DEGENERATIVE DISEASE OF THE LUMBAR SPINE

Degenerative Lumbar Instability and Spinal Stenosis

From pathology to the treatment window: conservative care, minimally invasive stabilization, and knowing when a surgical opinion is needed



Pathology
Identify the cause

Diagnosis
Match imaging to symptoms

Treatment Window
Conservative to minimally invasive

When to Refer
Know when a surgical opinion is needed

Nathan E. Sneddon, MD

Double board certified in anesthesiology and in interventional spine and pain management

Dynamic Spine and Pain Institute · Spokane, Washington



DISCLOSURES AND LEARNING OBJECTIVES

What this presentation is — and is not

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DISCLOSURE

The presenter has no financial relationship with any device manufacturer, pharmaceutical company, or other commercial entity relevant to this material. No commercial support was received for the preparation or delivery of this presentation.

A NOTE ON TERMINOLOGY

Procedures and implants are discussed by category, with trade names used only where they identify the study or evidence base being cited — most published trials in this field are device-specific. Where a cited study's authors have industry affiliations, that is noted.



LEARNING OBJECTIVES

1. Review the diagnosis and pathology of lumbar spinal stenosis and degenerative lumbar instability.
2. Compare the indications, benefits, and limitations of minimally invasive treatments for lumbar spinal stenosis.
3. Recognize the patients who may benefit from referral for minimally invasive treatment — and those who should go to a surgeon instead.



SCOPE OF THE PROBLEM

Lumbar spinal stenosis is common, disabling, and over-diagnosed on imaging

19.4%

of adults aged 60-69 have absolute acquired stenosis on imaging in a community cohort [2]

~103M

people worldwide are estimated to have symptomatic lumbar spinal stenosis [4]

#1

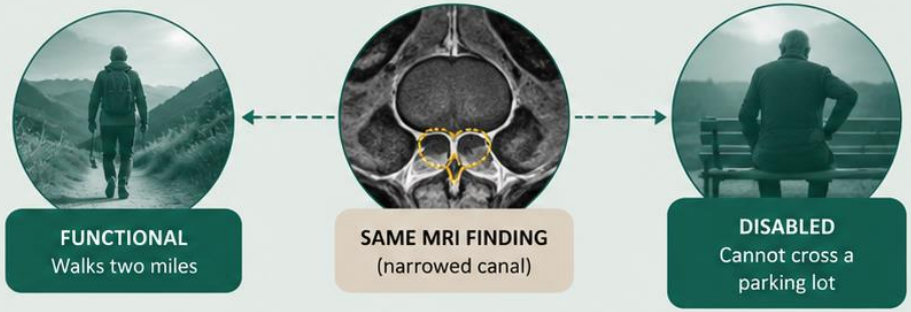
preoperative diagnosis for spine surgery in adults older than 65 years [3]

~1 in 3

asymptomatic adults over 60 have abnormal lumbar MRI findings [30]

THE CLINICAL CONSEQUENCE

Lumbar spinal stenosis is a clinical syndrome, not a radiographic finding. Canal and foraminal narrowing are near-universal with age; their presence on a scan says little about whether a given patient is symptomatic. The diagnosis rests on the history, with imaging used to confirm the level and characterize what is narrowing it. This matters for treatment selection: the same MRI can belong to a patient who walks two miles and to one who cannot cross a parking lot.



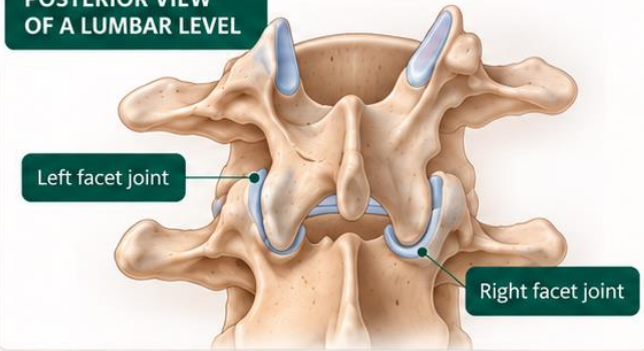
Kalichman et al., Spine J 2009 [2]; Ravindra et al., Global Spine J 2018 [4]; Katz et al., JAMA 2022 [3]; Boden et al., J Bone Joint Surg Am 1990 [30].

ANATOMY

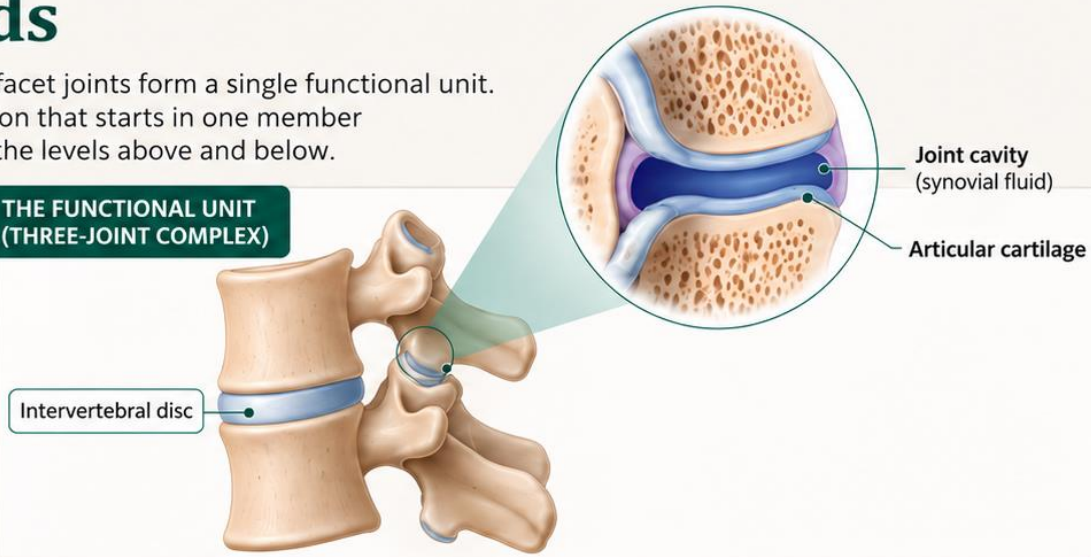
The three-joint complex and how degeneration spreads

At every lumbar level, one intervertebral disc and two facet joints form a single functional unit. Kirkaldy-Willis described the consequence: degeneration that starts in one member eventually alters loading in the other two, and then in the levels above and below.

