

MSc Orthopaedic Engineering Spinal Trauma

Mr M J H McCarthy
Consultant Spinal Surgeon



No Disclosures No Conflicts of Interest



Aims / Objectives

- Pathophysiology of Spinal Cord Injury
- Investigations
- Initial Management
- Spinal Fractures:
 - Describe the aims of surgical fixation in the spine
 - Fixation
 - Front, Back, Both
 - Explain the rationale and mechanics of different approaches



Suspecting a Spinal Injury

- Mechanism of Injury
- Unconscious
- Neurological Deficit
- Spinal Pain / Tenderness

Goals of Spine Trauma Care

- Protection
- Detection
- Optimize conditions for neuro recovery
- Maintain / restore spinal alignment
- Minimize loss of spinal mobility
- Obtain healed and stable spinal column
- Rehabilitation
- #s = Manage the ass soft tissue injury

Management of Spinal Injury

- ABCDE / ATLS Approach
- Protection - **THINK SPINAL CORD INJURY**
 - Maintain airway with spine control
 - Always aim to have a team of 6 for transfers (min 4 for log rolls)
- Detection
 - Level of injury
 - Complete or Incomplete cord injury
 - Spinal or Neurogenic shock
- Management
 - Conservative or Surgical treatment

Immobilise The Entire Spine



The Spinal Board

- Transport device
- Remove ASAP
- Regular log rolls
- Pressure sores
- Same goes for some collars...

Assessment

- **History**
 - Pain
 - Mechanism
 - Immediate post injury neurology
 - Associated injury
- **Examination**
 - Spine
 - Tenderness
 - Gap
 - Step
 - Marked spasm
 - Spinal cord
- **Imaging**

Examination

- Spinal Cord
- Partial / Complete SCI
 - Sensory level
 - Sensory modality
 - Motor level
 - Sphincter tone
 - Bulbocavernosus reflex

Examination

SCI in the Unconscious Patient

- Flaccid areflexia
- Diaphragmatic breathing
- Pain response above clavicle
- Bradycardia / Hypotension
- Priapism



Spinal “Shock”

- Refers to the flacid paralysis, areflexia and lack of sensation secondary to physiologic spinal cord “shut down” in response to injury
- Usually resolves within 24 hours when reflex arcs caudal to injury return
- Lowest that can be tested clinically
 - bulbocavernosus reflex
- Importance of spinal shock
 - determining whether a patient has a complete or incomplete spinal cord injury

Neurogenic Shock

- State of inadequate tissue perfusion and oxygenation due to:
- Reduced sympathetic outflow (T1-L2) with resultant unopposed vagal tone
- Hypotension due to loss of blood vessel tone with resultant venous pooling
- Bradycardia due to reduced cardiac stimulation
 - distinguishes neurogenic shock from other types of shock (e.g. hypovolaemic, cardiac, anaphylactic)

Spinal Cord Injury

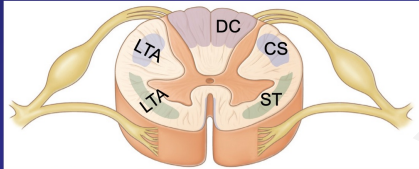
- Primary (at the time of injury)
- Secondary (occurring after the injury)
- Complete spinal cord injury
 - no sensation or voluntary motor function below the level of the injury
- It can only be confirmed after the resolution of spinal shock when reflex activity has returned
- The level of the injury is defined as the first with useful partial neurological function >3/5
- The overall prognosis for recovery of neurological function in complete lesions is poor

Spinal Cord Injury

- Incomplete spinal cord injury means that there is some function caudal to the injury
- In general, the greater the function the faster the recovery and better the prognosis
- Sacral sparing after spinal cord injury
 - the presence of sacral sensation, voluntary rectal tone and great toe movement
 - indicates intact long tract neurones and the potential for recovery
- Prognostic for predicting recovery except in lesions involving the conus medullaris or cauda equina

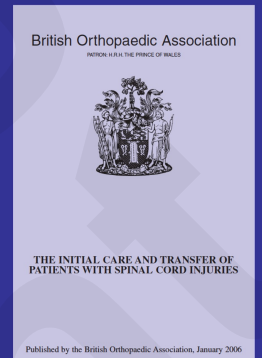
Cord Syndromes

- Anterior
- Posterior
- Central
- Brown-Sequard



Spinal Cord Injury

- Of 569 patients admitted to Spinal Cord Injuries Centre in UK:
 - 9% missed at presentation
 - 5% experienced further avoidable deterioration
 - 1/3 of those missed had significant head injury
- Multiple Fractures in 5%
- Use of Steroids
 - NOT recommended



Spinal Injury Screening

- Clinically
 - Cooperative patient
 - Alert and orientated
 - Able to concentrate on spine
 - Normal neurological exam
 - No spinal pain or tenderness
 - No pain or tenderness with voluntary movement
 - Probably not possible in the field

Spinal Injury Screening

- Altered consciousness or symptoms
 - Radiological imaging required
 - Presume the spine is unstable
 - Protect

Spinal Injury Screening

- Lateral Cervical X-Ray
 - Detects 85% cervical fractures
- Image the entire spine
 - 10% with one fracture have another non contiguous injury

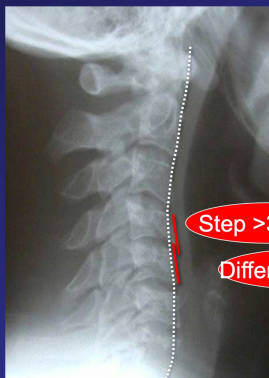
Lateral C Spine Assessment

- Name / Age
- Date
- Type of Radiograph
- A : ADEQUACY / ALIGNMENT
- B : BONE
- C : CARTILAGE (Facets / Discs)
- D : DENS
- E : EXTRAAXIAL SOFT TISSUE



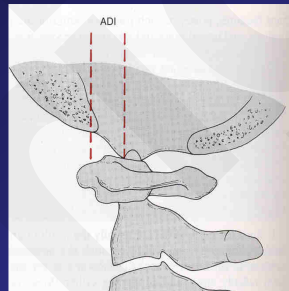
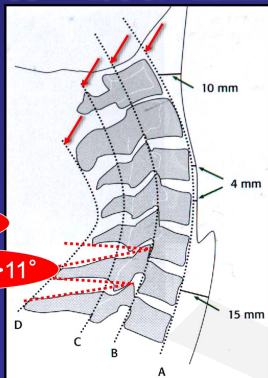
DISC SPACE WIDENING

C2 = $<1/3$ or $<5\text{mm}$
C5 = $<2/3$ or $<22\text{mm}$



Step $>3.5\text{mm}$

Difference $>11^\circ$

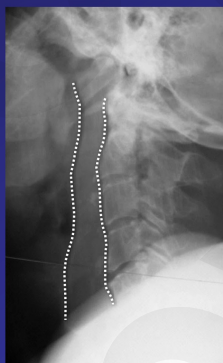
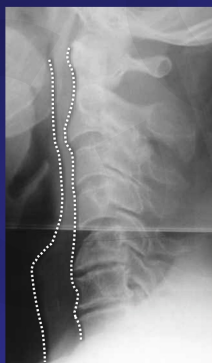


Atlas Dens Interval (ADI)

ADI = 3mm ($<5\text{mm}$)

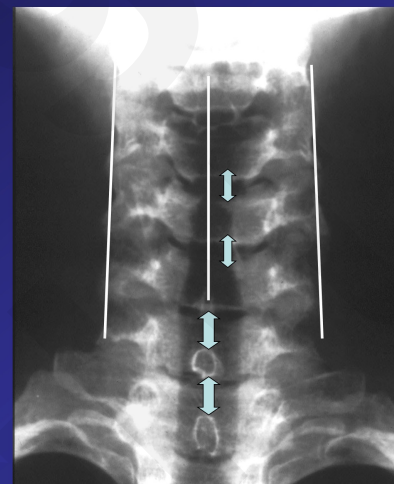
$>5\text{mm}$ = Transverse + Accessory ligament rupture

Steels Rule of Thirds



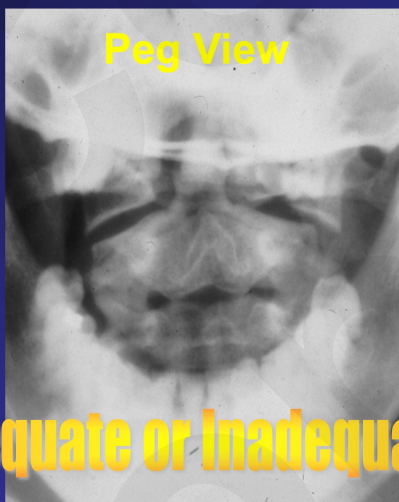
AP View

Alignment
VBs
Lat Masses
IV Joints Luschka
SPs
Discs



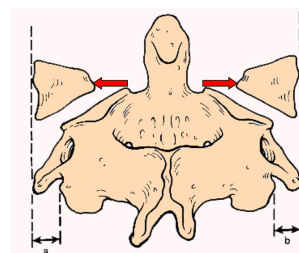
Peg View

Dens
C1 LMs



Adequate or Inadequate?

