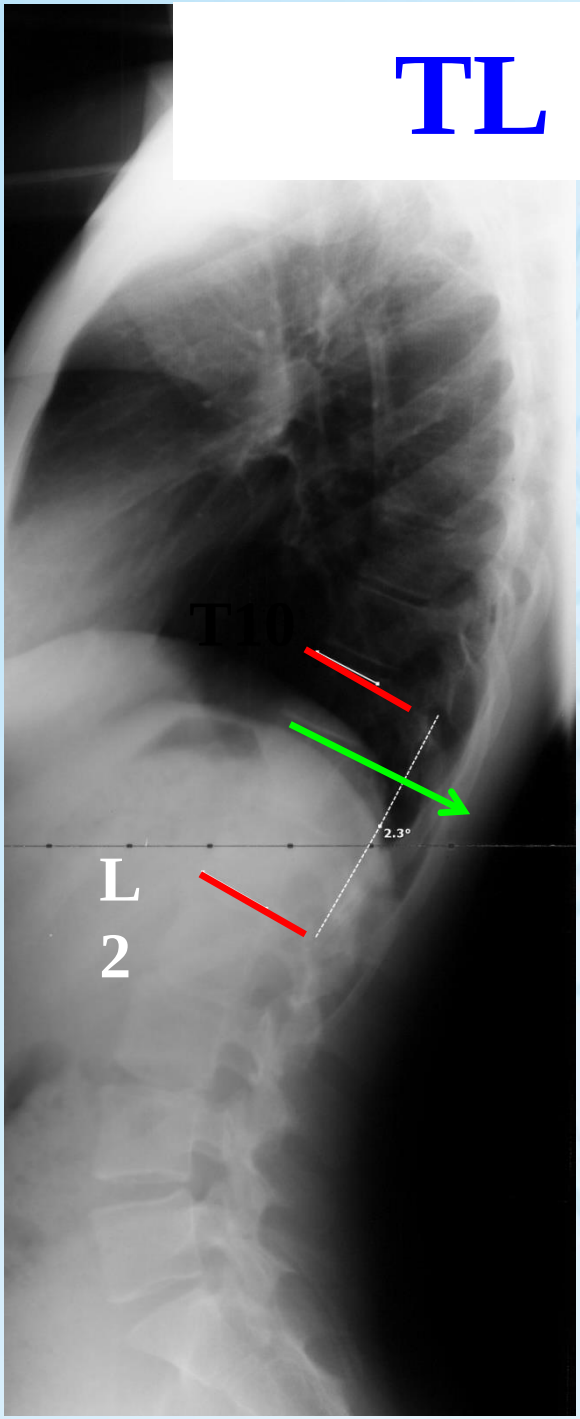
Lumbar lordosis:

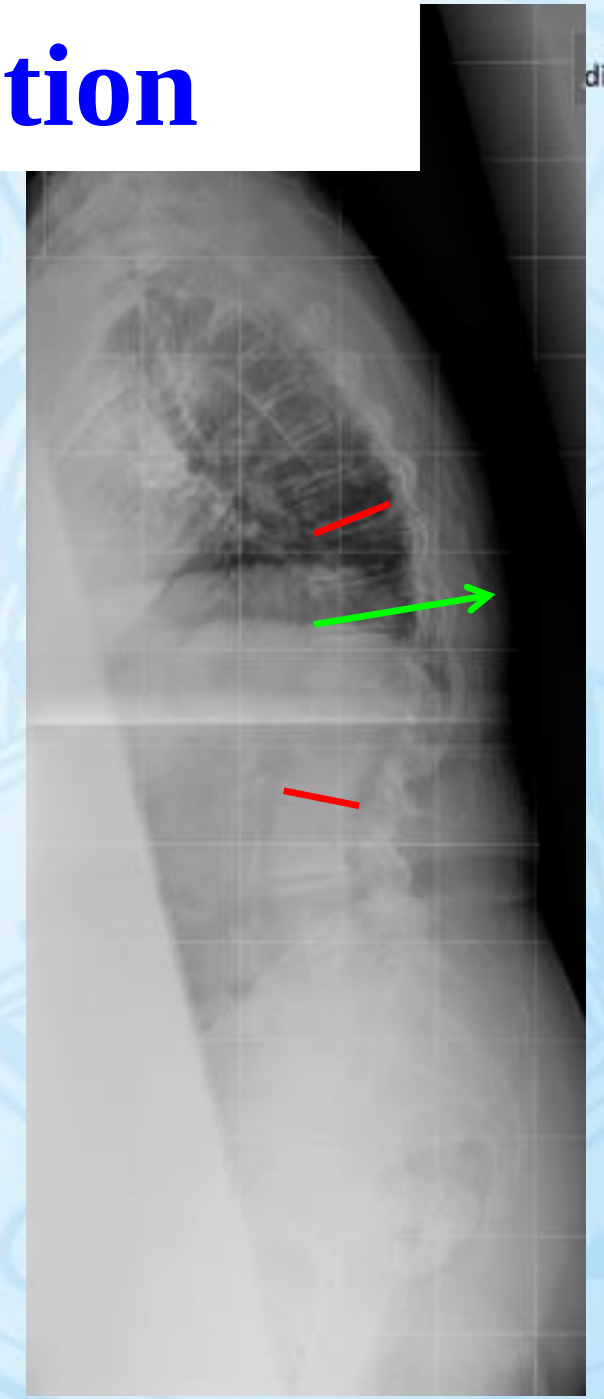
48° ± 18





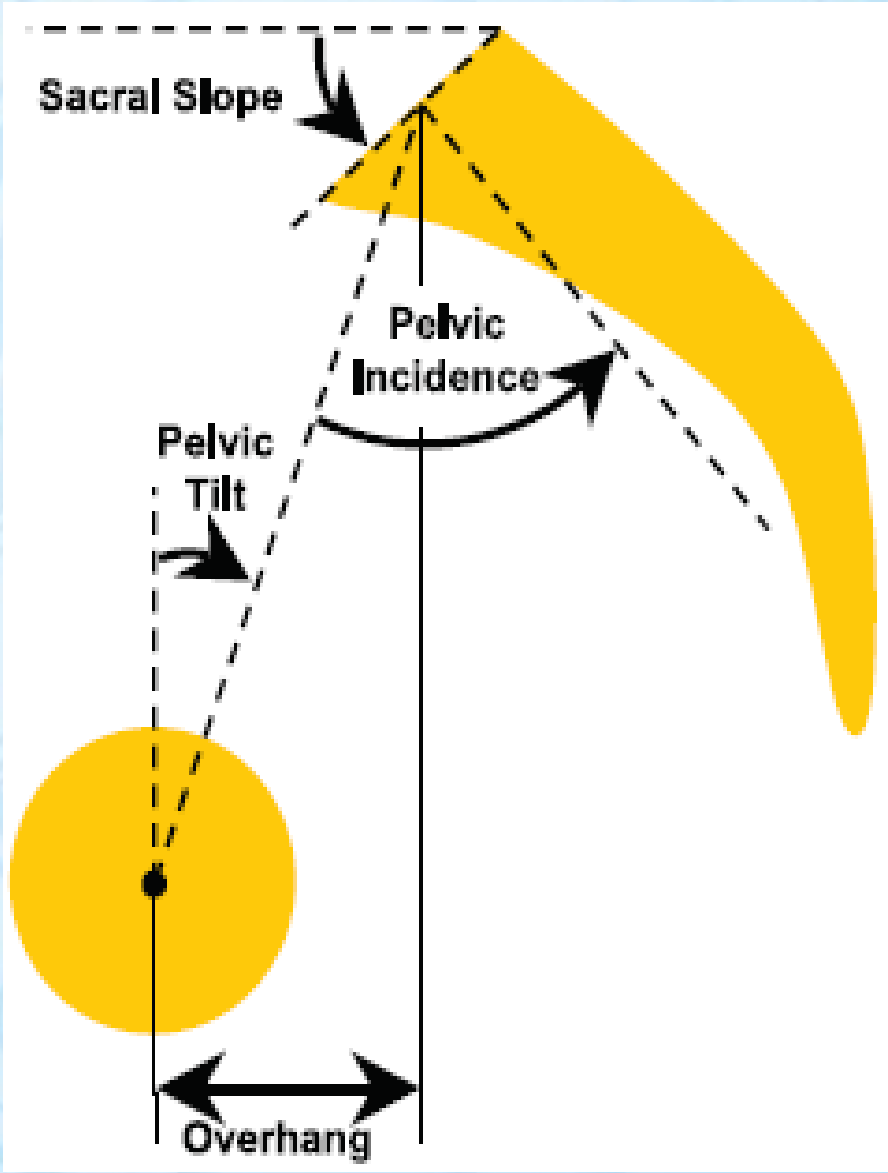
TL Junction





Pelvic measures

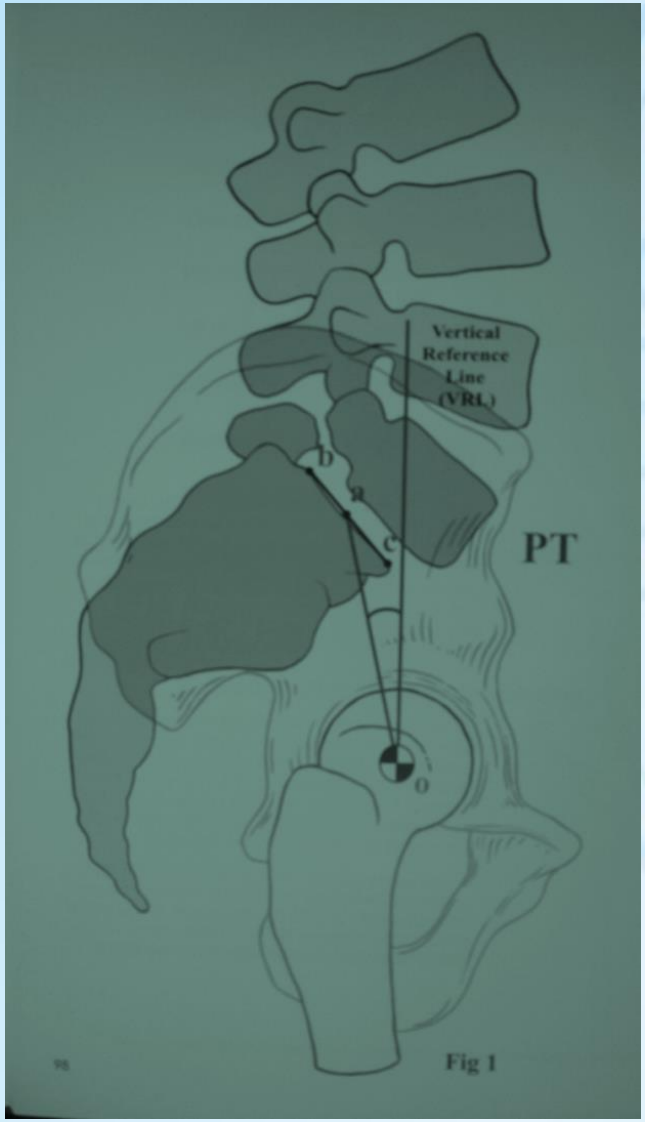
- Sacral slope (SS)
- Pelvic tilt (PT)
- Pelvic incidence (PI)



Sacral slope

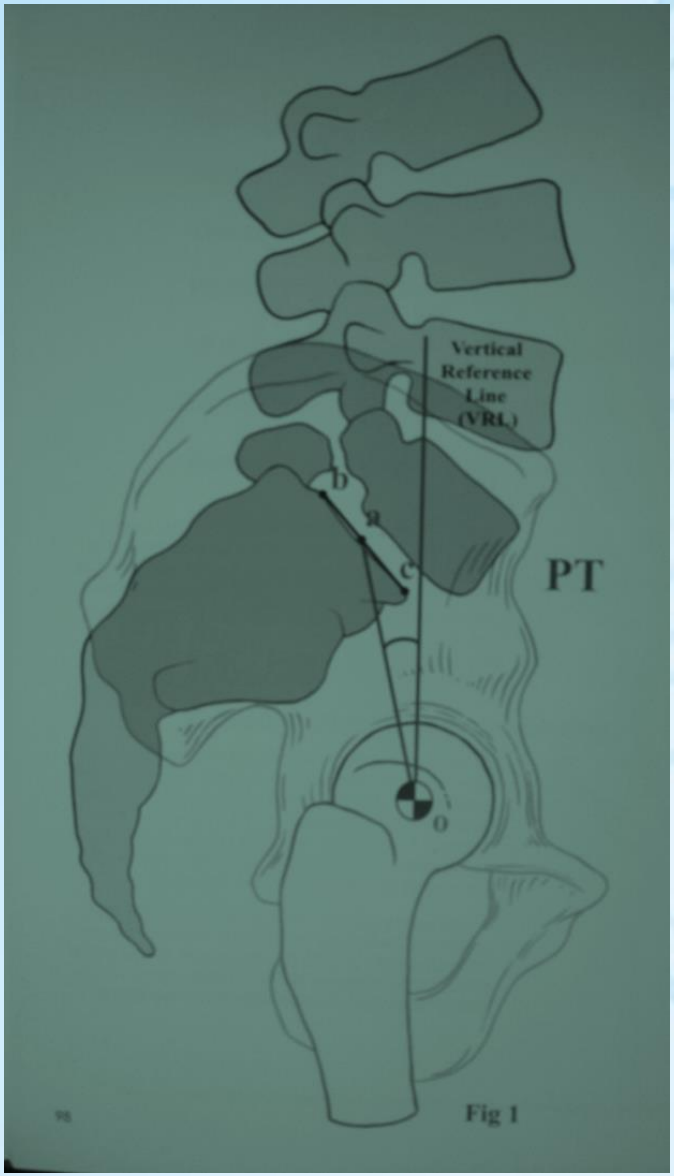
- Horizontal & cranial sacral end plate tangent
- 41° ± 8.4° (Vialle JBJS 2005)

Pelvic tilt



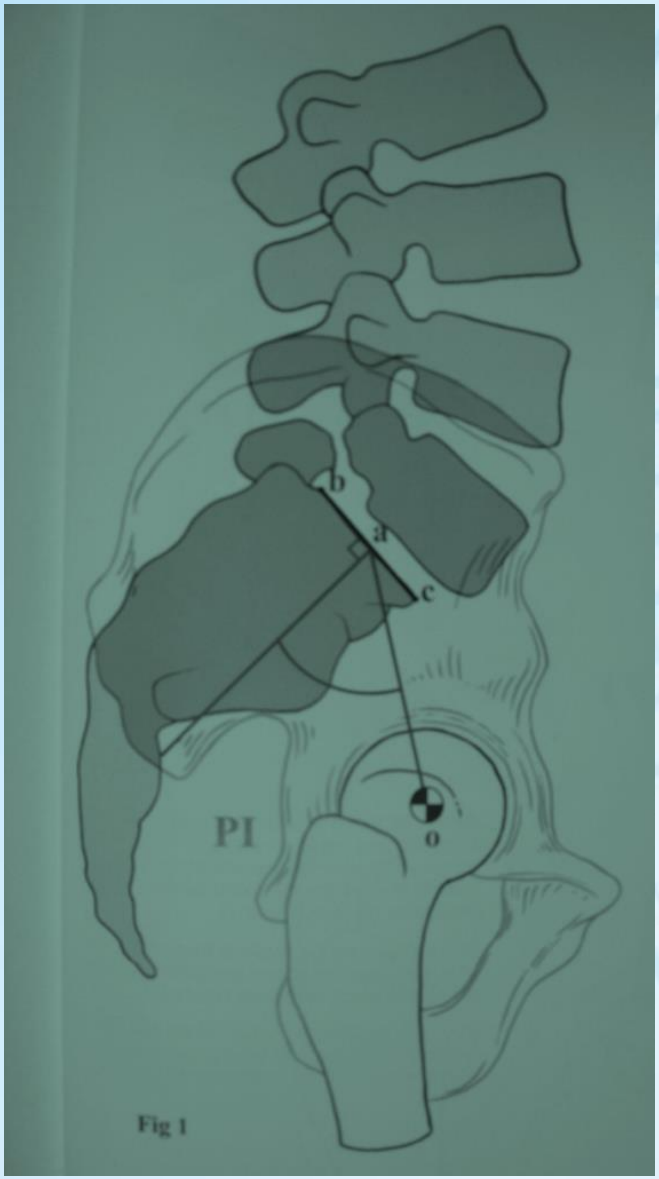
- Vertical line between
  1) middle of cranial sacral end plate
  2) centre of the bicoxo-femoral axis
- 13° ± 6° (Vialle JBJS 2005)

Significance of pelvic tilt



- Centre of gravity over LL
- Maintains sacral plate posterior to the hip
- Increases with age

Pelvic incidence



- Key parameter
- Perpendicular to:

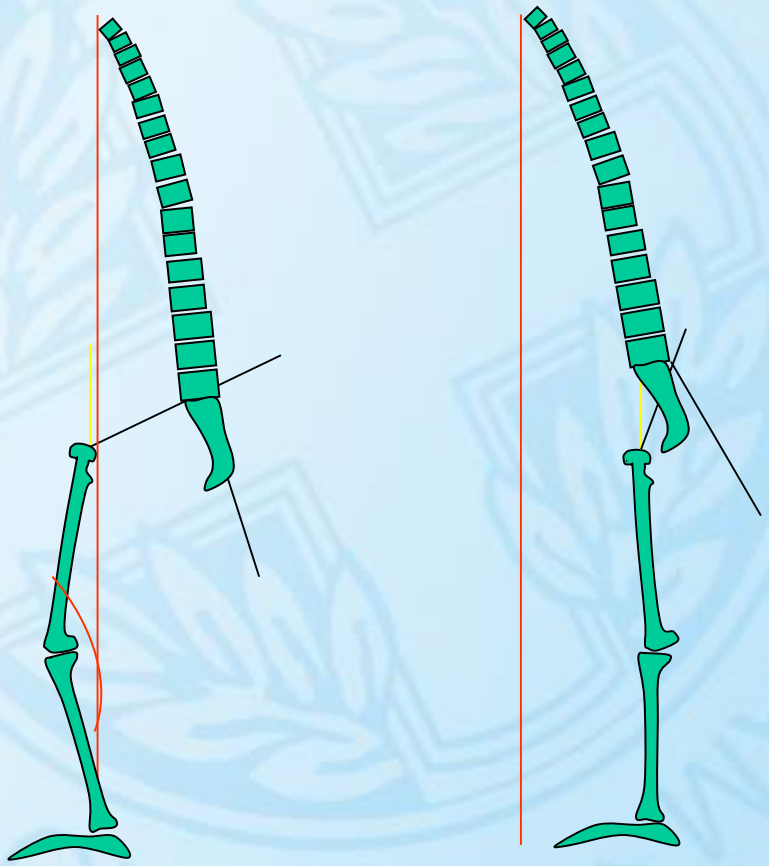
  the middle of the sacral end plate

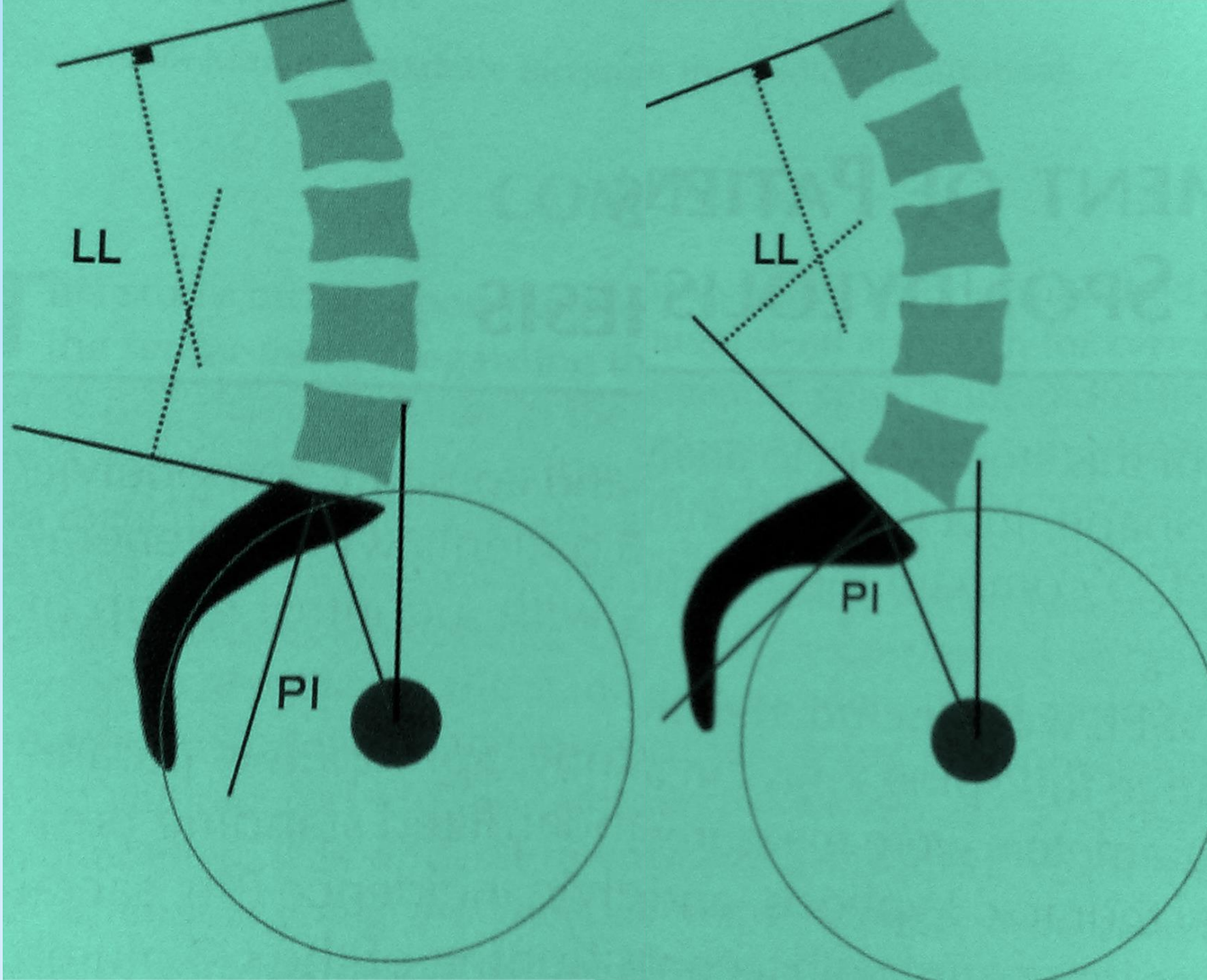
  mid-point of femoral heads
- 55° ± 10.6° (Vialle JBJS 2005)