POSTERIOR VIEW OF A LUMBAR LEVEL

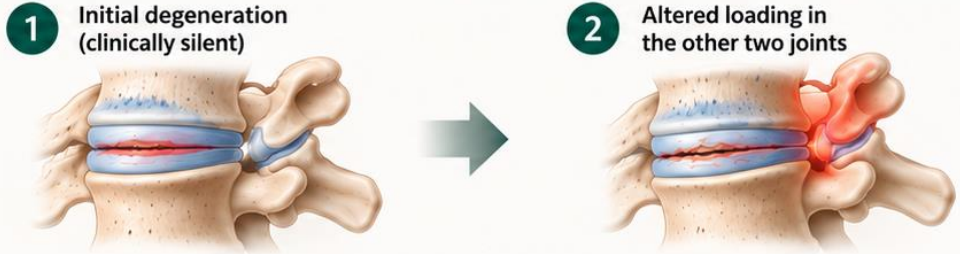


THE FUNCTIONAL UNIT (THREE-JOINT COMPLEX)



HOW DEGENERATION SPREADS

Degeneration in one member of the functional unit alters loading in the other two, and then in the levels above and below.



Original schematic prepared for this presentation; concept after Yong-Hing K, Kirkaldy-Willis WH, Orthop Clin North Am 1983 [1]. Not to anatomical scale.

THE DEGENERATIVE CASCADE

Kirkaldy-Willis: three phases, each with different treatment implications

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PHASE 1 DYSFUNCTION



KEY FEATURES

- Little demonstrable pathology
- Complaints are mild and infrequent
- Physical signs subtle or absent, and imaging often normal

TREATMENT IMPLICATIONS

Conservative treatment is highly successful. Surgery has no role at this phase.

PHASE 2 INSTABILITY



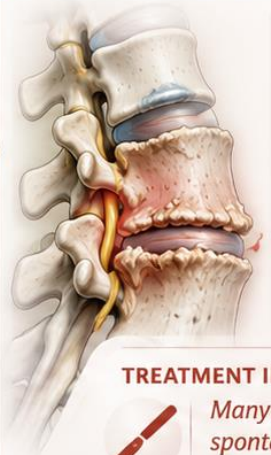
KEY FEATURES

- Abnormal movement of the motion segment
- Complaints become more severe and more frequent
- Physical signs and radiologic abnormalities now appear

TREATMENT IMPLICATIONS

Conservative care continues to succeed, but surgery may become necessary — and when it does, it should often include stabilization.

PHASE 3 STABILIZATION



KEY FEATURES

- Severe facet and disc degeneration produce osteophytes
- Excess movement gives way to reduced movement
- Fixed entrapment of the spinal nerves

TREATMENT IMPLICATIONS

Many patients improve spontaneously. When surgery is required, decompression alone is generally sufficient.

DYSFUNCTION
Primarily chemical/biologic

INSTABILITY
Primarily mechanical

STABILIZATION
Primarily structural

The phase determines whether the problem is chemical, mechanical, or structural — and therefore whether the answer is biologic, stabilizing, or decompressive.

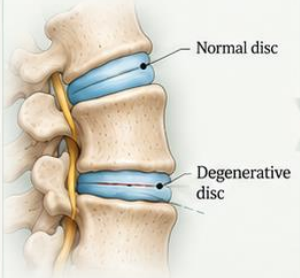
Yong-Hing K, Kirkaldy-Willis WH. Orthop Clin North Am. 1983;14(3):491-504 [1]. See also Kirkaldy-Willis et al., Spine 1978 [5].

A WORKING FRAMEWORK

Six clinical phases mapped onto the Kirkaldy-Willis cascade

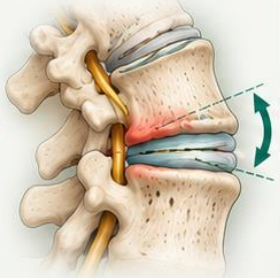
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1 Disc degeneration



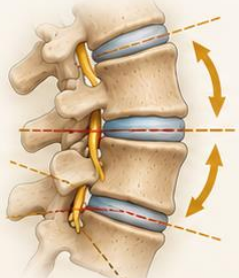
- Biologic and inflammatory changes
- Minimal instability
- No significant stenosis

2 Micromotion instability



- Loss of intrinsic restraint
- Excess segmental motion begins
- Facet and endplate pain

3 Angular imbalance



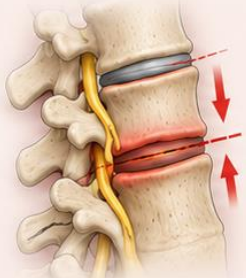
- Segment tilts and loads asymmetrically
- Early slip and foraminal narrowing

4 Dynamic stenosis



- Neural compression appears with loading and extension
- Relieved by sitting or flexion

5 Vertical collapse



- Loss of disc height and vertical load support
- Foraminal collapse
- Radicular pain

6 Fixed stenosis



- Compression is structural and no longer positional
- Neurologic deficit
- Disability

CHEMICAL / BIOLOGIC → MECHANICAL → STRUCTURAL

The three-phase cascade is Kirkaldy-Willis's [1]. The six-phase breakdown is a practical teaching subdivision used in this presentation to link pathology to symptoms and treatment; it is not a validated classification system. Colour indicates treatment centre of gravity: green = conservative/biologic; amber = the minimally invasive window; terracotta = surgical.

DEFINITIONS THAT MATTER

Segmental instability: the working definition

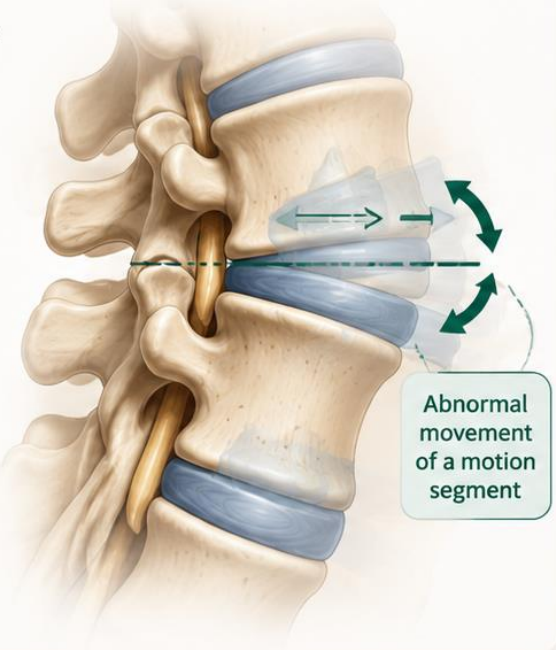
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THE WORKING DEFINITION

Abnormal movement of a motion segment — **abnormal in quality, in quantity, or in both.**

Kirkaldy-Willis defined it functionally rather than by a number, and that ambiguity has never been fully resolved.