Instability



$a + b > 7\text{mm}$
(transverse ligament rupture)

CT Indications

- Plain Radiographs have failed to visualise all the cervical spine
 - Cervico-thoracic junction
 - Intubated patient (no odontoid peg view) – continue brain CT down to C3
- Plain Radiographs show injury
 - Confirm and further categorise extent of injury

MRI in Spinal Trauma

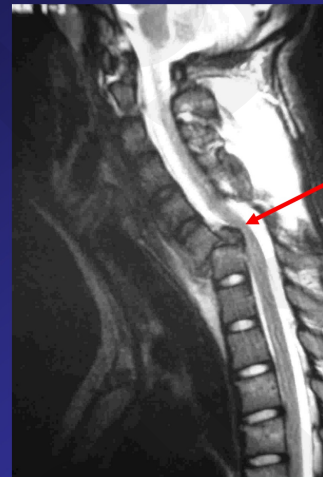
- Overview for exclusion of injury in difficult cases (ankylosing spondylitis)
- Ligamentous injury
- Unexplained neurology
- Prognosis in neurological injury
- Is surgical fixation safe?
 - Extruded disc may be made worse by surgical manipulation

Radiology of Cervical Spine

dislocation with
normal neurology

MRI

reduction

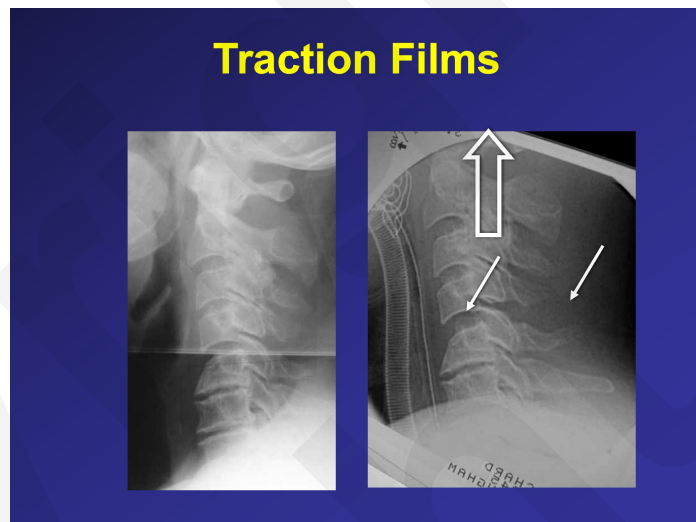
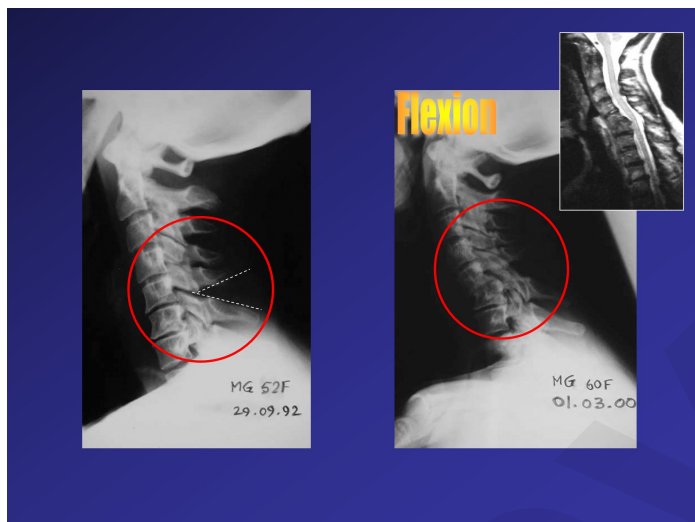


Erect XRs

- Load bearing - physiological
- Normally done in collar
- Useful adjunct after a CT showing a “stable injury” – checks for development of load bearing deformity and ligament injury

Dynamic XRs

- Physiological
- Normally done at 2 weeks post injury to check for stability or after treatment in a collar to ensure no latent instability



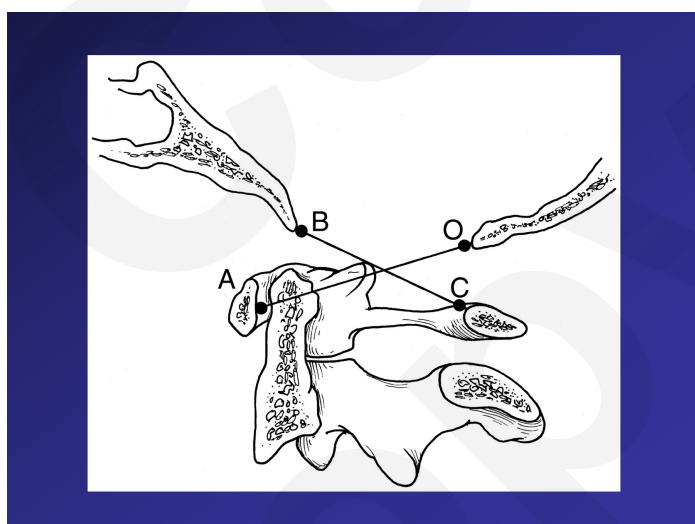
Clinical Instability

The loss of the ability of the spine under physiological loads to maintain its pattern of displacement so that there is no initial or additional neurological deficit, no major deformity and no incapacitating pain



Upper Cervical Instability

- $>8^\circ$ axial rotation C0-1 to one side
- Powers ratio distance BC / OA > 1 (occipito - cervical dislocation)
- Increased odontoid basion distance - the tip of the odontoid should be in line with basion, with the odontoid basion distance 4-5mm adults and up to 10mm in children
- $>1\text{mm}$ C0-1 translation in flexion / extension (this is a specialist investigation, not in the acute trauma setting)
- $>7\text{mm}$ overhang C1-2 (total left and right)
- $>45^\circ$ axial rotation C1-2 to one side
- Atlantodens interval $>5\text{mm}$ (should be $<3\text{mm}$)



Lower Cervical Instability

- Horizontal vertebral body translation $>3.5\text{mm}$ or 20%
- Difference in intervertebral angulation between adjacent levels $>11^\circ$
- Vertebral body height loss
- Disc space $>1.7\text{mm}$
- Facet fracture, subluxation or widening
- Flexion teardrop – small antero-inferior body fracture

Consequences of SCI

- Inadequate ventilation
- Abdominal evaluation compromised
- Occult compartment syndrome

Management of Spinal Injury

- Treat life threatening injuries first
- Ventilation and Oxygenation
- Maintain blood pressure
- Maintain spinal cord perfusion

Management of Hypotension

- Haemorrhagic shock until proven otherwise
- Consider neurogenic shock
- Monitor urine output

Facet Dislocation Algorithm 1

- After CT Dx d/w t/f to Spinal Surgeon ASAP
- **No Neurological Deficit**
 - MRI
 - No Disc Lesion
 - Closed reduction by sequential traction then urgent op
 - Urgent / Emergent op if evolving neurological deficit
 - Disc Lesion
 - Urgent / Emergent op
- Recovery $\propto$ duration

Realign
Stabilize
Decompress – Direct / Indirect
Prevent Late Pain / Deformity

Facet Dislocation Algorithm 2

- After CT Dx d/w t/f to Spinal Surgeon ASAP
- **Partial Neurological Deficit / Obtunded**
 - MRI
 - No Disc Lesion
 - Closed reduction by sequential traction then urgent / emergent operation
 - Disc Lesion
 - Urgent / emergent operation
- Recovery $\propto$ duration

Realign
Stabilize
Decompress – Direct / Indirect
Prevent Late Pain / Deformity

Facet Dislocation Algorithm 3

- After CT Dx d/w t/f to Spinal Surgeon ASAP
- **Complete Neurological Deficit**
 - Is there any need for MRI?
 - Prognostic / surgical planning
 - Attempt at closed reduction?
 - Surgical facilities not immediately available
 - Emergency Operation
- Recovery $\propto$ duration

Realign
Stabilize
Decompress – Direct / Indirect
Prevent Late Pain / Deformity

SPINE • VOLUME 18 • NUMBER 3 SUPPLEMENT • 1991

Treatment of Cervical Spine Injuries with Anterior Plating 86 pts

Indications, Techniques, and Results

James Y. Ho, MD, K. ZUBER, MD, and D. MARCHESI, MD

Series of Nineteen Traumatic Cervical Spine Injuries Stabilized with Anterior ASIF Plate Fusion Technique

DANIEL R. RIPA, MD, MARK G. KOWALL, MD, JAMES J. JOSEPH, JR., MD, and JOSEPH J. RUSIN, MD

Anterior Reduction for Cervical Spine Dislocation 41 pts

Rudy Rand, MD, Jean Ouellet, MD, Edward J. Harney, MD, Greg Berry, MD, and Vincent Arlet, MD

The Radiographic Failure of Single Segment Anterior Cervical Plate Fixation in Traumatic Cervical Flexion Distraction Injuries 87 pts

Michael G. Johnson, MD,* Charles G. Fisher, MD,† Michael Boyd, MD,‡ Tobias Pizen, MD,§ Thomas R. Island, PhD,|| and Marcel F. Dvorak, MSc

Key Points

- A 13% radiographic failure rate is reported for anterior plate fixation of distractive flexion injuries of the subaxial cervical spine where 75% of the subjects had bilateral facet injuries.