Spino-pelvic compensation

- PI regulates PT
- Higher PI

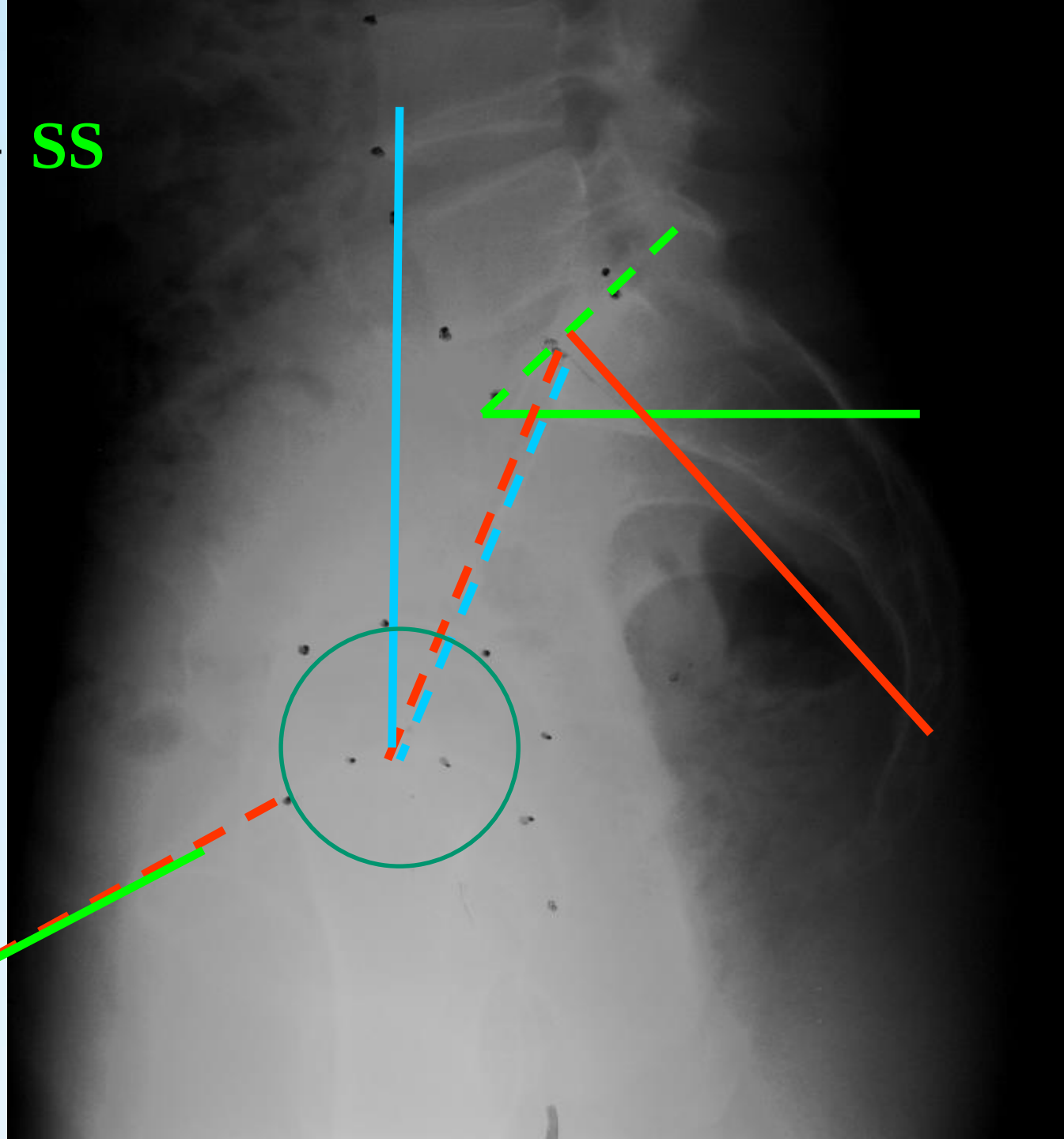
Better compensation




LL
PI
LL
PI

P = PT + SS

I



Spine Publish Ahead of Print
DOI: 10.1097/BRS.0b013e31823e15e2

Schwab et al. SPINE 2011

SRS-Schwab Adult Spinal Deformity Classification: A Validation Study

Curve types

T Thoracic only
with lumbar curve < 30°

L TL / Lumbar only
with thoracic curve <30°

D Double Curve
with at least one T and one TL/L, both > 30°

S Sagittal Deformity
for coronal curve <30° AND moderate to severe modifier(s)

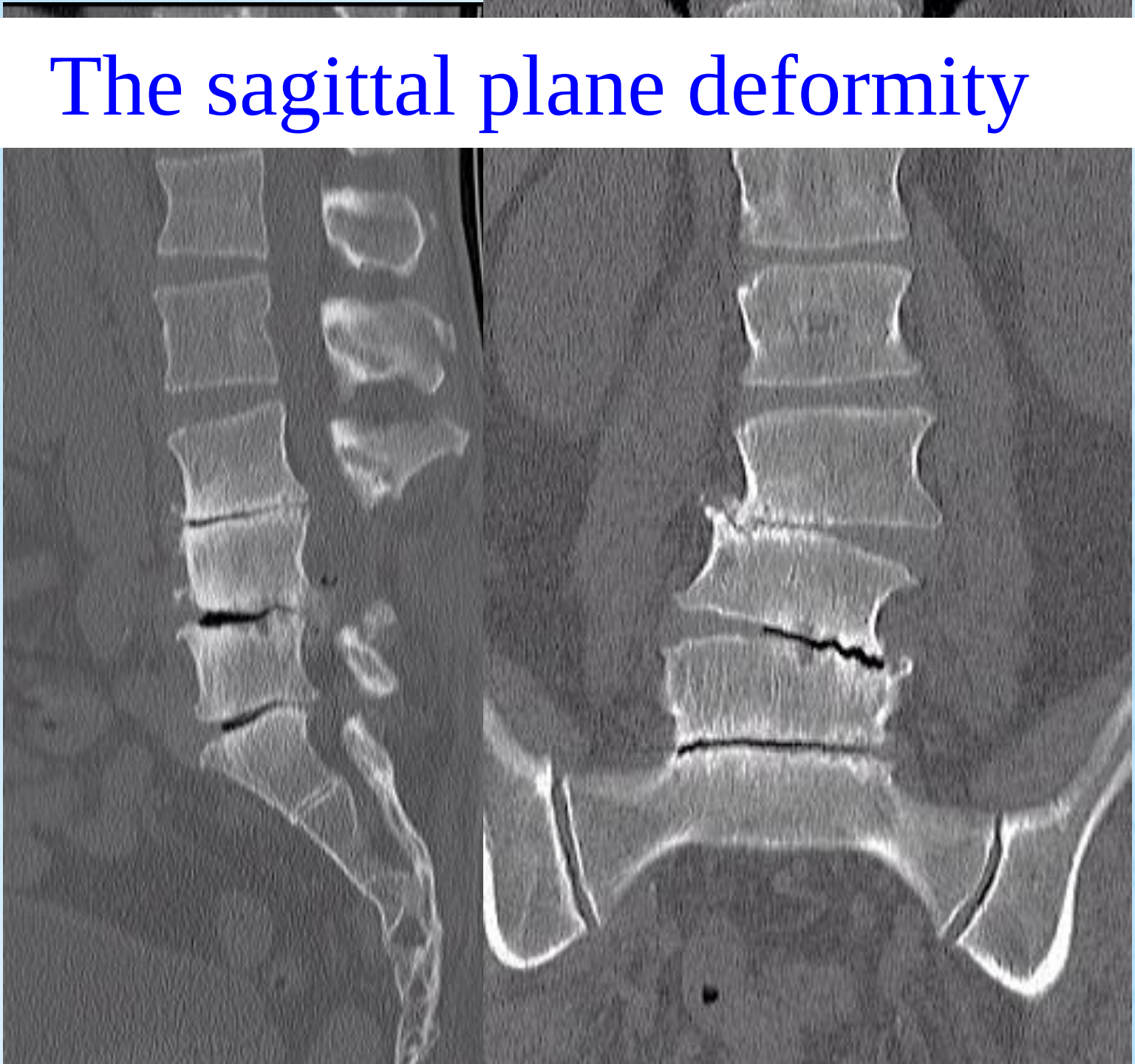
Modifiers

PI minus LL
A : within 10°
B : moderate 10-20°
C : marked >20°

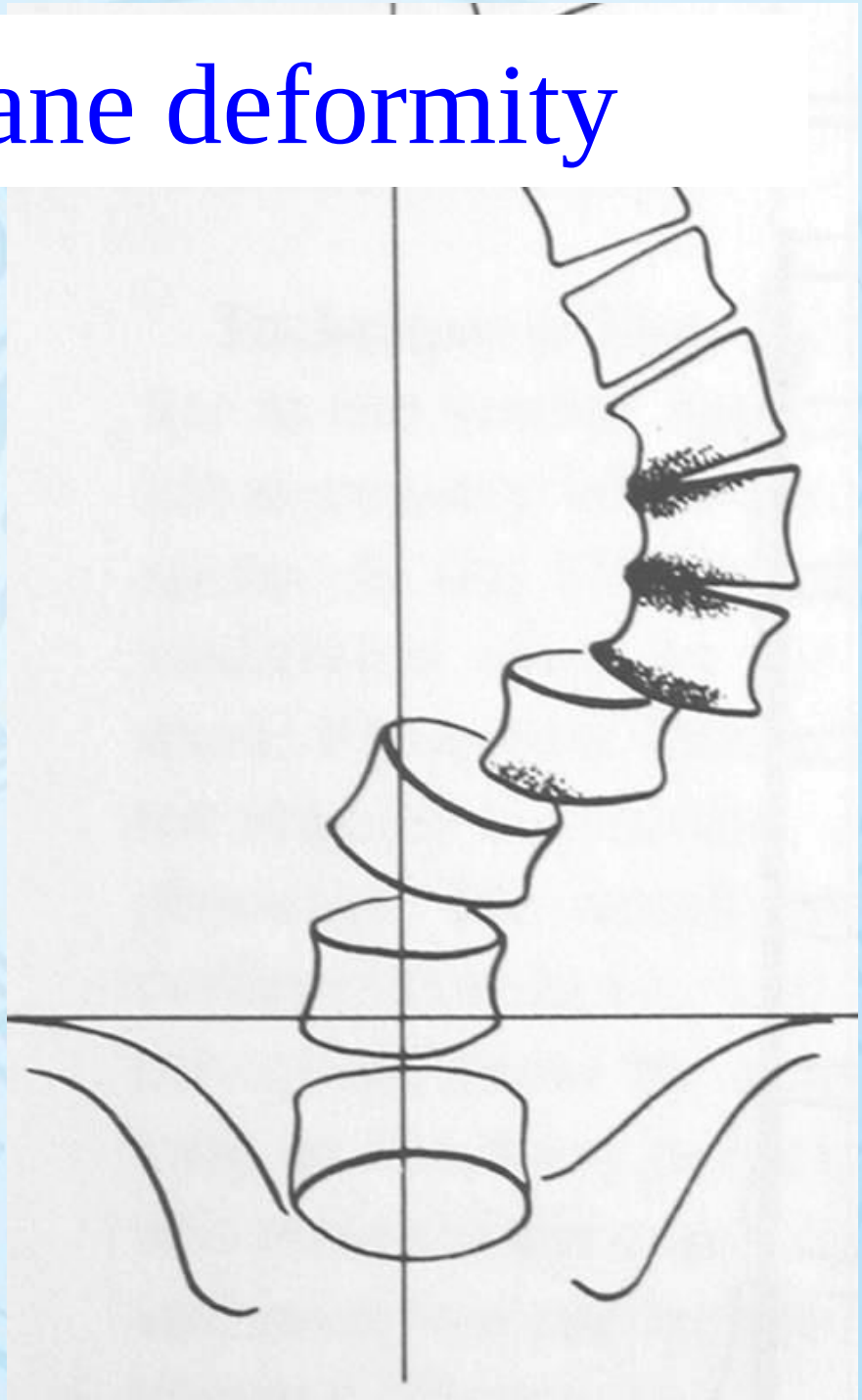
Pelvic Tilt
L : PT<20°
M : PT 20-30°
H : PT>30°