Surveyed spine surgeons **do not agree on a single definition** of instability in degenerative spondylolisthesis, and the conventional radiographic thresholds were never validated against a gold standard.

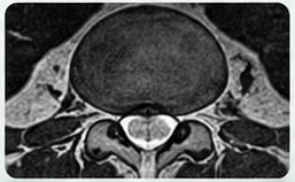


WHY THIS IS NOT JUST ACADEMIC

Two patients can have the same MRI and different mechanics. One has a segment that moves normally and simply has a bulging disc; the other has a segment that translates and angulates well beyond normal.

Only the second is a candidate for a stabilizing procedure — and the difference is invisible on a single static image.

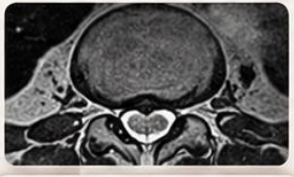
SAME MRI APPEARANCE



Disc bulge, minimal movement

Not unstable

SAME MRI APPEARANCE



Translates and angulates beyond normal

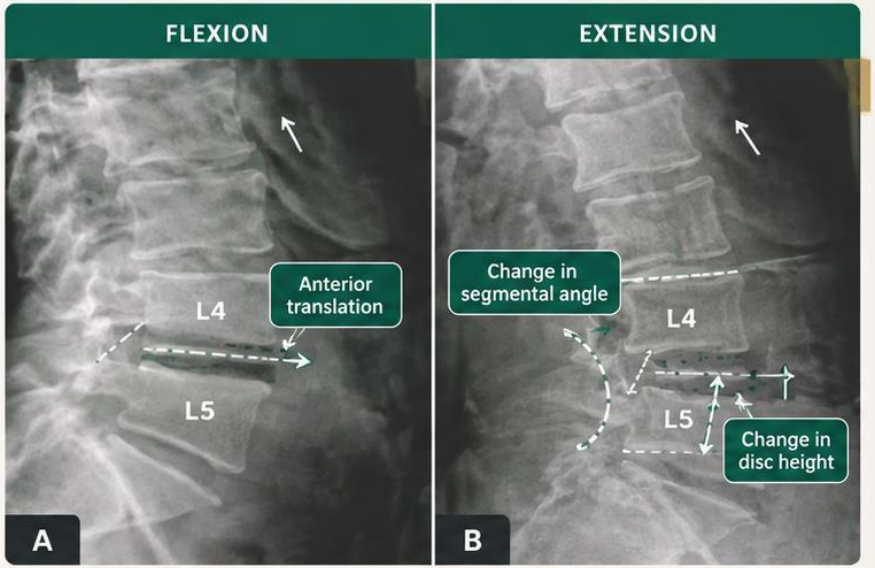
Mechanically unstable

Definition per Yong-Hing & Kirkaldy-Willis 1983 [1]. Surgeon disagreement: Spina et al., Clin Spine Surg 2019 [31]. Threshold validity: Hipp et al., Int J Spine Surg 2015 [9] and N Am Spine Soc J 2025 [8].

MEASURING INSTABILITY

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From flexion-extension films to automated motion metrics



Flexion (left) vs. extension (right): dynamic anterolisthesis at L4–L5, visible only with positional imaging.

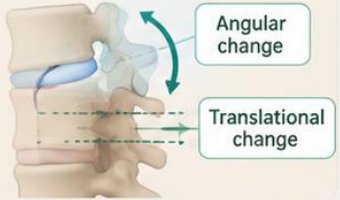
STATIC FINDINGS

Spondylolisthesis grade, disc height loss, facet effusion, vacuum phenomenon in disc or facet.



DYNAMIC FINDINGS

Change in translation and in segmental angle between standing flexion and extension films.



EMERGING METRICS

Automated motion analysis reports translational, angular, and vertical instability indices; early work suggests vertical instability and dynamic slip may predict who benefits from adding fusion.



AUTOMATED MOTION METRICS

Translational instability
Anterior or posterior movement between flexion and extension

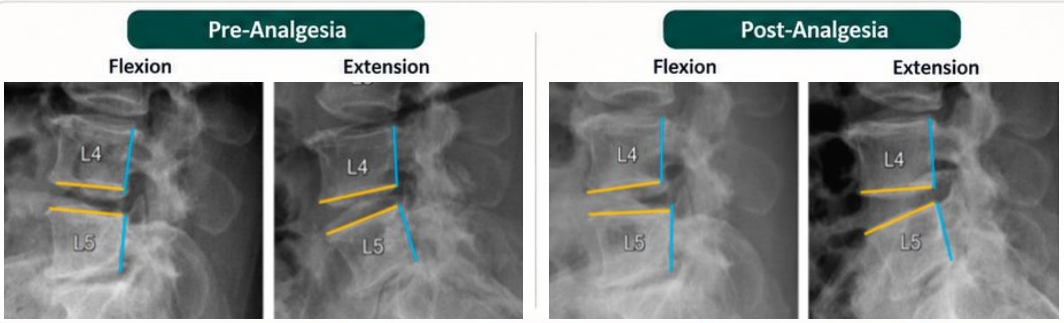
Angular instability
Change in segmental angle (kyphotic or lordotic)

Vertical instability
Change in disc height under load

Dynamic slip is the change in sagittal translation between flexion and extension; dynamic angulation is the change in segmental angle. Conventional thresholds are >4.5 mm and >15°, though consensus-based rather than validated. Image: Alsaleh K et al., Cureus 2019;11(4):e4268, PMC6529051, CC BY 4.0. https://pmc.ncbi.nlm.nih.gov/articles/PMC6529051/

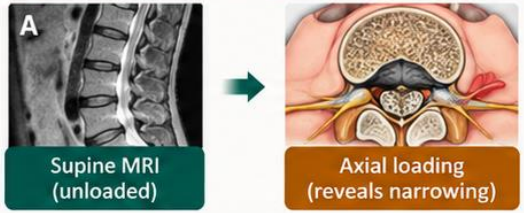
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Four reasons segmental instability is routinely under-detected



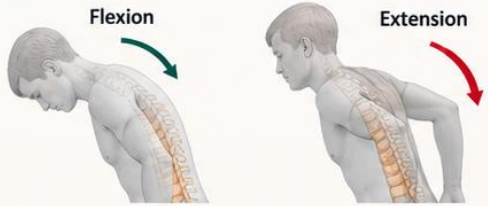
Motion and alignment abnormalities can be present pre-analgesia and diminish or disappear post-analgesia, leading to false-negative studies.

