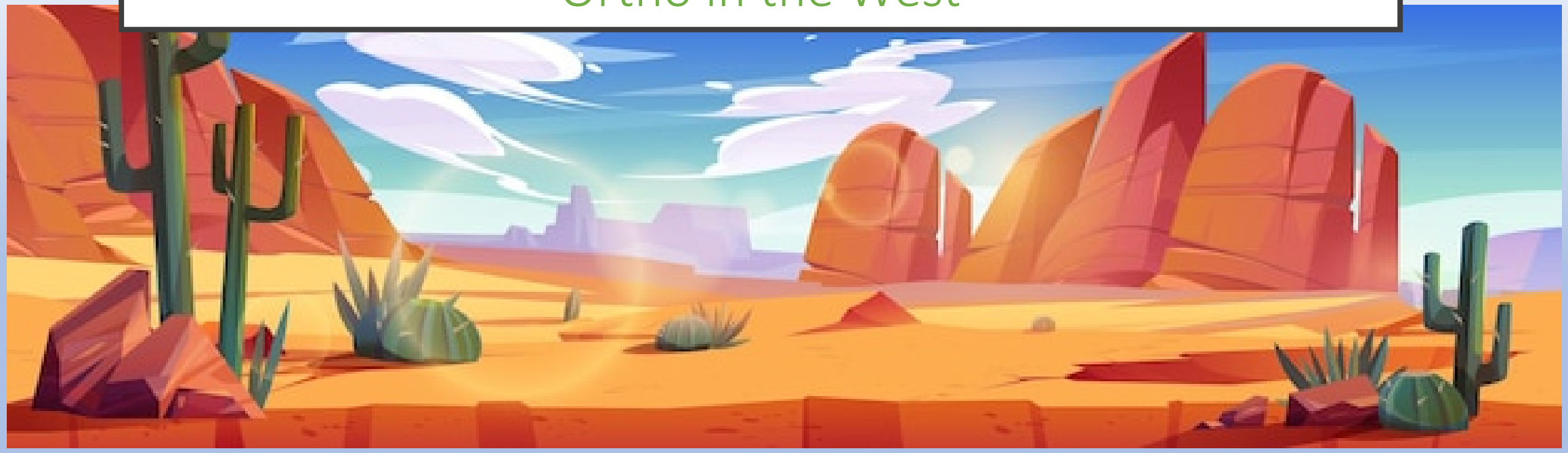
Ortho in the West



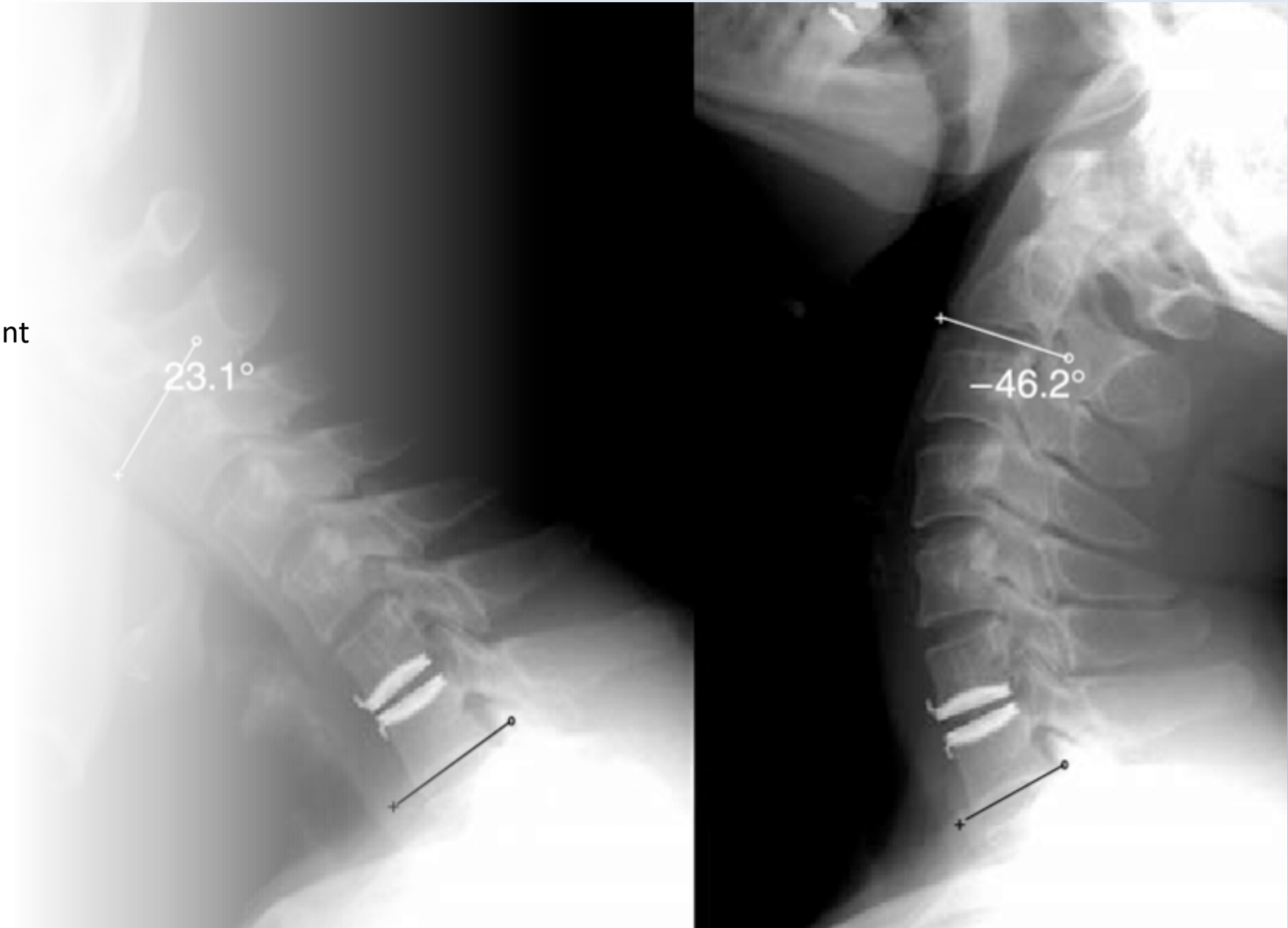
ADR. . . Why not?

Joshua Abrams

Desert Institute for Spine Care

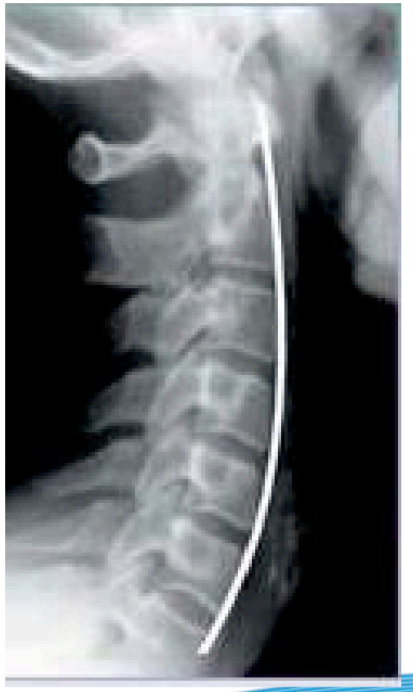
Why? Or Why not?

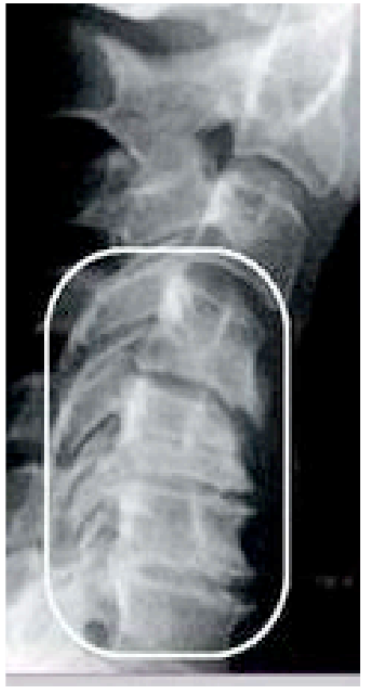
- Adjacent segment disease?
- Does Artificial disc replacement REALLY decrease this rate?



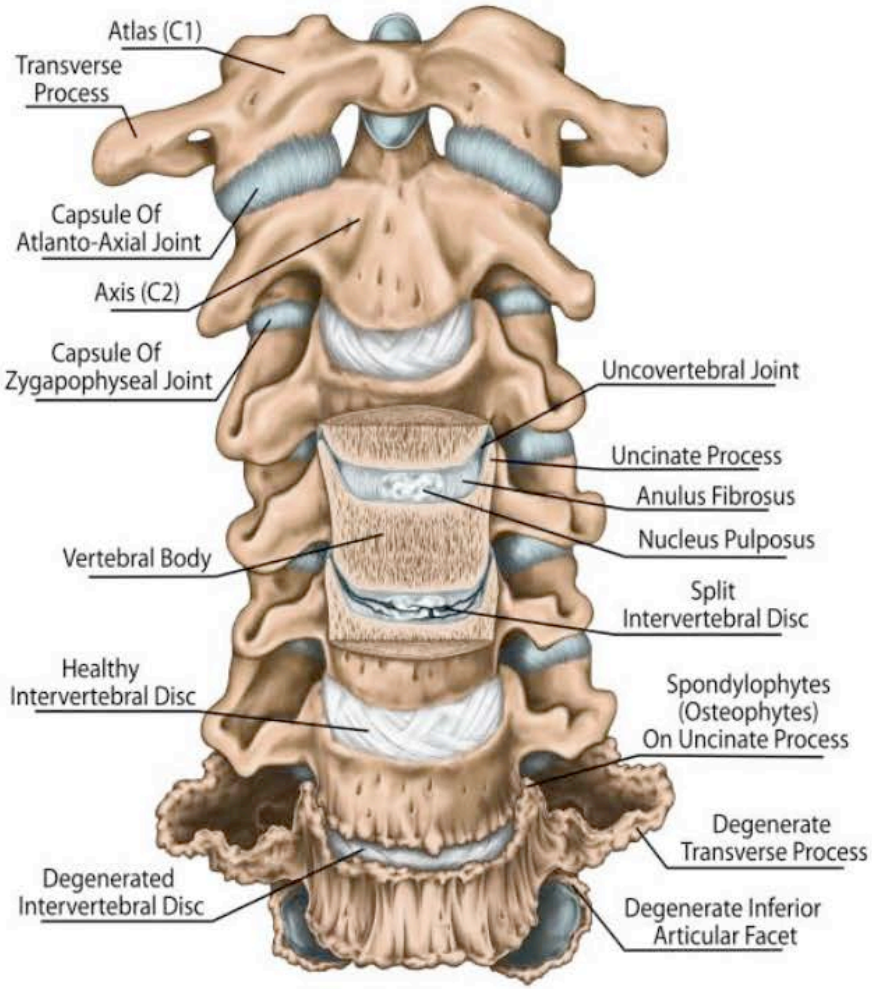
Degeneration of Discs

- Natural process that all people undergo as they age
  - Nucleus dehydrates, compromising its cushioning ability
  - Annulus may also begin to degenerate under the repeated stress of daily activities or trauma => disc herniation and loss of disc height



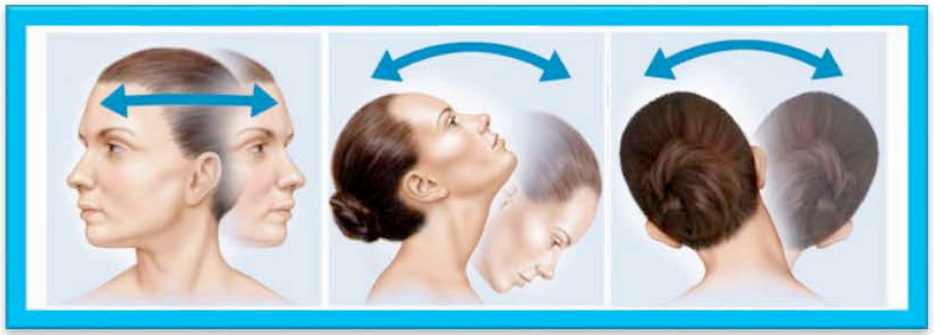


- Disc Degeneration
  - Characterized by the disc drying out
  - Decrease in height
  - Herniated Disc
- Osteophytes
- Spinal Stenosis
- Radiculopathy / Myelopathy



Patients with herniated disc(s) often present with one or more of the following symptoms:

- Pain in the neck, shoulder, and arm(s) – with or without neck movement
- Neck stiffness
- Numbness, tingling, or weakness in the hands
- Weak or absent upper extremity reflexes
- Weakness in the lower extremities or effects on walking gait (if spinal cord involvement)
- Headaches



Common affects on the functions of daily life:

- Difficulty driving – turning of the head
- Difficulty lifting objects
- Difficulty working, reading, concentrating
- Difficulty with personal care (washing, dressing)
- Effects on recreational activities / exercise

Epidemiology/Demographics of Neck Pain

- Cervical/neck pain is common reason for visiting doctor
  - Over 6 million patient visits in the US for neck pain
  - Represents 1.5 % of all health care visits to hospitals and physician offices[1]
  - About 2/3 of the population will experience neck pain at some point in their life[2]
  - Women are affected almost twice as much as men[2]

- Main causes of neck pain
  - Soft tissue strain (ligaments, tendons)
  - Cervical disc disorders
  - sudden force (whiplash)

- Often improve with time and non-surgical care

- Pain can be accompanied by numbness in neck or arms and limit daily activities/ability to work

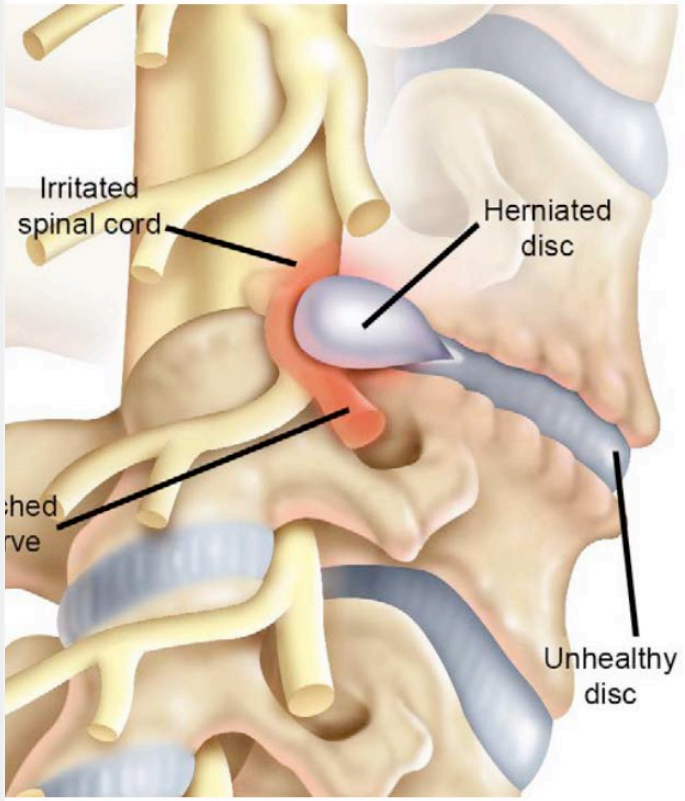
Radiculopathy And Myelopathy

Radiculopathy

- Radiculopathy is characterized by pain that seems to radiate from the spine, extending outward to cause symptoms away from the source of the spinal nerve root irritation.
- Causes of radiculopathy:
  - deformities of the discs between the vertebrae,
  - deformities of the bone around the exiting nerves
  - inadequate blood supply to the spinal nerve roots.

Myelopathy

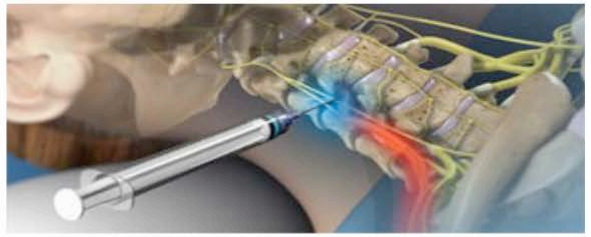
- Describes any neurologic deficit related to the spinal cord or Cauda Equina.
  - *Cervical spondylotic myelopathy (CSM)*, is caused by arthritic changes (spondylosis) of the cervical spine, which result in narrowing of the spinal canal (spinal stenosis)
  - When due to trauma, it is known as (acute) spinal cord injury.
  - When inflammatory, it is known as myelitis.
  - Disease that is vascular in nature is known as vascular myelopathy.