Radiographic Failure		
	Yes	No
Facet fracture	Yes 10 (26%)	No 28 (74%)
Endplate fracture	Yes 9 (64%)	No 5 (36%)
	No 2 (3%)	58 (97%)

**P = 0.004, Pearson χ^2 test
†P < 0.001, Fisher exact test*

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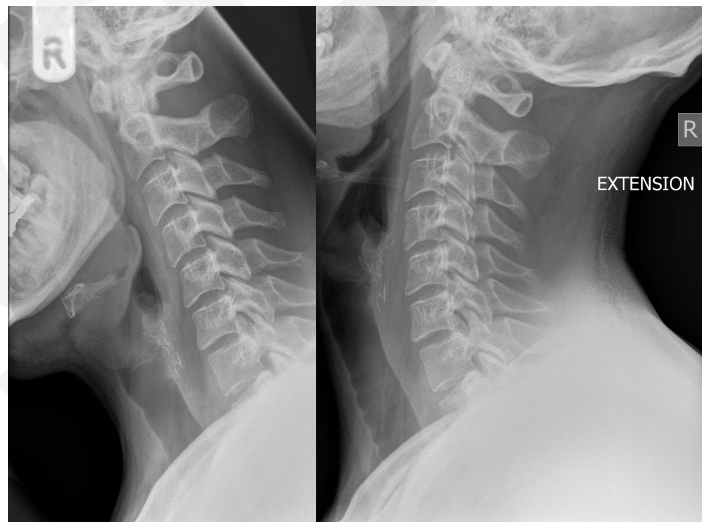
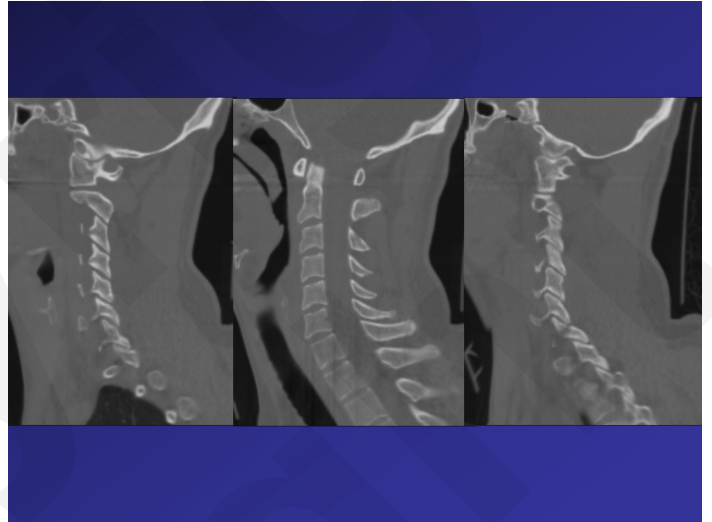
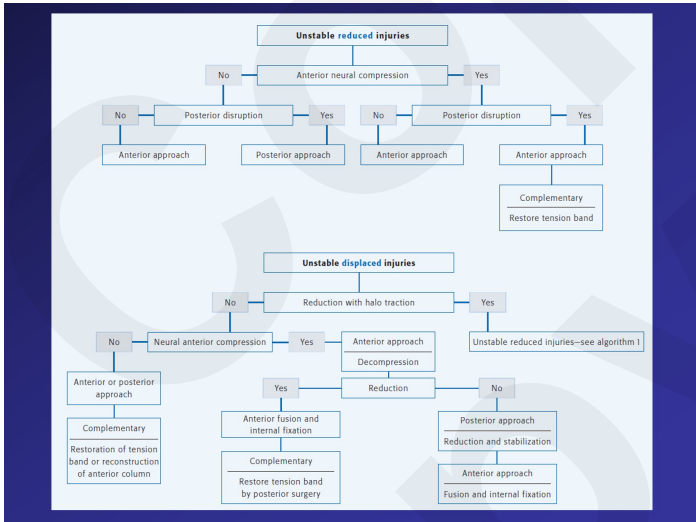
Comparison of Outcomes for Unstable Lower Cervical Flexion Teardrop Fractures Managed With Halo Thoracic Vest Versus Anterior Corpectomy and Plating

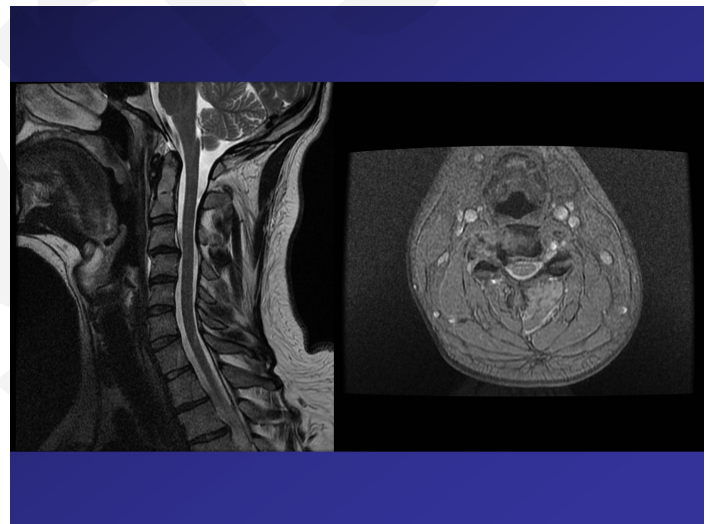
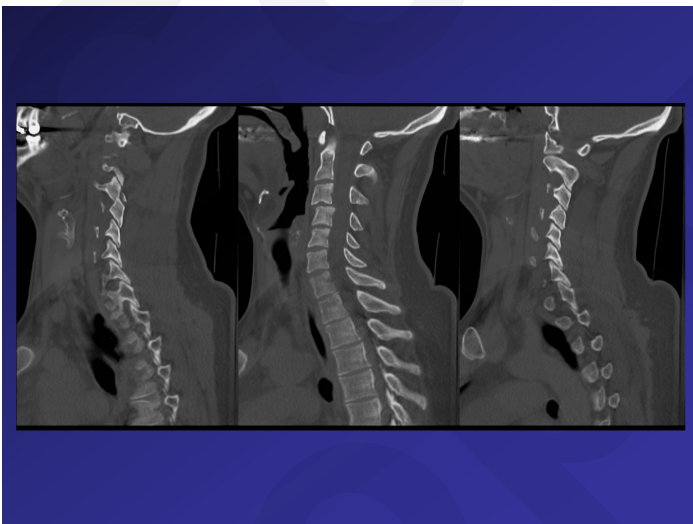
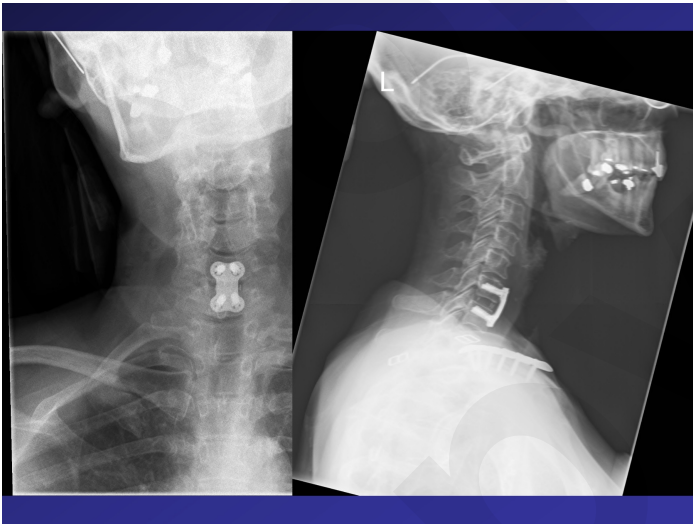
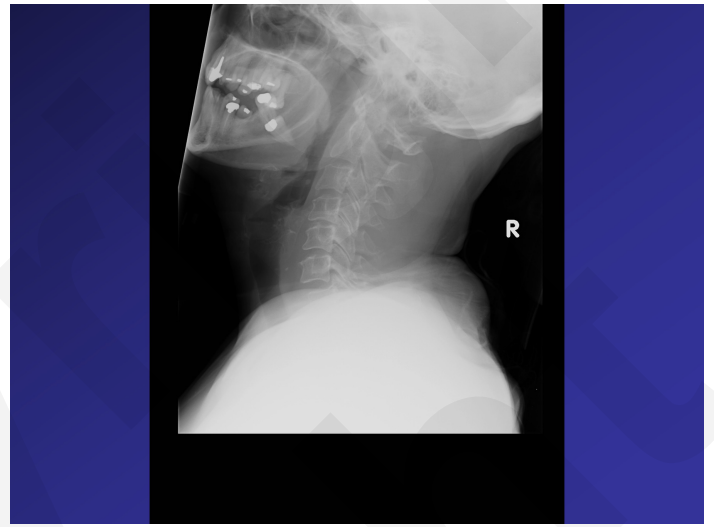
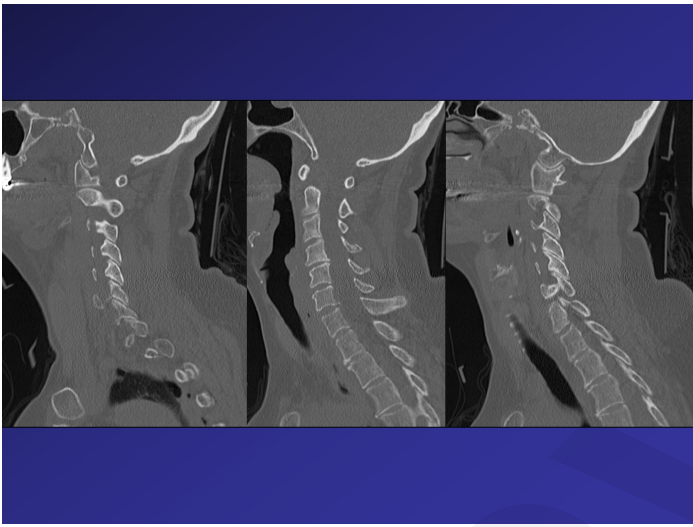
24 Halo vs 21 Op