Global Balance
N : SVA < 4cm
P : SVA 4 to 9.5cm
VP : SVA > 9.5cm

The sagittal plane deformity



The coronal plane deformity



Spino-pelvic pathology patterns

Progressive kyphosis

↓

Gravity line drifts forwards

↓

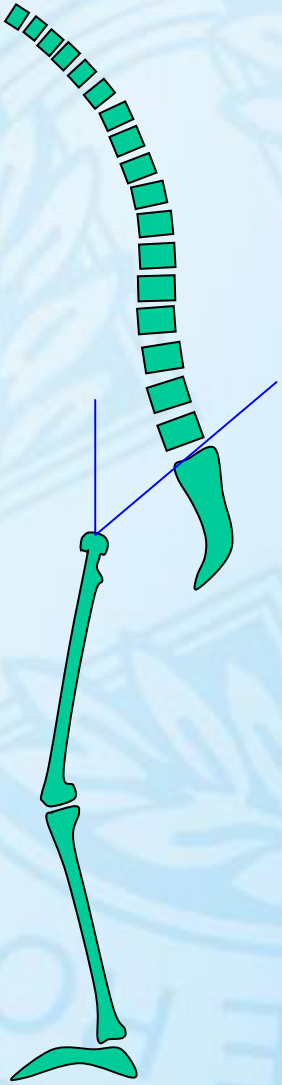
Pelvis rotates backwards

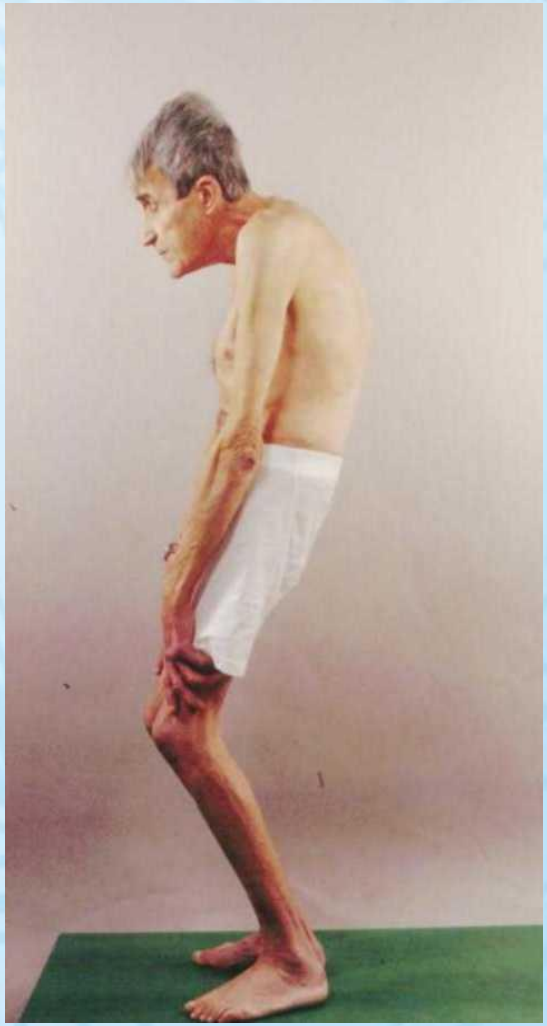
↓

Sacral slope decreases

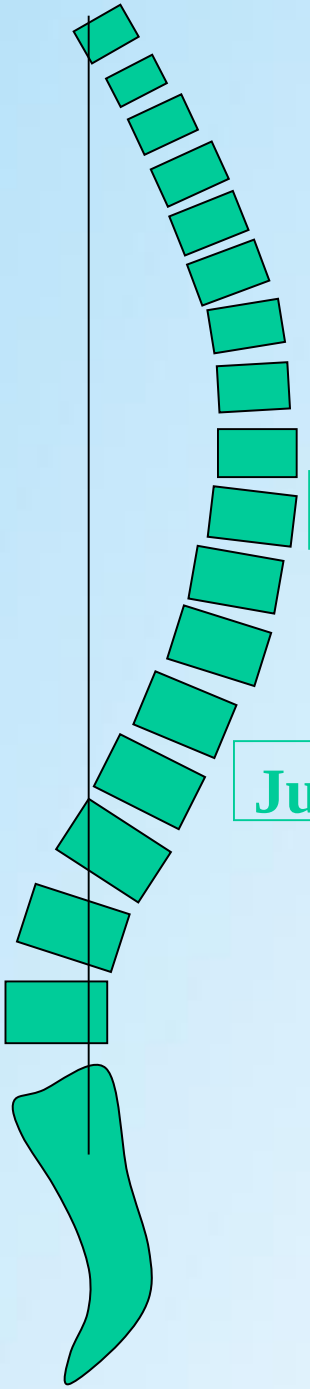
↓

Knee flexion



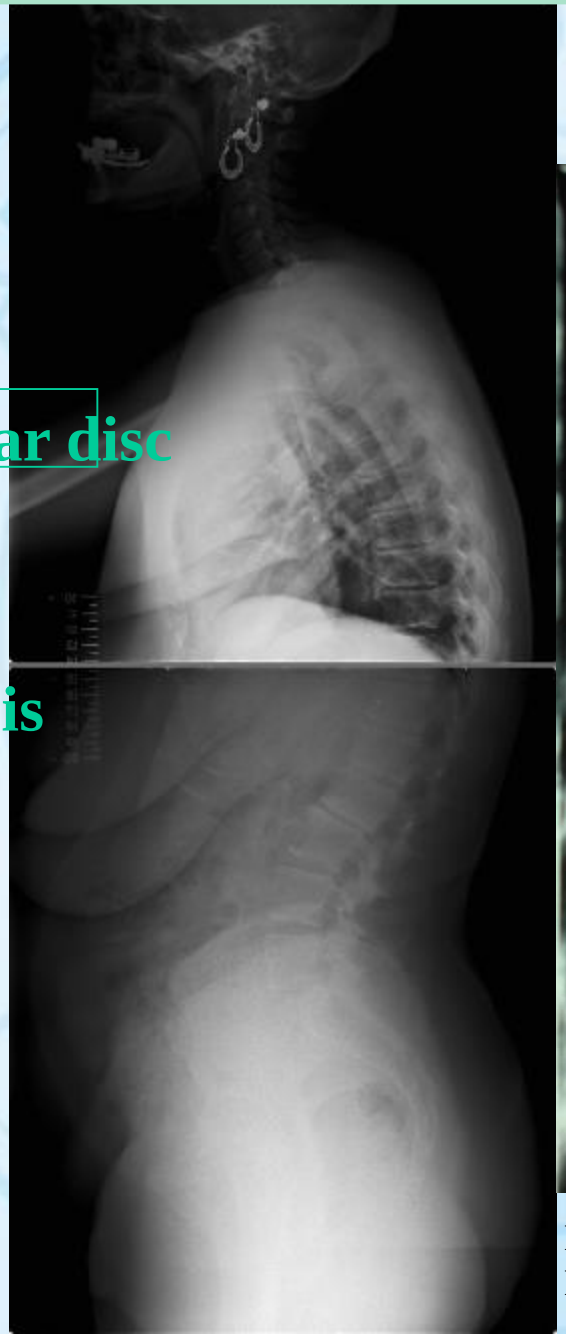


Type 1: Non-harmonious spine



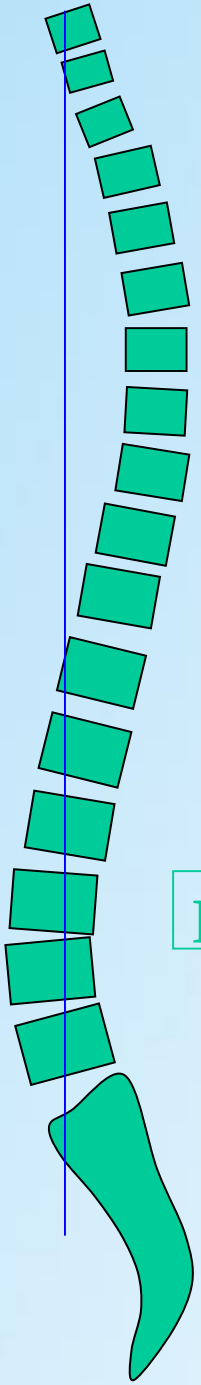
Thoraco lumbar disc

Junctional listhesis

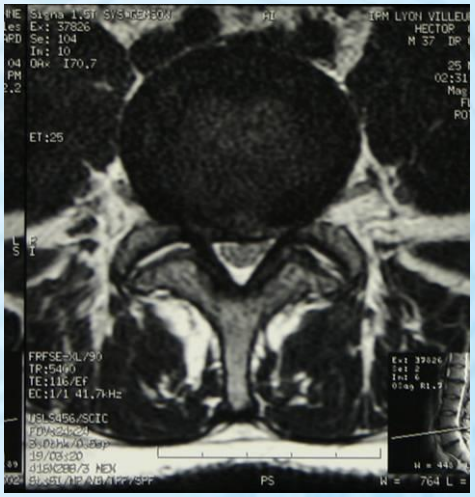


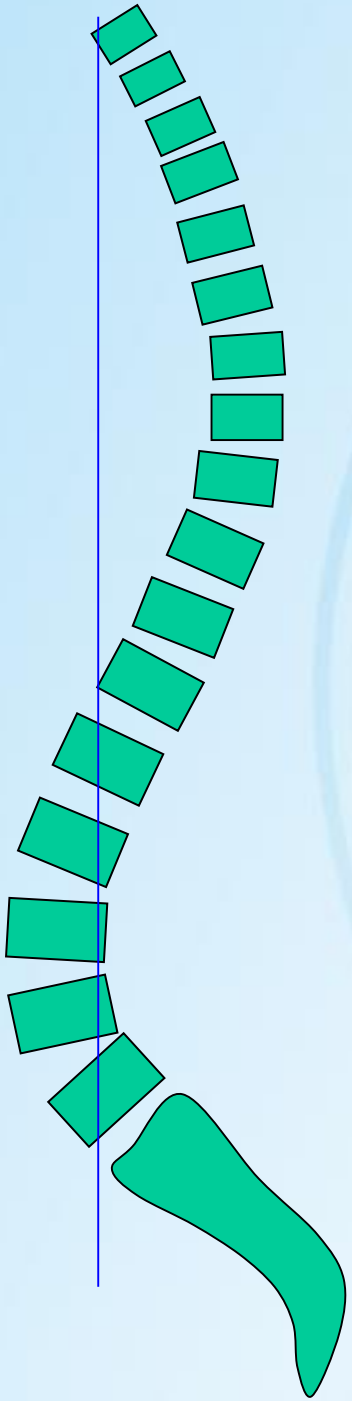
Eurospine 2007
Bruxelles

Type 2: Harmonious but Flat Back



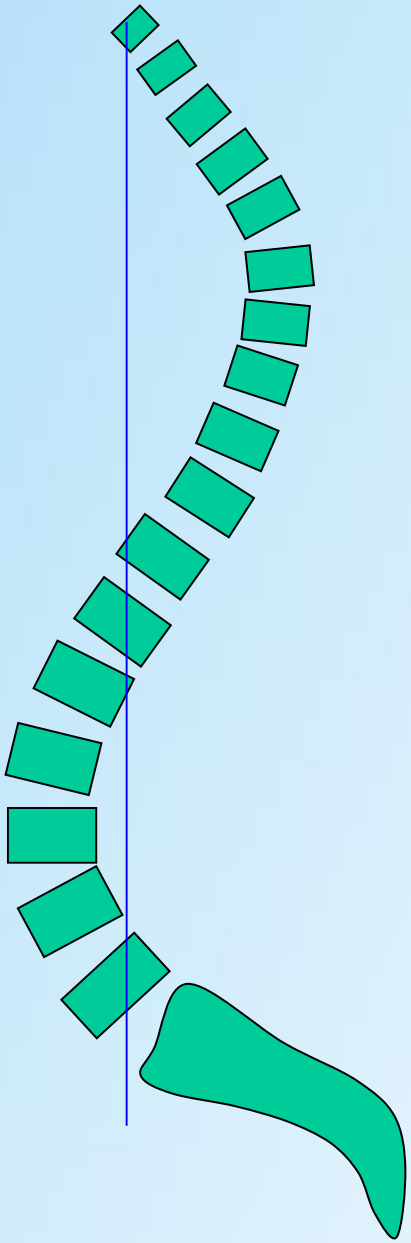
Early disc degeneratic





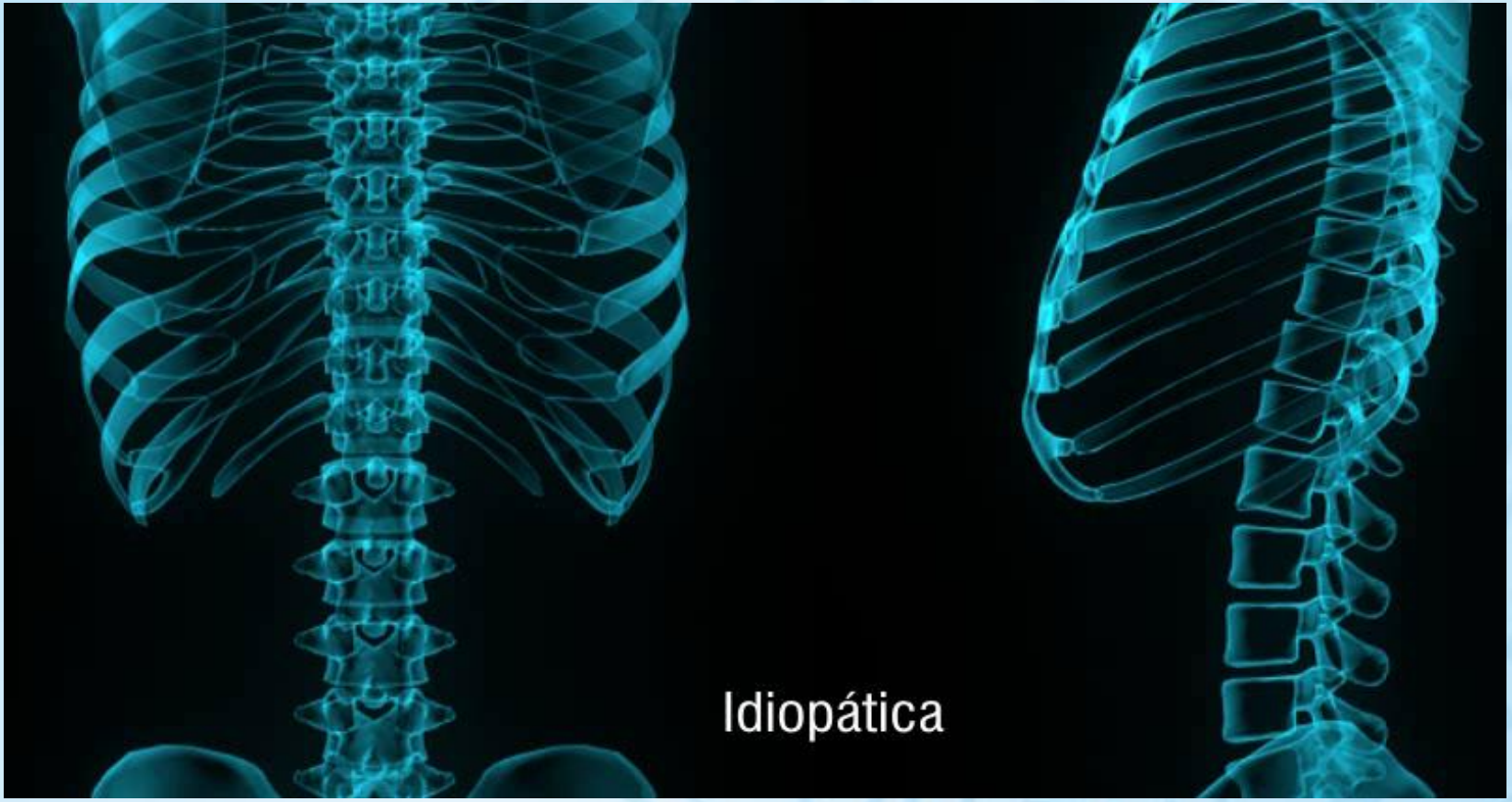
Type 3:The most harmonious ("probably a good back")

Type 4: Harmonious but hyper-curved.

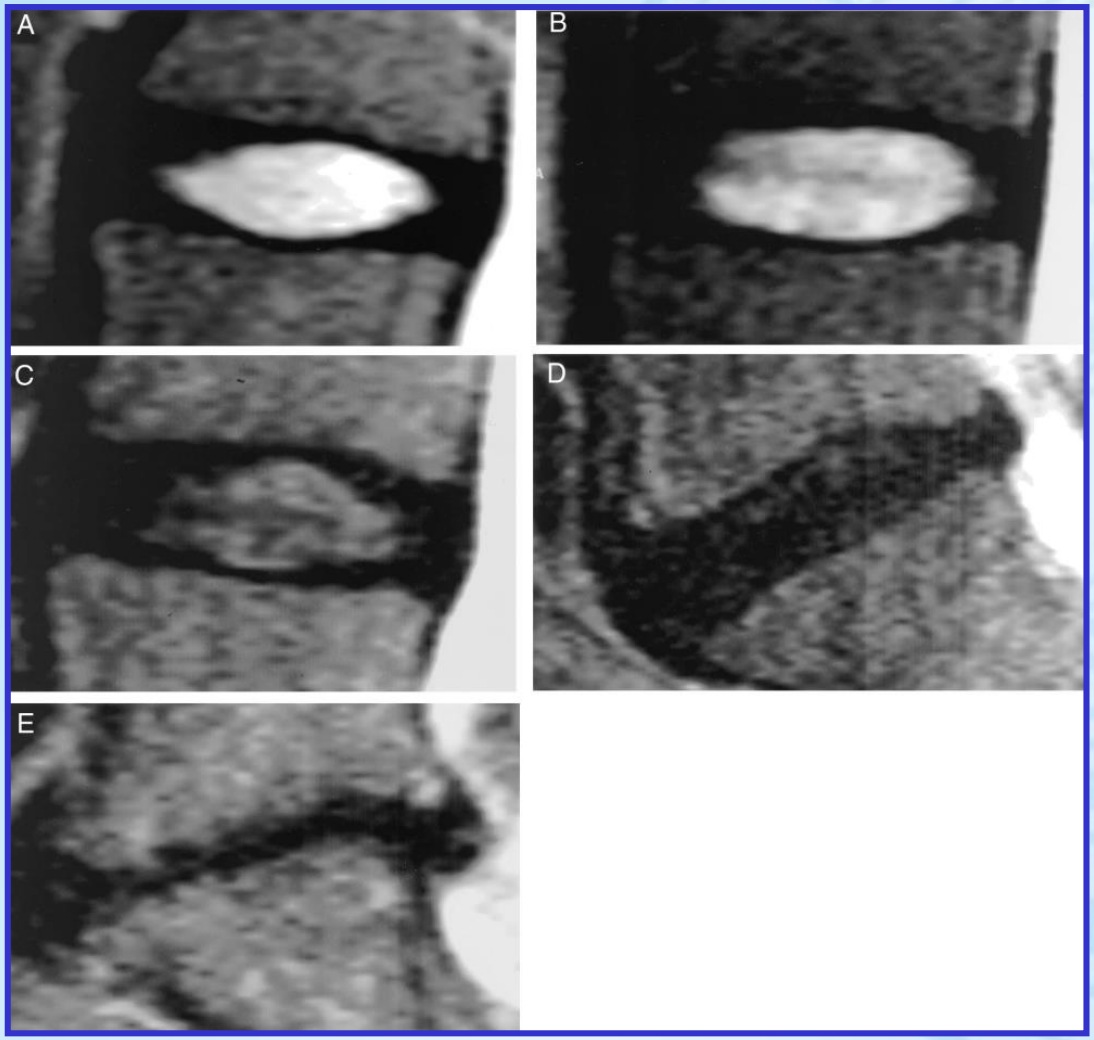


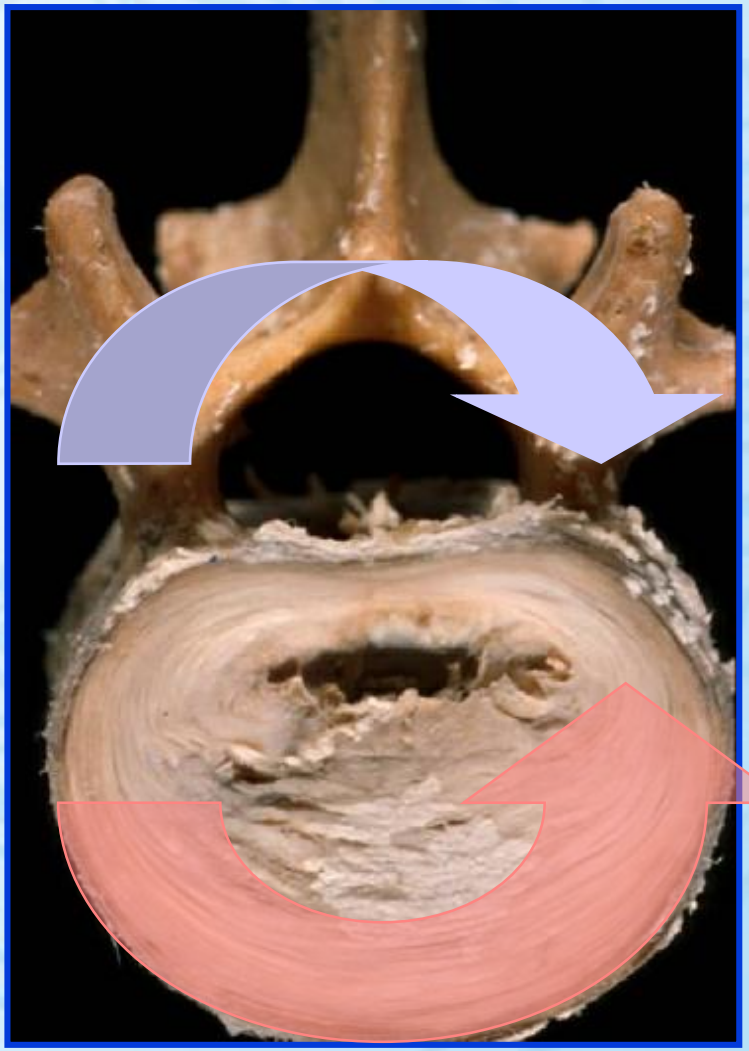
- When young: very strong
  - High PI
  - Good lordosis
- With aging
  - will lose lordosis
  - pelvic tilt increases to compensate for anterior imbalance