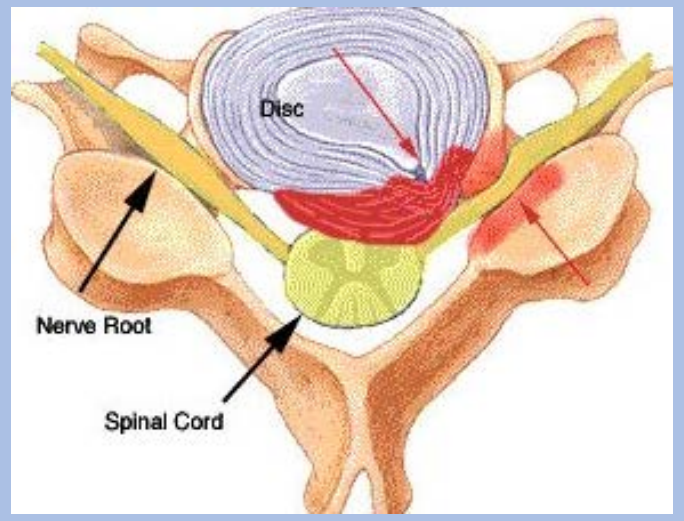
Conservative Care

The standard initial treatment regimen involves 6 weeks of conservative (non-surgical) care:

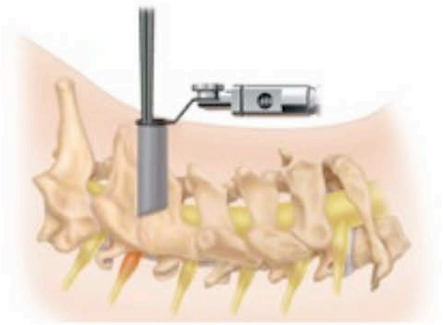
1. Rest, activity modifications
2. Physical therapy, controlled exercises, stretches, bracing
3. Anti-inflammatory and analgesic medications
4. Chiropractic treatments, cervical traction
5. Pain injections /blocks
6. Acupuncture



If no relief, or symptoms get progressively worse, various surgical options can be discussed

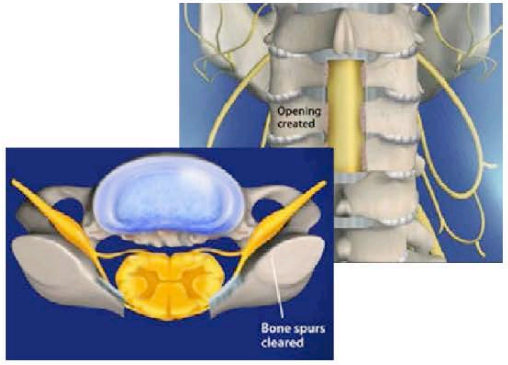


Foraminotomy

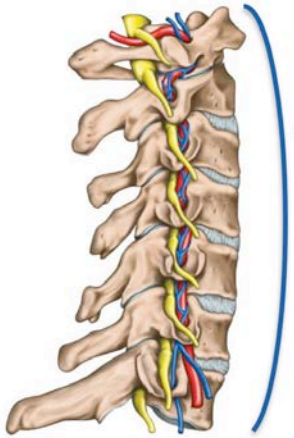


emoval of bone and tissue
t is compressing the nerve
through minimal incisions,
tilizing endoscopic tubes,
ameras, and instruments

Laminectomy

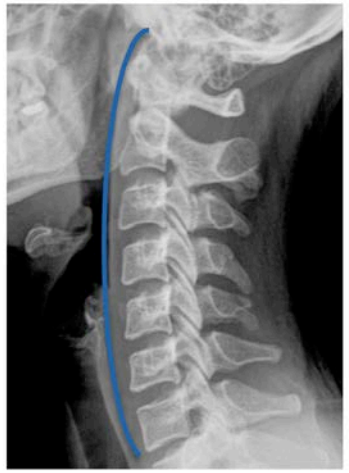


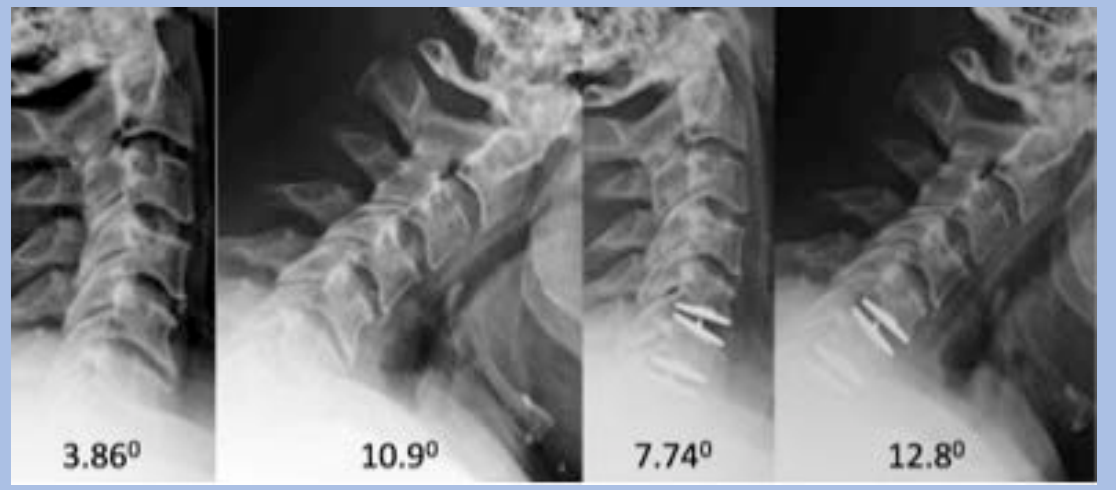
Removal of a portion of a bony posterior arch (lamina) and associated ligaments that surround the spinal cord, leading to relief of pressure on nerve tissues



Lordotic curve

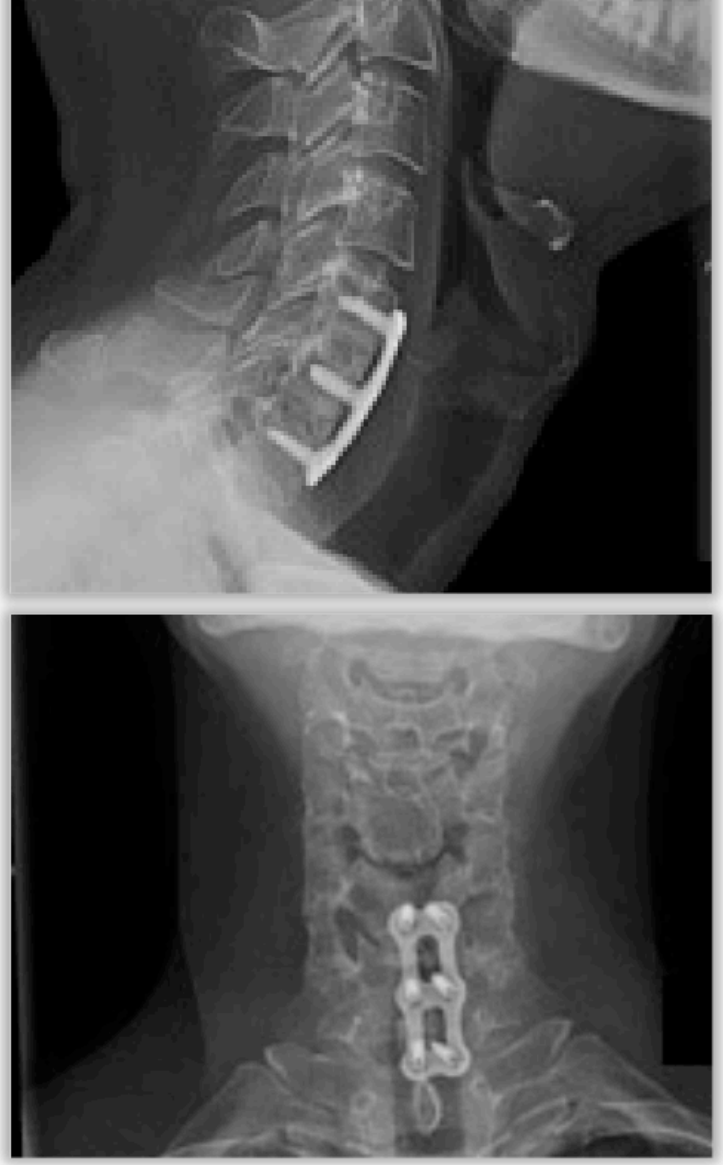
Typically 20 to 40 degrees in the Cervical spine





Anterior Cervical Discectomy and Fusion (ACDF) is an inpatient or outpatient surgical procedure where:

- The bulging disc is removed
- Neural structures are relieved of pressure and pain
- A bone spacer or plastic/metallic implant is placed in the disc space to restore disc height and fuse the vertebrae together
- Often, a metal plate is placed on the front of the vertebrae to help stabilize the segment until fusion occurs

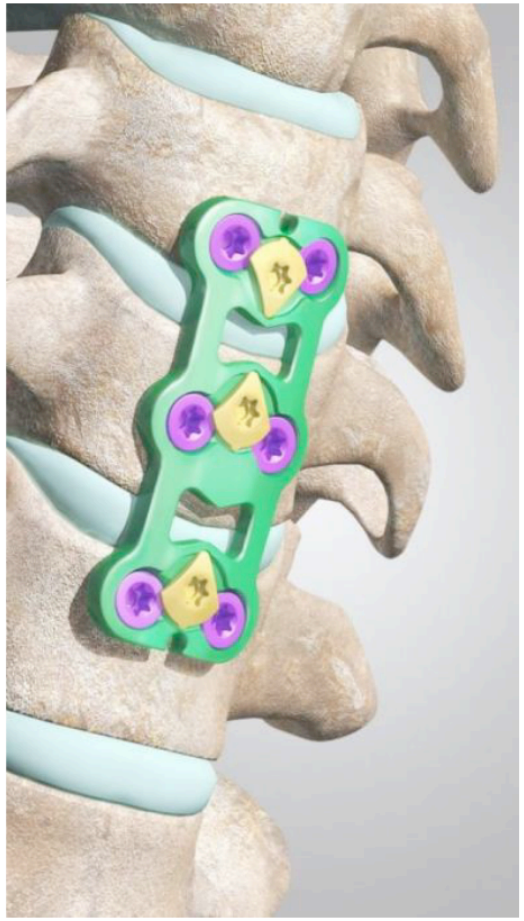


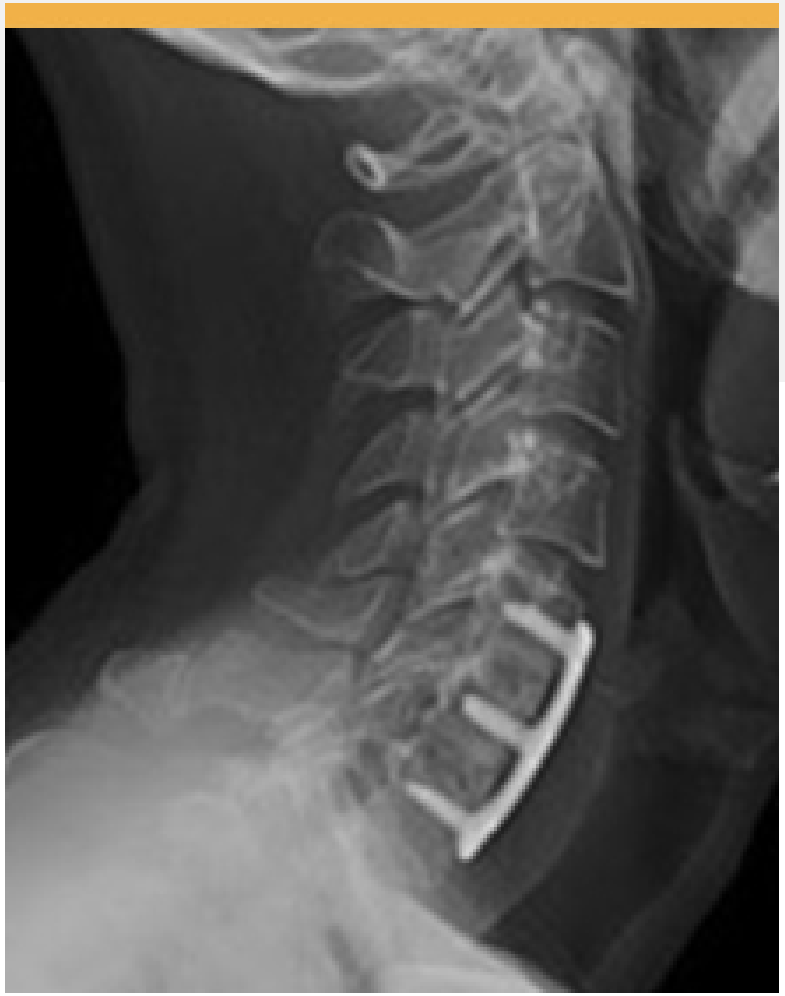
Example of a two-level fusion from C5-C7

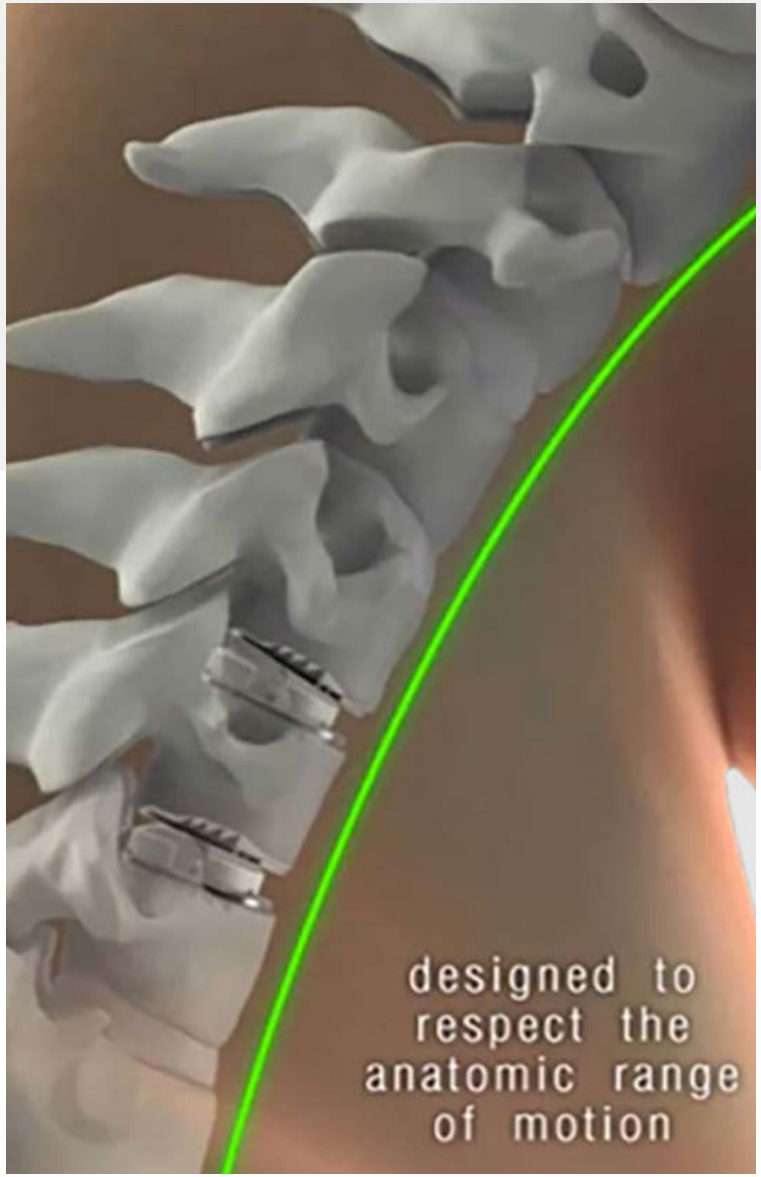
Fusion has been used successfully for more than 50 years and is very familiar to most spine surgeons. **However, fusion changes the normal biomechanics of the cervical spine with potential long-term consequences.**

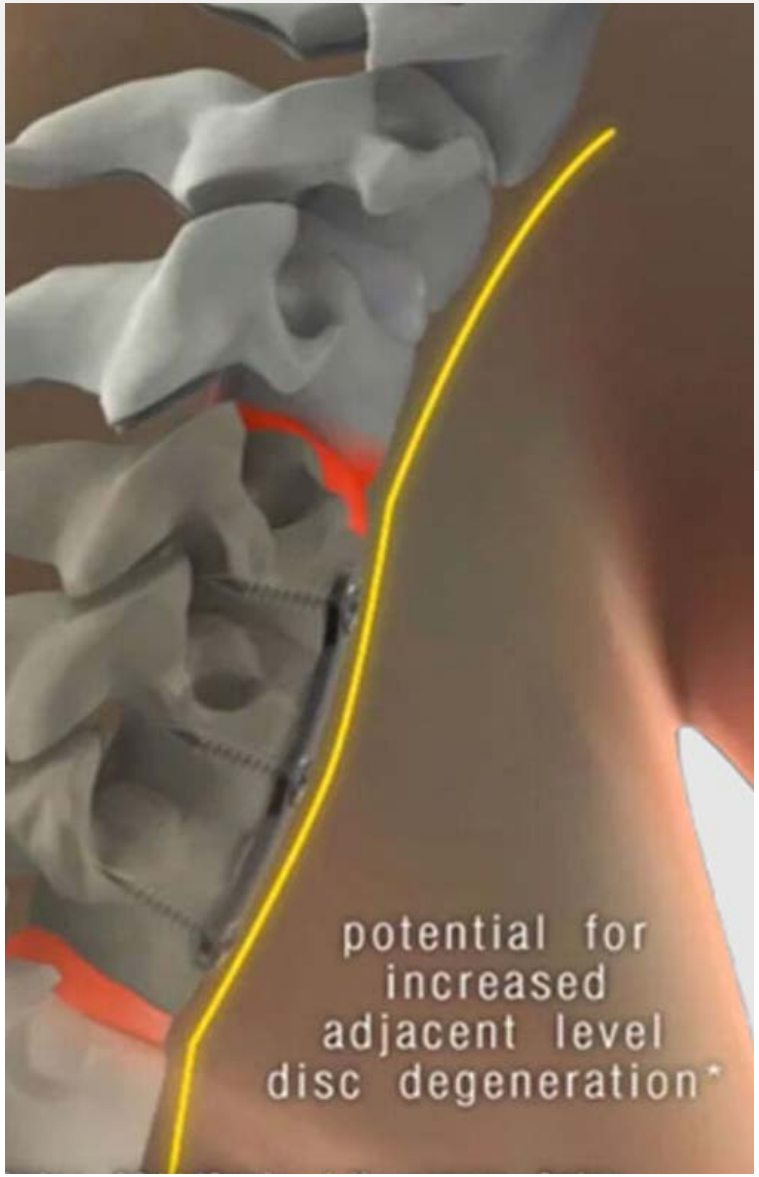
Clinical Disadvantage of ACDF

- Level above or below typically begins to degenerate (adjacent-level degeneration)
  - 25.6% of cervical fusion patients predicted to have second surgery within 10 years[4]
- Why?
  - Hardware (plate and screws) may impact adjacent levels
    - 23.7% of ACDF patients developed moderate to severe ossification at adjacent level[5]
  - Adjacent level has to compensate loss of motion of fused level
    - Extra motion fatigues adjacent disc and accelerates its degeneration[6]