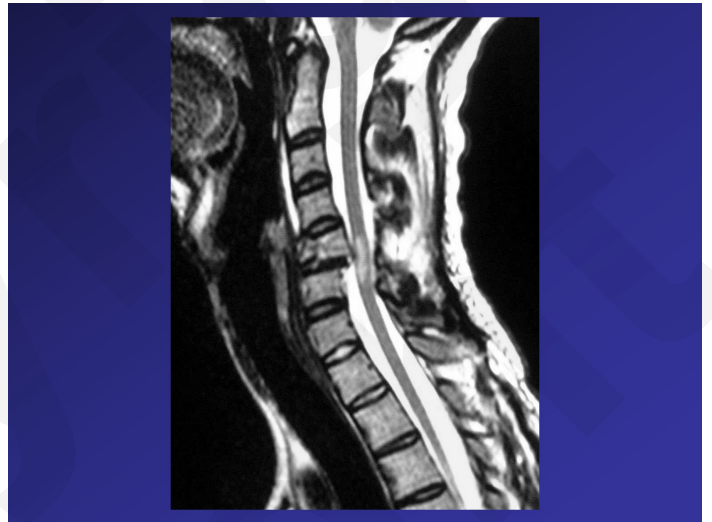
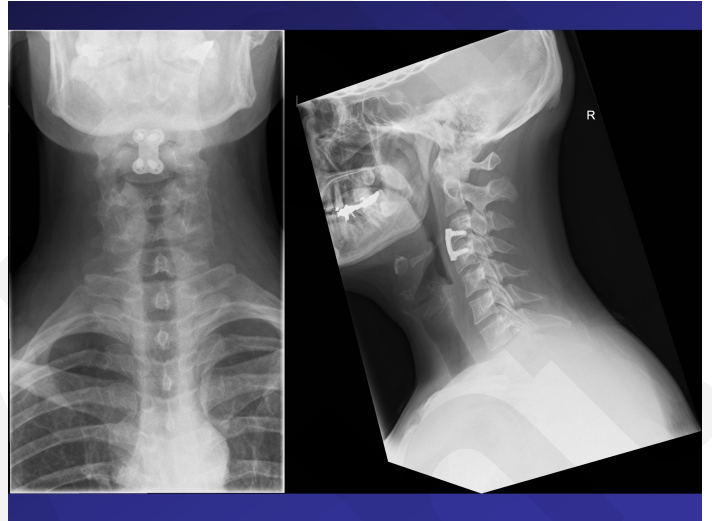
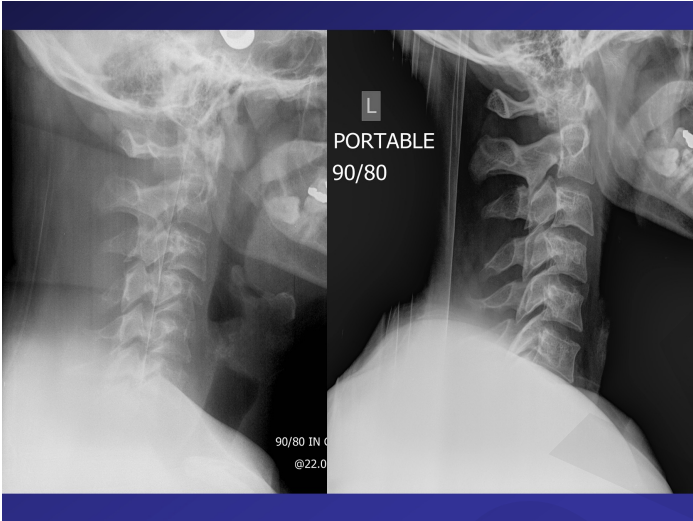
Charles G. Fisher, MD, MHSc, FRCSC, Marcel F. S. Dvorak, MD, FRCSC, Jordan Leith, MD, FRCSC, and Peter C. Wing, MB, MSc, FRCSC

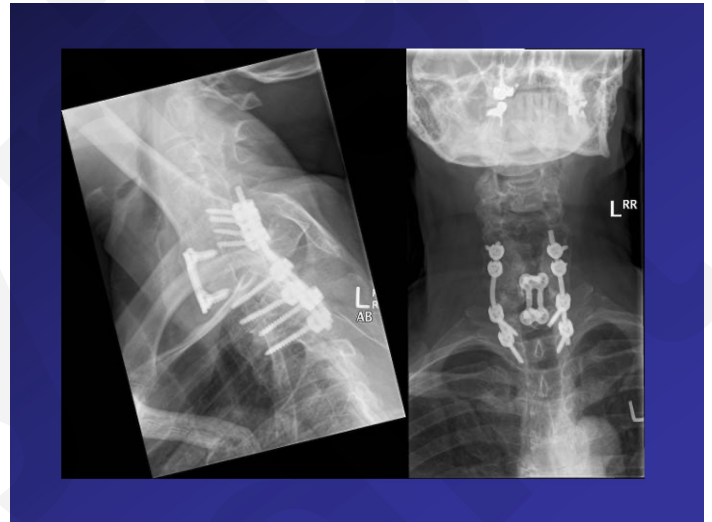
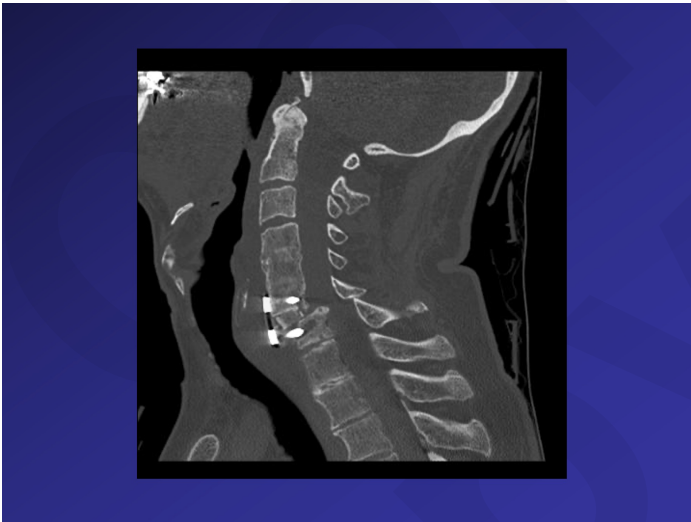
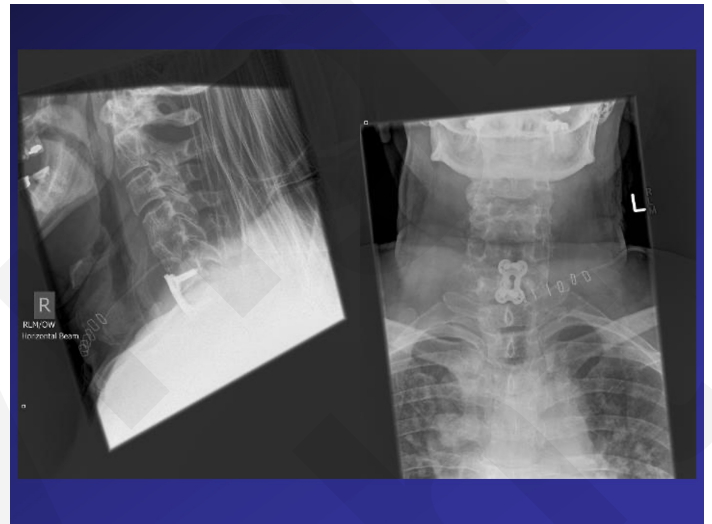
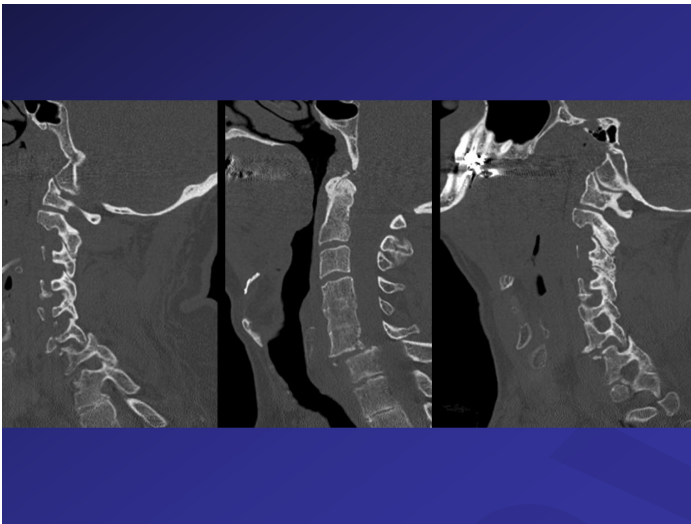
Conclusions. The results of this study indicate that anterior cervical plating is a safe and effective treatment for cervical teardrop fractures, and that it is superior to the halo thoracic vest for restoring and maintaining sagittal alignment and for minimizing treatment failures.

No Failures Fixation

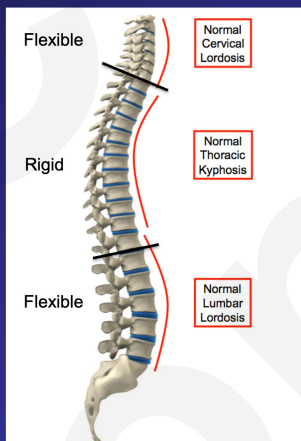








Thoracolumbar Fractures



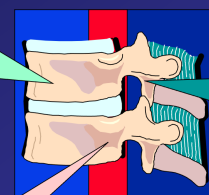
The column theory THREE COLUMNS

ANTERIOR COLUMN

- anterior longitudinal ligament
- anterior half of vertebral body
- anterior part of annulus fibrosis

MIDDLE COLUMN

- posterior longitudinal ligament
- posterior half of vertebral body
- posterior part of annulus fibrosis



POSTERIOR COLUMN

- neural arch
- ligamentum flavum
- facet joint capsules
- interspinous ligament

• Denis 1983

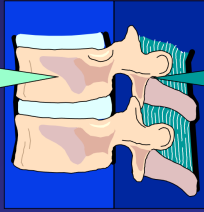
- conceptual rather than anatomical
- based on biomechanical studies

The column theory

TWO COLUMNS

ANTERIOR COLUMN

- solid column of vertebral bodies
- compression-resistant



POSTERIOR COLUMN

- hollow column of neural canal
- tension-resistant

- AO Magerl 1993
- anatomically based concept

AO CLASSIFICATION OF THORACOLUMBAR FRACTURES

A **Compression**

- caused by axial compression
- affects vertebral body
- posterior complex intact