1 Supine imaging unloads the spine



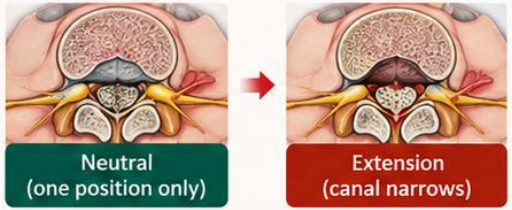
A recumbent MRI removes the load and posture that produce the symptoms. Axial loading reveals narrowing that conventional studies miss. [33]

2 Effort-dependent films



Flexion-extension radiographs depend on patient effort. Pain, spasm, and fear-avoidance all produce false-negative studies. [8]

3 Position changes the canal



Canal and foraminal dimensions change measurably with posture; a neutral image describes one position only. [32]

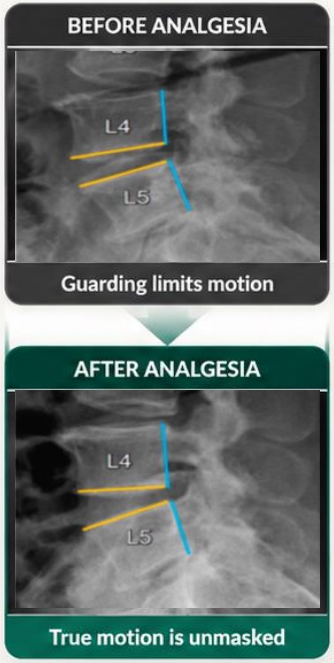
PRACTICAL CONSEQUENCE: *A normal flexion-extension study in a guarded, painful patient does not exclude segmental instability.*

Willen & Danielson, Spine 2001 [33]; Chou et al., J Clin Med 2021 [6]; Infusa et al., Spine 1996 [32]; Yong-Hing & Kirkaldy-Willis 1983 [1].

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Guarding hides instability — and it is reversible

One hundred patients with low-grade degenerative spondylolisthesis had standing flexion-extension radiographs, received 30 mg of intramuscular ketorolac, and were re-imaged. With pain controlled, measured motion increased and the proportion of patients meeting instability criteria rose sharply — same patients, same criteria, same day.



Category	Before analgesia	After analgesia	
Translation > 4.5 mm	4.0%	42.0%	10.5× increase
Angulation > 15°	4.0%	32.0%	8.0× increase
Slip > 15%	0.7%	16.7%	23.9× increase
Patients meeting instability criteria	6.0%	38.0%	6.3× increase

PRACTICAL CONSEQUENCE — **A normal flexion-extension study in a guarded, painful patient does not exclude segmental instability.**

Chou SH et al. Pain control affects the radiographic diagnosis of segmental instability in patients with degenerative lumbar spondylolisthesis. J Clin Med. 2021;10(17):3984 [6].

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Taking the history: the questions that carry the most weight

1 Walking tolerance

How far can you walk before your legs bother you? Has that distance been shrinking?





2 Positional relief

Does leaning on a cart, sitting, or bending forward bring relief? Is standing upright worse than walking?





3 Where the pain is

Is it in the back, the legs, or both? Does it follow a specific nerve distribution, or is it diffuse?



4 Onset and pattern

Did symptoms start gradually, or was there a specific event? Are there good days and bad days, or is it constant?



5 Prior treatment response

What has been tried, and did relief last days, weeks, or not at all? A pattern of brief relief points toward a mechanical driver.



6 Function, not just pain

What does this stop you from doing? Grocery shopping, walking the dog, standing at church — concrete function anchors severity better than a pain score.



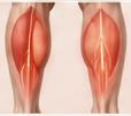
A focused history identifies the mechanical pattern, correlates with imaging, and helps determine the best treatment approach.

Structured around the diagnostic approach in Katz et al., JAMA 2022 [3] and Suri et al., JAMA 2010 [29].

CLINICAL PRESENTATION

Neurogenic versus vascular claudication

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	Neurogenic (spinal) Lumbar spinal stenosis	Vascular Peripheral arterial disease (PAD)
Trigger	 Standing and walking, especially extension (downhill, standing upright)	 Walking distance, independent of posture; worse uphill
Relief	 Sitting or forward flexion — the "shopping-cart sign"	 Standing still; does not require sitting or flexion
Onset of relief	 Slow, over minutes, and position-dependent	 Rapid, often within a minute of stopping
Pulses	 Normal	 Diminished or absent
Skin and hair changes	 Absent	 Often present — hair loss, shiny skin, cool extremities
Pain character	 Radiating, often bilateral, may include numbness or weakness	 Cramping, typically calf, reproducible at a consistent distance

Key takeaway: Neurogenic claudication is posture-dependent and positional. Vascular claudication is distance-dependent.

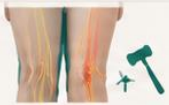
Differentiating features summarized from Suri et al., "Does this older adult with lower extremity pain have the clinical syndrome of lumbar spinal stenosis?" JAMA 2010 [29].
Many patients, especially older adults, have overlapping neurogenic and vascular disease.

CLINICAL PRESENTATION

The physical exam: what to look for, and its real limits

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FINDINGS WORTH DOCUMENTING

1		**Gait**	Watch for a stopped, forward-flexed posture that widens the canal — patients often adopt it unconsciously.
2		**Lumbar extension**	Reproduction of leg symptoms with standing extension supports the diagnosis; relief with flexion supports it further.
3		**Straight leg raise**	Usually negative in pure neurogenic claudication from stenosis; a positive test suggests a coexisting radiculopathy or disc herniation.
4		**Strength, sensation, and reflexes**	Focal deficits point toward a specific nerve root and toward a more advanced phase.
5		**Pulses and skin**	Normal pulses and skin argue against a vascular contributor.
6		**Romberg and gait stability**	Proprioceptive loss from chronic compression can affect balance independent of pain.

THE HONEST LIMITATION

The physical exam for lumbar spinal stenosis has only modest sensitivity and specificity. No single finding rules the diagnosis in or out. The exam is most useful for excluding other causes, localizing a level, and detecting red flags — the history still carries most of the diagnostic weight.



Use the exam to support the history, rule out other causes, and look for red flags.

KEY TAKEAWAY | **The exam informs and refines the diagnosis, but the history still carries most of the weight.**

Suri et al., JAMA 2010 [29]; Katz et al., JAMA 2022 [3].