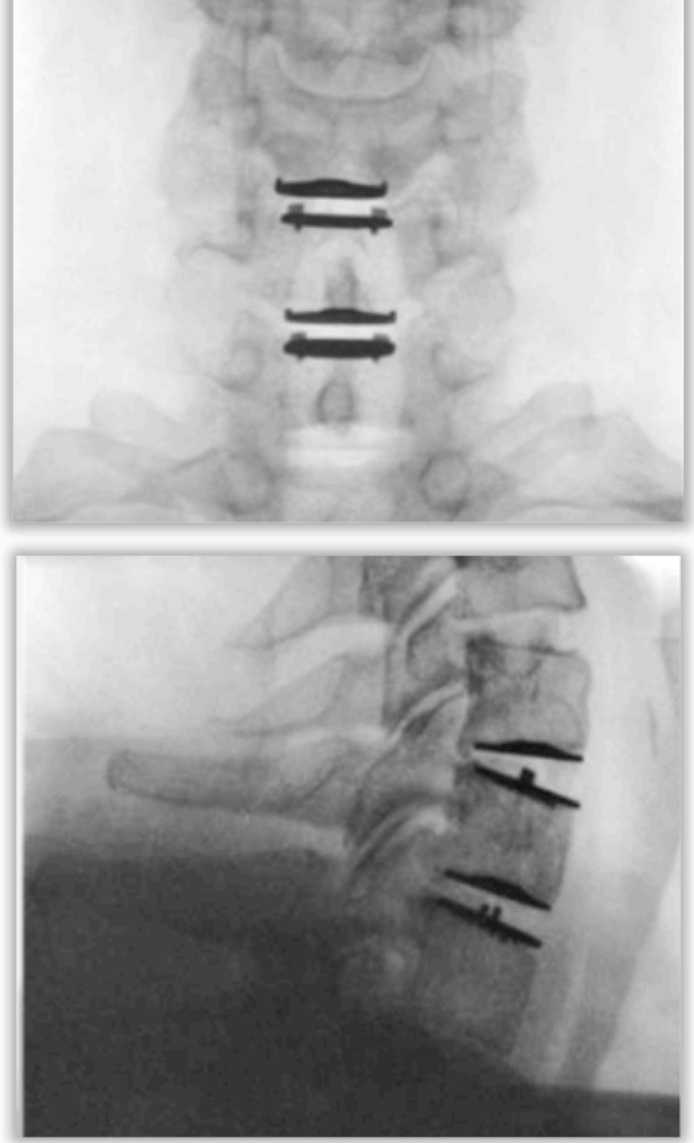



designed to
respect the
anatomic range
of motion


potential for
increased
adjacent level
disc degeneration*

A disc replacement procedure is an inpatient or outpatient surgical option instead of fusion where:

- The bulging disc is removed and the neural structures are relieved from pressure and pain
- A disc replacement device is placed in the disc space that restores and maintains disc height, while allowing natural neck motion to continue

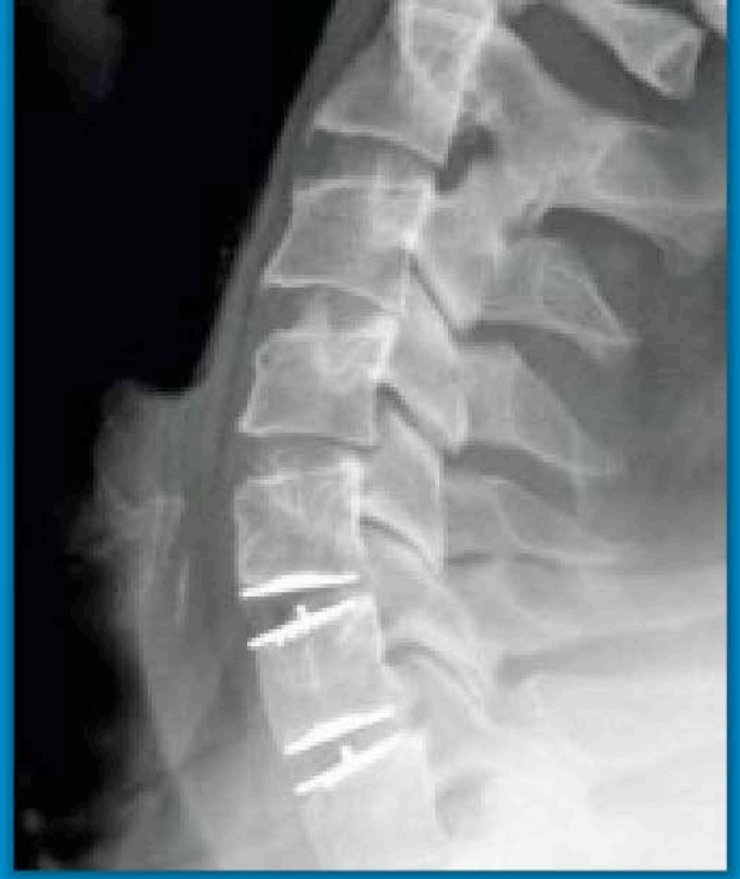


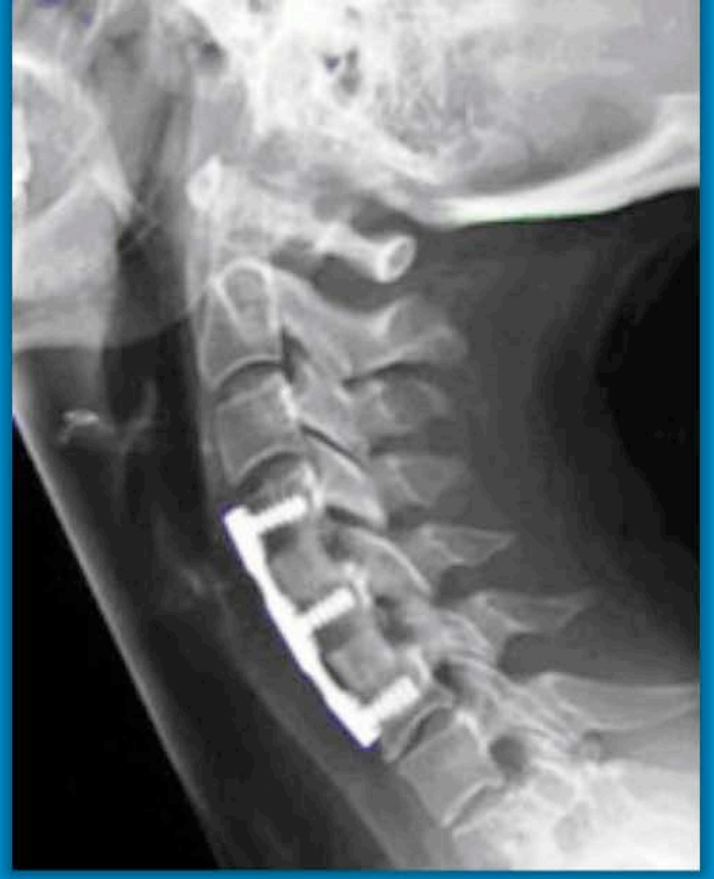
Example of a two-level disc replacement from C5-C7

Disc replacement has been used for more than 20 years globally with proven clinical results. **Disc replacement is designed to maintain normal cervical spine biomechanics and has demonstrated certain clinical advantages over fusion.**

Total Disc Replacement Surgery: History

- 1955 – Hamby / Cleveland: Cement
- 1962 – Nachemson: Silicone injection/ ball
- 1966 – Fernström: Ball bearing
- 1970's and 1980's - Silicon/ Dacron mesh, Rubber, Polyethylene, Fiber Lamilae, Accroflex and Charite disc for lumbar
- 1989-1991 – Cummins Disc/Frenchay/ Prestige disc for Cervical
- 1999 - Hilibrand et al: Adjacent level study





Total Disc Replacement vs Fusion

Lessons Learned:
Long-Term Effects of Fusion

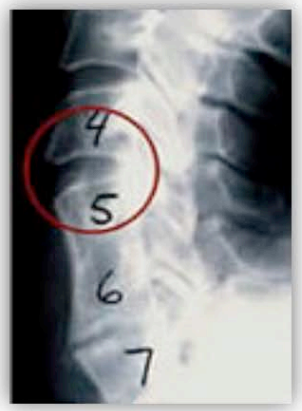
Pain relief from fusion comes with consequences

- Fusion changes the normal biomechanics of the spine. The levels above and below the fusion compensate for the loss of motion at the fused level by taking on significantly more motion and stress[3]

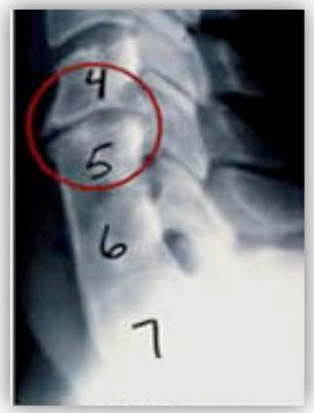
Multiple clinical studies comparing fusion to disc replacement have shown:

- 2-6x higher reoperation rates for fusion patients[4,5,6]
- Increased radiographic adjacent level degeneration for fusion patients[7,8,9]

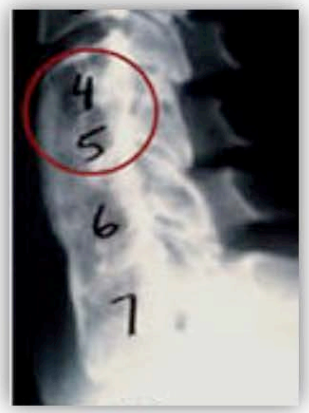
Adjacent Segment Degeneration[10]



1977



1984



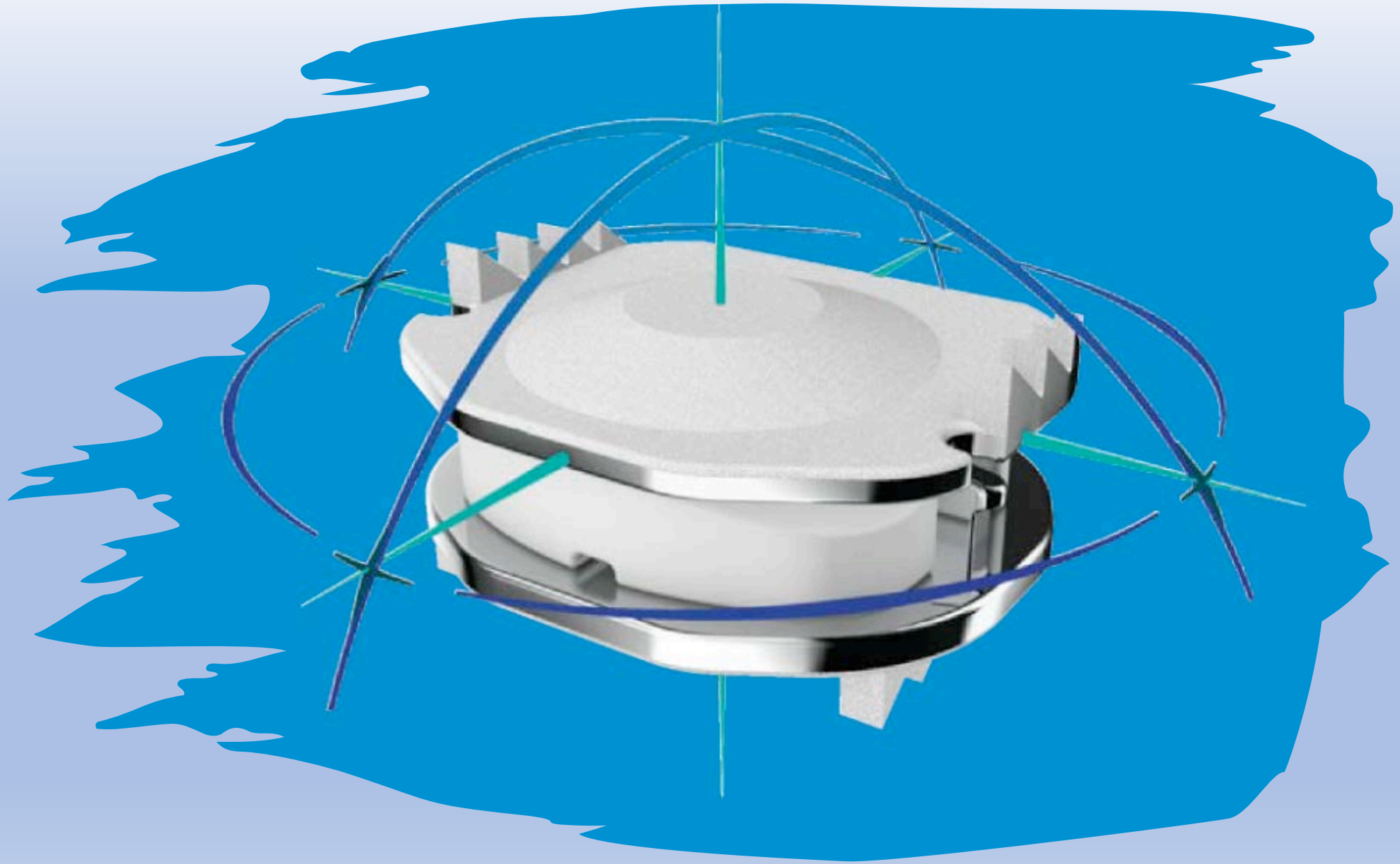
1989

In Contrast: Clinical Results of Cervical Disc Replacement

Disc replacements are designed to maintain physiologic motion and minimize the downsides of fusion

IDE clinical studies have shown for disc replacement vs fusion:[6,11,12,13]

Less radiographic adjacent level degeneration	Fewer reoperations	Better disability improvement	Maintenance of motion	Faster return to work
*Up to **3.5x** less*	*Almost **4x** fewer*	*Up to **16.5%** better*	*Up to **7 years out***	*Up to **3** **weeks faster***



Medtronic

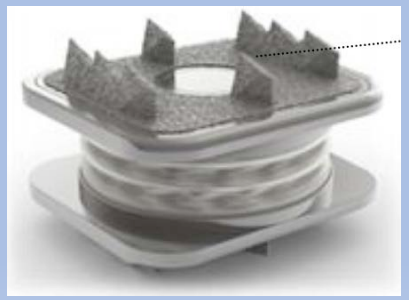
CENTINEL SPINE.

zimmer | spine

SimplifyMedical

Ball and Socket with articulating surface

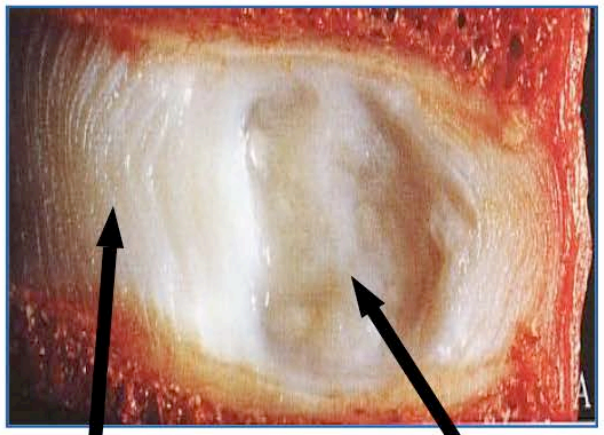
ORTHOFIX

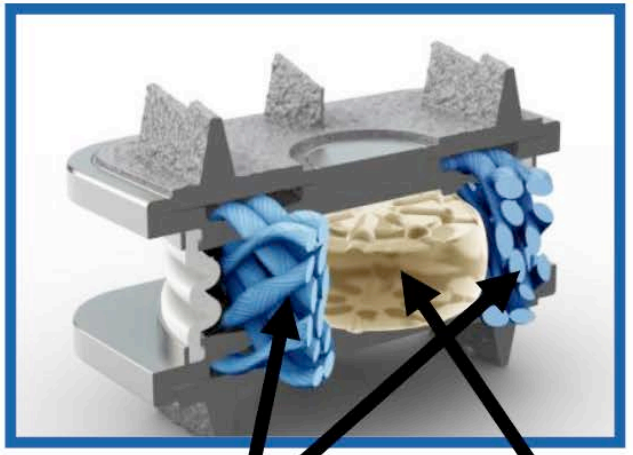


6 degrees of motion with center of rotation – most constrained

Spinal Kinetics Artificial Disc Design Goal

Design an Artificial Disc that has the *Physiologic Characteristics* of a Natural Disc





Mobi-C

- gned by experienced French surgeon team
- First implanted – November 2004 in Orleans, France
- Entered into FDA IDE one and two-level studies in 2006 (FDA approved August 2013)
- mplanted in over 35 countries

Key Results from the FDA Clinical Trial

Mobi-C Study Overview

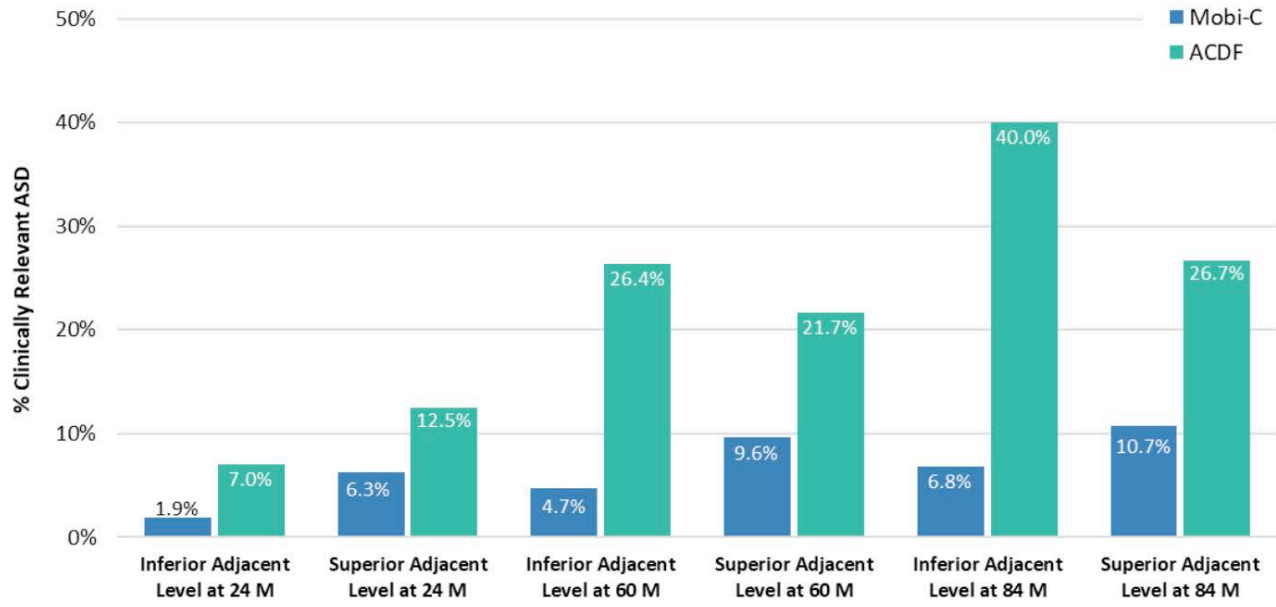
The Mobi-C Clinical Study is the largest concurrent cervical disc clinical trial ever conducted