1

Impaction

- deformation due to compression of vertebral body
- stable



2

Split

- horizontal body split in coronal or sagittal plane
- unstable



3

Burst

- compression with significant loss of vertebral body height
- unstable

B **Distraction**

- disruption of disc or both spinal columns due to distraction
- A1 & B1 due to flexion-distraction
- anterior tension disruption
- anterior-posterior distraction through disc or open A fracture of vertebral body
- B2 due to hyperextension (rare)



1

Posterior disruption (ligamentous)

- Spontaneous disruption with facet dislocation - distraction - fracture unstable



2

Posterior disruption (osseous)

- Transverse disruption through laminae - pedicles - pars interarticularis
- unstable



3

Hyperextension

- anterior tension through disc
- may extend posteriorly

C **Rotation**

- anterior and posterior columns together with rotation
- disruption of disc and all ligaments
- widespread asymmetrical fracture



1

Type A with rotation

- wedge, split or burst fracture of vertebral body
- with rotation



2

Type B with rotation

- usually flexion-distraction injuries with rotation



3

Rotational shear

- also or oblique vertebral body fracture

Table 2

Thoracolumbar Injury Classification and Severity Score

Injury Characteristic	Qualifier	Points
Injury morphology		
Compression	—	1
Burst	—	+1
Rotation/translation	—	3
Distraction	—	4
Neurologic status		
Intact	—	0
Nerve root	—	2
Spinal cord, conus medullaris	Incomplete	3
	Complete	2
Cauda equina	—	3
Posterior ligamentous complex integrity		
Intact	—	0
Suspected/Indeterminate	—	2
Disrupted	—	3

+ = 1 additional point given to the morphology

≤ 3 = non op
4 = grey
≥ 5 = op

Stable **Partial** **Unstable**

A

Compression

?

B

distraction

C

rotation

Load-sharing classification

McCormack, Gaines et al (Spine 1994)

28 pts

COMMINUTION

APPOSITION

KYPHOSIS



1. Little

< 30% comminution



2. More

30-60% comminution



3. Gross

> 60% comminution

on sagittal CT



1. Minimal

minimal spread



2. Spread

< 2mm of < 50%



3. Wide

> 2mm of > 50%

on axial CT



1. Little

< 4° correction



2. More

4-9° correction



3. Most

> 9° correction

on lateral x-ray - POST OP

score from 3 to 9

≤ 6 = posterior surgery

> 6 = anterior surgery

Old Instrumentation
Not Externally Validated

lying vs standing
Prediction of correction

New AO Classification

Spine
DIAGNOSTICS

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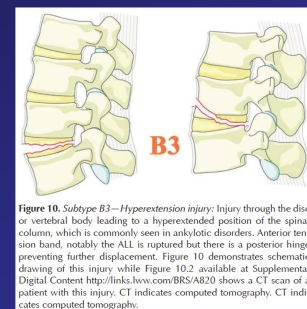
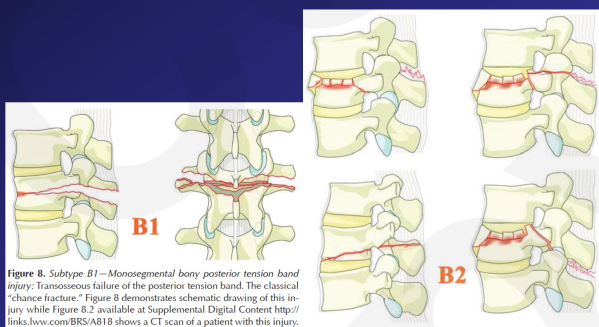
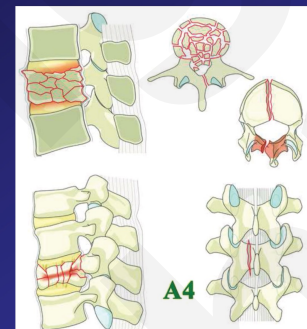
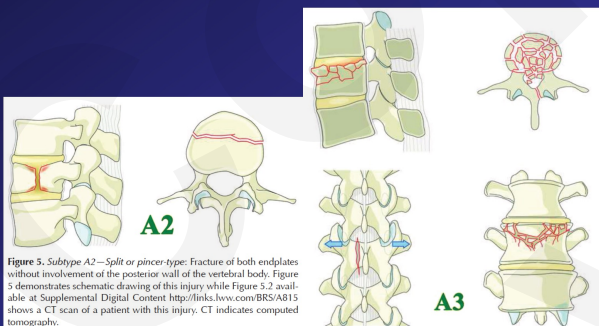
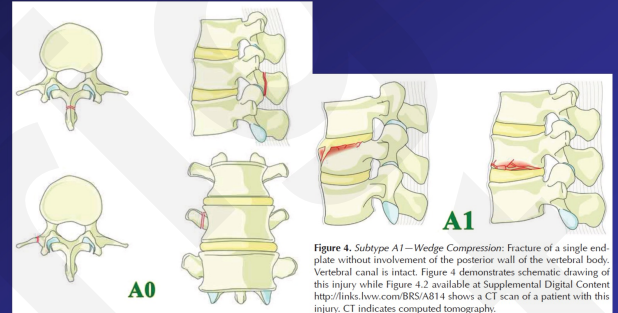
AOSpine Thoracolumbar Spine Injury Classification System

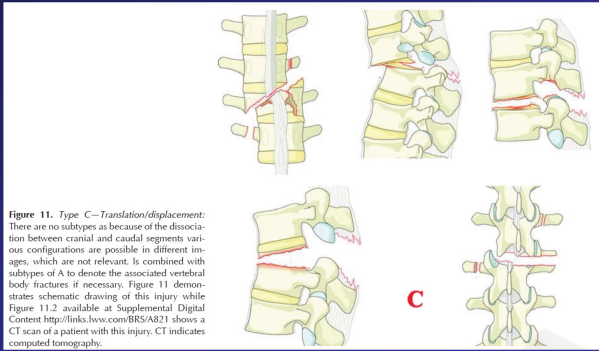
Fracture Description, Neurological Status, and Key Modifiers

1. Morphologic classification of the fracture
2. Neurological status
3. Clinical modifiers

1. Morphological Classification

- **Type A:** Compression
- **Type B:** Failure of posterior or anterior tension band without evidence of either gross translation or the potential for gross translation
- **Type C:** Failure of all elements leading to dislocation or displacement in any plane or complete disruption of a soft-tissue hinge even in the absence of translation





2. Neurological Status

- N0: Intact
- N1: Transient deficit resolved
- N2: Symptoms / signs radiculopathy
- N3: Incomplete SCI / CES
- N4: Complete SCI (ASIA A)
- Nx: Unable to assess

3. Clinical Modifiers

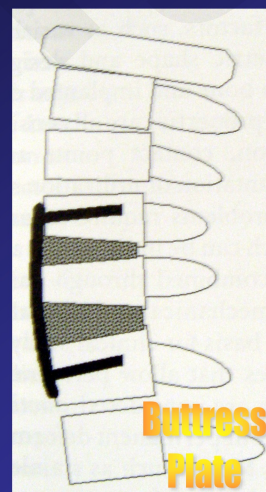
- M1: Indeterminate ligamentous injury
- M2: Patient specific comorbidity – AS, RA, DISH, OP, Burns

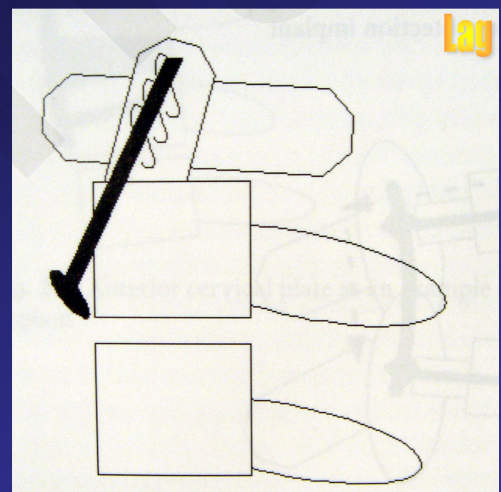
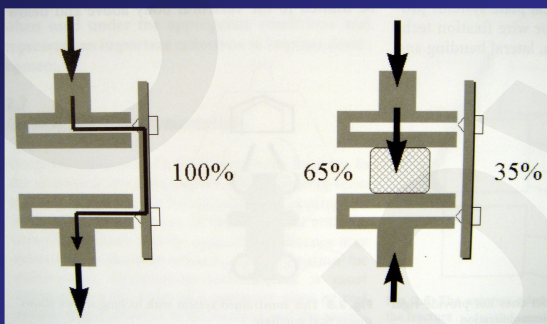
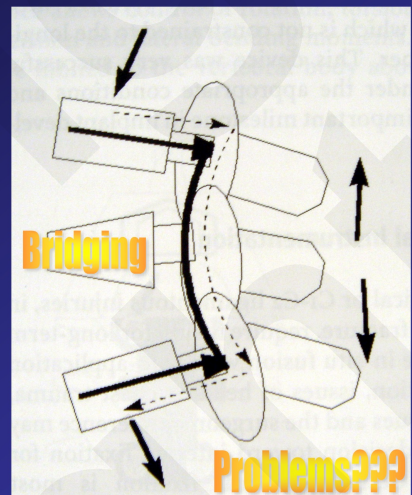
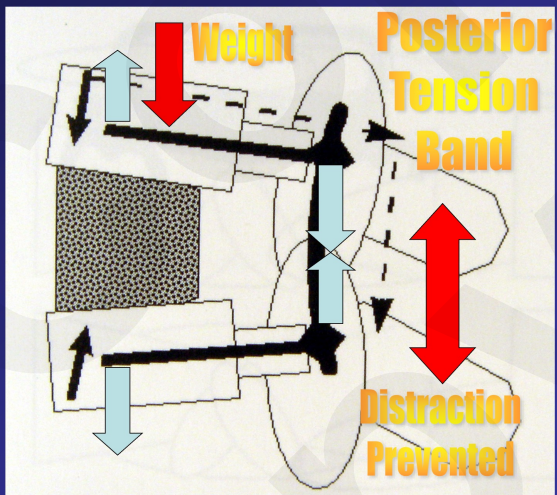
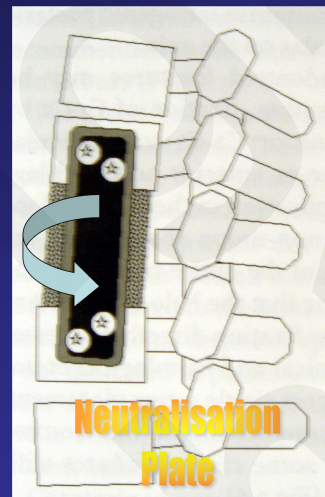
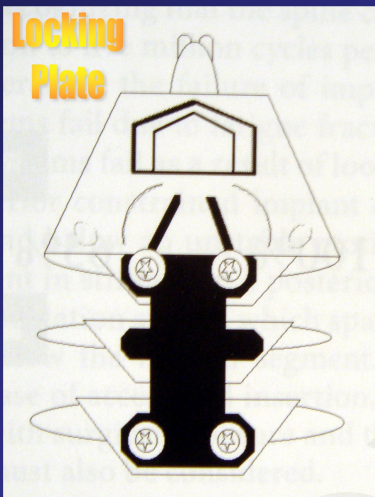
Thoracolumbar Instability