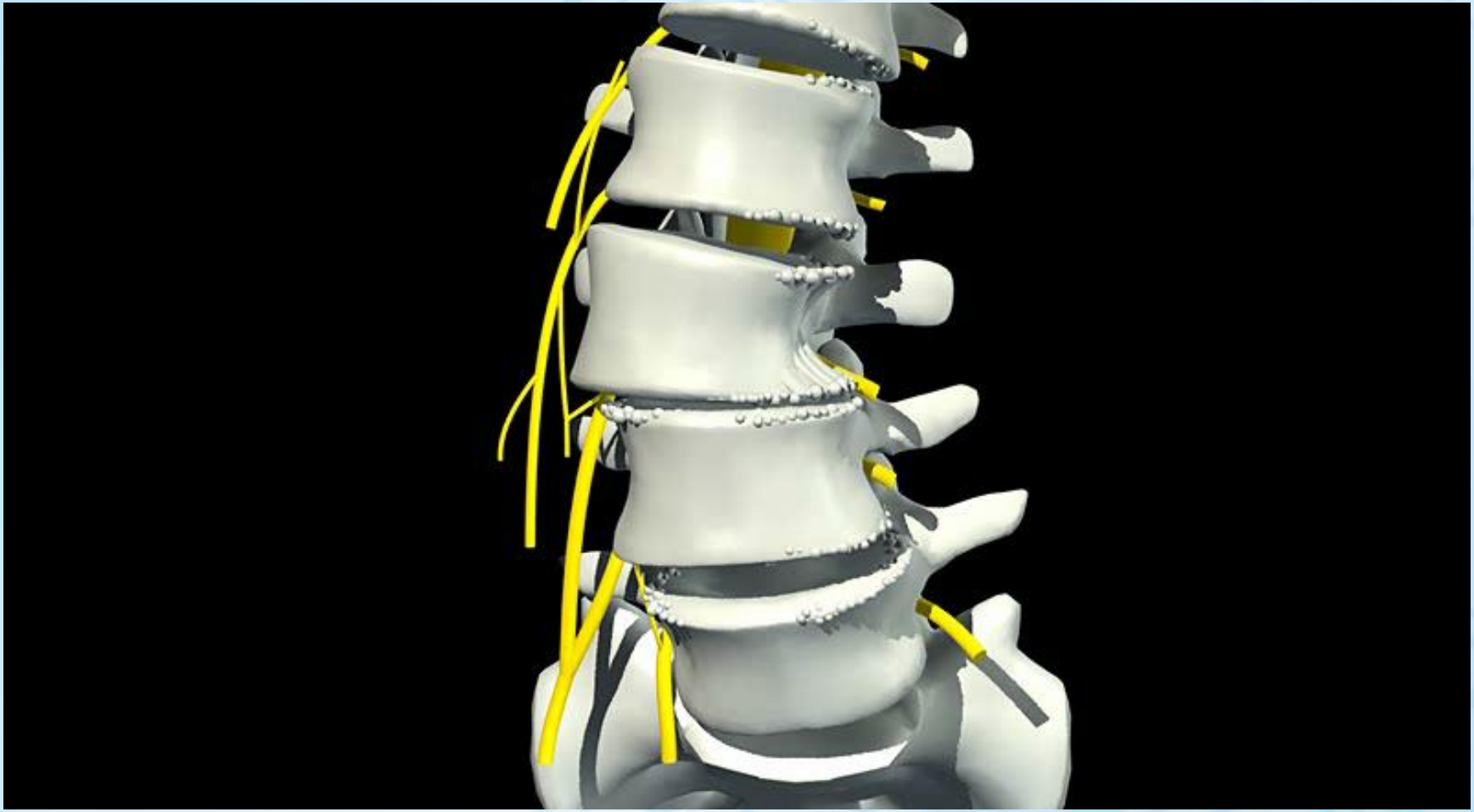
Lumbar stenosis + spondylolisthesis


Idiopática

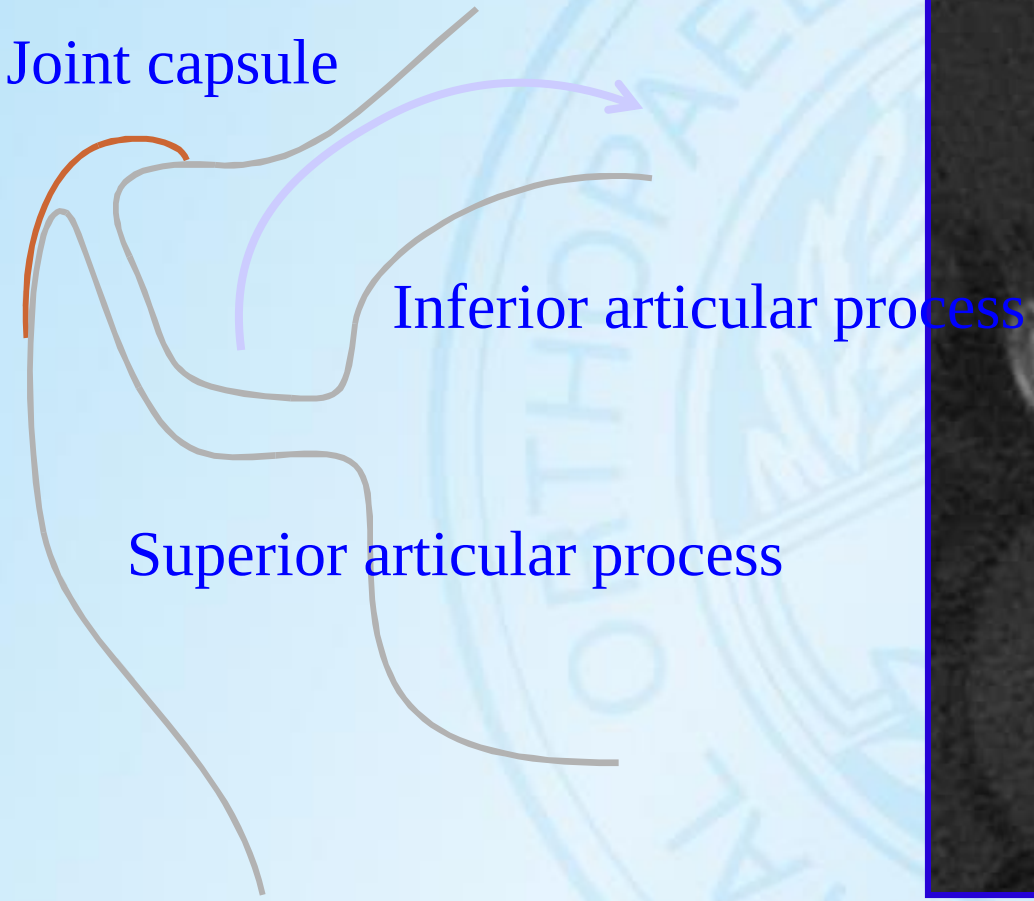
Disc degeneration

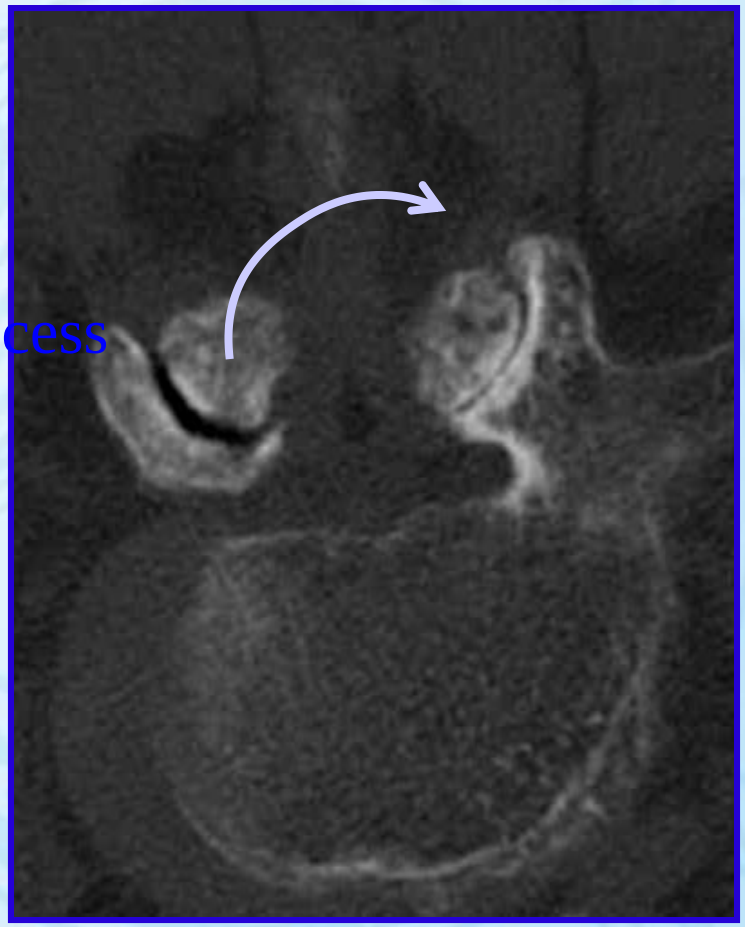






Facet joint changes

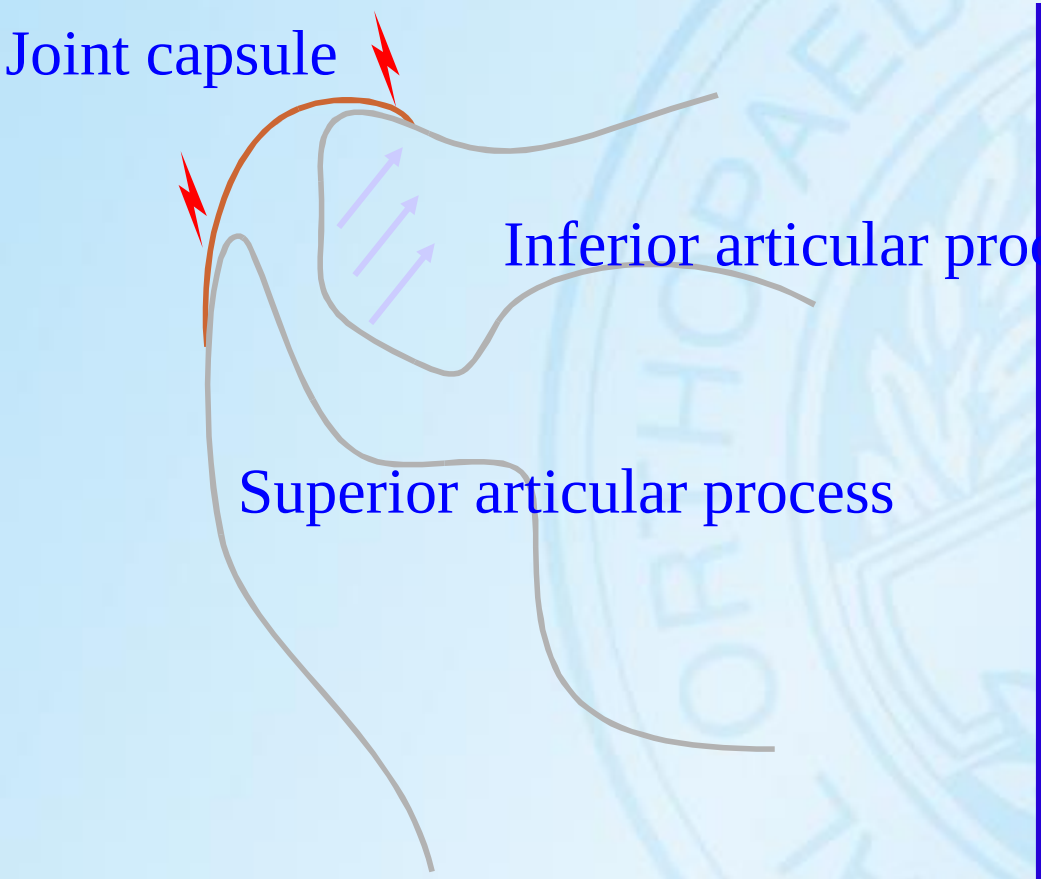


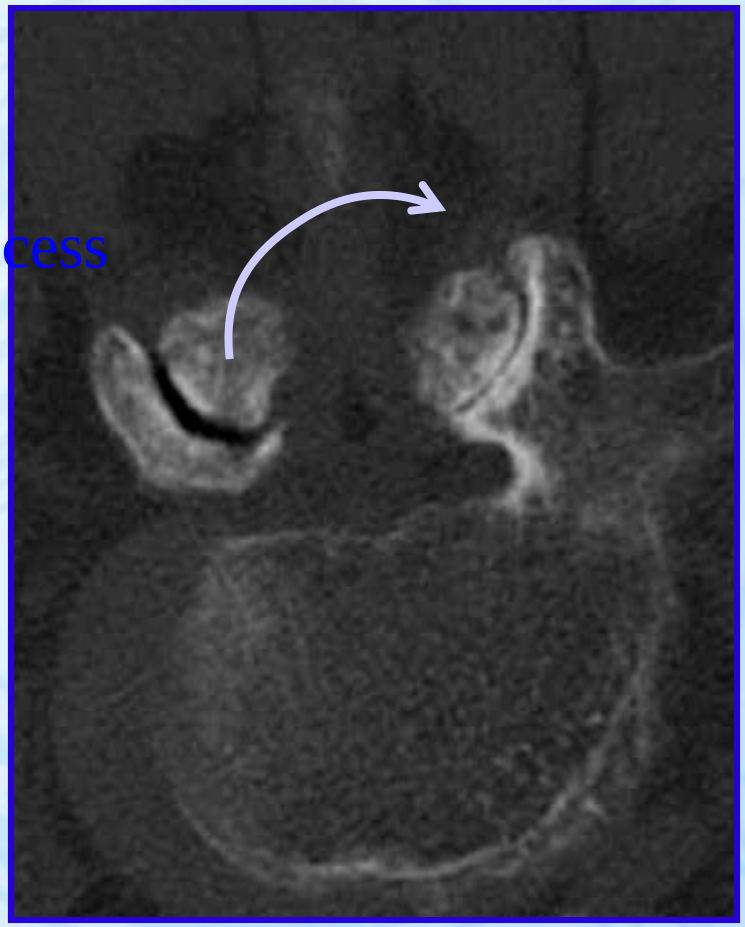


Increased axial rotation in disc degeneration

Courtesy Bronek Boszczyk

Facet joint changes

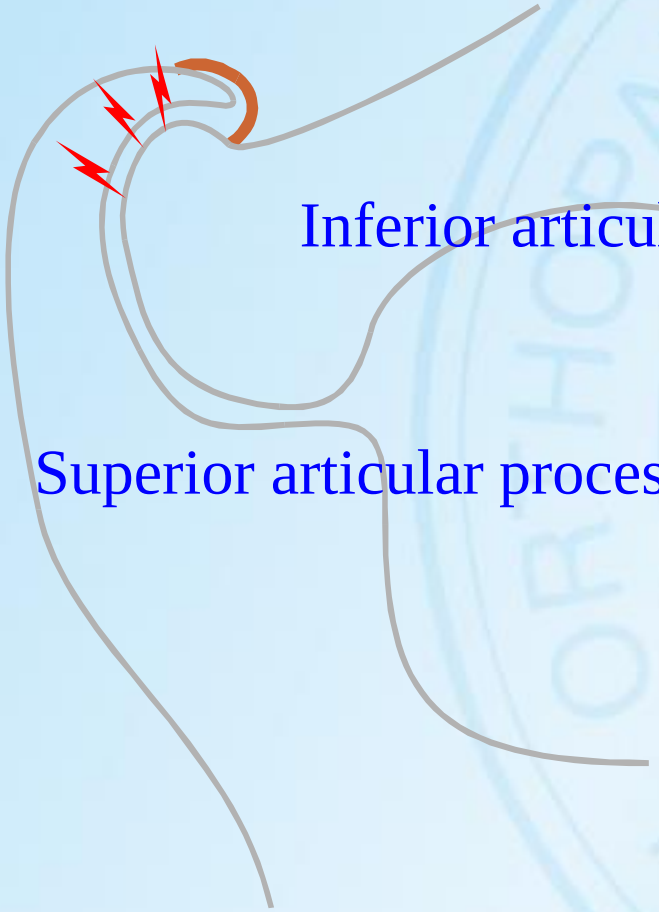




Increased axial rotation in disc degeneration results in shear of the enthesis and direct pressure upon the capsule

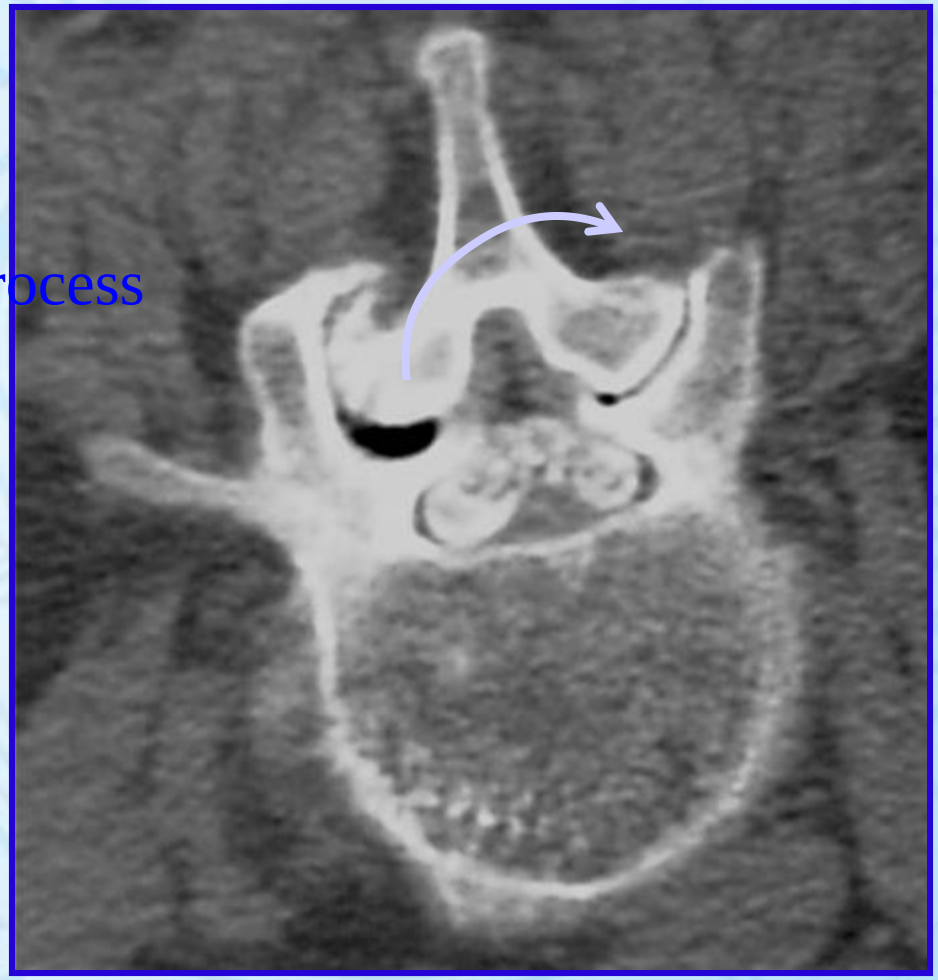
Courtesy Bronek Boszczyk

Facet joint changes



Inferior articular process

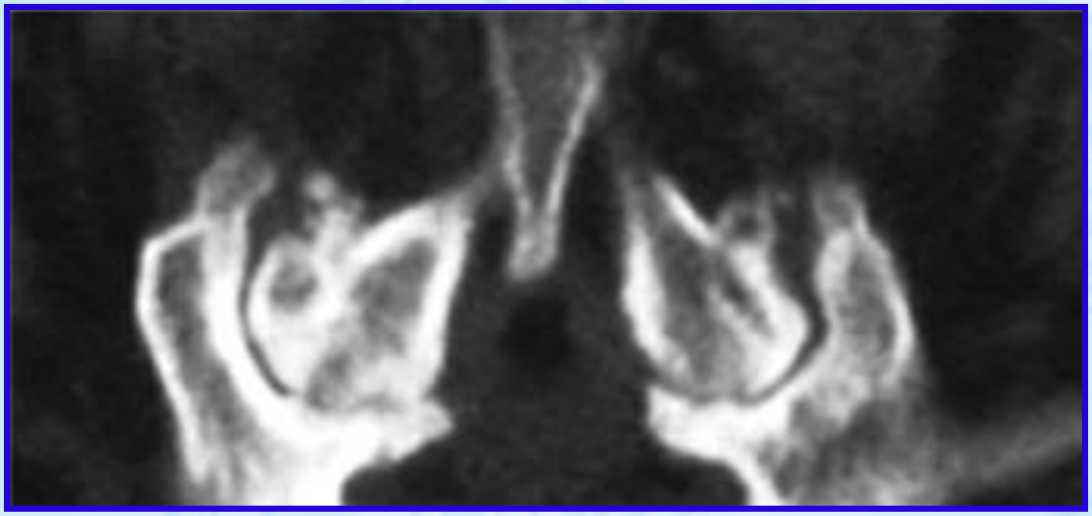
Superior articular process



Encompassing joint formation develops through direct contact of enthesophytes in advanced degeneration

Courtesy Bronek Boszczyk

Facet joint changes



In contrast to other joints, reactions of the joint capsule / enthesis are seen before permanent cartilage damage

Early restoration of disc biomechanics may prevent progression to stage of permanent damage

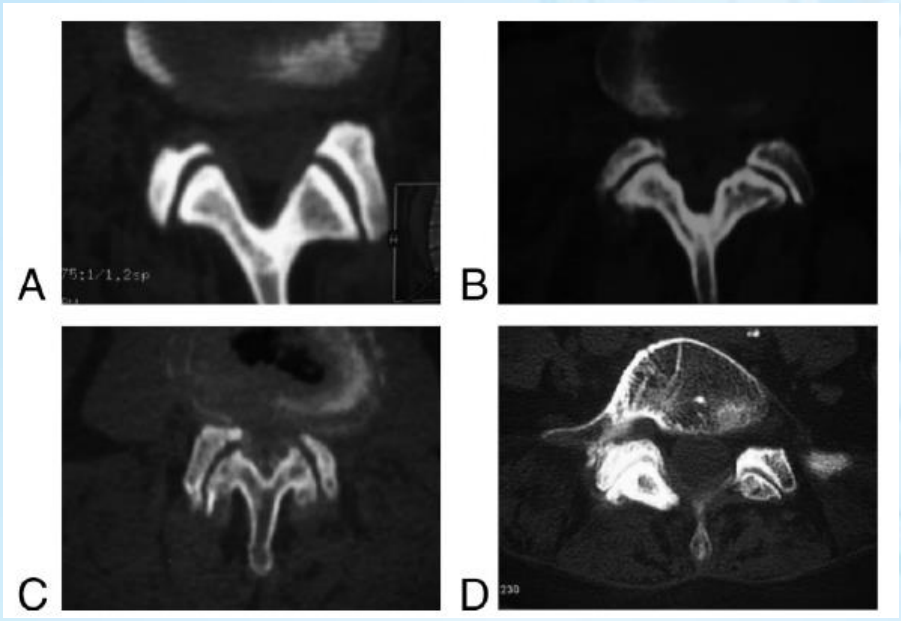
Vernon-Roberts & Pirie Rheumatol Rehabil 1977
Fujiwara et al. Eur Spine J 1999