- The study was conducted at 24 centers in the U.S. with 59 operating surgeons
- 599 patients were involved in the Mobi-C one and two-level study
- 647 levels of Mobi-C were implanted during the study
- Patients were randomized to receive either Mobi-C or ACDF with allograft bone and anterior cervical plate
- Two-year results were submitted to the FDA for product approval; study patients are followed for 7 years
- Mobi-C received FDA approval in August 2013 for both one and two-level indications

Adjacent Segment Degeneration Through 7 Years

Mobi-C two-level patients consistently demonstrated less adjacent segment degeneration[14] than fusion patients through 7 years

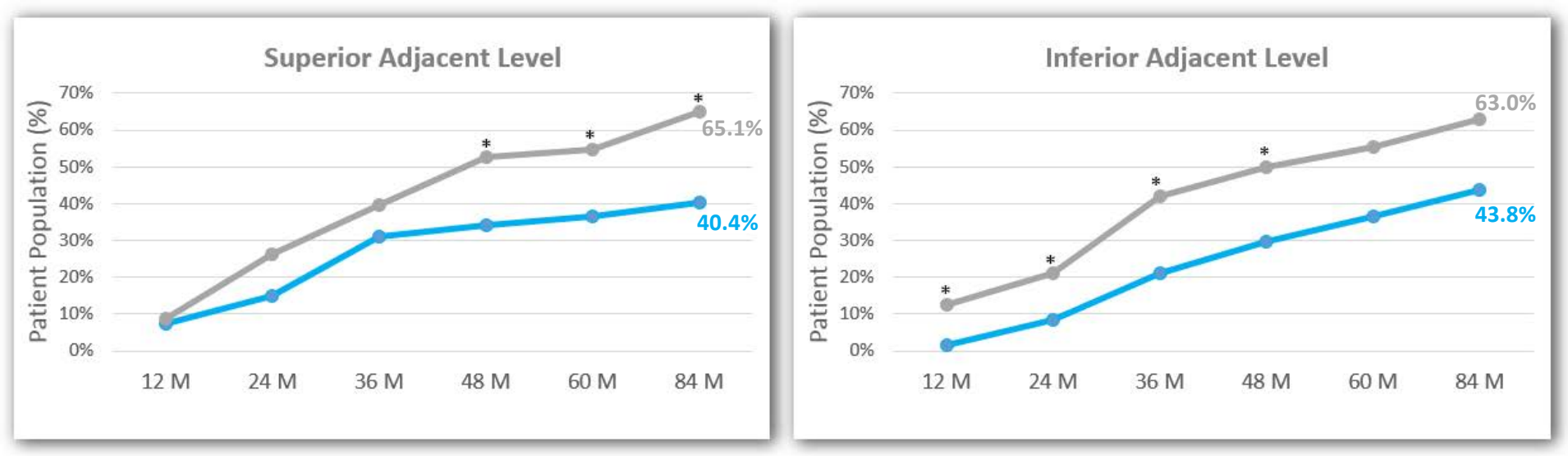
Patients x-rays were analyzed at every study visit to evaluate disc height and bony changes compared to baseline



ADJACENT SEGMENT DEGENERATION AT TWO-LEVELS*

Adjacent Segment Degeneration – 1 level One-Level

ACDF group demonstrated a noticeably greater prevalence of adjacent segment degeneration than TDR group at both the superior and inferior adjacent levels.

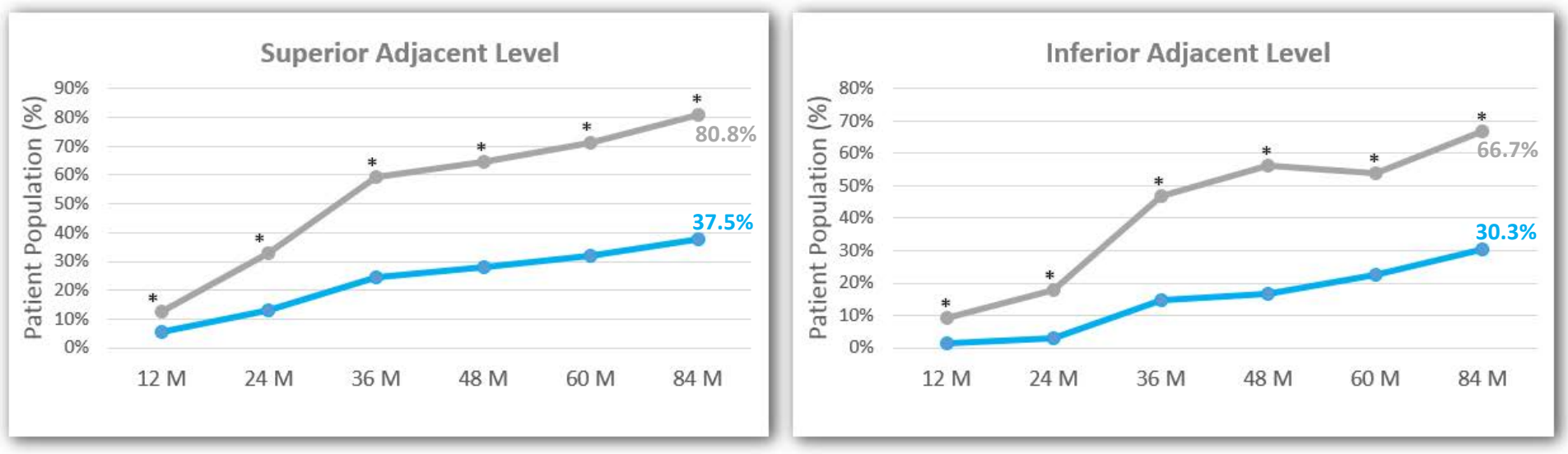


**Statistically significant difference in patients with degeneration versus those without (p<0.05; Fisher's exact test)*

Note: ASD defined as at least 1 increase in Kellgren-Lawrence grade from baseline.

Adjacent Segment Degeneration – 2 level Two-Level

ACDF group presented with **double the prevalence** of radiographic degeneration compared to TDR group at both the inferior and superior adjacent levels.



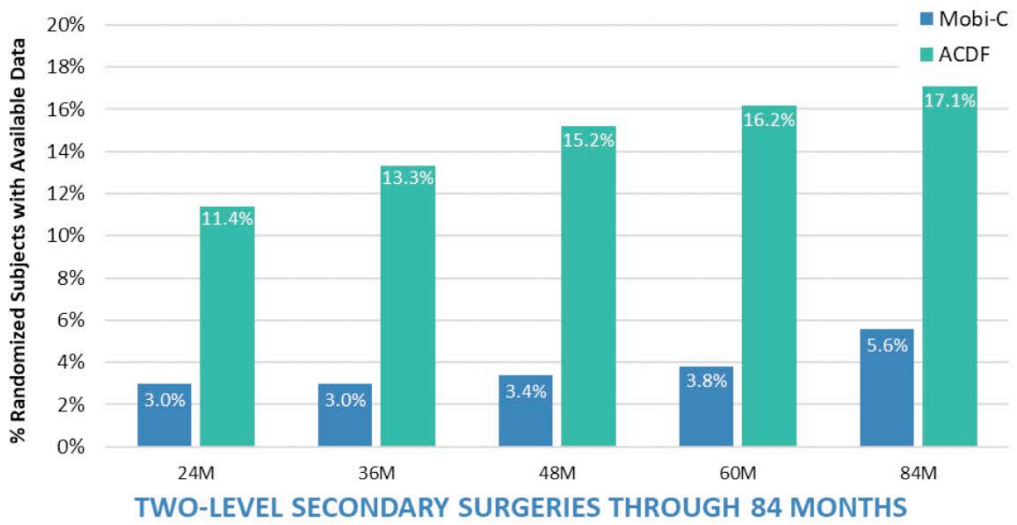
**Statistically significant difference in patients with degeneration versus those without (p<0.05; Fisher's exact test)*

Note: ASD defined as at least 1 increase in Kellgren-Lawrence grade from baseline.

Secondary Surgeries Through 7 Years

Patients that required removal, reoperation, revision, or supplemental fixation at the index level were considered study failures

Mobi-C subjects had fewer subsequent surgeries compared to ACDF subjects through 84 months

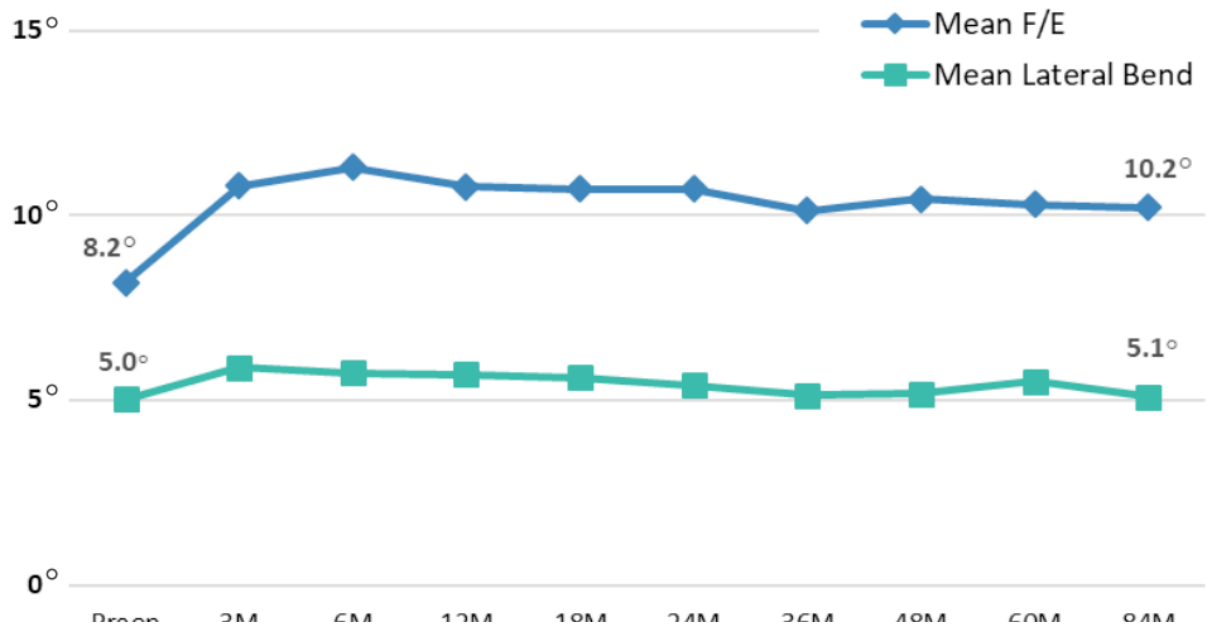


TWO-LEVEL SECONDARY SURGERIES THROUGH 84 MONTHS

Patient x-rays were measured for flexion/extension and side bending angles at every study visit

Mobi-C patients demonstrated on average:

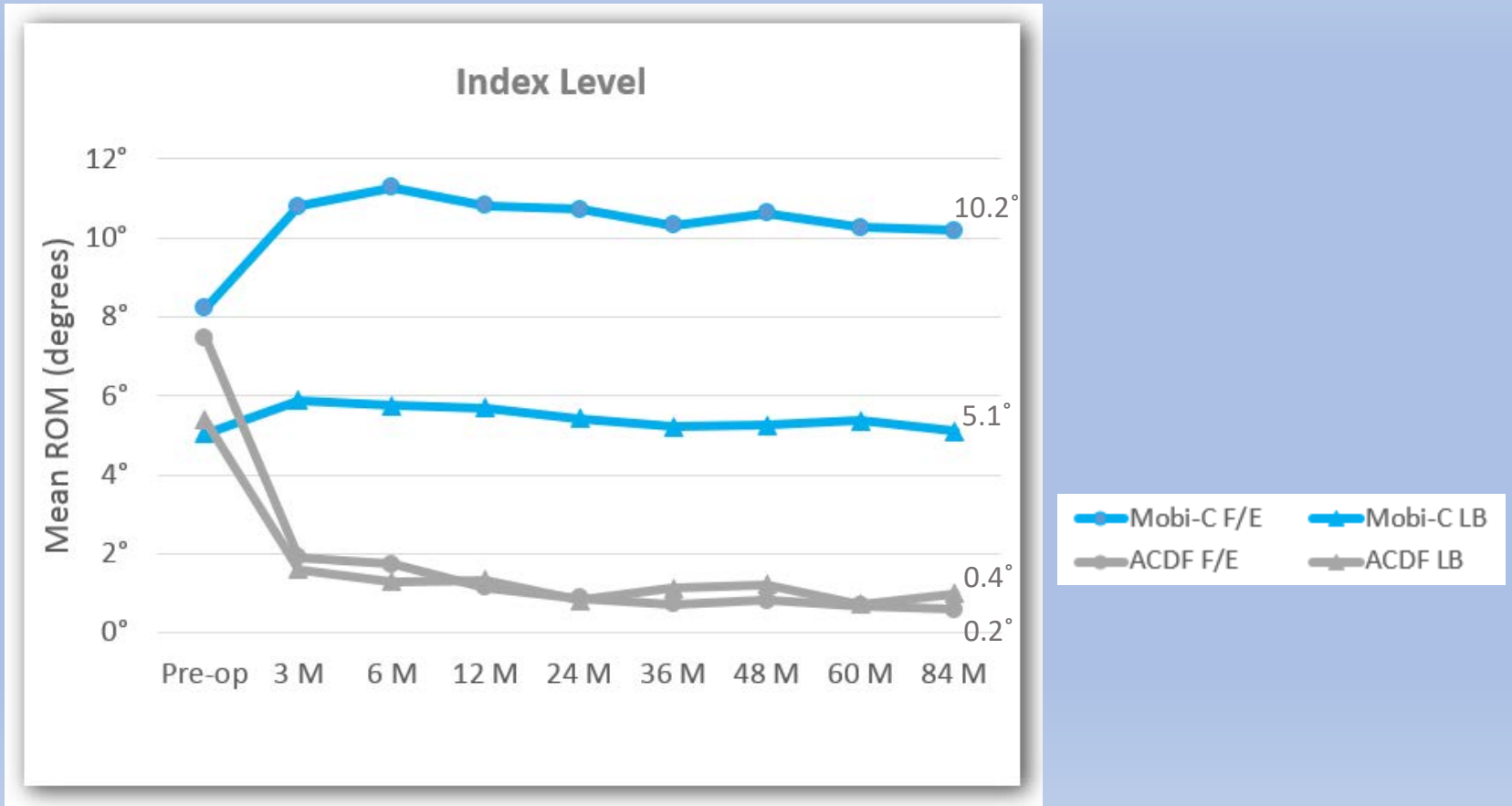
- Improvement from baseline that is maintained through 7 years
- Motion in a physiological range through 7 years[15]



Mean Range of Motion

One-Level

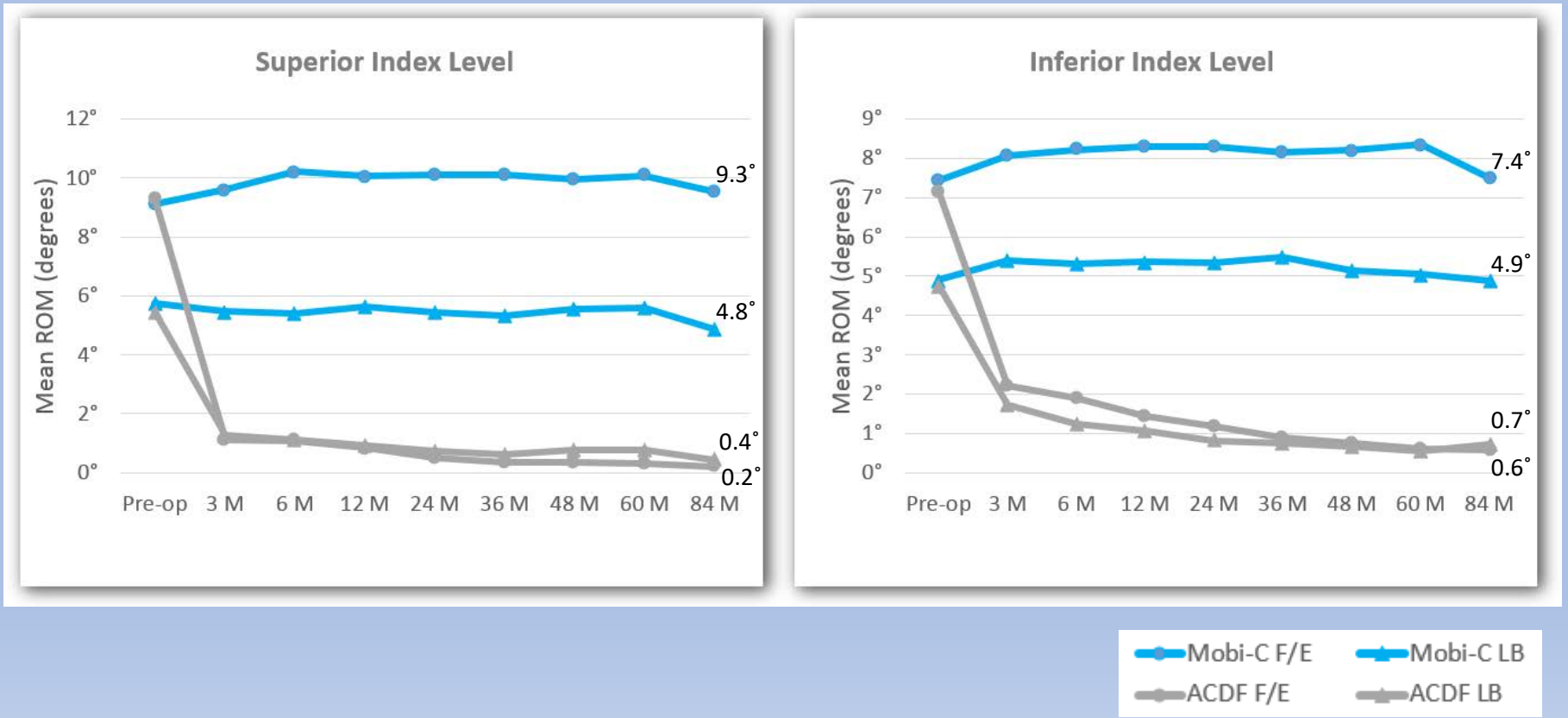
TDR group maintained range of motion in flexion/extension and lateral bending at the treated level.