- Neurological deficit
- Clinical posterior tenderness or deformity
- > 20-30° kyphosis (segmental or combined)
- > 30% loss of vertebral height (thoracic)
- > 50% loss of vertebral height (lumbar)
- > 50% canal compromise
- Rotational malalignment
- Fracture dislocation
- Multiple adjacent fractures (combined height loss > 50%)
- Scoliosis > 10°

AO Principles

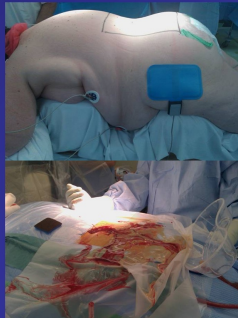
- Anatomic Reduction
- Stable Internal Fixation
- Atraumatic Technique
- Early Active Mobilisation





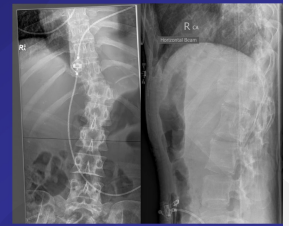
The Personalities

- Personality of the patient
 - Age
 - Comorbidity
 - Bone stock
 - Energy of injury / other injuries
 - Time since injury



The Personalities

- Personality of the fracture
 - Canal compromise
 - Neurologic compromise
 - Kyphosis
 - Anterior collapse
 - Progression



Munted

The Personalities

- Personality of the surgeon



Absolute Indications for Surgery

- Indications for decompression
 - Worsening neurological deficit in the presence of demonstrable neural compression despite attempts at postural reduction
- Indications for stabilisation
 - All cases requiring decompression
 - Complete ligamentous disruption associated with dislocation
- Open Thoracolumbar burst fractures
- Patient with complete neurological deficit
- Multiply injured patient

Relative Indications for Surgery

- Decompression surgery (+ stabilisation)
 - Dynamic neurology
 - Stable incomplete neurology in presence of demonstrable neural compression
- Stabilisation surgery
 - Loss of anterior body height >50%
 - Kyphosis >20-30 degrees
 - Canal stenosis >50%
 - Disruption of posterior ligamentous complex

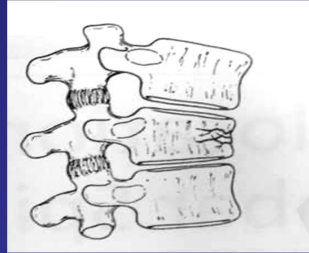
“Accepted” Indications for Surgery Thoracolumbar Burst Fractures

- Progressive neurologic deficit
- Progressive kyphosis ass. with neurologic deficit
- CT evidence of spinal canal compromise associated with an incomplete neurologic deficit
- Greater than 50% loss of vertebral body height
- Kyphosis greater than 30 degrees at level of #
- Spinal canal compromise greater than 50%

J Spinal Disord. 1990 Mar;3(1):39-46.

Compression / A1 Impaction

- Primarily involve anterior column in flexion
- Cause RTAs and Falls
- Most common thoracolumbar junction



Treatment

- Mobilise
- Pain Relief
- ? Brace
- ?????Operation

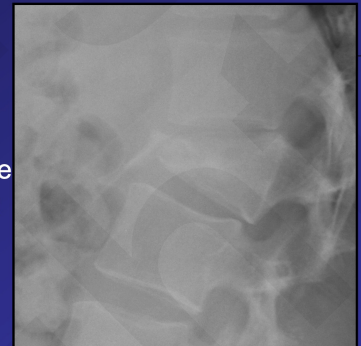


Outcome

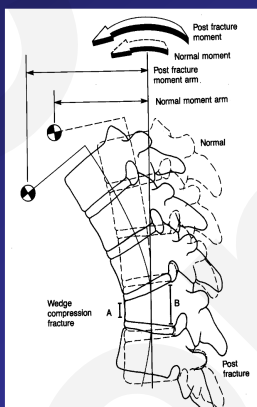
- Majority heal
- Low incidence of back pain
- Lumbar # more likely to be painful

Deformity – Standing Xrays

Gertsbein
>30 deg kyphosis
at union is associate
with increased pain



Post Traumatic Kyphosis



**Moment =
Force x
Distance**

*Goals for
Surgery*

Realign
Stabilize
Decompress
Prevent Late Pain / Deformity

Neurology

Biomechanics

clearance of
canal compromise

Maintain Function

Prevention of
neurological
deficit



Experimental Study of Thoracolumbar Burst Fractures

A Radiographic and Biomechanical Analysis of Anterior and Posterior Instrumentation Systems

Yasuhiro Shono, MD,* Paul C. McAfee, MD,† and Bryan W. Cunningham, BS‡

Anterior > Posterior

Biomechanical Evaluation of the Stability of Thoracolumbar Burst Fractures

Kenneth S. James, Karl H. Wenger, John D. Schlegel, and Harold K. Dunn

Importance of Intact Posterior Column

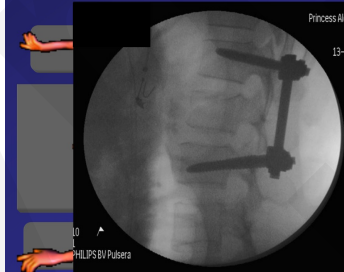
Anterior or posterior surgery

Posterior surgery is mainstay

posterior approach technically easy low morbidity

short segment pedicle fixation reduction of deformity & canal compromise

posterior approach Important for dislocation / realign



Dural laceration occurring with burst fractures and associated laminar fractures

FP Cammisa, FJ Eismont and BA Green
J Bone Joint Surg Am. 1989;71:1044-1052.

11/30 Dural Lacs

- Exception – facet fracture dislocations – i.e. remove posterior compressive fragments from the back

+ Posterior Fix + Decompression =

and destabilised!