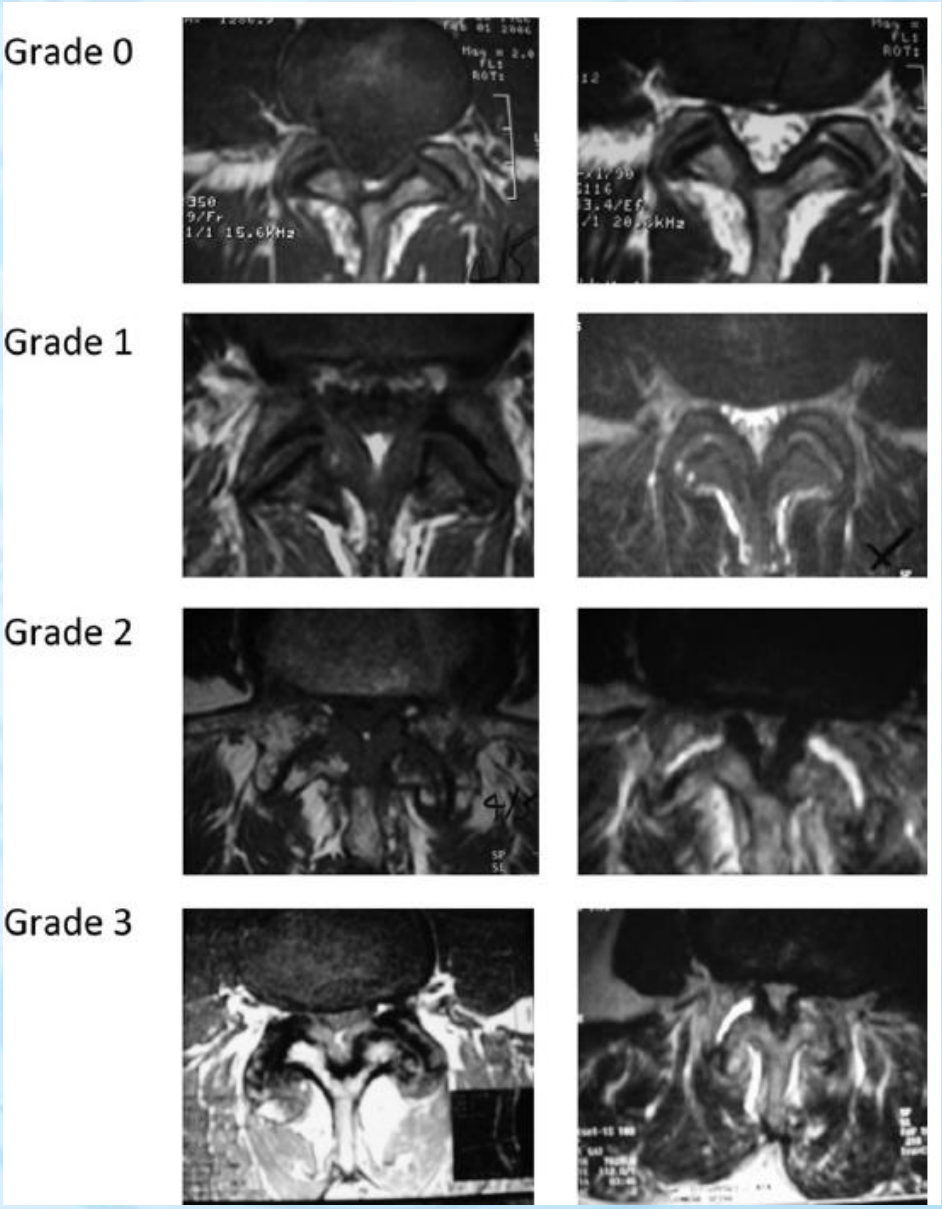
Courtesy Bronek Boszczyk

Facet joint degeneration

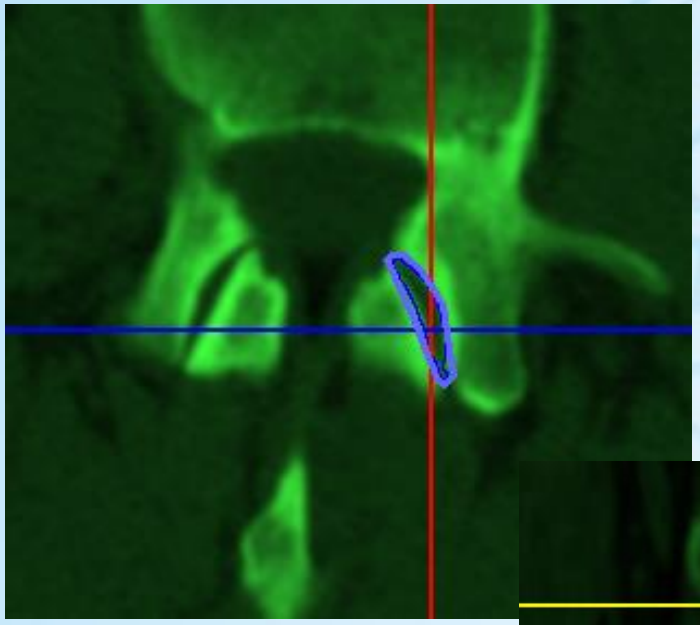
The Royal Orthopaedic Hospital NHS
NHS Trust

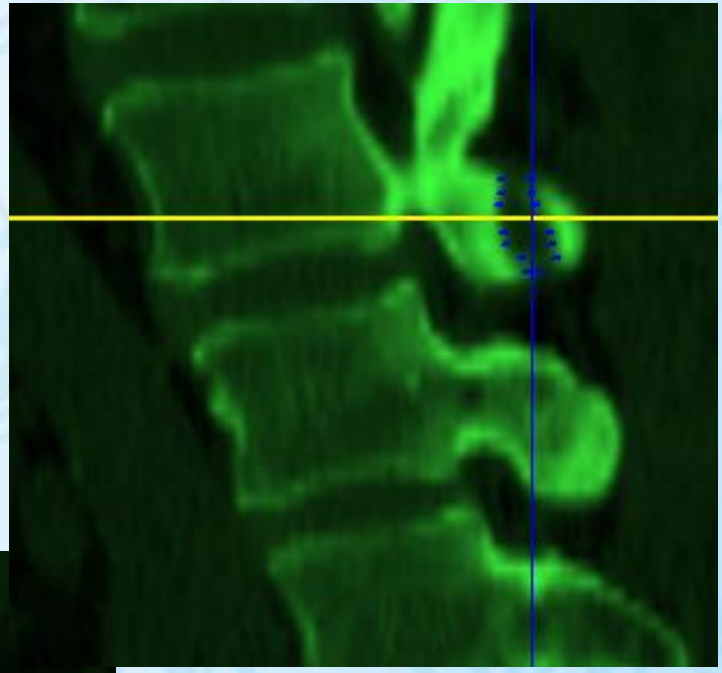
- Joint width
- Articular erosions
- Sub-chondral sclerosis
- Osteophytes

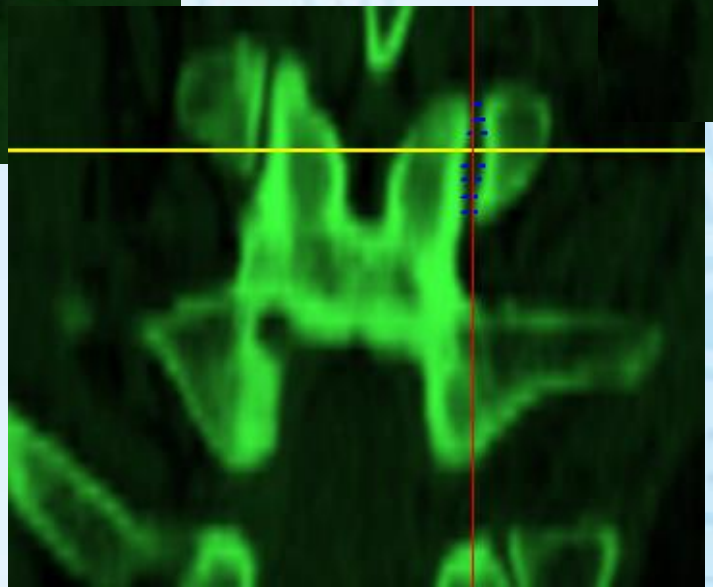




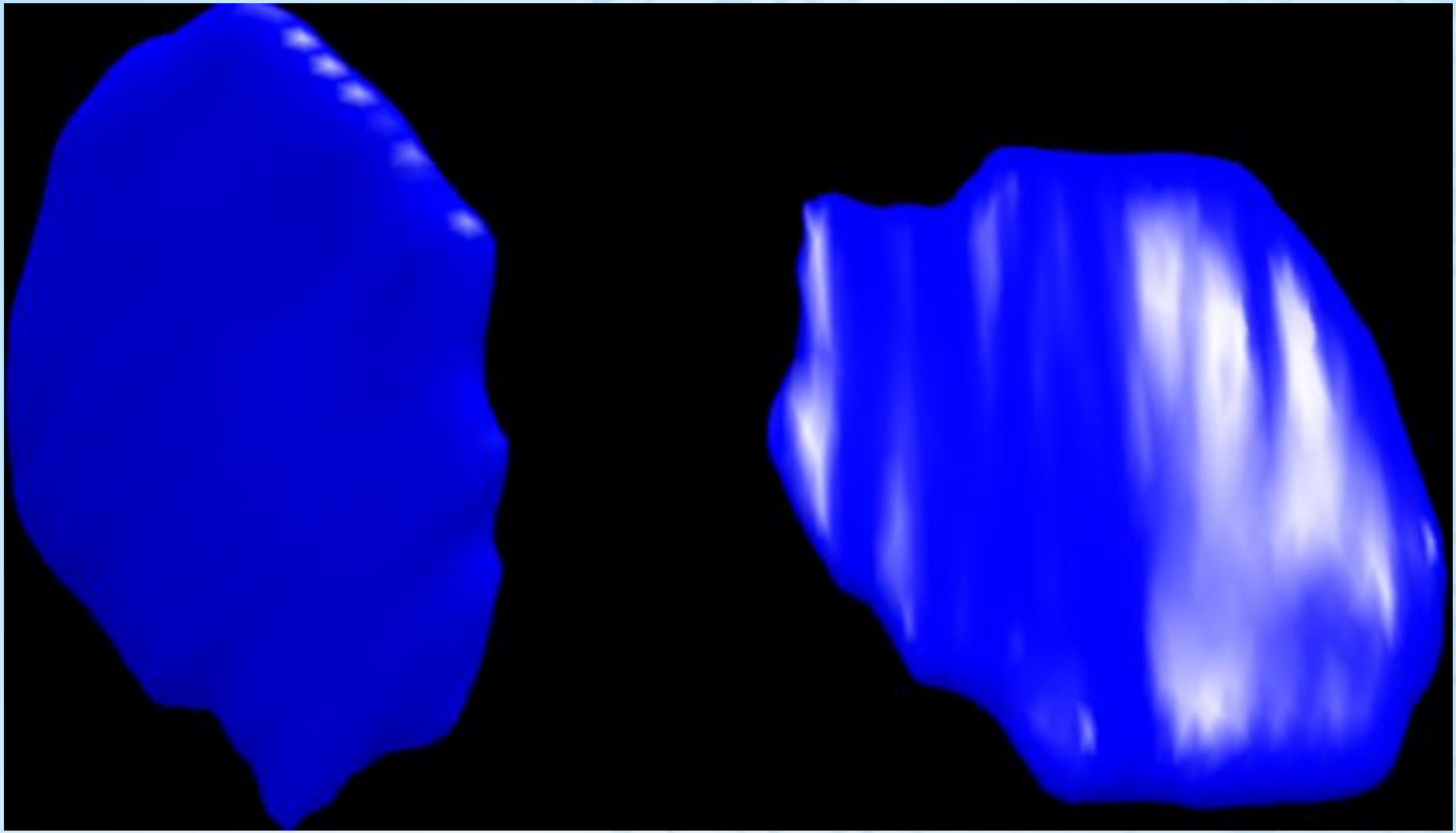
Facet joint changes







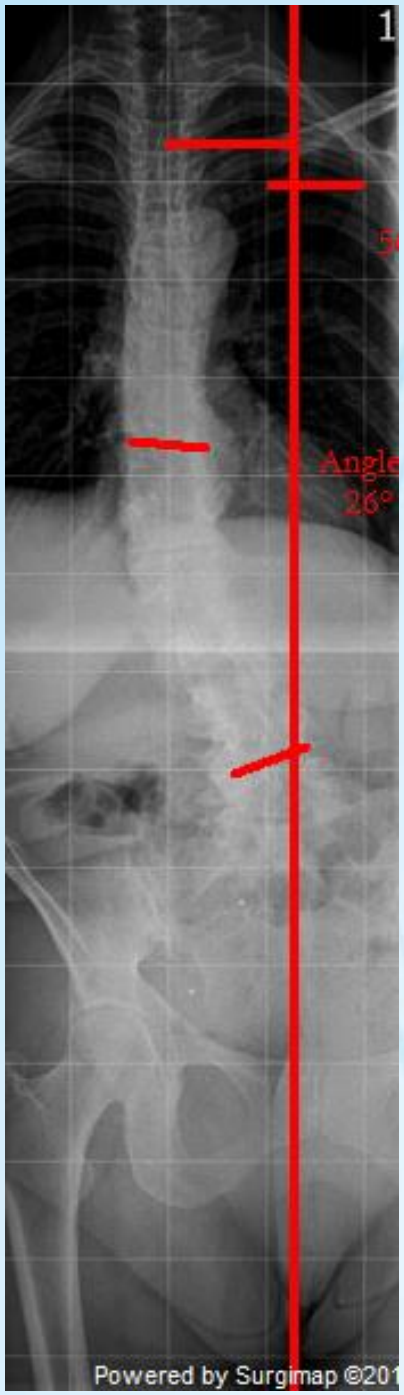
Two views of a typical facet joint contact space *object (for a normal spine)*

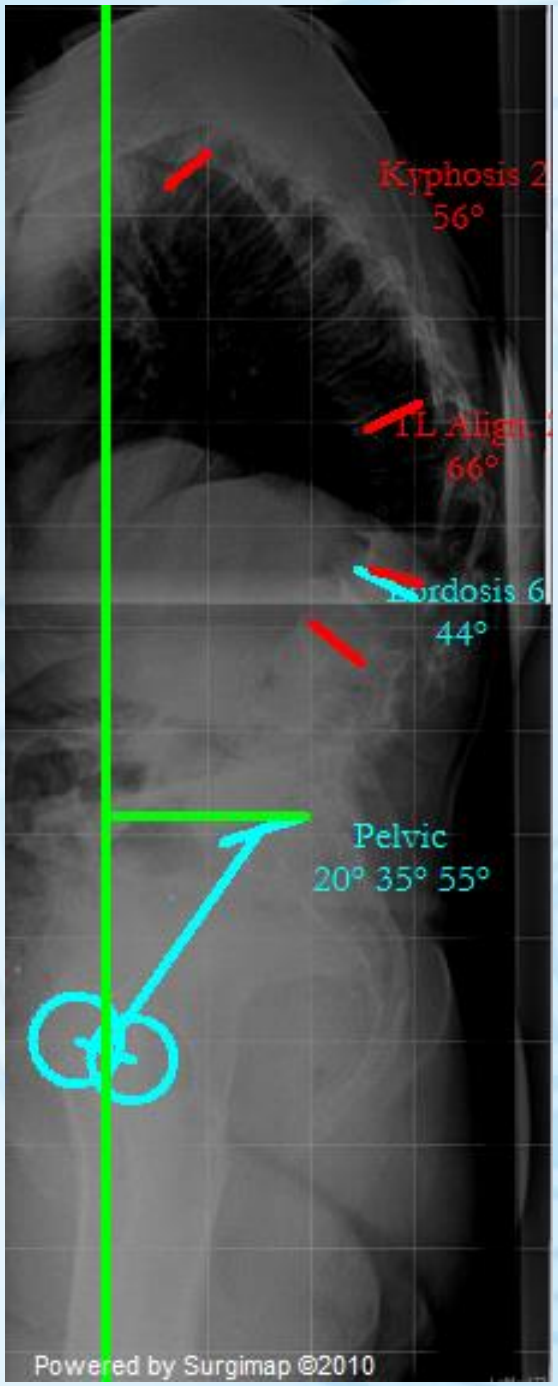


Volume (mm^3)	Surface area (mm^2)
309.50	404.25


Surface area of the facet joint contact space (mean ± stdev)
Surface area (mm2)
0
200
400
600
800
1000
1200
1400
L1-2-R
L1-2-L
L2-3-R
L2-3-L
L3-4-R
L3-4-L
L4-5-R
L4-5-L
L5-S1-R
L5-S1-L


Volume of the facet joint contact space (mean ± stdev)
Volume (mm3)
0
200
400
600
800
1000
1200
1400
L1-2-R
L1-2-L
L2-3-R
L2-3-L
L3-4-R
L3-4-L
L4-5-R
L4-5-L
L5-S1-R
L5-S1-L





59 / F

AP Cobb 26º

CSL 7 cm

Pelvic:

PI 55º

SS 20º

PT 35º

LL 44º

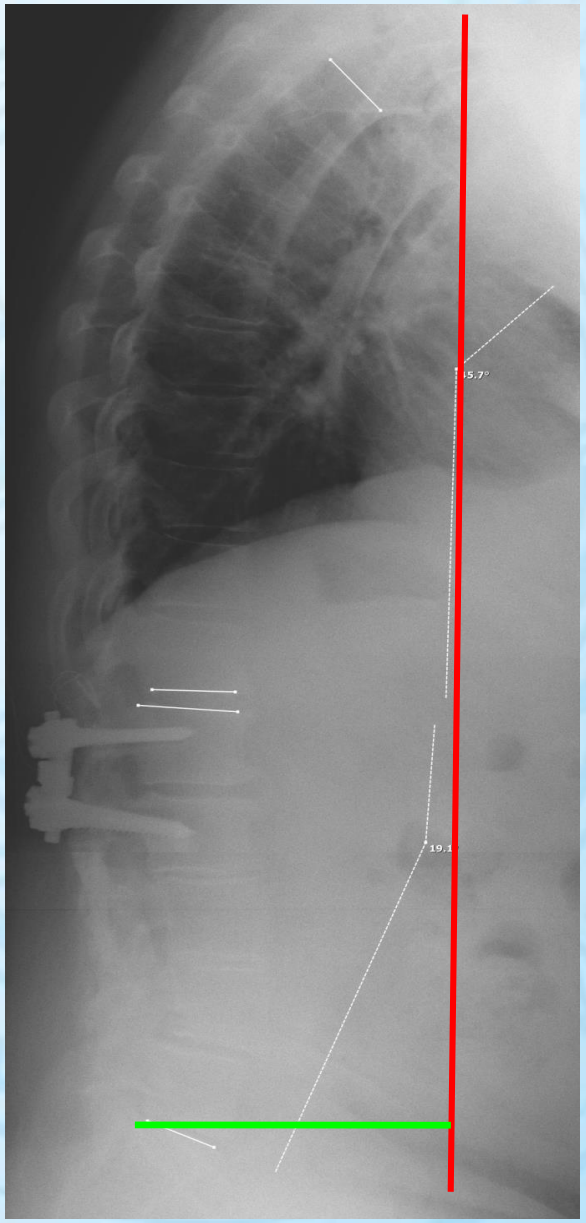
TL 66º

TK 56º

SVA 11 cm

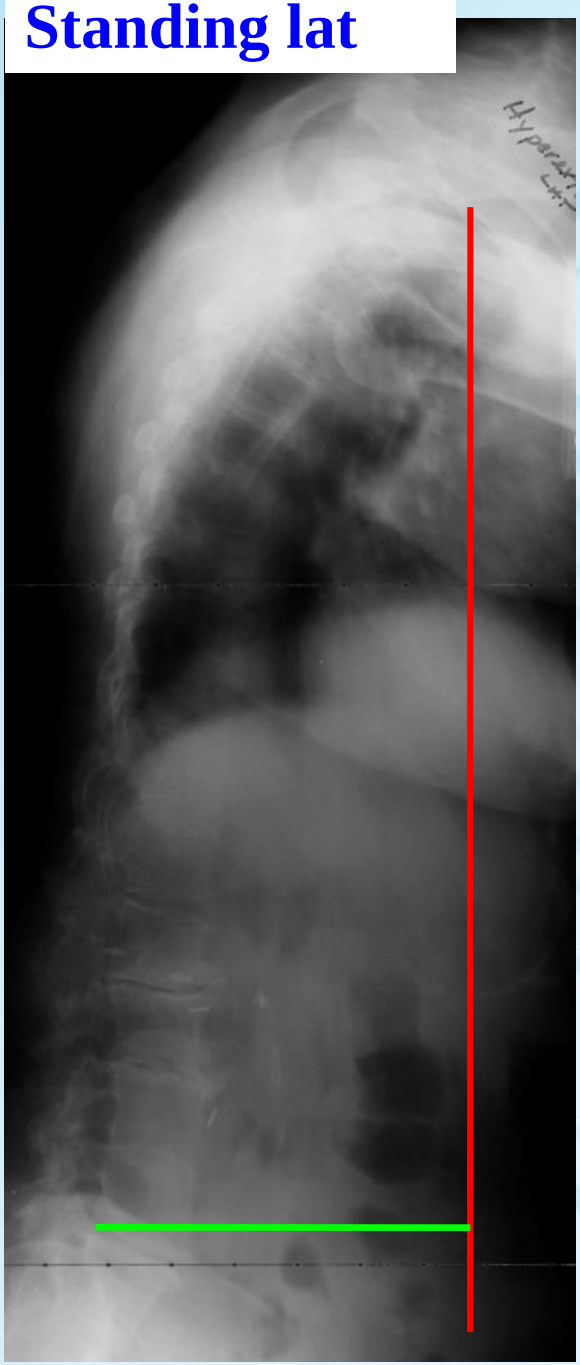
Clinical effects of plumb-line shifts

Glassman, Bridwell et al. Spine 2005



Fixed or flexible sagittal deformity

Standing lat



Hyperext lat

Aim 1: achieve fusion

- Good pain relief; 69 – 87%

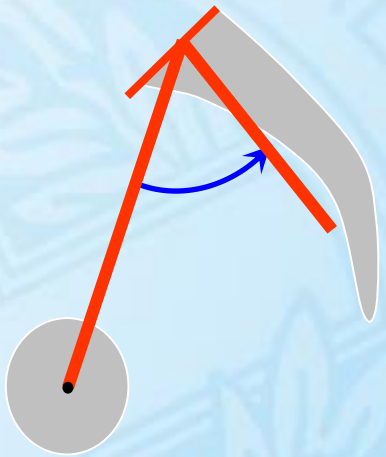
  Kostuik Clin Orthop 1973

  Swank JBJS Am 1981

- Improvement in the lumbar lordosis

- Anterior column load sharing

Aim 2: adaptation of lordosis



- Excise facet joints
- ‘Open’ degenerate disc spaces
- Measure the PI, and build in the lordosis