Mean Range of Motion

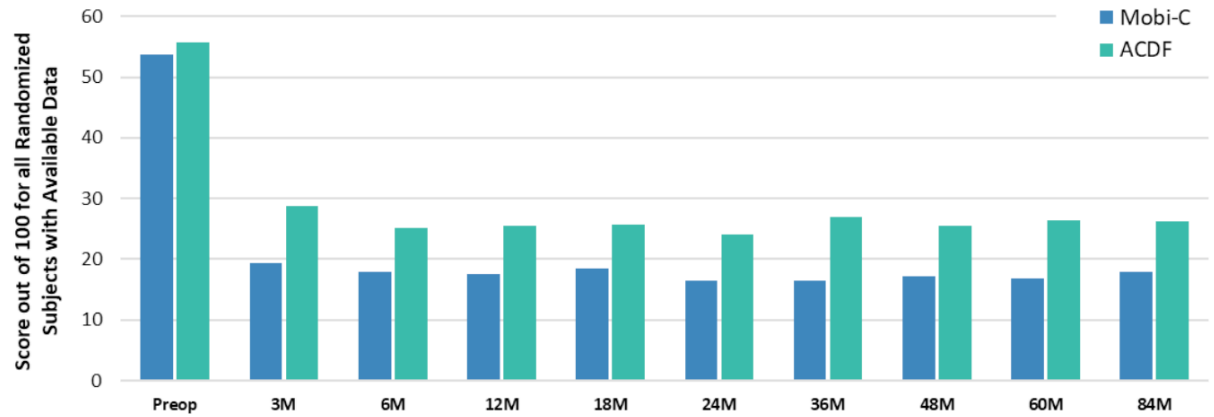
Two-Level

TDR group maintained range of motion in flexion/extension and lateral bending at both treated levels.



Neck Disability Index (NDI) Through 7 Years

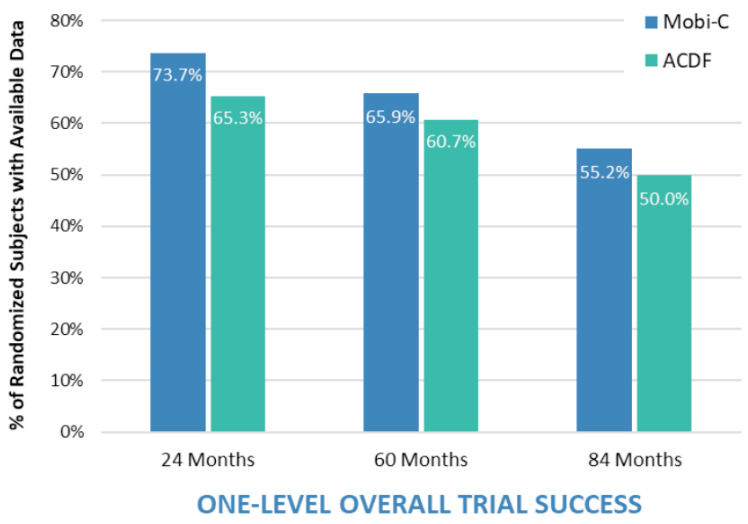
- A patient self-assessment (NDI) was administered and scored at every study visit
- Patients answered questions about their level of disability with driving, lifting, recreation, personal care, reading, sleeping, work, concentration, pain intensity, and headaches
- A score was calculated and recorded – total possible points = 100 (higher scores indicated more disability)
- **Mobi-C two-level patients demonstrated statistically significant better disability improvement vs fusion patients at every study time point**



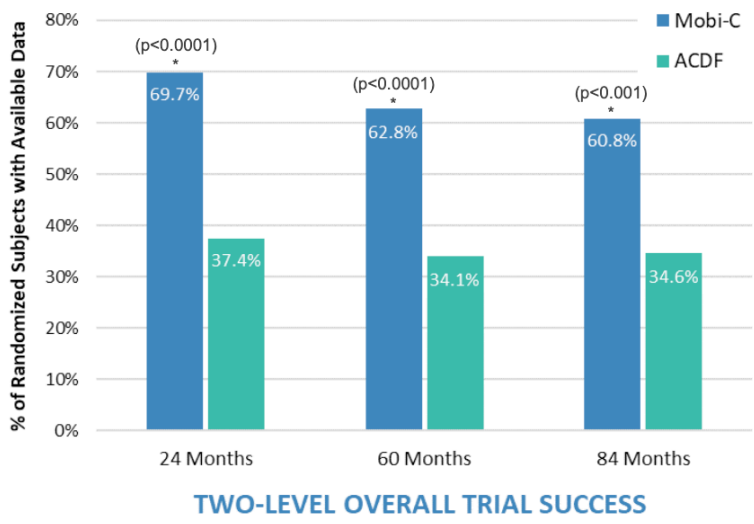
MEAN NDI OVER TIME AT TWO-LEVELS

- 1 level
  - Nonl
  - 84 month follow up

Non-inferiority to fusion at one-level
Statistical superiority to fusion at two-levels



ONE-LEVEL OVERALL TRIAL SUCCESS

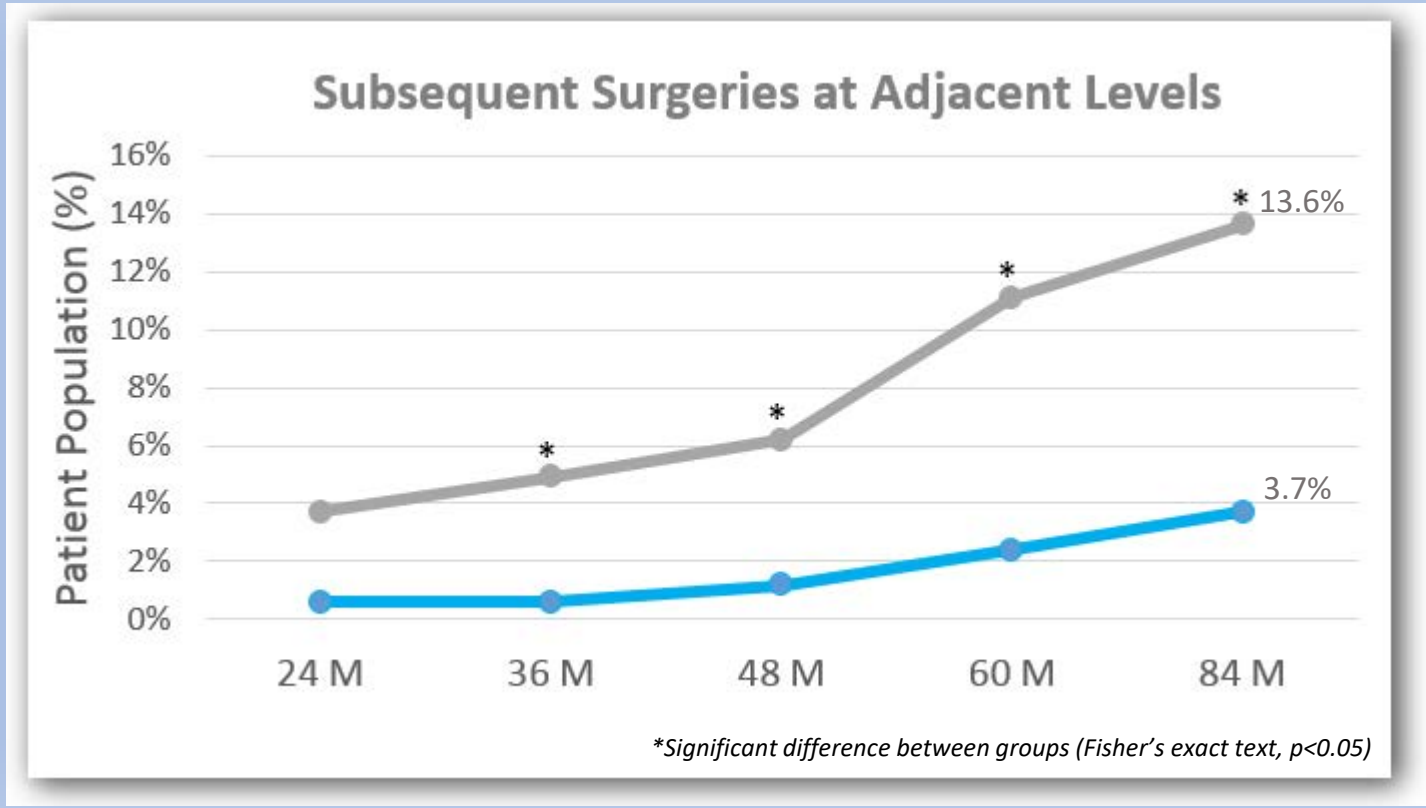


TWO-LEVEL OVERALL TRIAL SUCCESS

Subsequent Surgery Rate at Adjacent Level

One-Level

At 7 years, TDR patients had **significantly fewer** subsequent surgical interventions than ACDF patients did at the adjacent level.

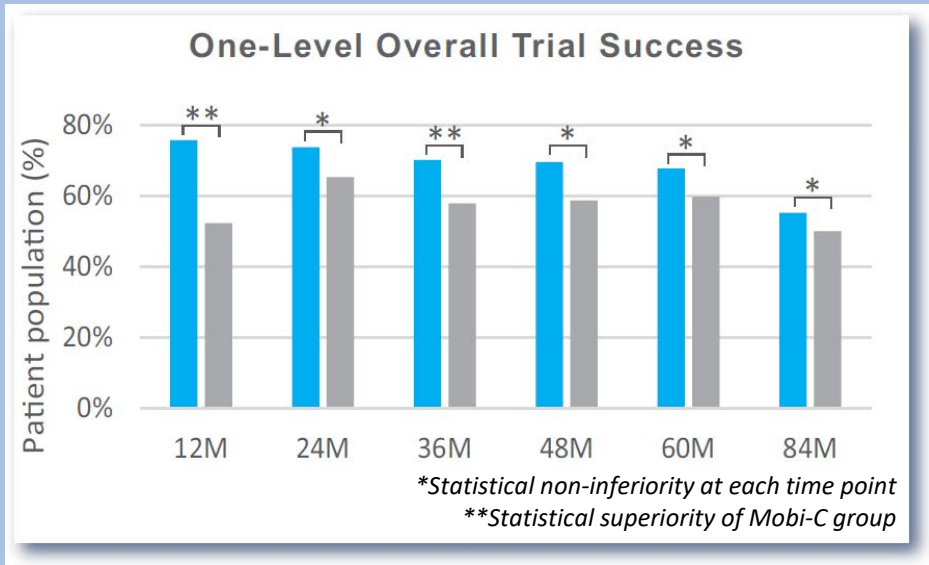


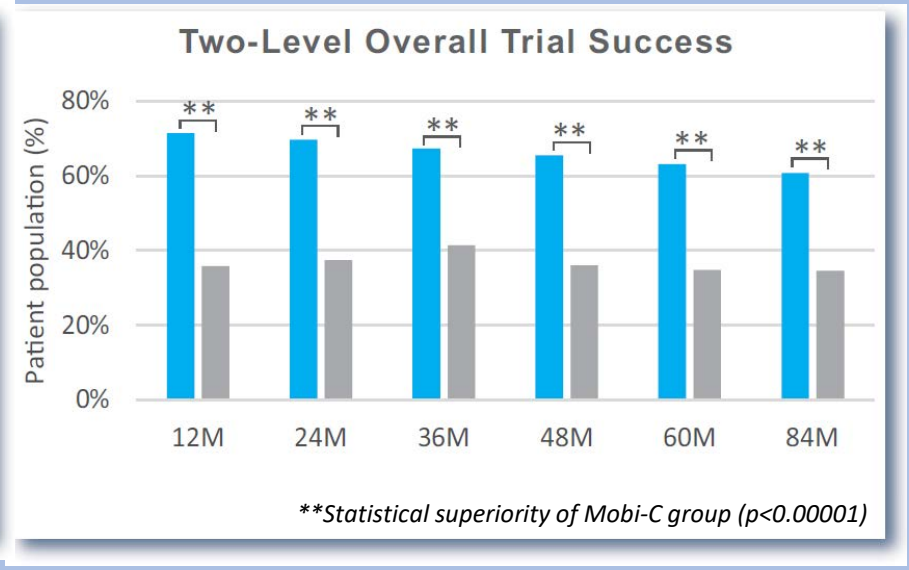
Most common reason for additional surgical intervention at an adjacent level was persistent radiculopathy and/or neck pain for TDR group, and pseudoarthrosis for ACDF group.

Study Conclusion

At 7 years and at each study follow-up time point,

- 2-level Mobi-C shows a statistical **superiority** in comparison to ACDF
- 1-level Mobi-C shows a statistical **non-inferiority** in comparison to ACDF





Overall Success & Components Success

Two-Level

Same as all postoperative time points, the composite success analysis demonstrated ***clinical superiority of two-level TDR over ACDF*** at 7 years.

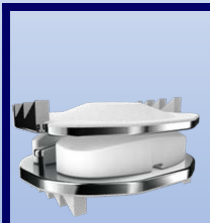
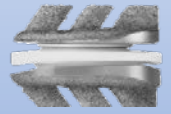
Primary drivers of TDR superiority due to significant difference in:

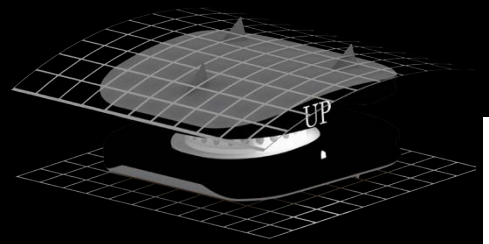
1. Successful NDI scores
2. Lower incidence of subsequent surgery
3. Lower incidence of neurological failure

	Mobi-C	ACDF	Difference
Composite success	60.8%	34.6%	26.2%*
NDI success	79.0%	58.0%	21.0%†
Subsequent Surgery	4.4%	16.2%	11.8%†
Neurologic failure	6.4%	17.1%	10.7%†
Adverse events	5.3%	8.6%	3.3%
Radiographic failure	10.1%	9.1%	1.0%

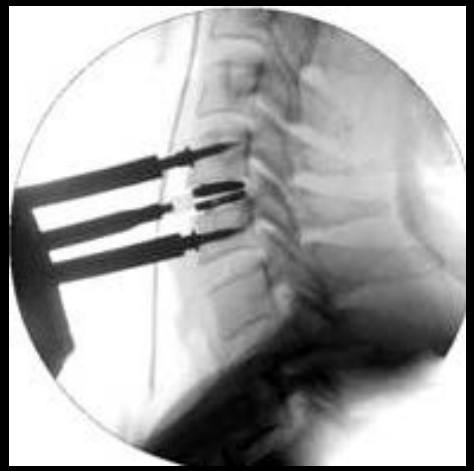
*Superiority of TDR vs. ACDF established with 95% lower confidence bound of difference > 0%. † $p<0.05$; Fisher's exact test.

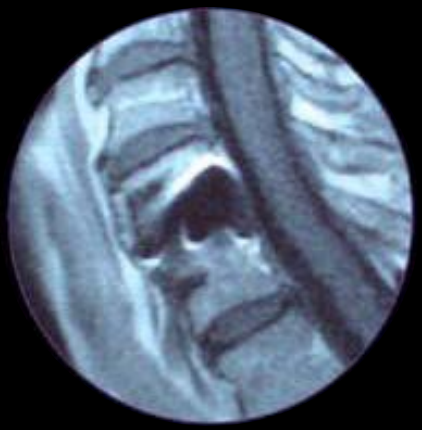
U.S. CDR Competitive Landscape

							
Company / Product	**LDR Mobi-C**	**DePuy Synthes Prodisc-C**	**Medtronic Prestige ST**	**Medtronic Bryan**	**Globus Secure-C**	**NuVasive PCM**	**Medtronic Prestige LP**
Two-Level Indication	**Yes**	No	No	No	No	No	Yes
One-Level Indication	**Yes**	Yes	Yes	Yes	Yes	Yes	Yes
Superiority	**Yes (Two-Level Only)**	No	No	No	Yes (One-Level Only)	No	Yes (1 and 2 levels)
Primary Fixation	**Inclined Lateral Teeth**	Central Keels	Anterior Screws	Press Fit (Milled Endplates)	Central Keels	Serrations	Lateral “Rails”
Heights	**5-7mm**	5-7mm	6-7mm	6mm	7-12mm	6.5-8mm	6-7mm