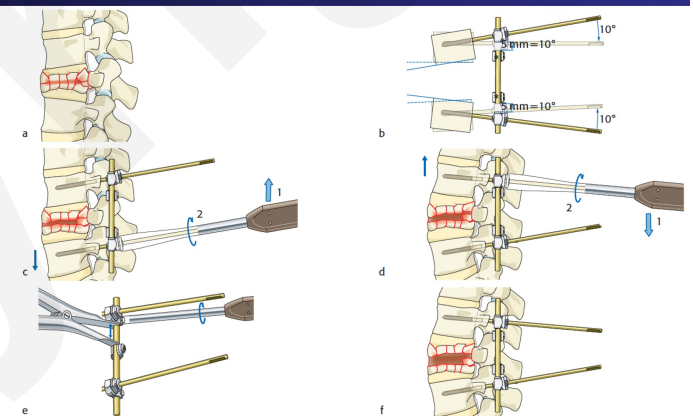
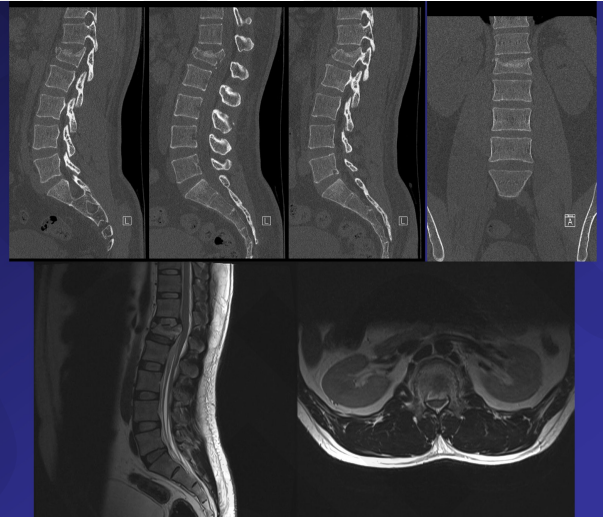
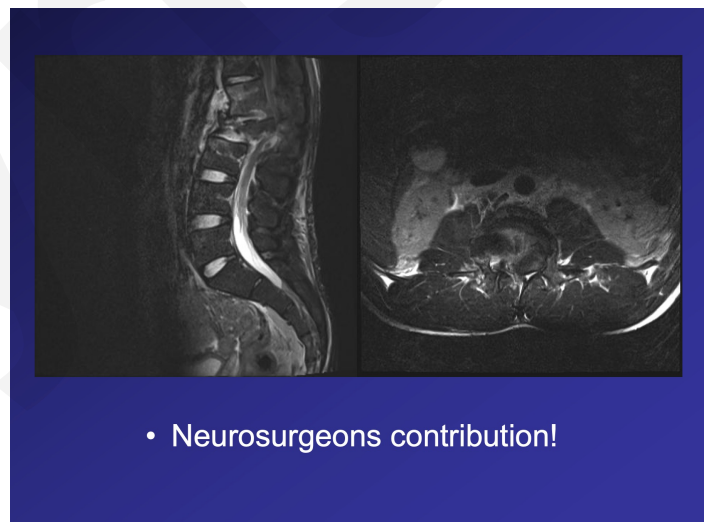
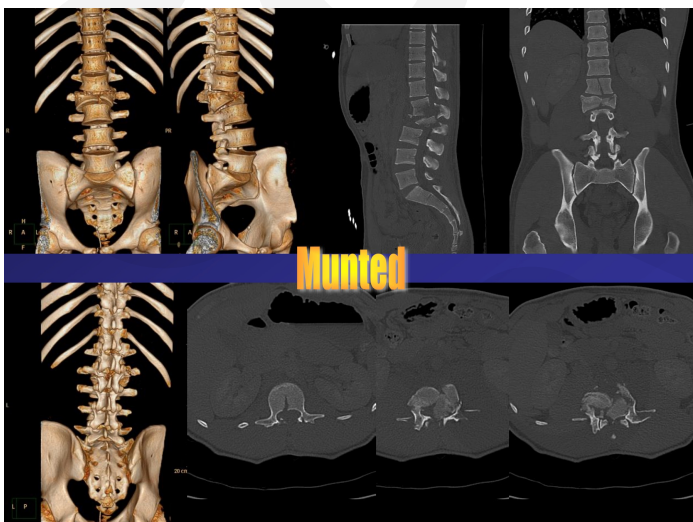
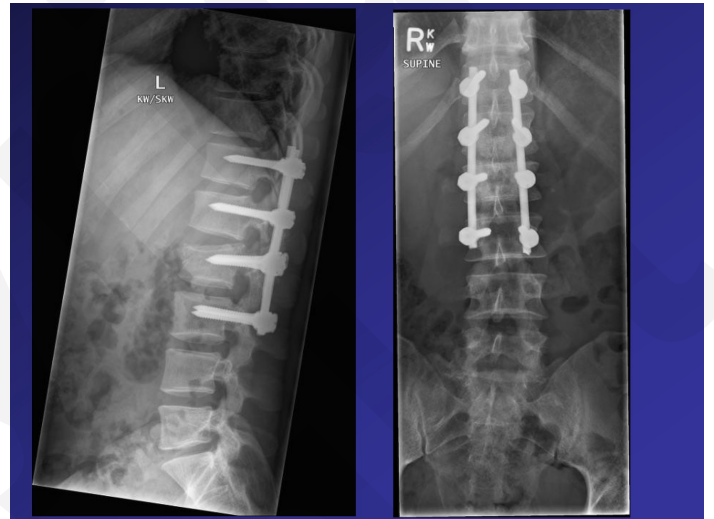
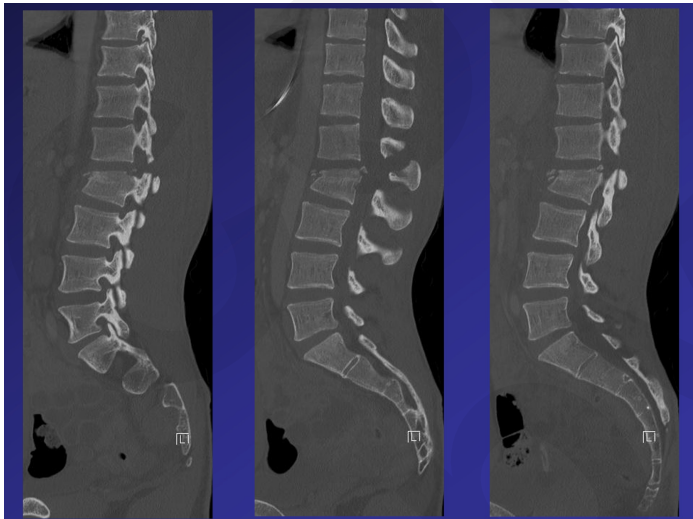
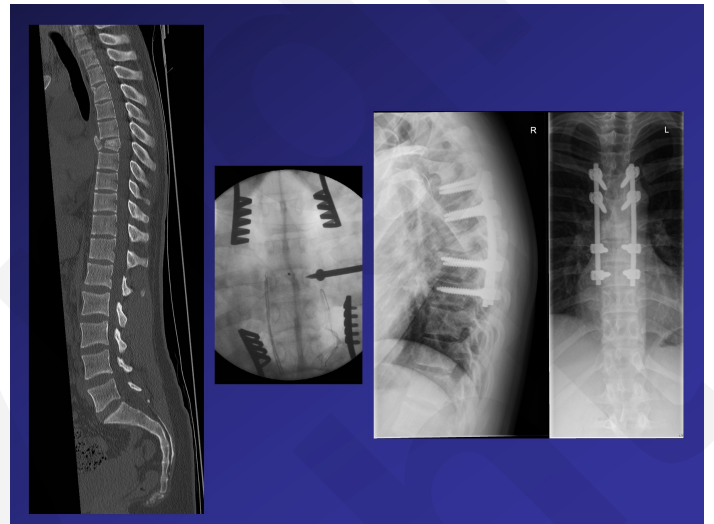
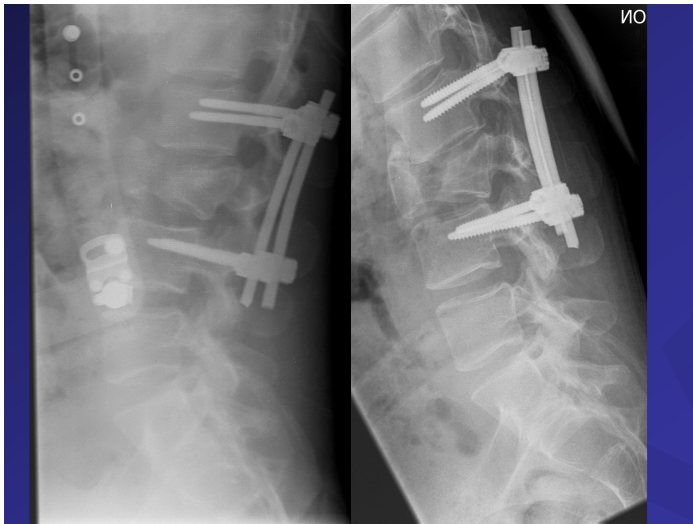
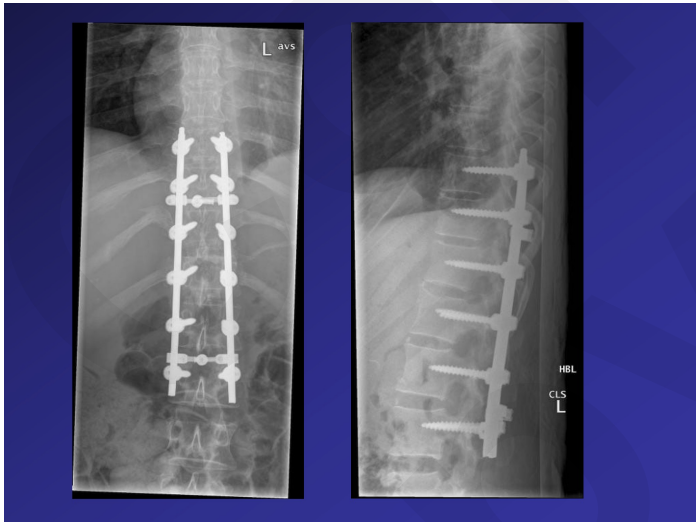
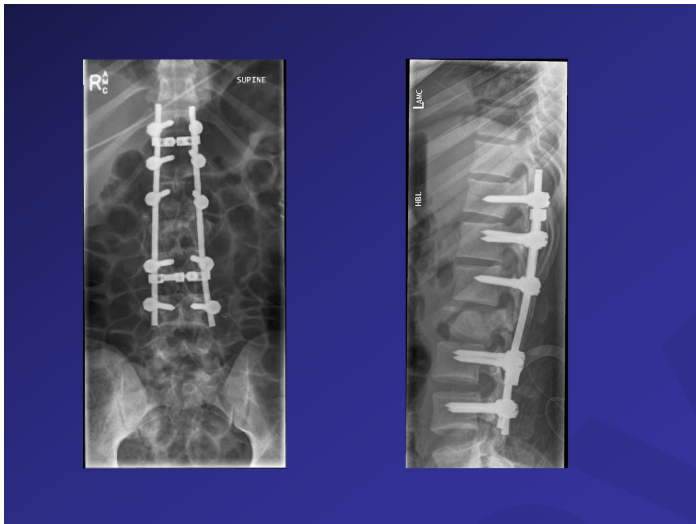


Fig 7.3.2-8a-f
a Type A3 burst fracture (with fractured posterior wall).
b Half rings (asterisks) are mounted on the rods. For each 10° of kyphosis correction, a 5 mm distance between the half ring and the clamp is needed.

c-d Using the cannulated socket wrench (1), the caudal and the cranial nuts are tightened (2) to secure the correction.
e-f Distraction is applied with the spreader forceps and final correction is achieved.