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1 Disc degeneration

A biologic and inflammatory problem inside the disc. There is minimal abnormal motion and no significant stenosis.

PATHOLOGY — IMAGING CORRELATE

Homogenous bright white structure → Inhomogenous white structure, possible horizontal band → Inhomogeneous gray structure, unclear distinction of AF and NP → Inhomogeneous, black structure,lost distinction of AF and NP → Collapsed disc space



Grade I (healthy)	Grade II (early changes)	Grade III (moderate degeneration)	Grade IV (advanced degeneration)	Grade V (severe collapse)

Sagittal MRI, Pfirrmann grades I (a, healthy) through V (e, severe collapse) — progressive disc dehydration and annular fissuring.

WHAT THE PATIENT SAYS

"My back aches after I have been active – it settles down when I rest."

Activity-related ache consistent with discogenic pain.



"It comes and goes. Some weeks are fine."

Fluctuating symptoms are common in early disc degeneration.



"Nothing goes down my legs."

Axial back pain without radicular symptoms is typical in Phase 1.



KEY TAKEAWAY

Disc degeneration is a biologic and inflammatory process and can cause axial back pain without significant instability or stenosis.

Phase description after Yong-Hing & Kirkaldy-Willis 1983 [1]; conservative management per Kreiner et al., NASS guideline [26] and Ammendolia et al., Cochrane 2013 [27].
Image: Sollmann N et al., Pain Medicine 2023;24(Suppl 1):S24-S38, PMC10403314, CC BY 4.0, Fig 3. https://pmc.ncbi.nlm.nih.gov/articles/PMC10403314/

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1 Disc degeneration — what to offer

REASONABLE OPTIONS AT THIS PHASE

1 Activity modification, education, and reassurance



- Explain the condition and the favorable natural history
- Modify activities that provoke symptoms
- Provide reassurance and set expectations

2 Structured exercise and physical therapy



- Core and hip strengthening
- Flexibility and postural training
- Gradual return to desired activities

3 Simple analgesia and short courses of NSAIDs



- Acetaminophen or NSAIDs as first-line options
- Short, time-limited course for flares
- Use lowest effective dose and monitor tolerability

4 Selective intradiscal and biologic approaches



- Consider diagnostic intradiscal injection in select patients
- Therapeutic biologic approaches when appropriate
- Individualize based on clinical presentation and patient goals

WHAT THIS IS NOT

This is not a mechanical stabilization problem. There is no abnormal motion to arrest and no compression to decompress.

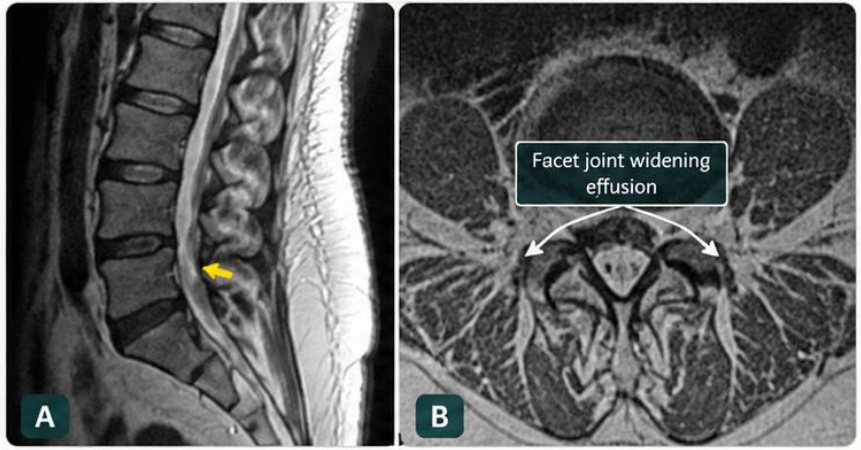
Phase description after Yong-Hing & Kirkaldy-Willis 1983 [1]; conservative management per Kreiner et al., NASS guideline [26] and Ammendolia et al., Cochrane 2013 [27].

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2 Micromotion instability

Loss of the disc and facet capsule's intrinsic restraint. The segment begins to move slightly more than it should during ordinary activity.

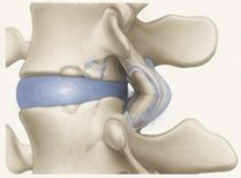
PATHOLOGY — IMAGING CORRELATE



Sagittal MRI (A) with facet effusion (arrow) and axial view (B) with measured facet joint widening — early signs the capsule has lost its restraint.

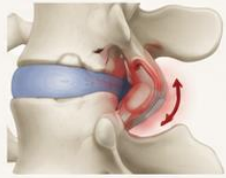
WHAT THIS MEANS

NORMAL



Disc and facet capsule provide stability with minimal motion.

MICROMOTION INSTABILITY



Disc degeneration and lax facet capsule allow abnormal, excess motion (micromotion).

WHAT THE PATIENT SAYS

- *"It catches when I stand up from a chair."*
- *"The first few steps in the morning are the worst."*
- *"Bending backwards hurts more than bending forwards."*

KEY TAKEAWAY | **Micromotion instability occurs when the disc and facet capsule lose their restraint, leading to abnormal segmental motion during everyday activity.**

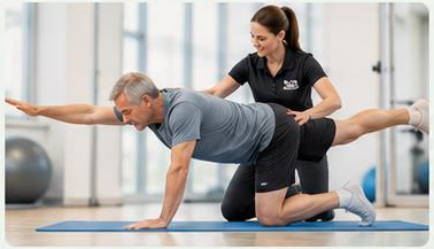
Load redistribution: Pollintine et al., Spine 2004 [7]. Detection of motion abnormality: Chou et al., J Clin Med 2021 [6].
Image: Singh A et al., Cureus 2023;15(6):e40403, PMC10292094, CC BY 4.0, Fig 2. https://pmc.ncbi.nlm.nih.gov/articles/PMC10292094/

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2 Micromotion instability — what to offer

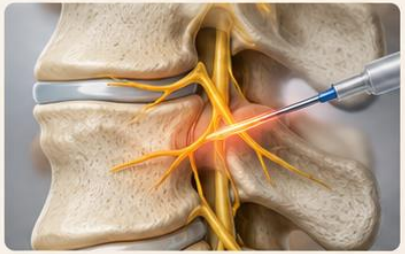
REASONABLE OPTIONS AT THIS PHASE

1 Continued physical therapy



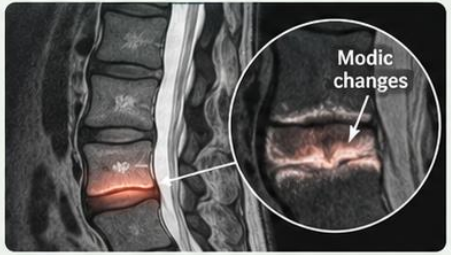
- Focus on segmental control and load tolerance
- Core and hip strengthening
- Improve stability and functional movement