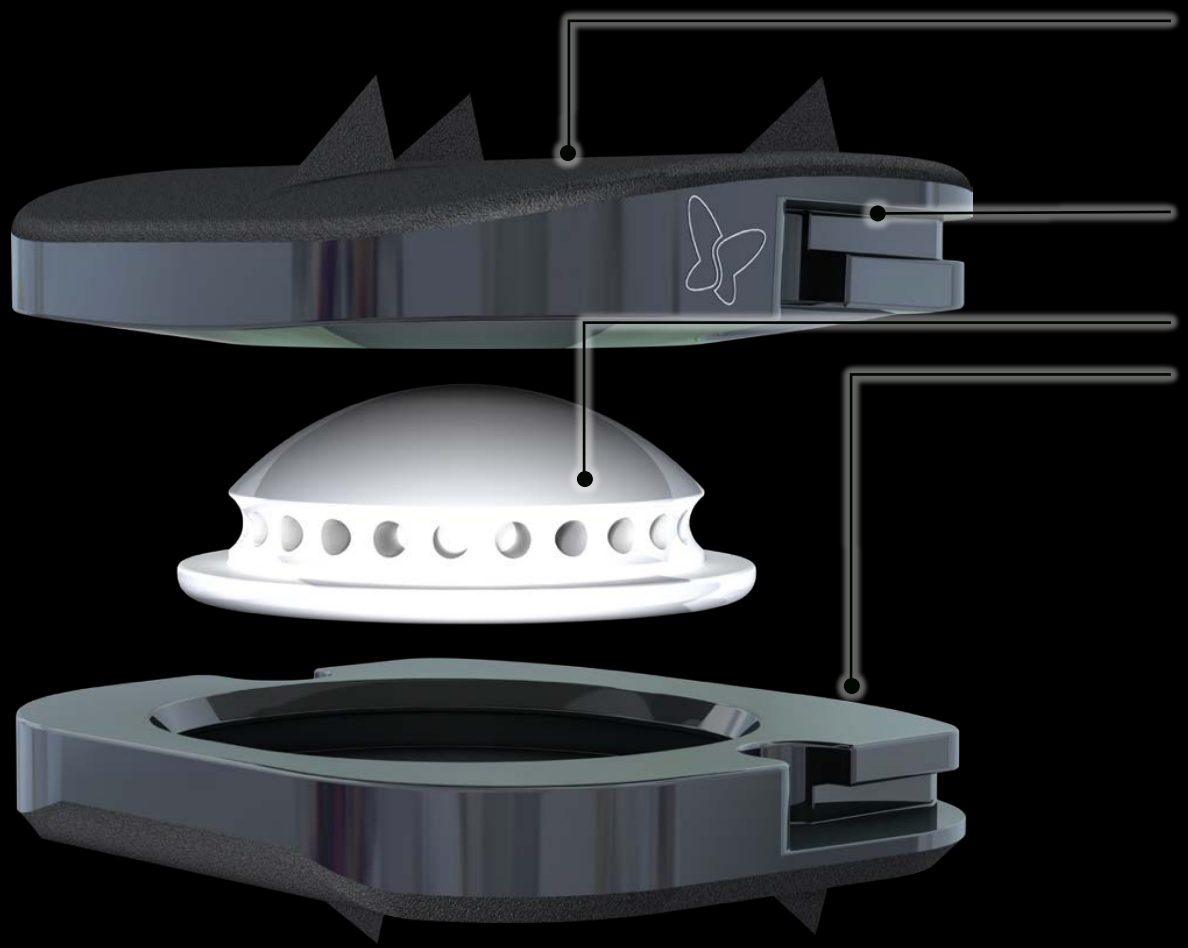
ile nucleus,





:D STATES) LAW TO INVESTIGATIONAL USE – PREPARED FOR UCI

MATERIALS



- Surface in contact to bone: coated with **Ti Plasma-Spray**, a projection of porous titanium. Optimal bone adhesion and osteointegration
- **Titanium** plates. Reduces artifacts, better MRI control compared to CoCr plates
- High density **PE**(polyethylene) Nucleus
- The internal surface coated with **Diamond Like Carbon (DLC)** layer. Physical reaction between injected gas and titanium plates. Limit wear debris

360º Rotation

0,6 mm

mm

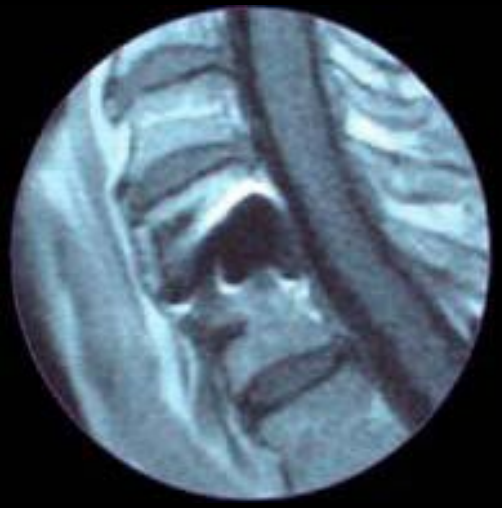
GUIDED MOBILE NUCLEUS

- Ultra High Molecular Weight polyethylene
- Securely clipped into the inferior endplate, prevent post-op expulsion
- Allows 6 degrees of Freedom
- Prevents excessive constraints on the facet joints
- Respects the natural center of rotation

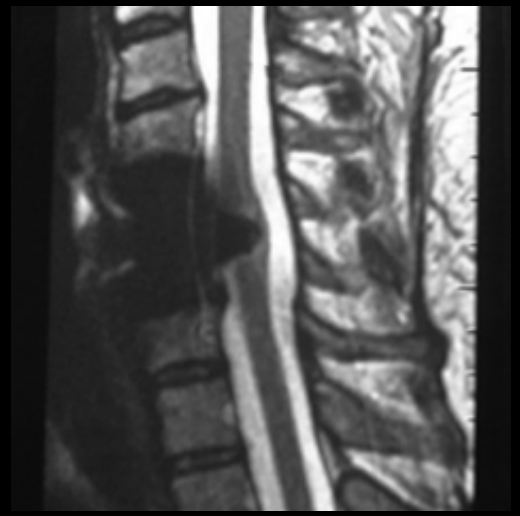
CLIPPING MECHANISM

LIMITED MRI ARTIFACT

- The titanium plates, coated with DLC reduce considerably artifacts under MRI for a better postoperative control
- Unobstructed evaluation of the spinal cord
- Satisfactory monitoring of the adjacent and operated levels



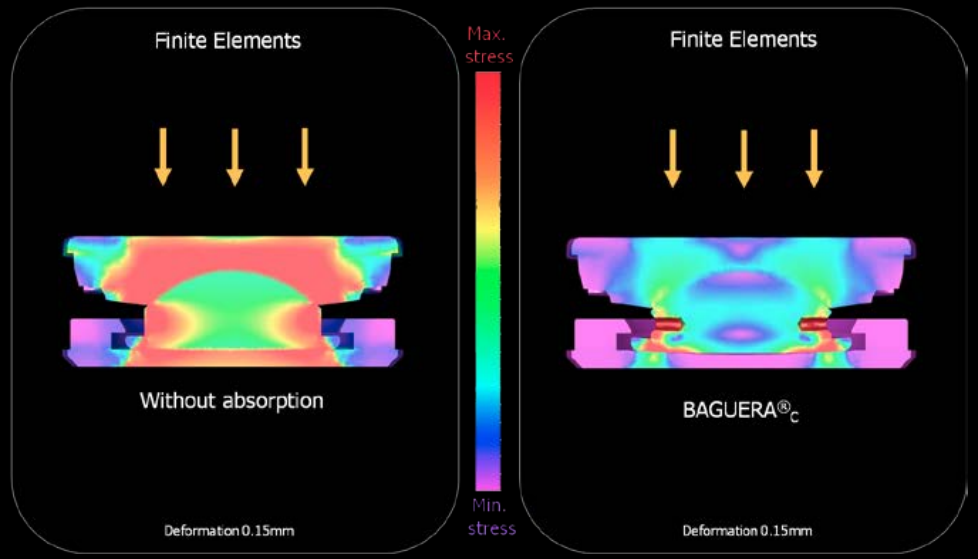
BAGUERA®C MRI image



Traditional CoCr alloy cervical artificial disc MRI image

BAGUERA®C has been tested and is be labeled as MR Conditional.

MRI Conditional icon for packaging and labelling both in color(left) and black and white(right)



BETTER STRESS DISTRIBUTION

- Concave shape of the inferior plate enables the deformation of the PE nucleus
- Possible absorption of shocks and vibrations
- Limit stress induced on adjacent levels

1-LEVEL CLINICAL TRIAL DESIGN

CHAP2

SPINEART

STUDY TITLE	A multicenter, prospective, randomized, clinical trial comparing the safety and effectiveness of BAGUERA®C Cervical Disc Prosthesis to Mobi-C® Cervical Disc for the treatment of patients with symptomatic cervical disc disease at a single level.
STUDY DESIGN	A multi-center, prospective, randomized, controlled study
PURPOSE	To evaluate the safety and effectiveness of BAGUERA®C Cervical Disc Prosthesis
STUDY DURATION	Appr. 9 years: _ 24-month enrollment + 24-month follow-up _ 5 year for post-approval requirements
RANDOMIZATION	2:1 randomization: _ Investigational group: BAGUERA®C Cervical Disc Prosthesis _ Control group: Mobi-C® Cervical Disc
EVALUATION SCHEDULE	Patients will be evaluated preoperatively, at the time of surgery, discharge, and at 6 weeks, 3, 6, 12, and 24 months after surgery. After 24 months, the patients will continue to be followed at 3, 4, 5, 6 and 7 years for post-approval study considerations.
INTENDED SUBJECT POPULATION	A minimum of 270 subjects (180:90) will be enrolled at up to 30 sites. Maximum sample size is 450

2-LEVEL CLINICAL TRIAL DESIGN

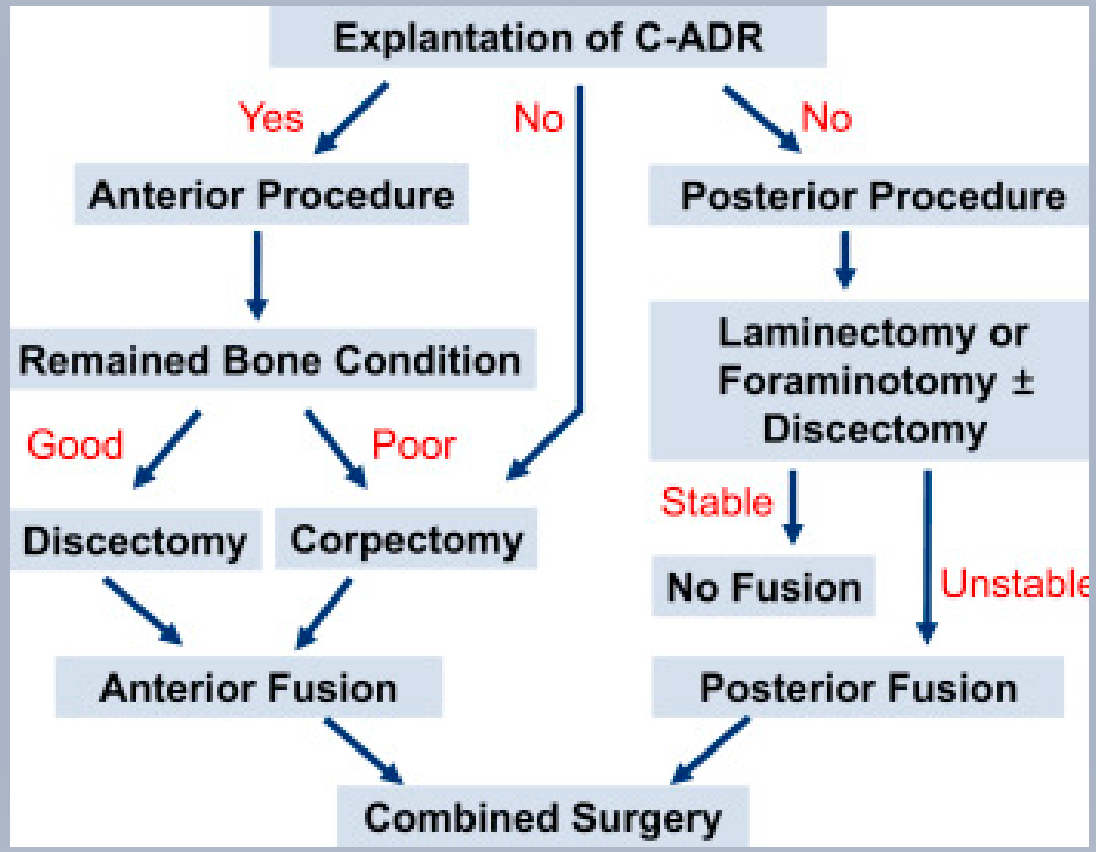
CHAP3

SPINEART

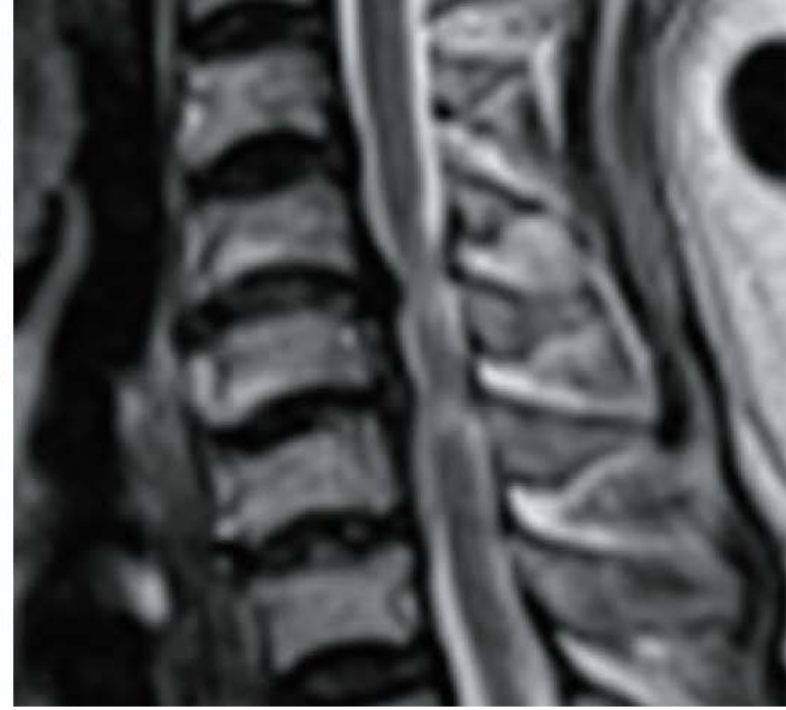
STUDY TITLE	A multicenter, prospective, randomized, clinical trial comparing the safety and effectiveness of BAGUERA®C Cervical Disc Prosthesis to Mobi-C® Cervical Disc in the treatment of patients with symptomatic cervical disc disease at two contiguous levels.
STUDY DESIGN	A multi-center, prospective, randomized, controlled study
PURPOSE	To evaluate the safety and effectiveness of BAGUERA®C Cervical Disc Prosthesis
STUDY DURATION	Appr. 9 years: _ 24-month enrollment + 24-month follow-up _ 5 year for post-approval requirements
RANDOMIZATION	2:1 randomization: _ Investigational group: BAGUERA®C Cervical Disc Prosthesis _ Control group: Mobi-C® Cervical Disc
EVALUATION SCHEDULE	Patients will be evaluated preoperatively, at the time of surgery, discharge, and at 6 weeks, 3, 6, 12 and 24 months after surgery. After 24 months, the patients will continue to be followed at 3, 4, 5, 6 and 7 years for post-approval study considerations.
INTENDED SUBJECT POPULATION	A minimum of 300 (200:100) subjects will be enrolled at up to 30 sites.

Revision surgeries following artificial disc replacement of cervical spine

- Author links open overlay panelJong-Beom Park [a], Han Chang [b], Jin S. Yeom [c], Kyung-Soo Suk [d], Dong-Ho Lee [e], Jae Chul Lee [f]
- Review of 21 revision surgeries.
  - 17 poor patient selection
  - 7 insufficient decompressions
  - 7 malpositions
  - 6 subsidence
  - 3 osteolysis
  - 1 post op infection