$LL = PI \pm 9^0$

Adult Deformity: Surgical goals

- Normalize & balance contours
- Fuse the least number of segments
- Neural decompression
- Obtain solid biological fusion

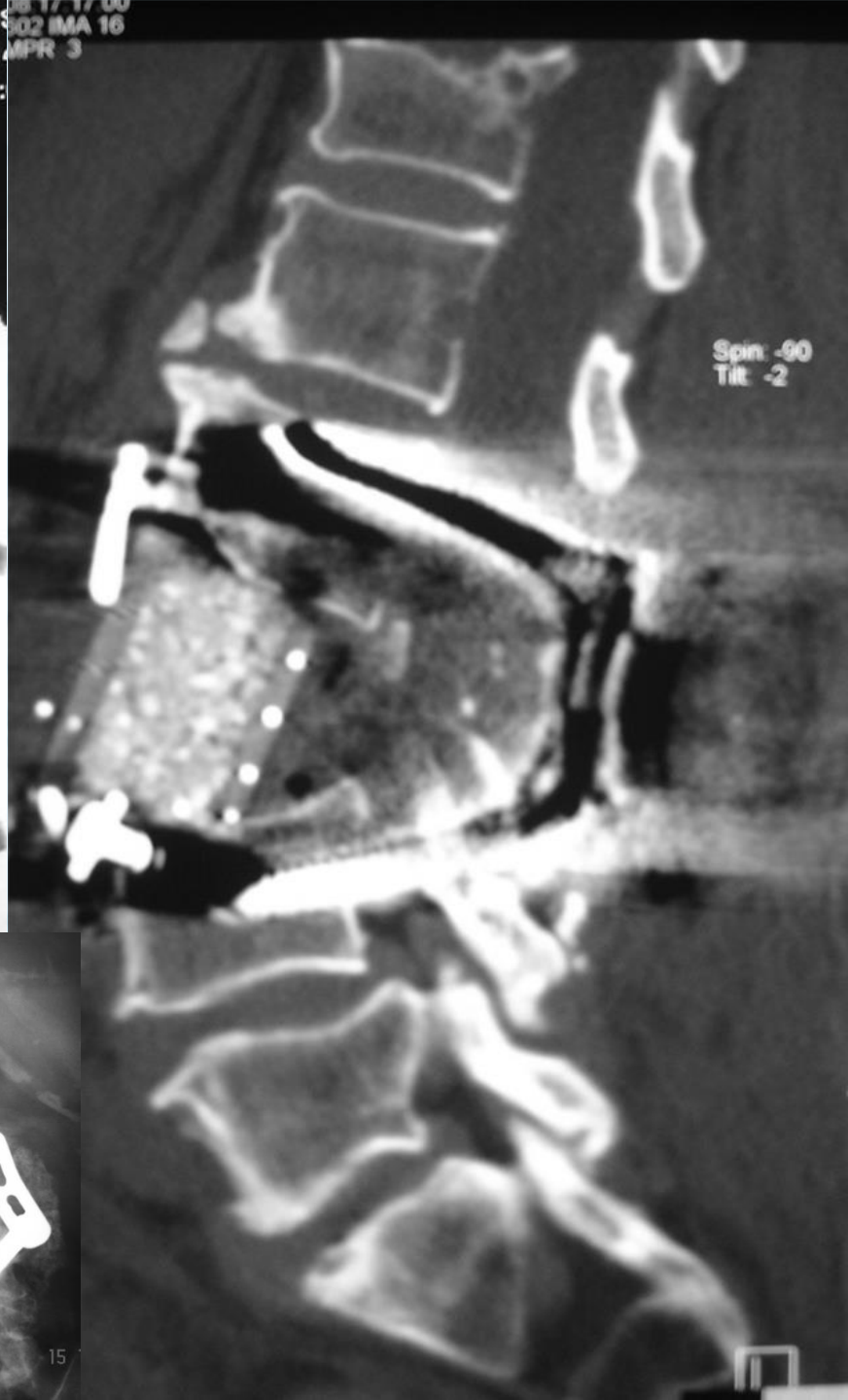
Adult Deformity: principles of surgery

The Royal Orthopaedic Hospital NHS NHS Trust

- Traction + erect full spine films
- Measure parameters
- Levels to instrument
- Levels to decompress
- Anterior column management


EXIT
EXIT
MM
86Y


COLUMBIA REGIONAL HOS
09/1
2:48:


Spin -90
Tilt -2

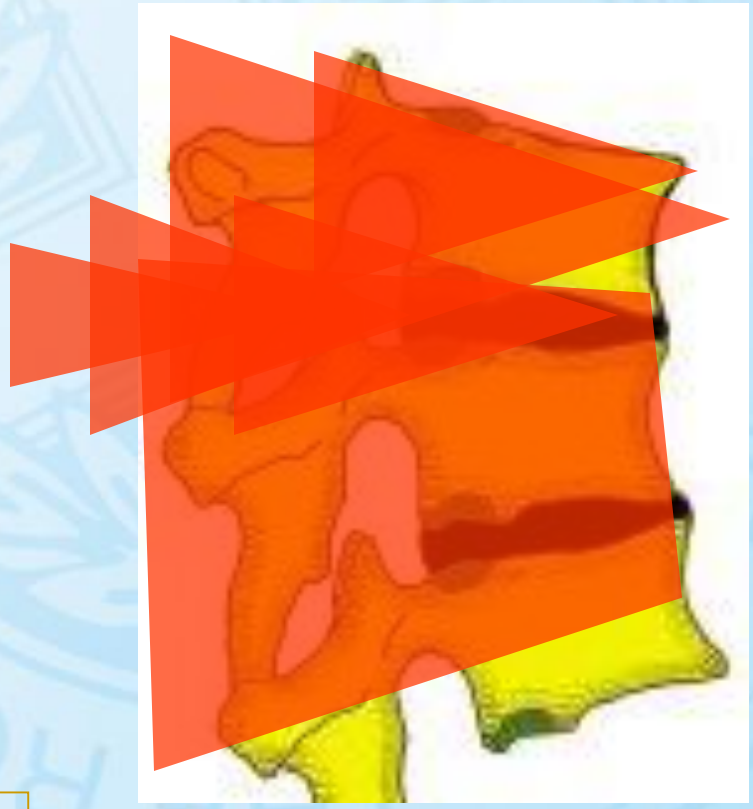

18 1:54PM


The Royal Orthopaedic Hospital NHS
NHS Trust

Advanced surgical strategies

Osteotomies

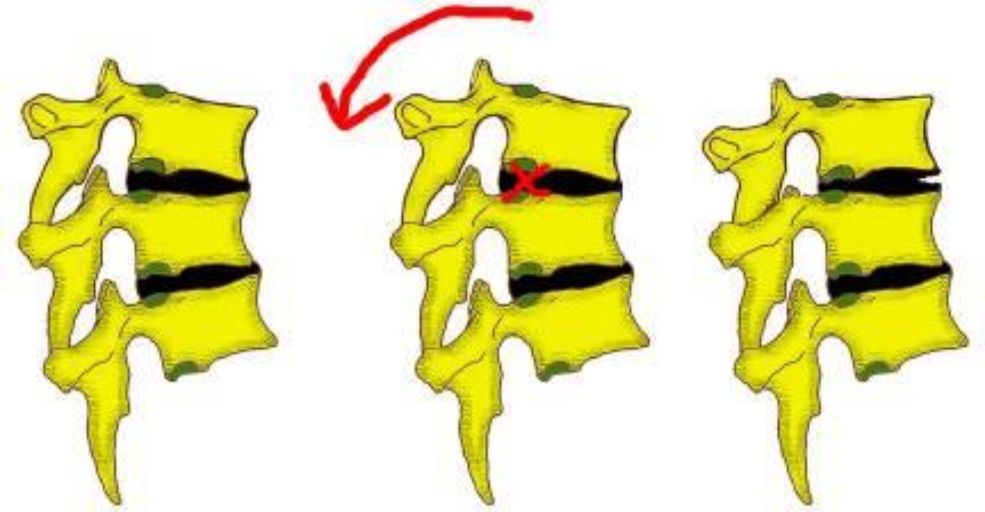
1. partial facet joint
2. complete facet joints
3. partial body#
4. partial body and disc #
5. complete body + discs #
6. >1 body, adjacent #

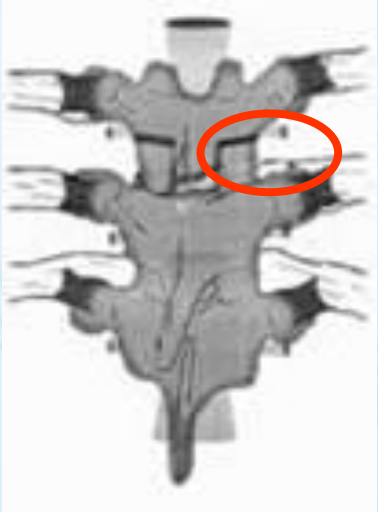


posterior vs. anterior/posterior

Courtesy Frank Schwab

Grade I - Partial Facet Resection



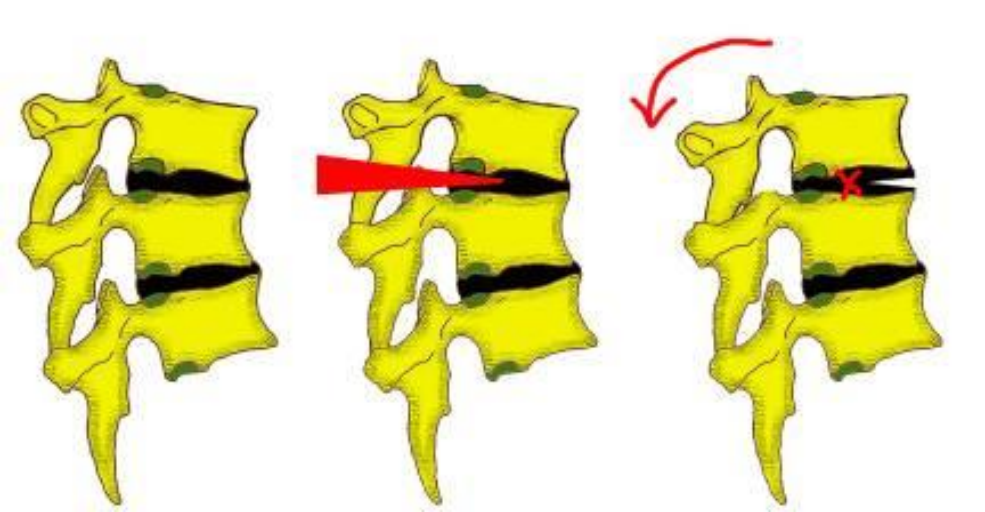


Best suited when anterior column flexibility

Inferior facet resection + capsule

Courtesy Frank Schwab

Grade II - Complete facetectomy



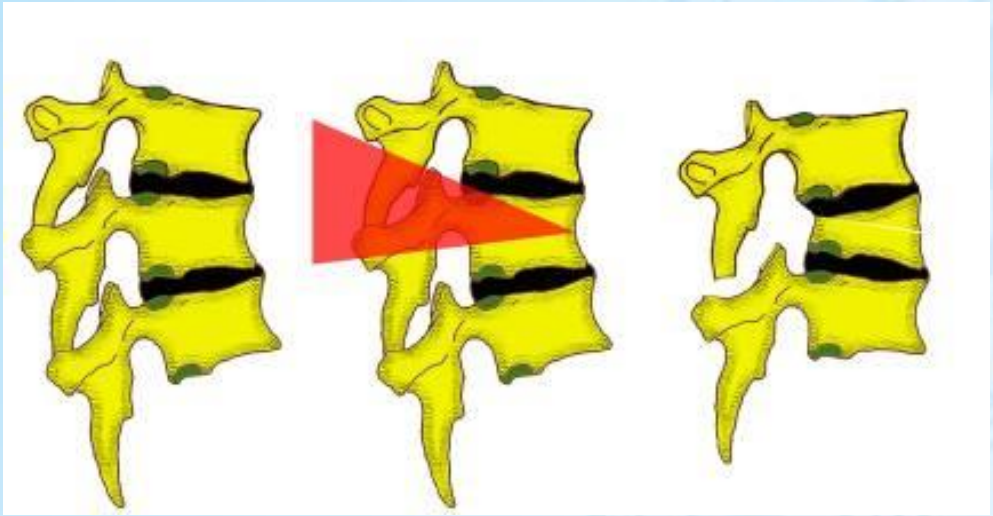
Anterior column mobility necessary

Superior and inferior facet resection

Spinous processes

Courtesy Frank Schwab

Grade III - Partial body resection



Most suited when >20˚ segmental correction needed

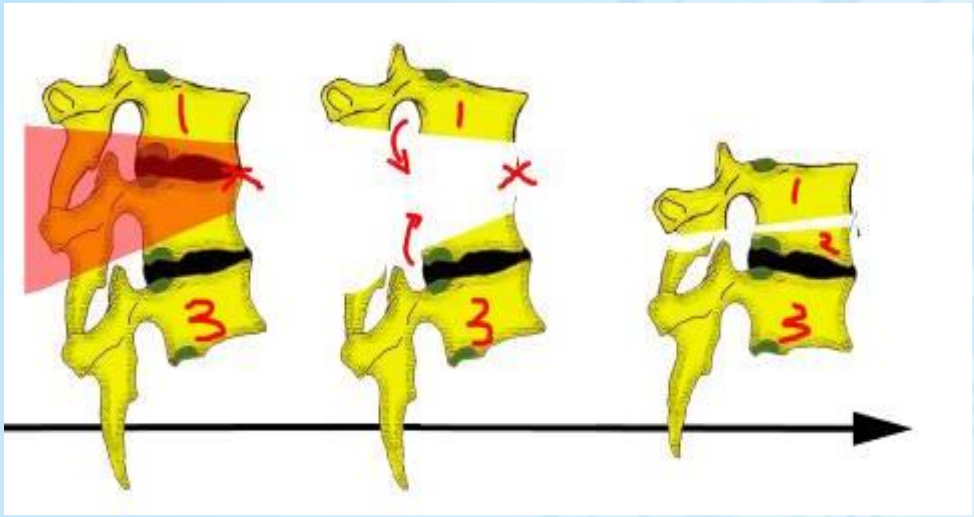
Appropriate even through fusion

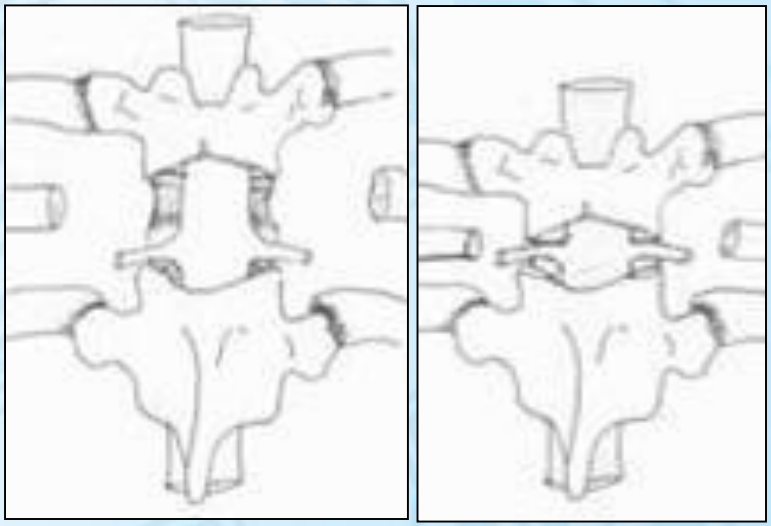
All levels of spine possible

Preferable below conus

Courtesy Frank Schwab

Grade IV - partial vertebra + disc





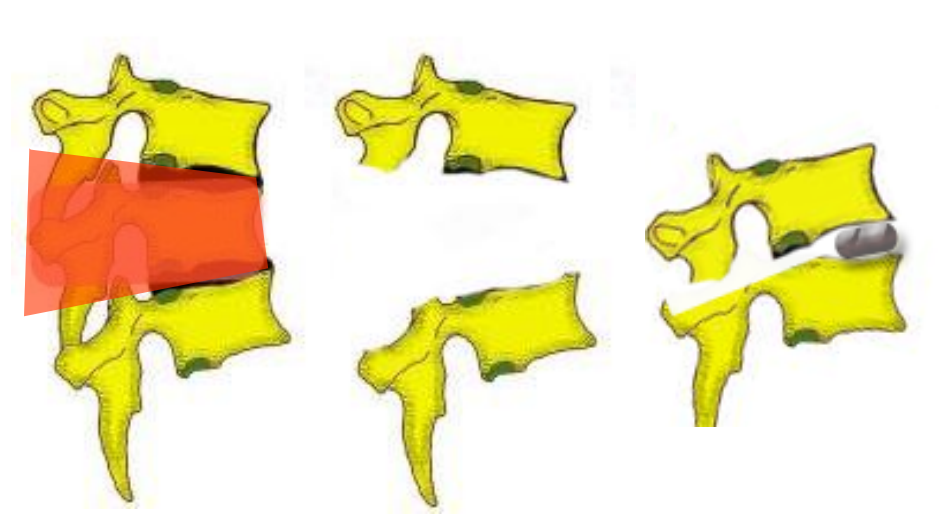
Permits limited 3-plane correction

Rib resection necessary in thoracic spine

Add anterior support/cage when marked shortening

Courtesy Frank Schwab

Grade V - Complete vertebra + discs



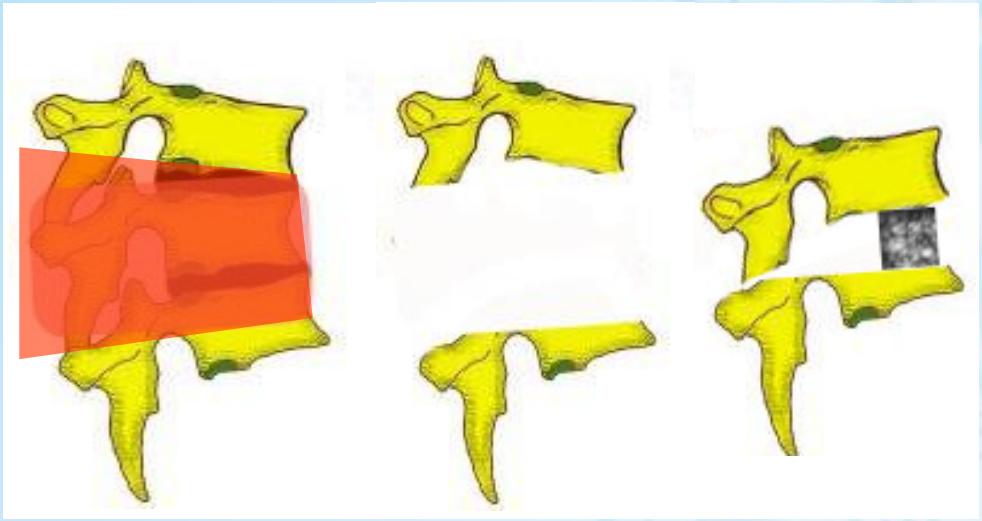
Permits 3-plane correction

Rib resection necessary in thoracic spine

Add anterior support/cage

Courtesy Frank Schwab

Grade VI - More than 1 Vertebra + discs



Permits 3-plane correction

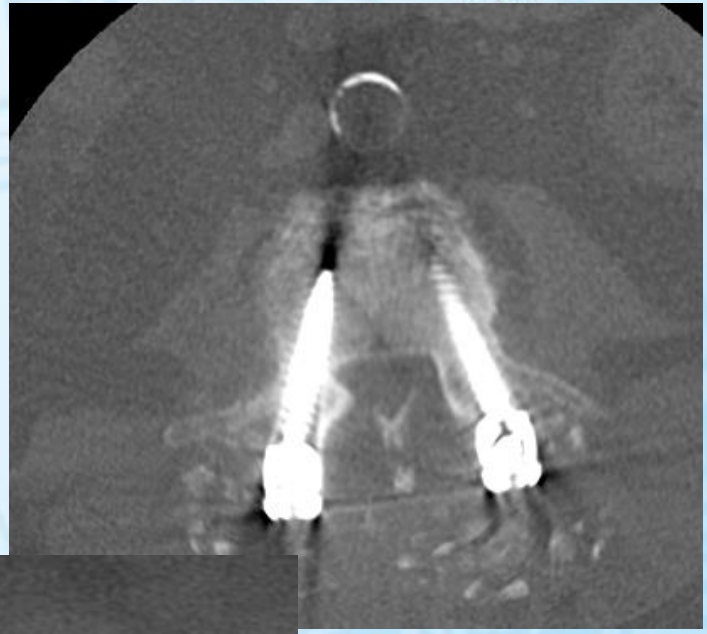
Rib resection necessary in thoracic spine