2 Medial branch blocks and radiofrequency ablation



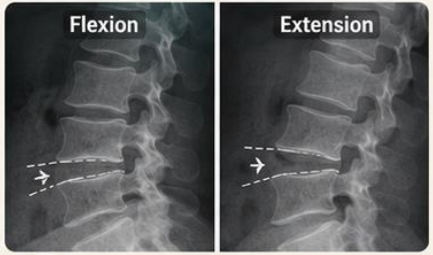
- Diagnostic medial branch blocks
- Radiofrequency ablation for facet-mediated axial pain
- Target patients with facet-generated pain

3 Basivertebral nerve ablation (Intracept®)



- Consider for patients with endplate (Modic) changes that correlate with pain pattern
- Targets basivertebral nerve to treat vertebrogenic pain
- Best for chronic axial low back pain without predominant radiculopathy

4 Standing flexion-extension imaging (repeat if needed)



- Consider standing flexion-extension radiographs
- Repeat with pain controlled if the first study is uninformative
- Evaluates for dynamic instability and abnormal segmental motion

WHAT THIS IS NOT

This is not radiculopathy and not neurogenic claudication.
Leg symptoms or a positive straight-leg raise point to a later phase.

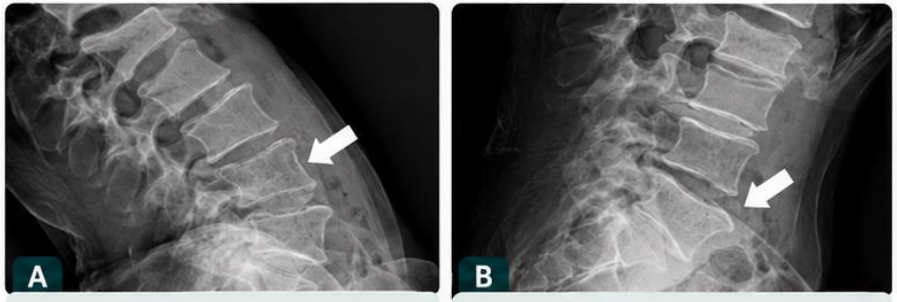
Load redistribution: Pollintine et al., Spine 2004 [7]. Detection of motion abnormality: Chou et al., J Clin Med 2021 [6].

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3 Angular imbalance

The segment no longer simply moves too much – it tilts. Asymmetric loading produces an early slip and begins to narrow the foramen.

PATHOLOGY — IMAGING CORRELATE



Flexion (or upright) | Extension (or upright)

Degenerative spondylolisthesis per Yong-Hing & Kirkaldy-Willis 1983 [1]. Arrows show angular translation with asymmetric loading.

WHAT THE PATIENT SAYS

- *"It is worse on one side."*
- *"My leg tingles when I stand in line, then it goes away when I sit."*
- *"I cannot stand at the counter for more than a few minutes."*

WHAT THIS MEANS

Segment tilts

The vertebra no longer just moves forward — it angulates, creating asymmetric loading.



Early foraminal narrowing

Angular imbalance begins to narrow the foramen and can irritate the exiting nerve.



Asymmetric loading

Uneven forces across the disc and facets promote further instability and degenerative change.



KEY TAKEAWAY | Angular imbalance indicates a more advanced stage of instability, with asymmetric loading, early slip, and foraminal narrowing.

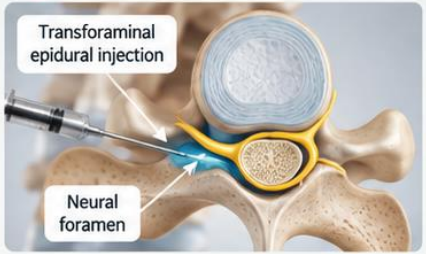
Degenerative spondylolisthesis per Yong-Hing & Kirkaldy-Willis 1983 [1]. Predictors of delayed instability: Blumenthal et al., J Neurosurg Spine 2013 [25].
Image: Musa G et al., Cureus 2022;14(9):e28948, PMC9584580, CC BY 4.0, Fig 1. https://pmc.ncbi.nlm.nih.gov/articles/PMC9584580/

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3 Angular imbalance — what to offer

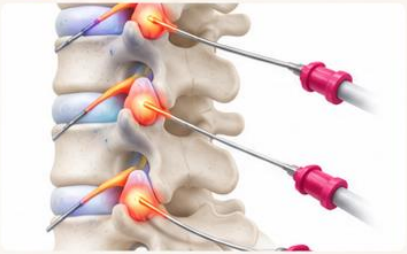
REASONABLE OPTIONS AT THIS PHASE

1 Transforaminal epidural steroid injection



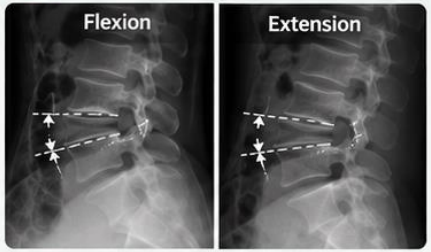
- Target to the symptomatic level and side
- Can reduce radicular pain and inflammation
- Useful for temporary relief and to confirm the pain source

2 Radiofrequency ablation (facet-mediated pain)



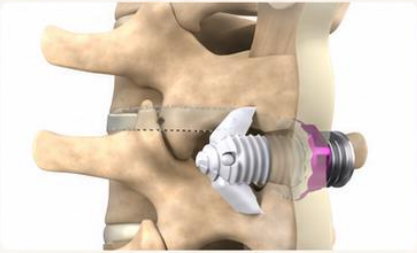
- Consider when facet-mediated axial pain coexists
- Targets medial branch nerves to interrupt pain signals
- Can provide longer-term relief (months–years)

3 Standing flexion-extension radiographs



- Characterize the slip and its dynamic component
- Assesss translation and angulation with motion
- Helps guide appropriate treatment selection

4 Consider stabilization (if mechanical failure)



- Consider when mechanical failure is clearly the driver
- Discuss when conservative care has failed
- Goal is to restore stability and prevent further progression

WHAT THIS IS NOT

This is not yet fixed stenosis. The narrowing still opens and closes with position, and the slip is still low grade.