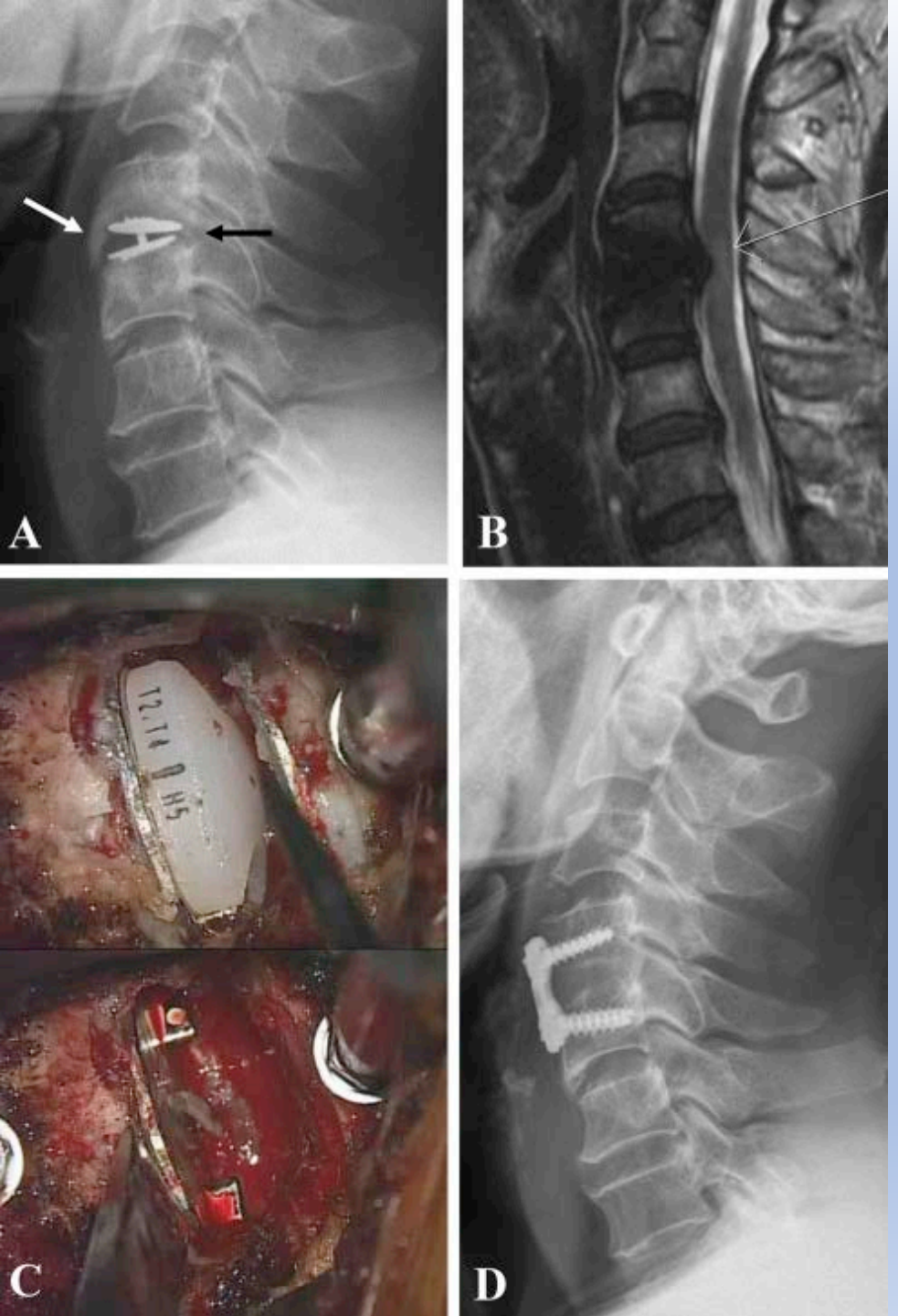


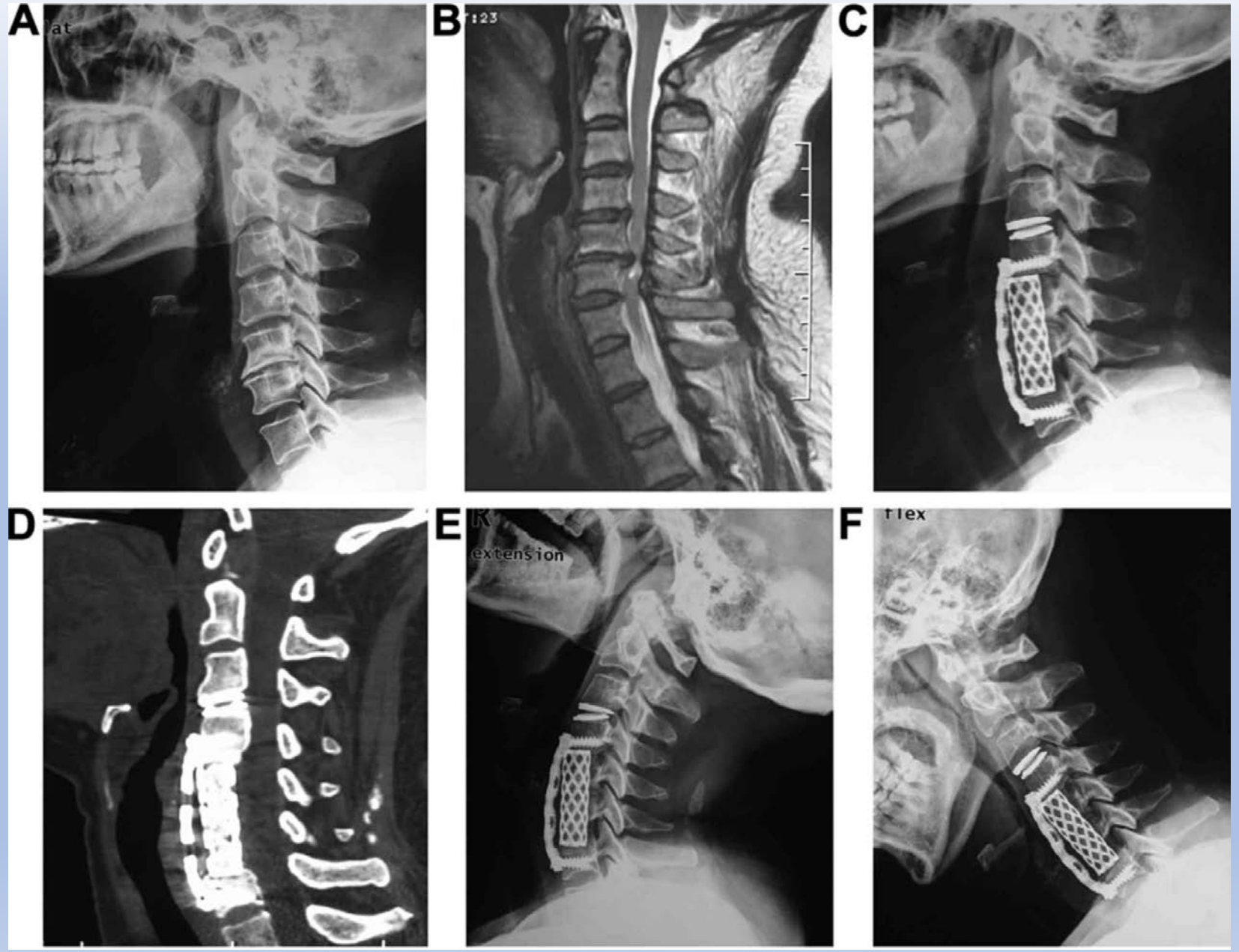
Preop Contraindications lead to failure



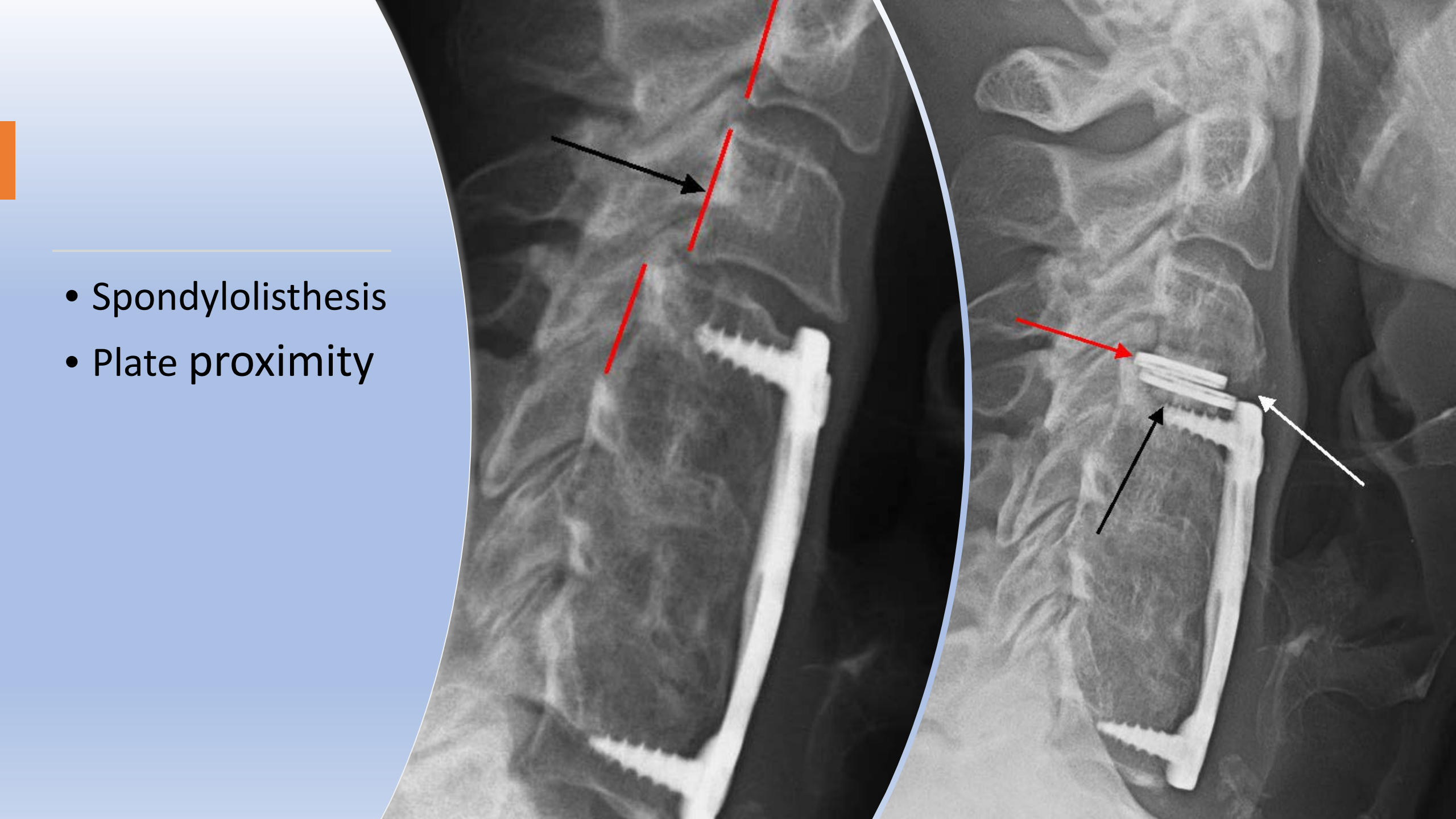
- Spondylolisthesis
- Inflammatory Arthritis
- Cervical cord compression (ie myelopathy)
  - OPLL
- h/o infection
- Multilevel adjacent fusion (kyphotic segment)
- Poor Patient selection

- But so does poor carpentry
  - Over aggressive Bone milling
  - Failure to address nerve compression