Anterior or posterior surgery

Anterior surgery for significant anterior comminution

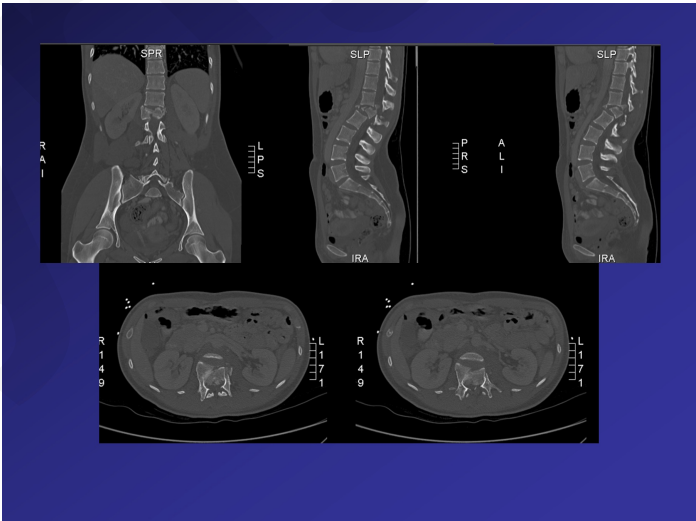
Corpectomy direct cord decompression vs. posterior indirect

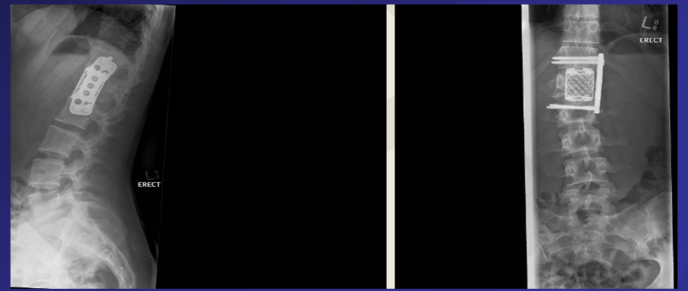
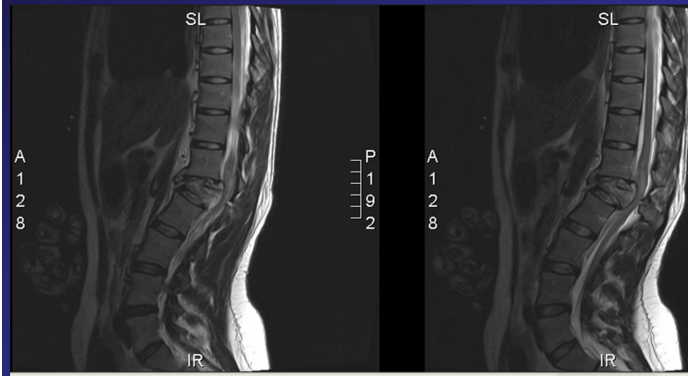
correction of deformity

posterior fixation cannot provide anterior column support

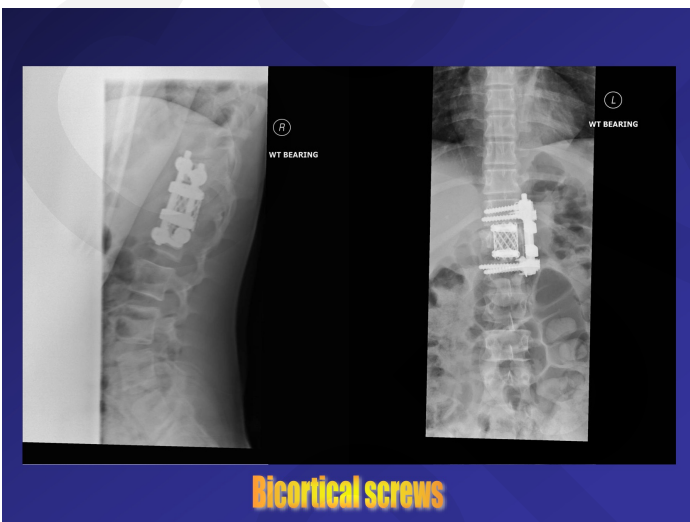
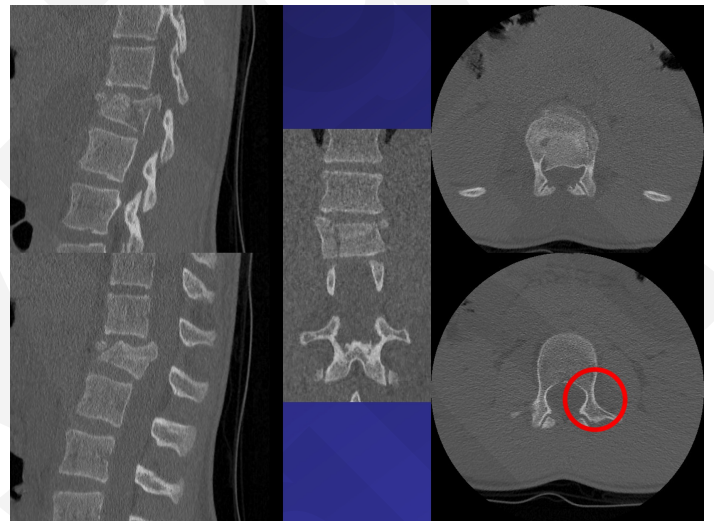
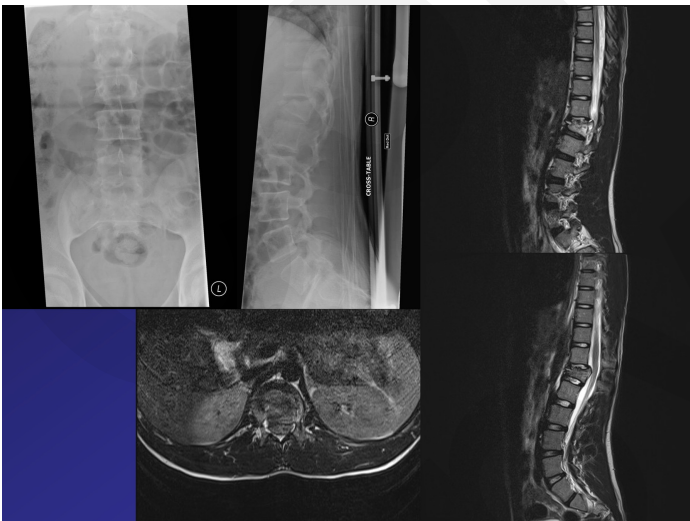
Cons:
Infrequent
Specialist Training

stabilization of instability

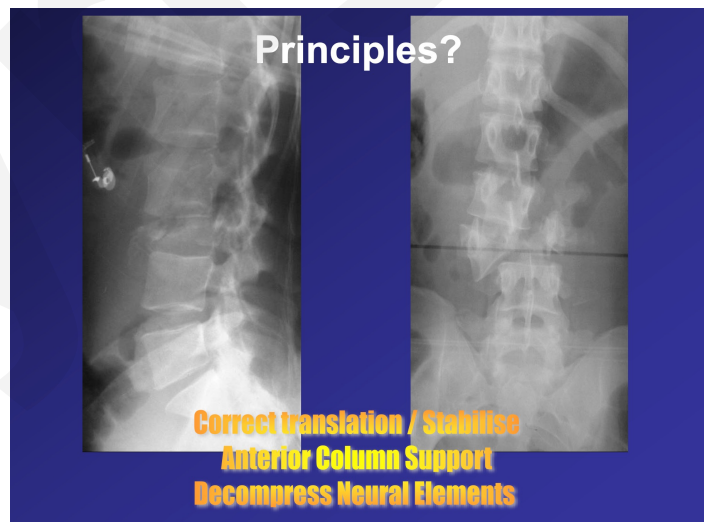




Bicortical screws

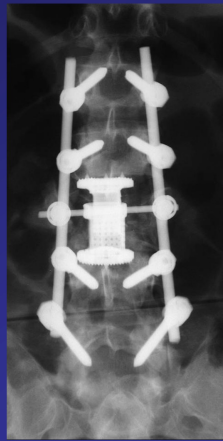


Bicortical screws



Principles?

**Correct translation / Stabilise
Anterior Column Support
Decompress Neural Elements**



- Remember – screws in the front can get in the way of screws in the back and vice versa

- Posterior
 - Realign
 - Restore Tension Band
 - Ligamentotaxis
 - Indirect Canal Decompression
- Posterior Qs
 - Short or long
 - +/- Fracture screws
 - +/- Cross Links
 - Decompression
 - Fuse
- Anterior
 - Column support
 - Decompression
- Anterior Qs
 - Structural Allograft
 - Cage Autograft
 - Expandable Cage
 - Rods or Plate

Timing of Surgery

Eur Spine J (2013) 22:2157–2166
DOI 10.1007/s00586-012-2624-1

REVIEW ARTICLE

A methodological systematic review of early versus late stabilization of thoracolumbar spine fractures

Fix Early

Complications and Outcomes

Stadhouder (Spine 2008)

- Thoracolumbar fractures
- Complications : 17% Nonop 21% Op (NS)
- Outcomes: VAS, ODI, GHQ similar at 2-6 years
- Employment: 88% Nonop, 83% op

Aims / Objectives

- Pathophysiology of Spinal Cord Injury
- Investigations
- Initial Management
- Spinal Fractures:
 - Describe the aims of surgical fixation in the spine
 - Fixation
 - Front, Back, Both
 - Explain the rationale and mechanics of different approaches

Aims / Objectives

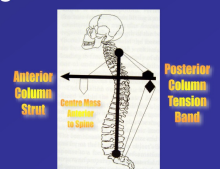
- Describe the aims of surgical fixation in the spine
- Fixation
 - Front, Back, Both
 - Does it matter?

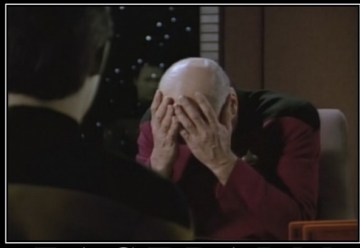
Depends on #

- Explain the rationale and mechanics of different approaches

Realign, stabilise, decompress

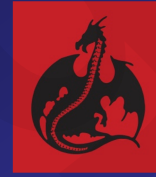
**Realign
Stabilize
Decompress
Prevent Late Pain / Deformity**





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