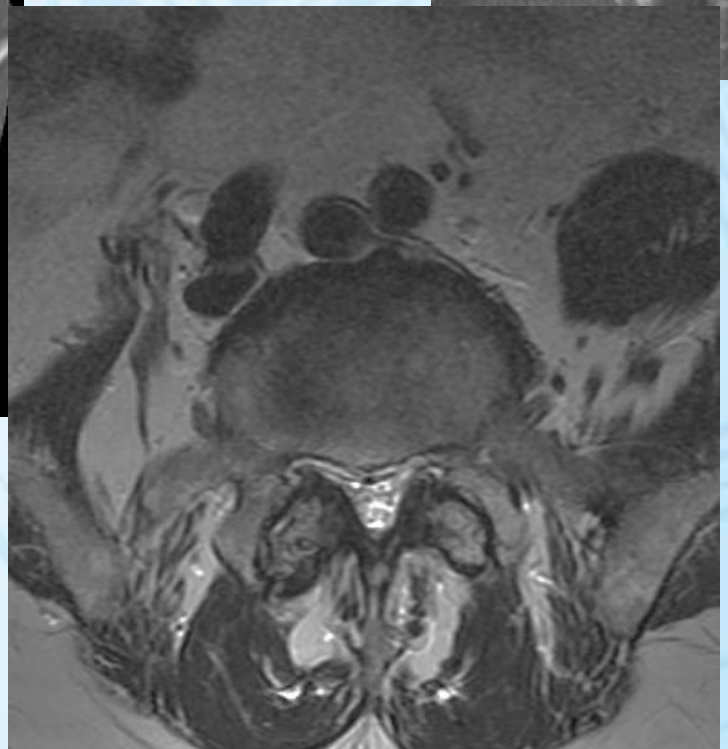
Add anterior support/cage

Courtesy Frank Schwab

Facetectomy

Facetectomy



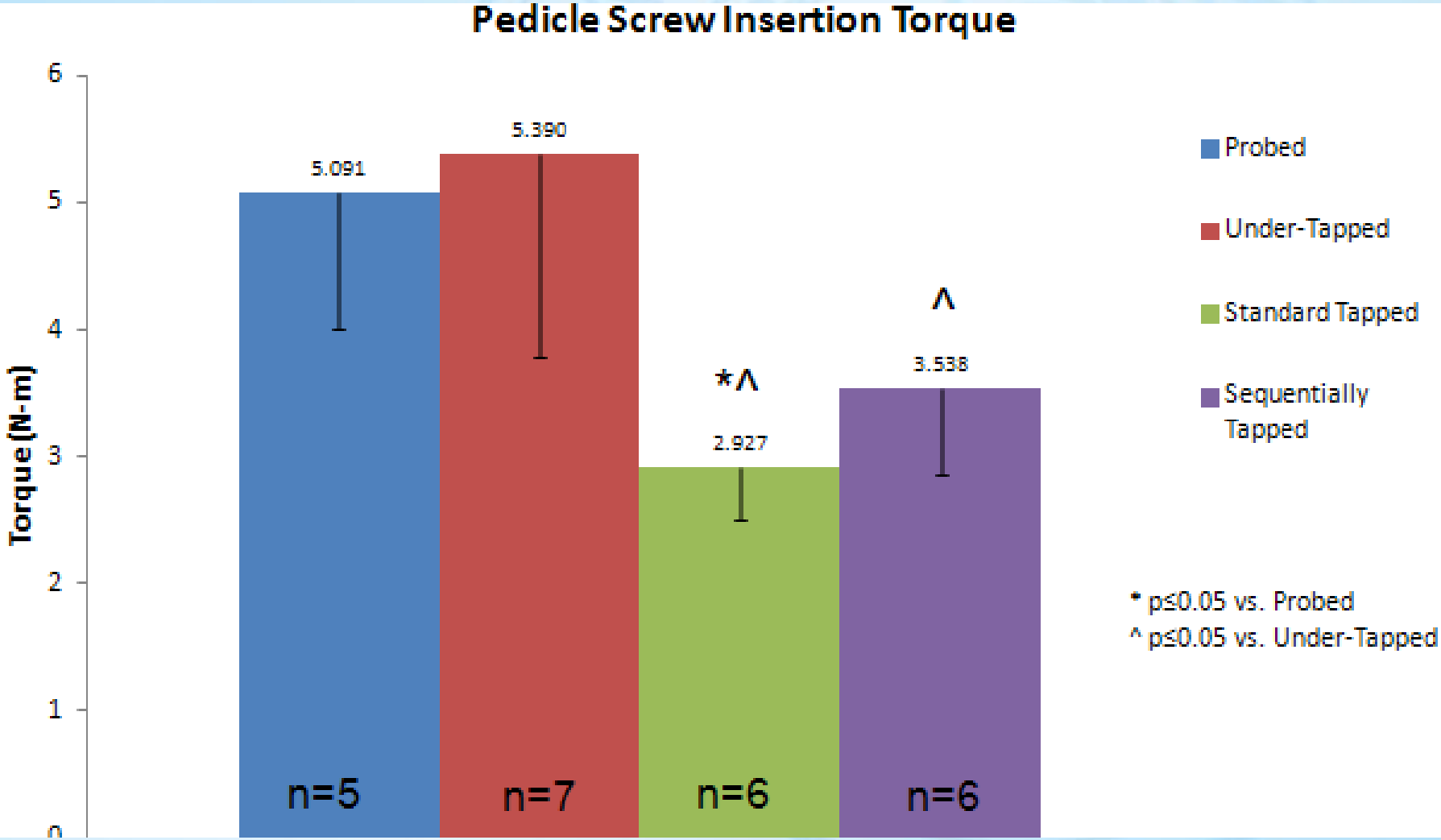


INSTRUMENTATION RELATED STRATEGIES

- Screws; alternative bone anchors
- Rods
- Reduction strategies
- Connector options
- Anterior column

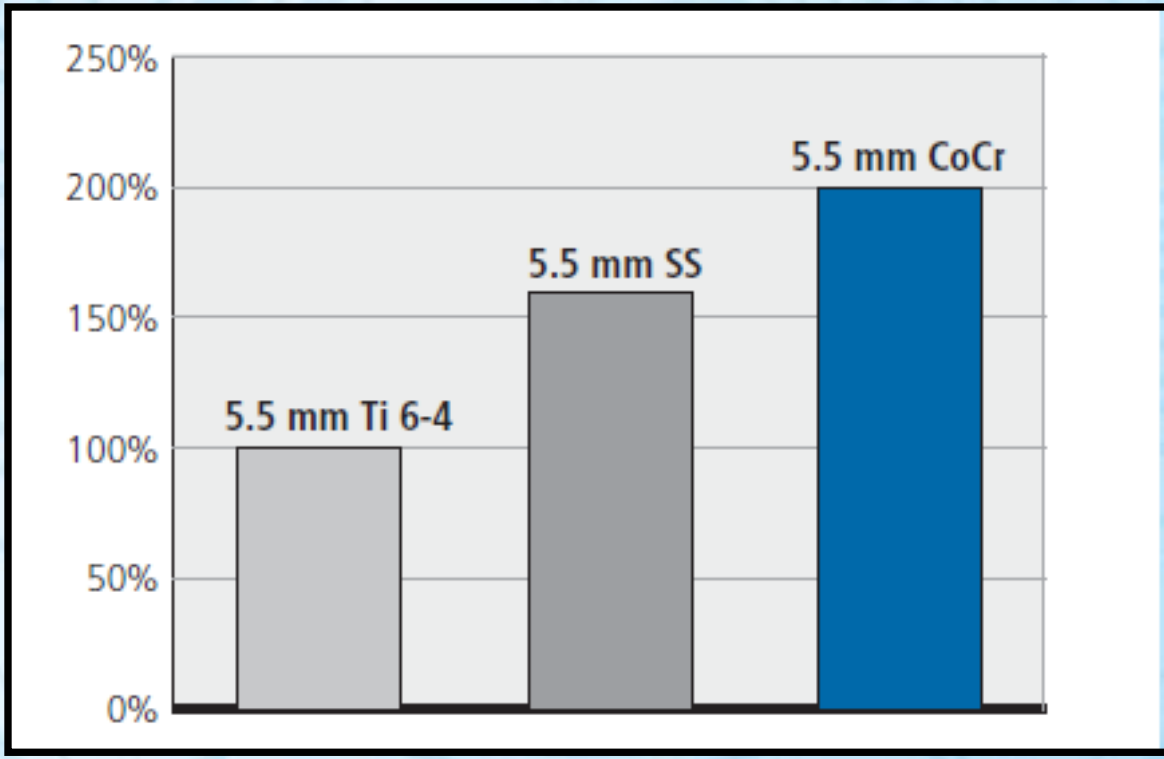
Pedicle Screw Pullout Strength of Four Different Screw Hole Preparation Techniques

Jwalant Mehta, FRCS (Orth), M.D.; Mark Moldavsky M.S.; Kanaan Salloum; Brandon Bucklen PhD; Saif Khalil PhD



CoCr Stiffness/Modulus

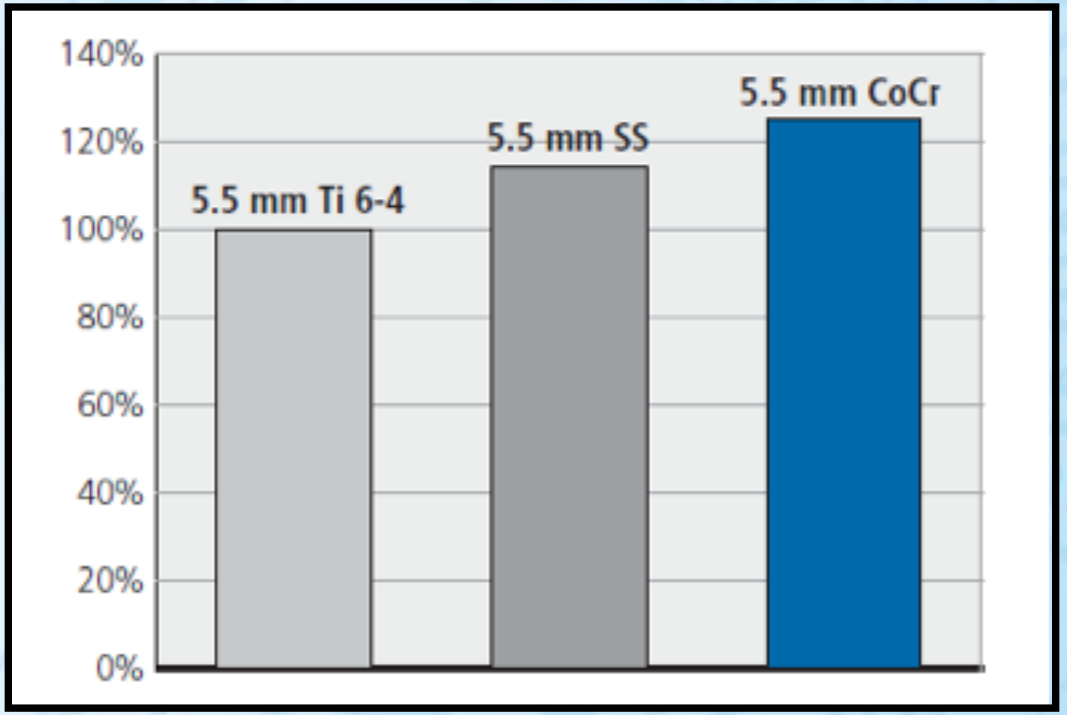
Firebird 5.5mm Cobalt Chrome Rods offer a 100% increase in stiffness compared to 5.5mm Titanium rods



Stiffness expressed as a percentage of Titanium 5.5mm Ti 6-4 ELI Rod Stiffness

CoCr Strength/Yield

Firebird 5.5mm Cobalt Chrome Rods offer a 25% increase in strength compared to 5.5mm Titanium rods

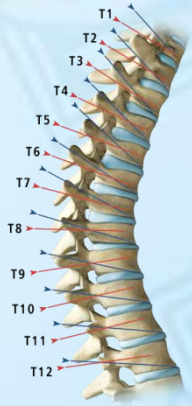


Strength expressed as a percentage of Titanium 5.5 mm Ti 6-4

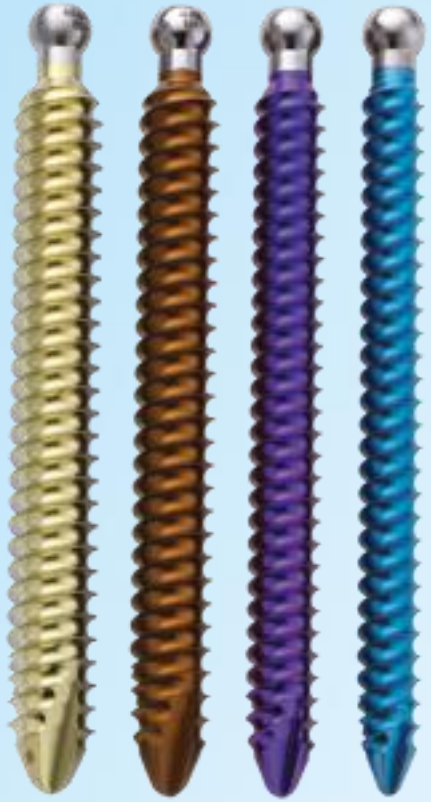
Firebird™ Deformity Correction System

The Royal Orthopaedic Hospital NHS
NHS Trust

Iliac Fixation
Hook Fixation
Thoracic Fixation
Reduction/Rotation



Iliac Bone Screws



Iliac Bone Screws

7.5 – 10.5mm diameters

60 – 100mm lengths

(10mm inc.)

2 of each per tray

Utilize all Firebird modular bodies

Mono Axial Lateral Offset Connector

Available in lengths from 15-35mm, 5mm incr.

Utilize modular head holders for insertion

80mm length for intra-op customization

Low Profile Offset Heads

Lowest profile option

Modular bone screw compatible

Now with an integrated set screw over the bone screw connection point

Lengths:

8 – 35mm, 3mm increments

Firebird Hooks

The Royal Orthopaedic Hospital NHS
NHS Trust

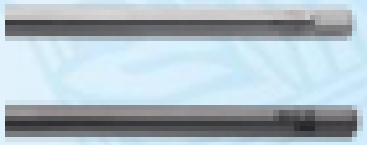
Implant	Image	Size / Style	Features / Use
Angled Hook		Left, Right Small, Medium (throat)	Supralaminar Ramped base reduces the potential for canal encroachment by blade
Laminar Hook		Small, Medium, Large (throat) Narrow, Wide (blade)	Inframlaminar or supralaminar In the canal or as a transverse process hook
Offset Hook		Left, Right Medium, Large (throat)	Inframlaminar or supralaminar Permits medialization of the rod when used on the transverse process
Pedicle Hook		Small, Medium, Large (throat)	Inframlaminar Bifid tip engages pedicle of thoracic vertebra
Thoracic Hook		Small, Medium (throat) Narrow, Wide (blade)	Inframlaminar or supralaminar Ramped base of hook reduces the potential for canal encroachment by the blade