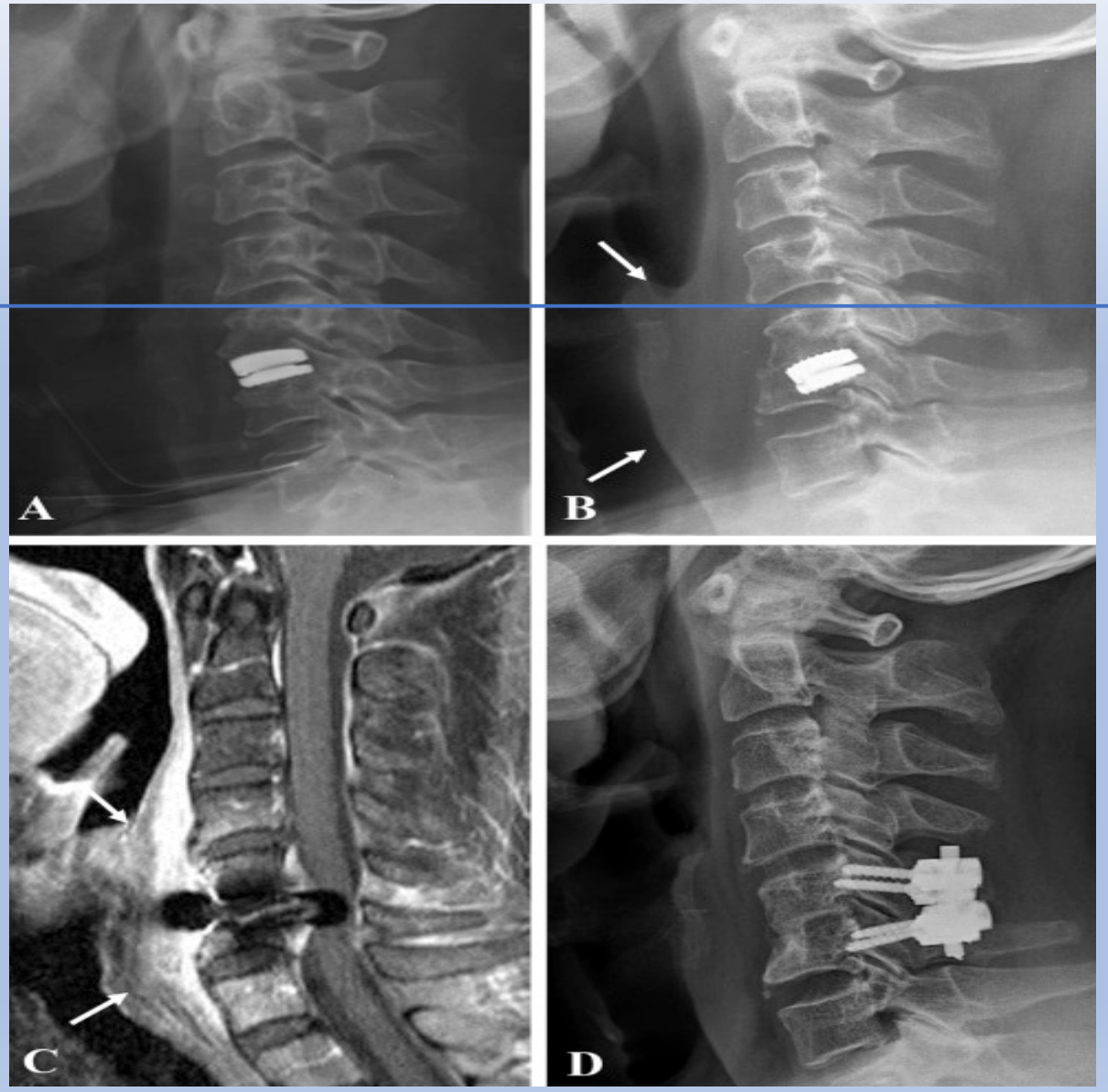

A
B
C
D

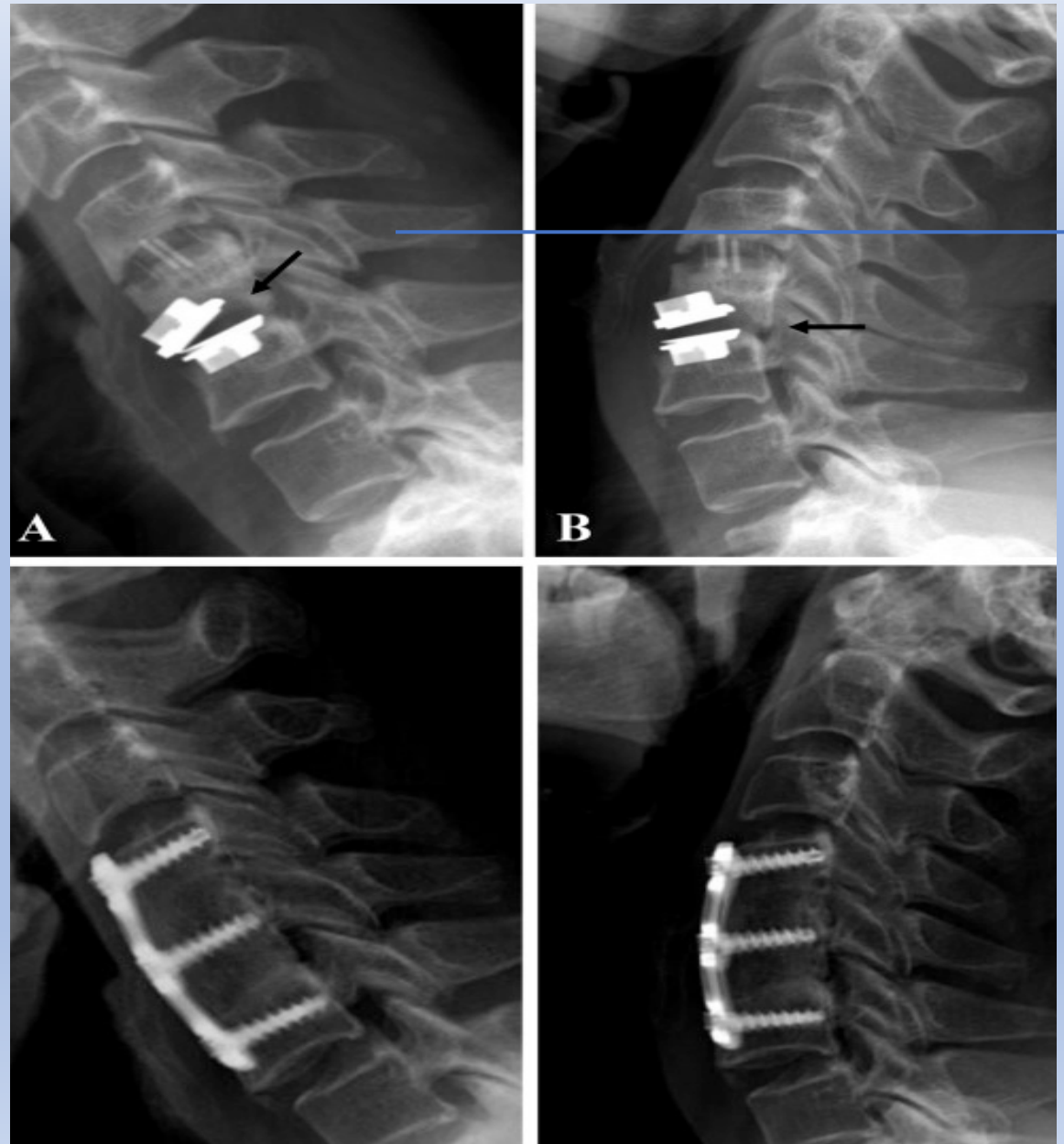

A
B
C
D
E
extension
F
flex

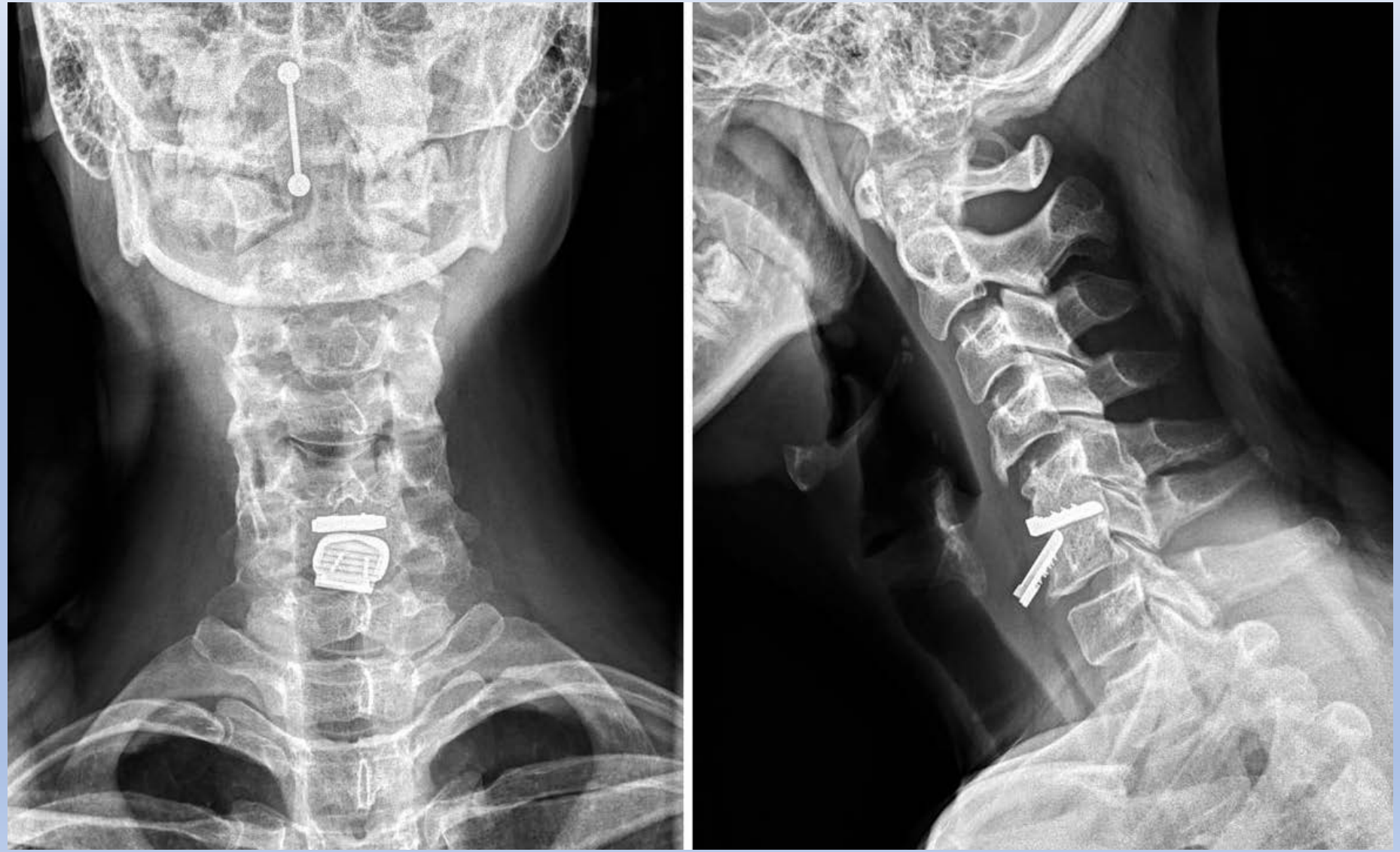
- Spondylolisthesis
- Plate proximity

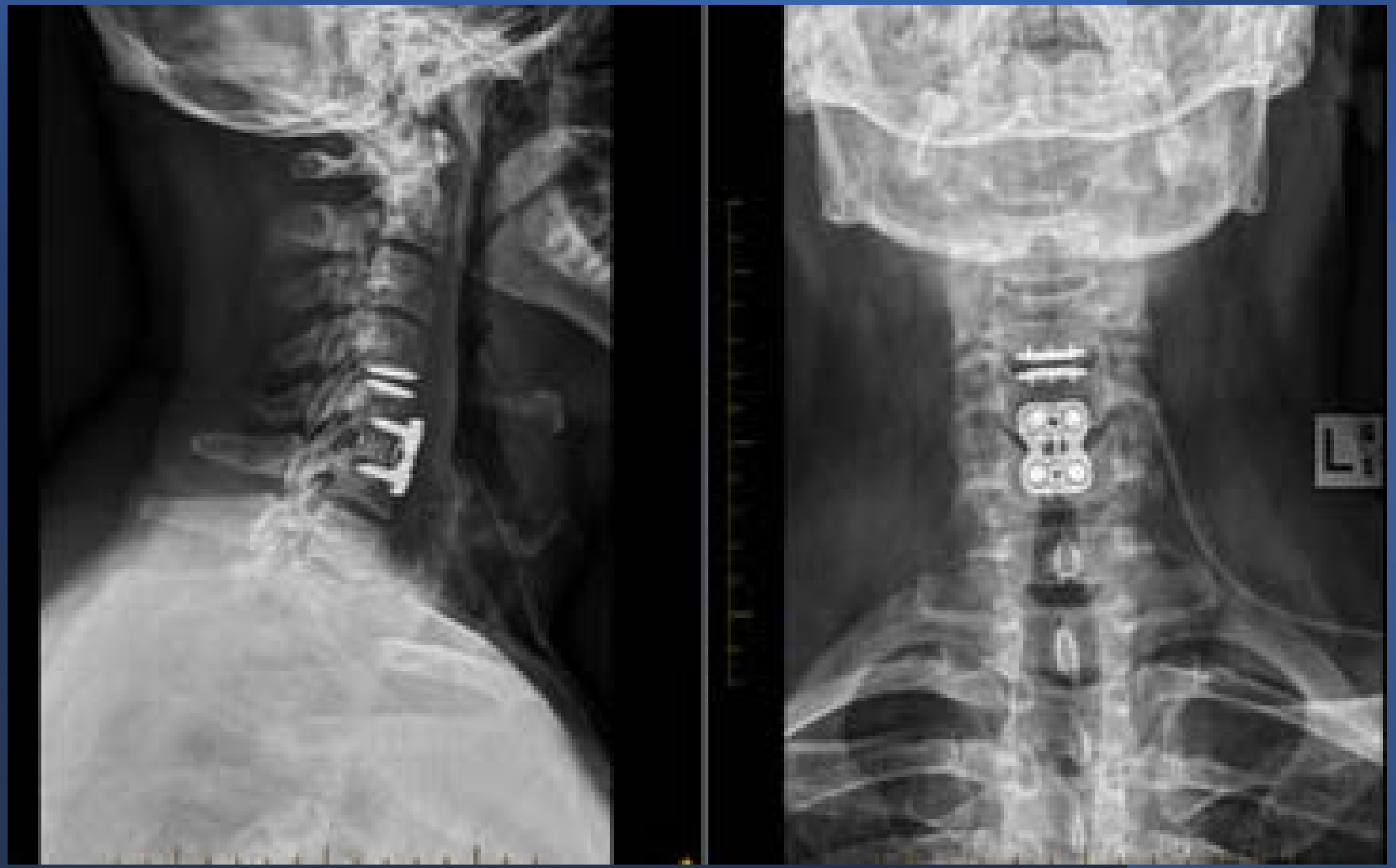


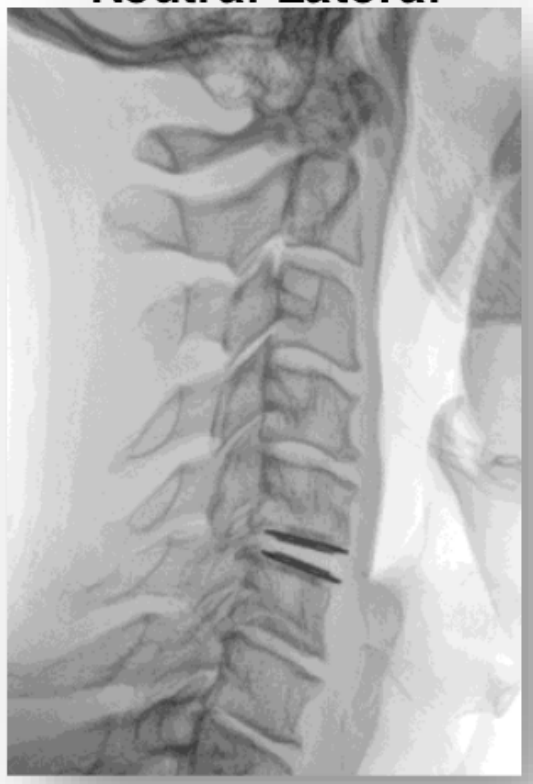
- Subsidence
  - Implant dislodgement
  - Cord compression

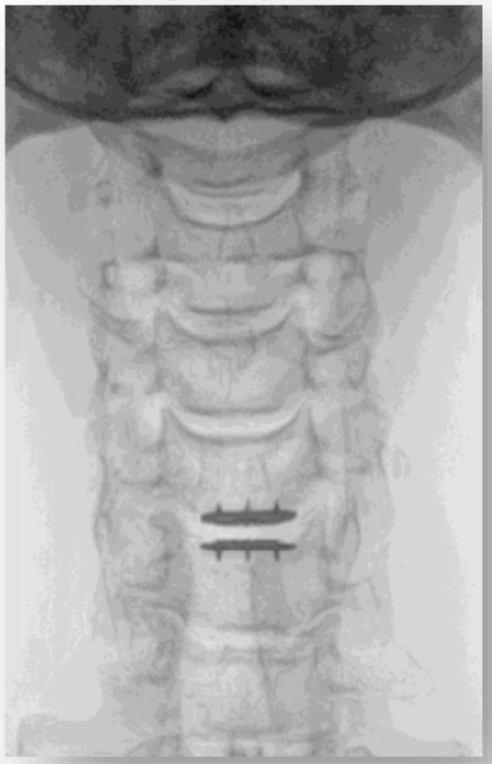


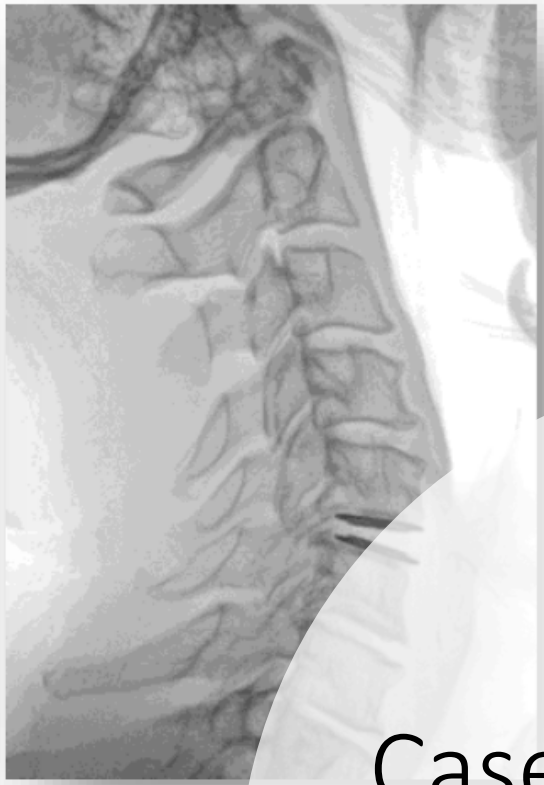

A
B

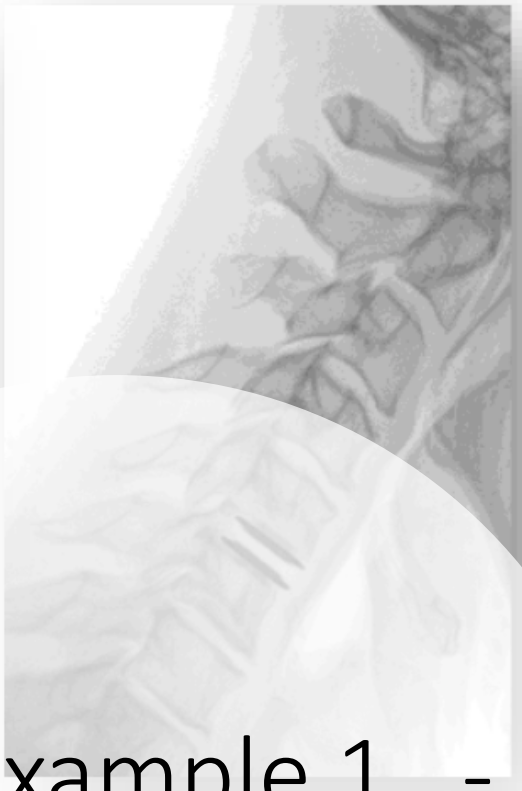


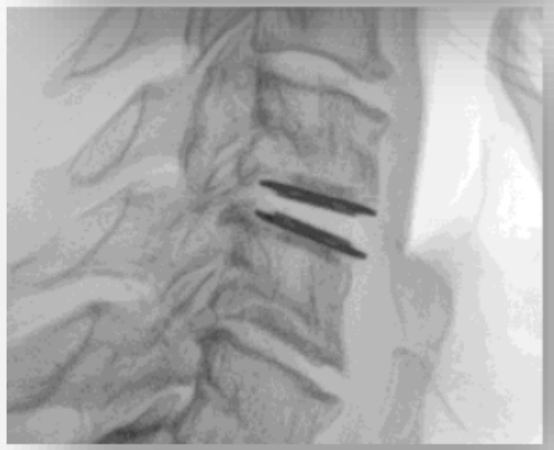


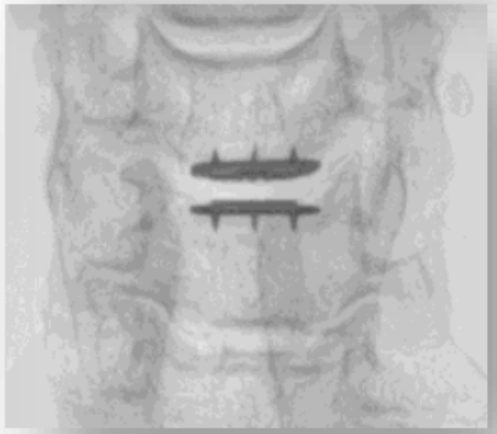






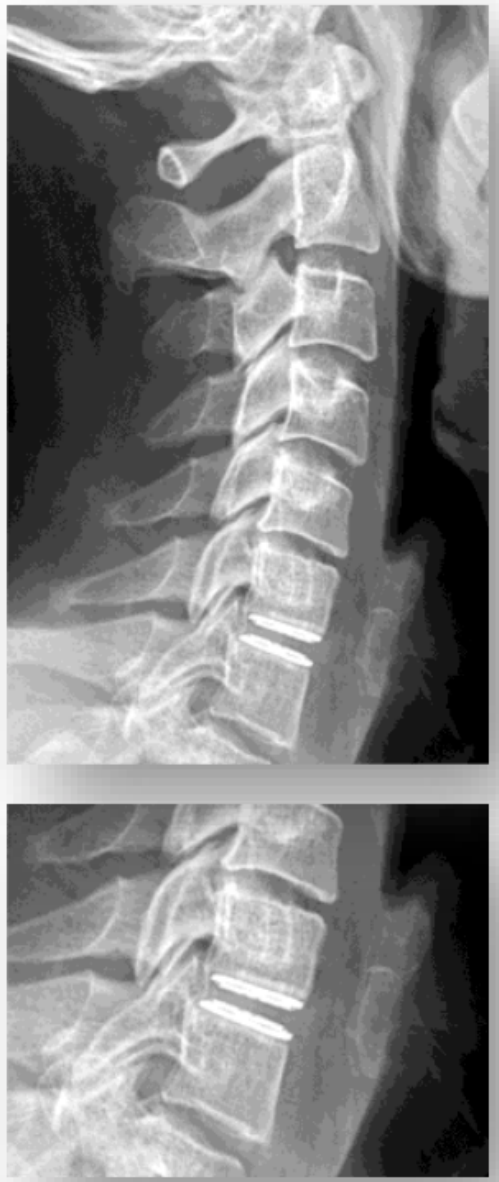




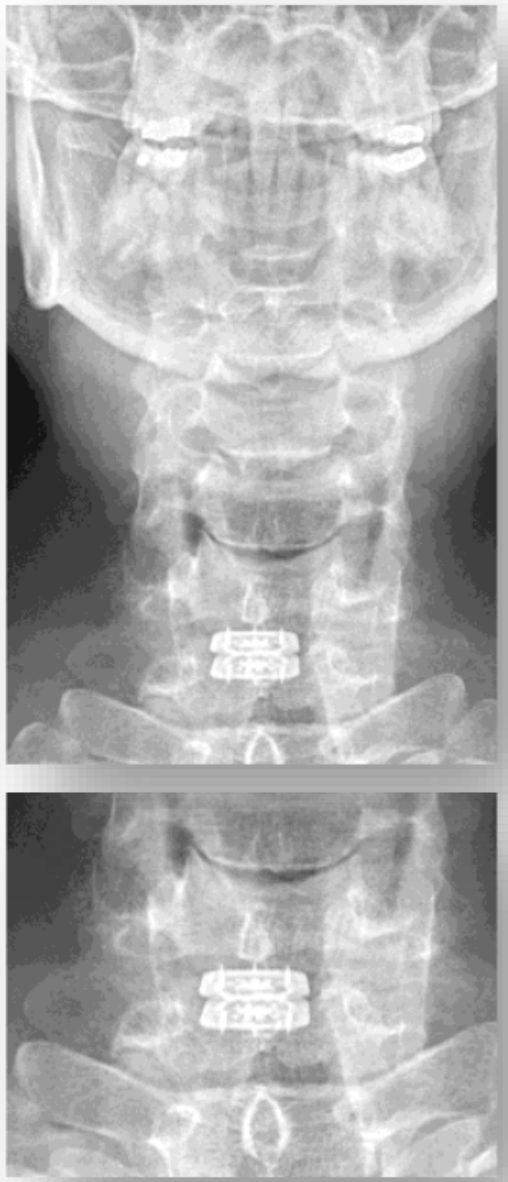


Case Example 1 - 1 year post op

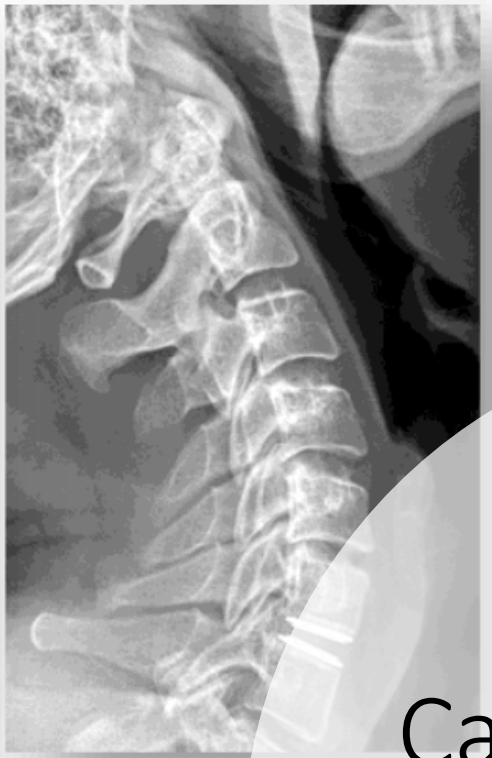
Neutral Lateral



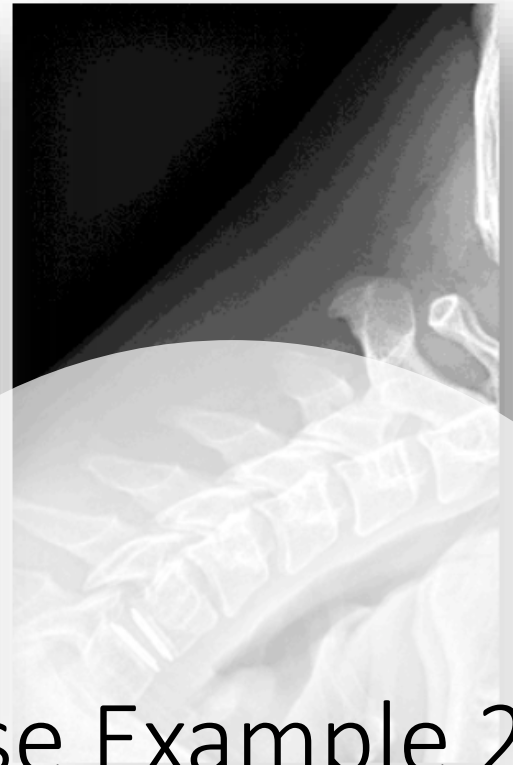
Neutral AP



Extension



Flexion



Case Example 2 - 1 year post op

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