Degenerative spondylolisthesis per Yong-Hing & Kirkaldy-Willis 1983 [1]. Predictors of delayed instability: Blumenthal et al., J Neurosurg Spine 2013 [25].

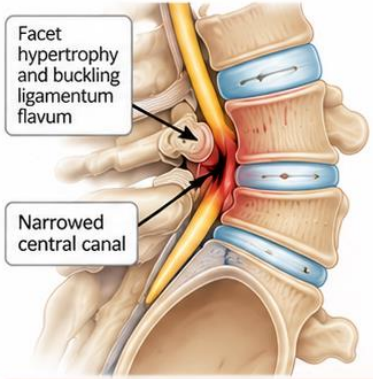
4 Dynamic stenosis

The central canal now closes under load. Neurogenic claudication appears, and the patient can relieve it by changing posture.

Dynamic SPINE AND PAIN INSTITUTE

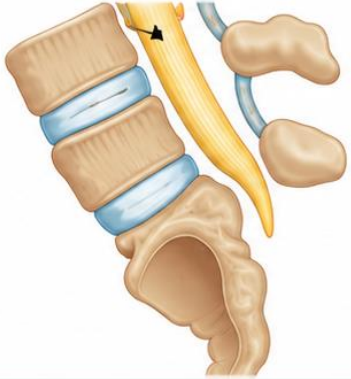
PATHOLOGY — IMAGING CORRELATE

A. EXTENSION (STANDING/UPRIGHT)
Canal narrows under load



Extension, standing, or walking reduces canal diameter by facet approximation and ligamentum flavum buckling, compressing neural elements.

B. FLEXION (SITTING/FORWARD)
Canal opens and symptoms improve



Sitting or forward flexion increases canal diameter and reduces compression, which often relieves symptoms.

KEY POINTS



Load-dependent narrowing
The central canal narrows under mechanical load (extension/standing), leading to neurogenic claudication.



Posture dependent
Forward flexion (sitting, leaning) increases canal space and relieves symptoms.



Neurogenic claudication
Leg symptoms appear with walking or standing and improve with sitting or flexion.



Imaging correlation
Dynamic or positional imaging often shows canal narrowing in extension and improvement in flexion.

WHAT THE PATIENT SAYS



"I can push a cart around the whole store, but I cannot stand in the checkout line."



"Walking uphill is easier than walking downhill."



"I walk a block, sit for a minute, and then I can go again."

KEY TAKEAWAY

Dynamic stenosis means the canal narrows with load and opens with flexion. Neurogenic claudication improves by changing posture.

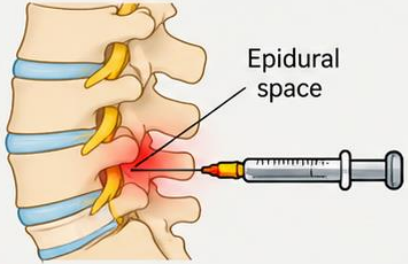
Positional canal change: Inufusa et al., Spine 1996 [32]; axial-loaded imaging: Willen & Danielson, Spine 2001 [33]. Clinical syndrome: Suri et al., JAMA 2010 [29].
Image: Yamada K et al., Sci Rep 2021;11;23297, PMC8648848, CC BY 4.0, Fig 1. https://pmc.ncbi.nlm.nih.gov/articles/PMC8648848/

4 Dynamic stenosis — what to offer

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REASONABLE OPTIONS AT THIS PHASE

1 Epidural steroid injection
for the inflammatory component of claudication



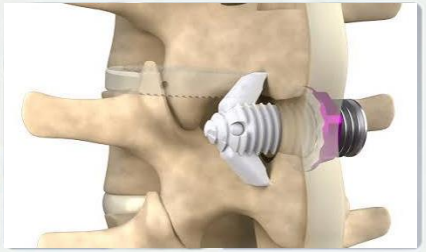
- Reduces inflammation and nerve irritation
- Target the symptomatic level(s)
- Can provide diagnostic and therapeutic benefit

2 Minimally invasive decompression (MILD)
when ligamentum flavum hypertrophy is dominant



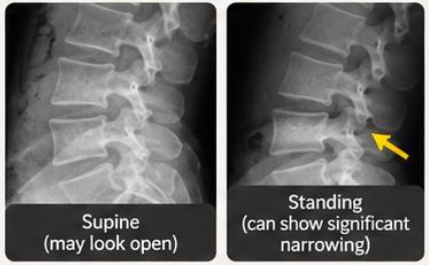
- Removes portions of hypertrophic ligamentum flavum
- Minimally invasive, outpatient procedure
- Helps improve walking tolerance and quality of life

3 Interspinous-interlaminar fixation (Minuteman)
in selected patients with retained positional relielf



- Stabilizes the interspinous space and limits extension
- Maintains motion and preserves native anatomy
- Best for patients with symptom relief when flexed (sits better than stands)

4 Consider axial-loaded or upright imaging
when symptoms outrun the supine study



- Standing or axial-loaded imaging can reveal dynamic narrowing not seen on supine MRI
- Helps correlate symptoms with position and determine optimal treatment

WHAT THIS IS NOT — This is not vascular claudication, which eases with standing and is unaffected by spinal posture.

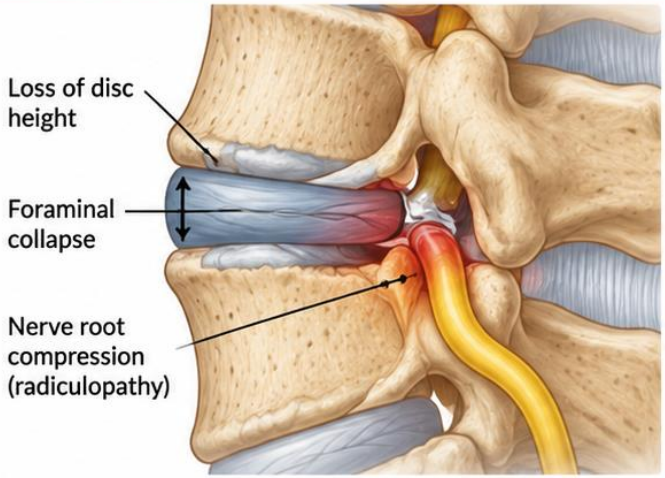
Positional canal change: Inufusa et al., Spine 1996 [32]; axial-loaded imaging: Willen & Danielson, Spine 2001 [33]. Clinical syndrome: Suri et al., JAMA 2010 [29].