Thoracic Fixation

Rods, 5.5 X 450mm

Cobalt Chrome

Titanium

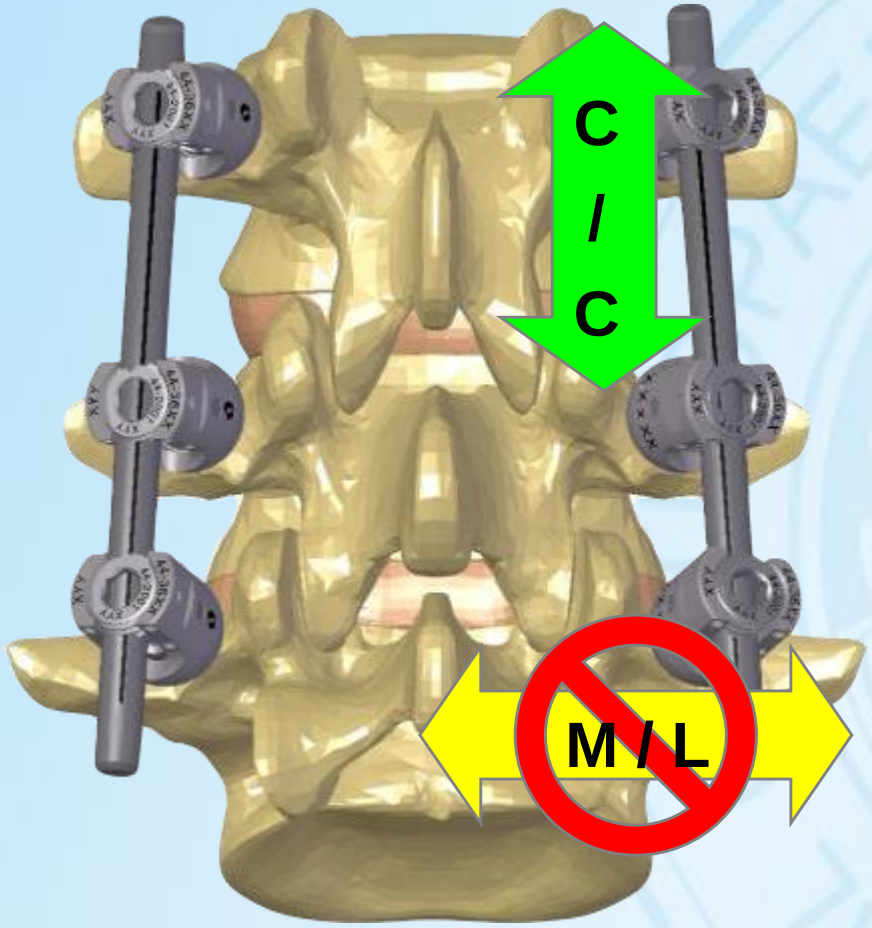


Uniplanar Screws

Diameter = 4.0 – 6.5mm

Length = 25 – 45mm

Uni-Planar Screws



Cephalad/Caudad

Allows Cephalad/Caudad movement

Assist with rod placement in kyphotic deformities

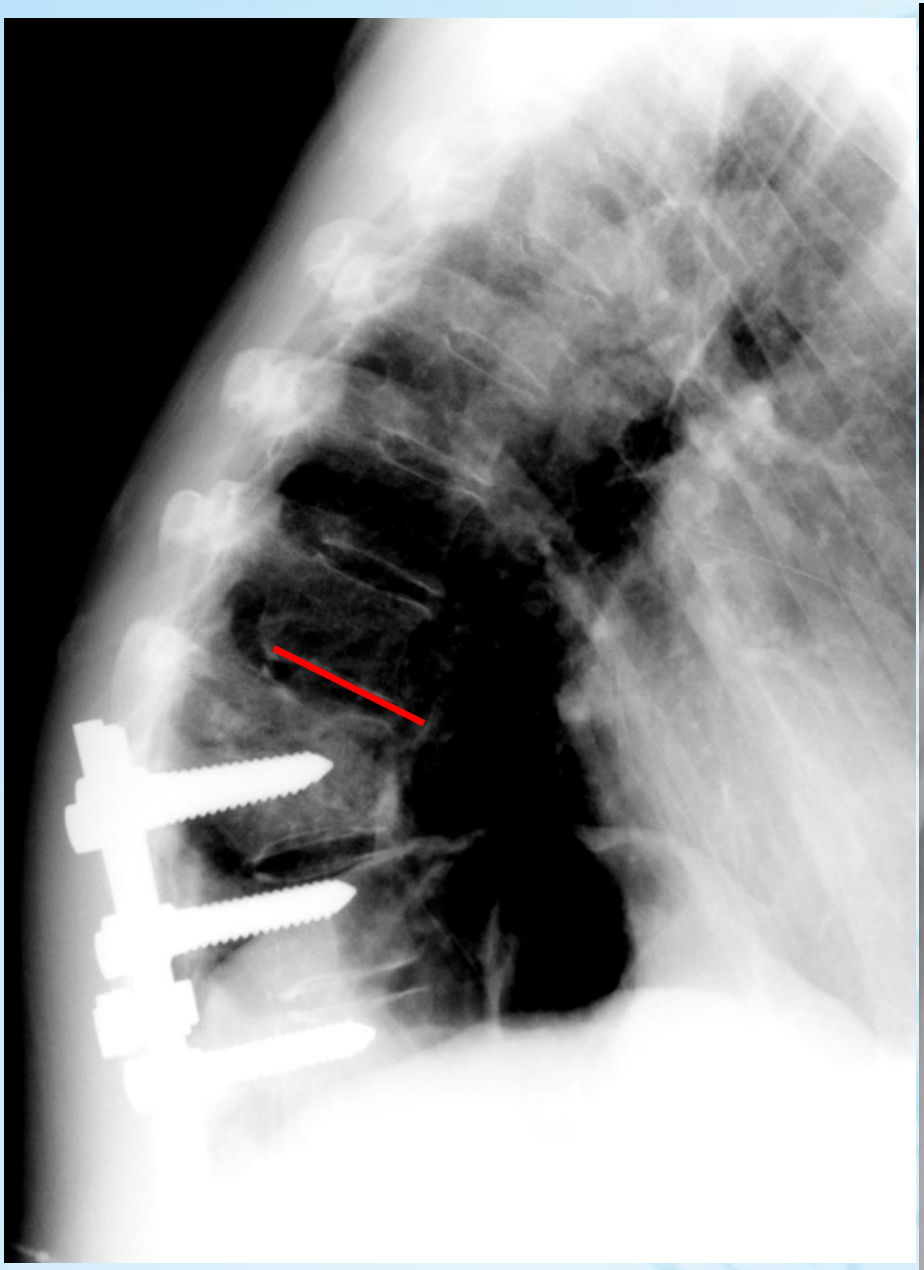
Medial/Lateral

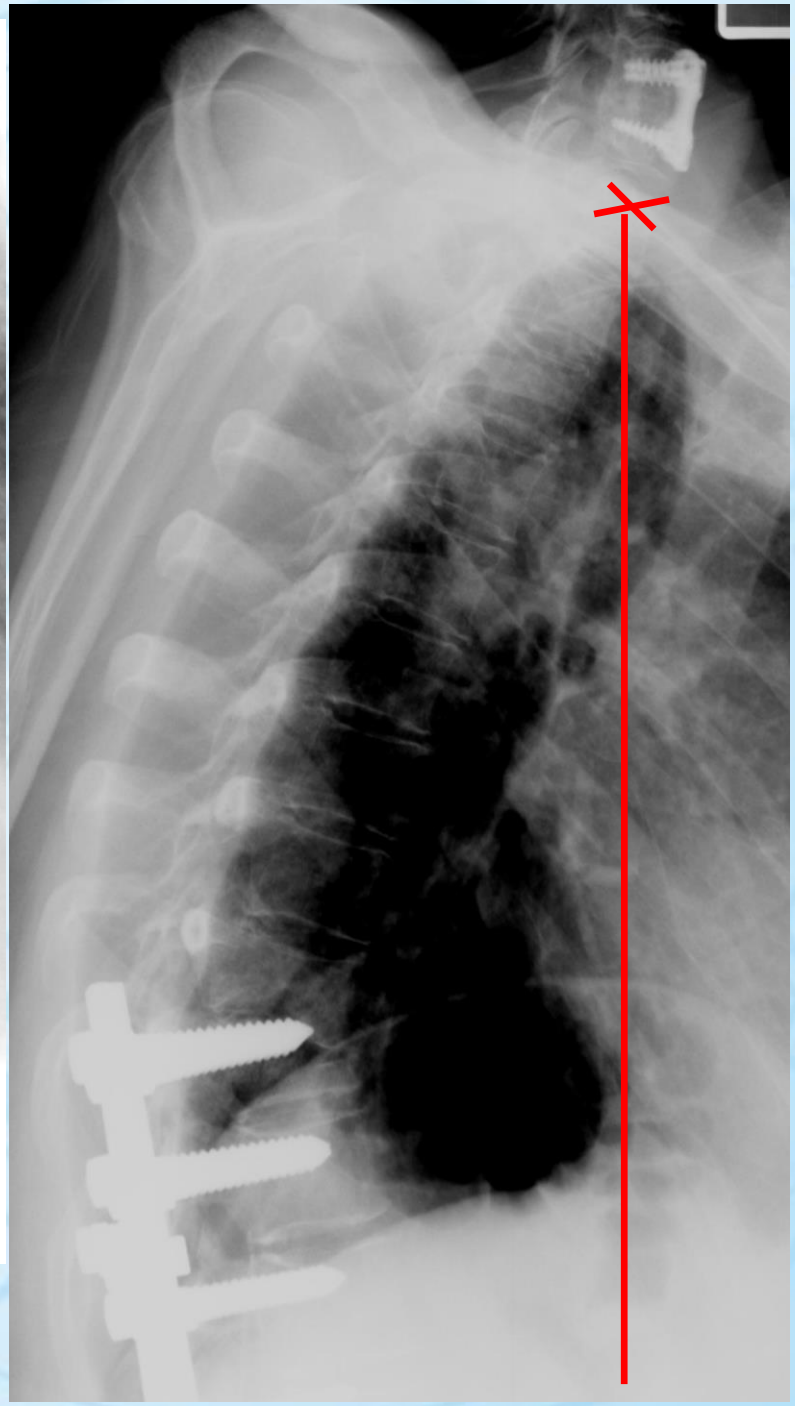
Prevents Medial / Lateral movement

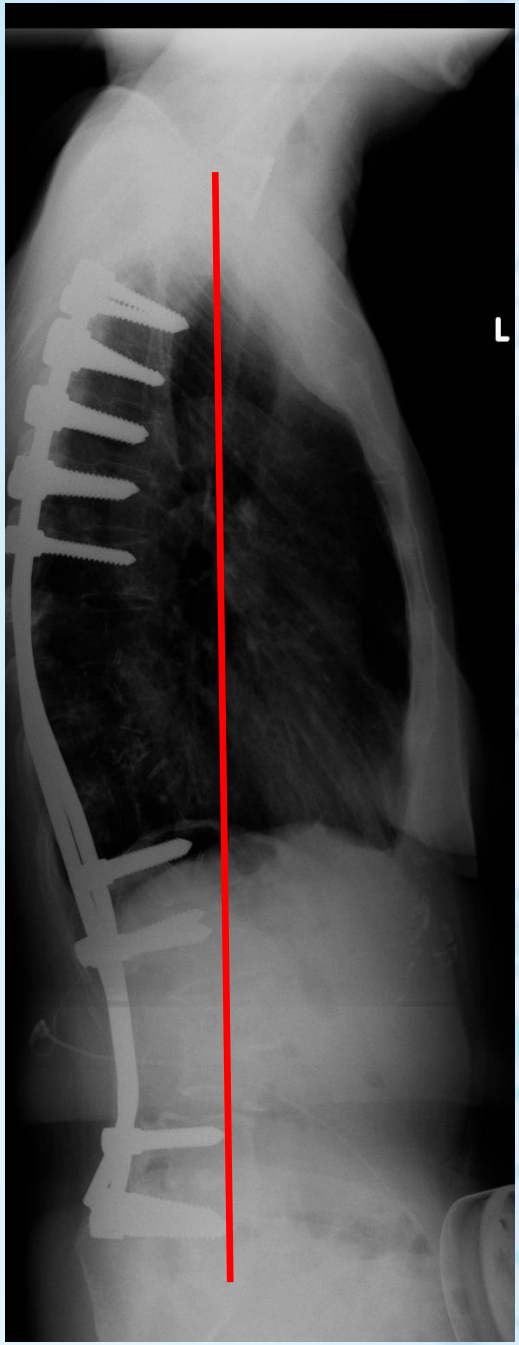
Correction Capability of Mono Screw

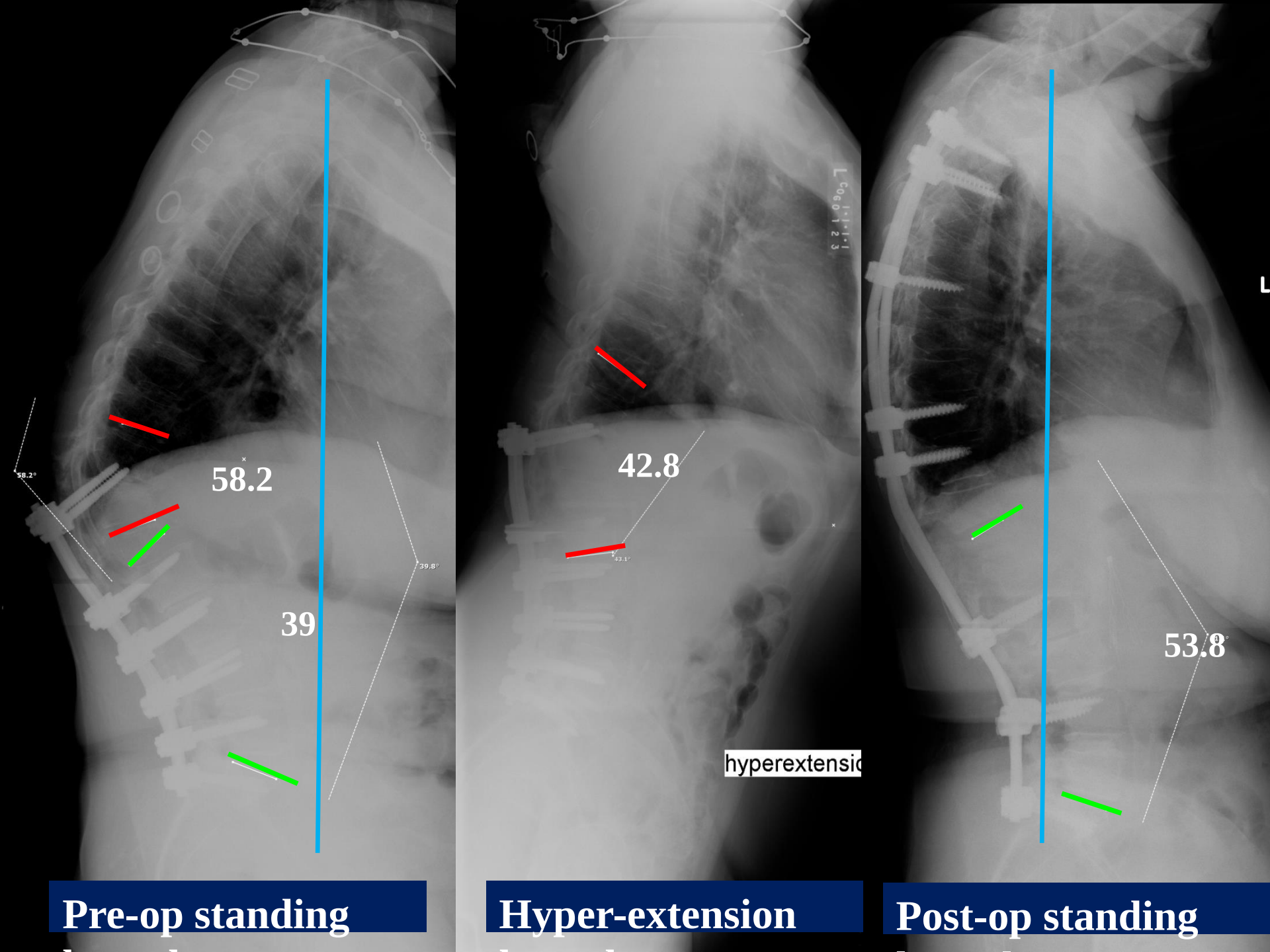
Problems

- Realistic expectations
- Medical co-morbidites
- Osteoporosis
- Junctional problems

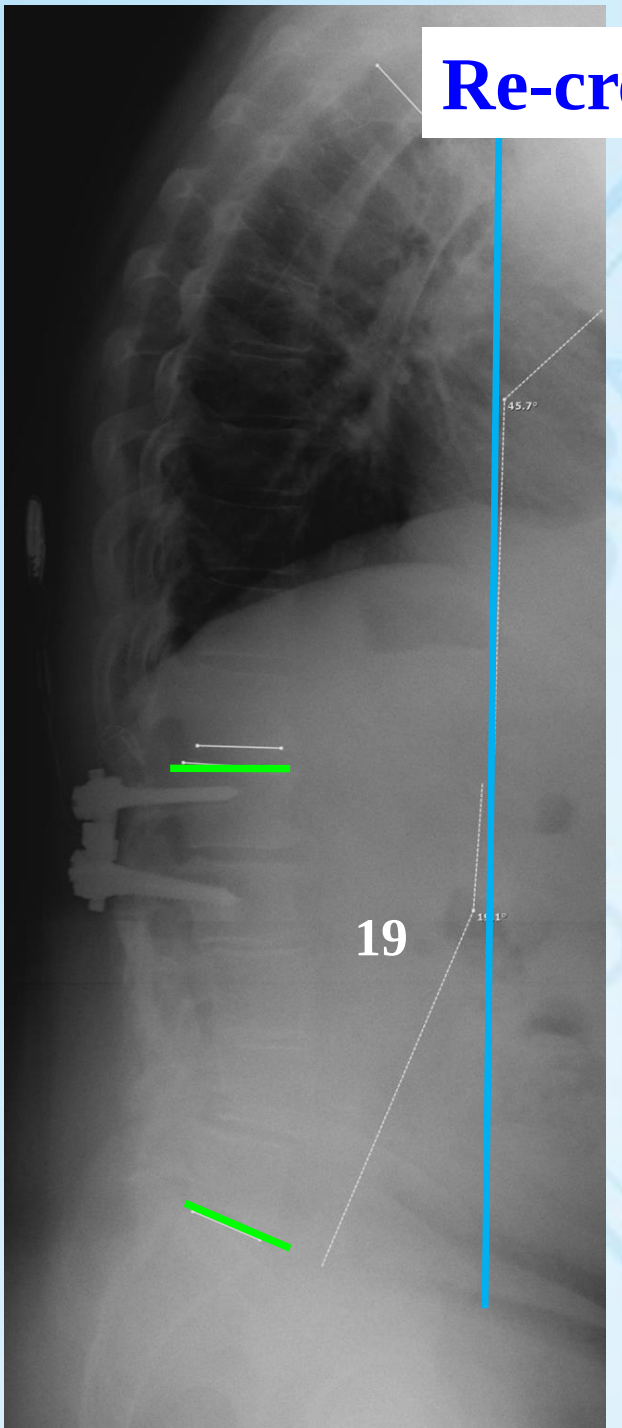


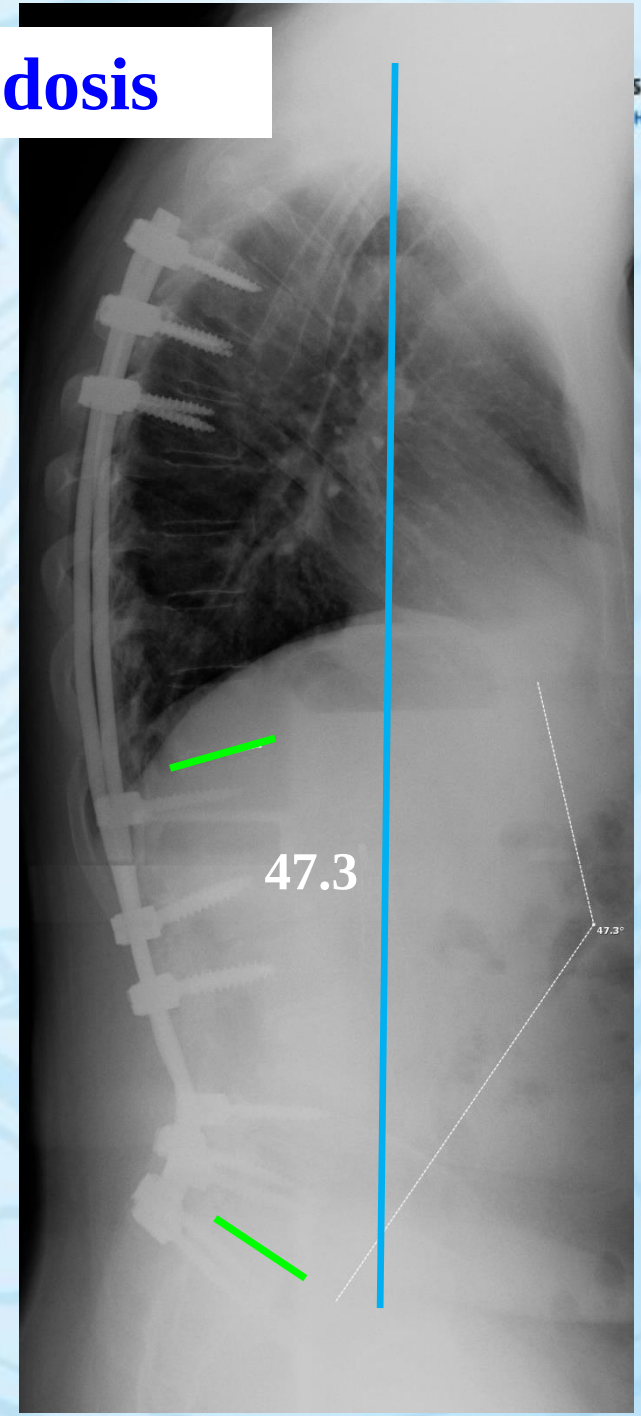



L


58.2
39
42.8
hyperextensio
53.8
Pre-op standing
Hyper-extension
Post-op standing

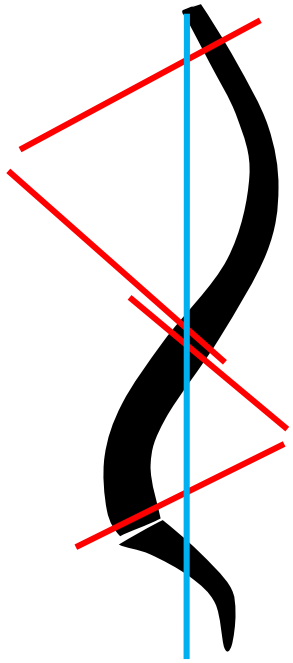
Re-create lordosis





Aims of intervention

- Restore balance without stressing junction
- Adaptation of the lordosis
- Restore plumb line



The new 36 – 24 - 36