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5 Vertical collapse

Disc height and vertical load support are lost. The foramen collapses, and a true radiculopathy joins the claudication.

PATHOLOGY — IMAGING CORRELATE





Sagittal MRI showing advanced disc space collapse (arrow) with disproportionate foraminal height loss at the affected level.

WHAT THE PATIENT SAYS

"Sharp pain shoots down the back of my leg into my foot."

"I cannot stand at the sink long enough to do the dishes."

"The injections help for a few weeks and then it comes back."

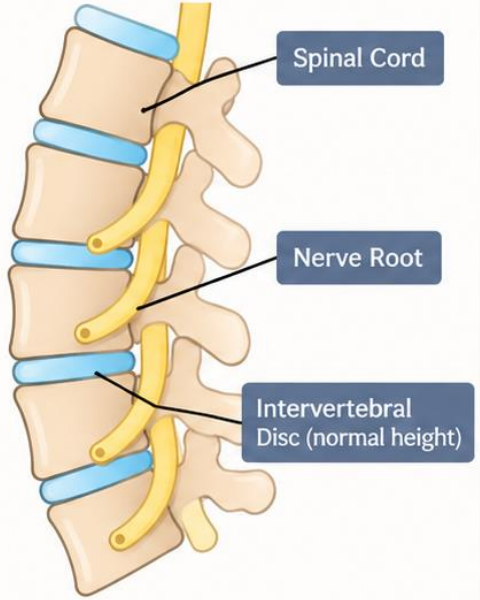
- Loss of disc height and vertical load support
- Foraminal collapse leading to nerve root compression
- Often associated with true radiculopathy in addition to claudication
- Symptoms typically worse with standing and walking, improved with sitting/flexion

Foraminal geometry with disc height loss: Inufusa et al., Spine 1996 [32]. Motion metrics and surgical selection: Hipp et al., N Am Spine Soc J 2025 [8].
Image: Musa G et al., Cureus 2022;14(9):e28948, PMC9584580, CC BY 4.0, Fig 2. https://pmc.ncbi.nlm.nih.gov/articles/PMC9584580/

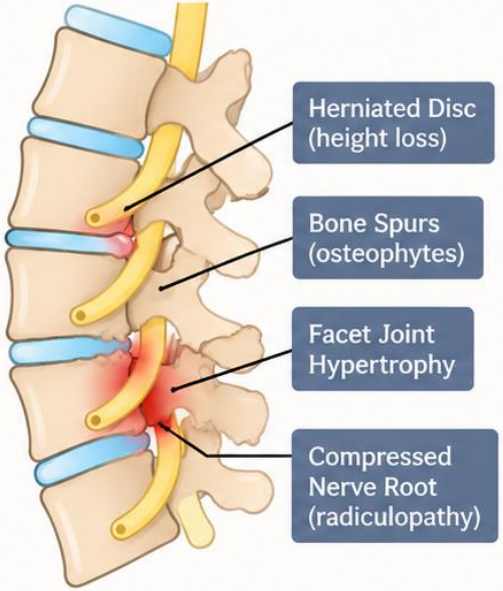
5 Vertical collapse — what to offer

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Healthy Spine



Vertical Collapse



REASONABLE OPTIONS AT THIS PHASE

Transforaminal injection
for the radicular component, recognizing the relief is usually temporary.

Direct decompression
where the compressing tissue is fixed — bone, dense osteophyte, or fibrosed ligament.

Height-restoring or stabilizing procedures
where flexion-extension imaging shows a segment that still distracts.

Surgical consultation
where collapse is advanced, multilevel, or accompanied by deformity.

What this is not: *This is not a decompression-only problem in every case, and it is not a lost cause. Whether the collapse is still partly reducible is the deciding question.*

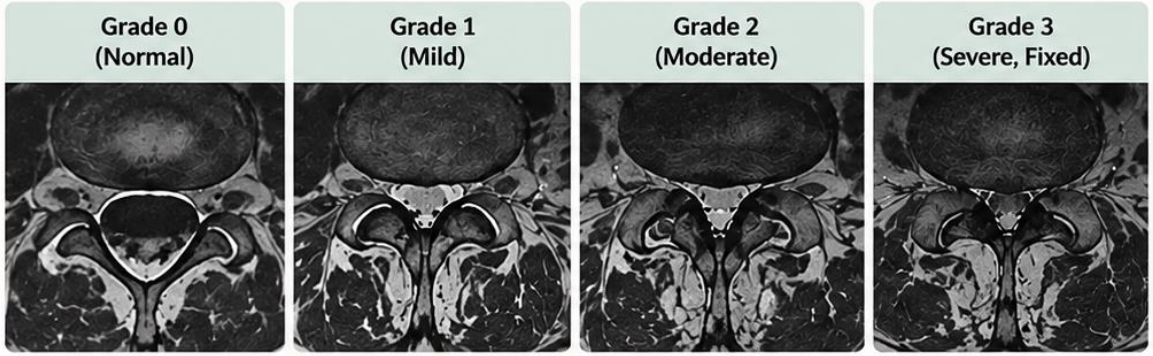
Foraminal geometry with disc height loss: Inufusa et al., Spine 1996 [32]. Motion metrics and surgical selection: Hipp et al., N Am Spine Soc J 2025 [8].

6 Fixed stenosis

The compression is now structural and no longer positional. This is the phase in which posture no longer helps.

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PATHOLOGY — IMAGING CORRELATE



Axial MRI grading atlas, grade 0 (A, normal) through grade 3 (D, severe, fixed) lateral recess stenosis.

WHAT THE PATIENT SAYS

- *"Bending forward used to help. It does not any more."*
- *"My foot catches when I walk."*
- *"There is no position that makes it better."*

KEY FEATURES OF FIXED STENOSIS

- Structural compression from disc collapse, bone spurs, and/or hypertrophic facets/ligamentum flavum.
- Symptoms persist despite changes in posture or position.
- Often associated with neurologic findings (e.g., persistent radiculopathy, neurogenic claudication).
- Often requires surgical consultation for definitive decompression +/- stabilization.

What this is not: *This is not a decompression-only problem in every case, and it is not a lost cause. Whether the collapse is still partly reducible is the deciding question.*

Phase description and surgical implication per Yong-Hing & Kirkaldy-Willis 1983 [1]. Red-flag and referral considerations per Katz et al., JAMA 2022 [3]. Image: Splettstösser A et al., World J Radiol 2017;9(5):223-229, PMC5441455/, CC BY-NC 4.0, Fig 2.

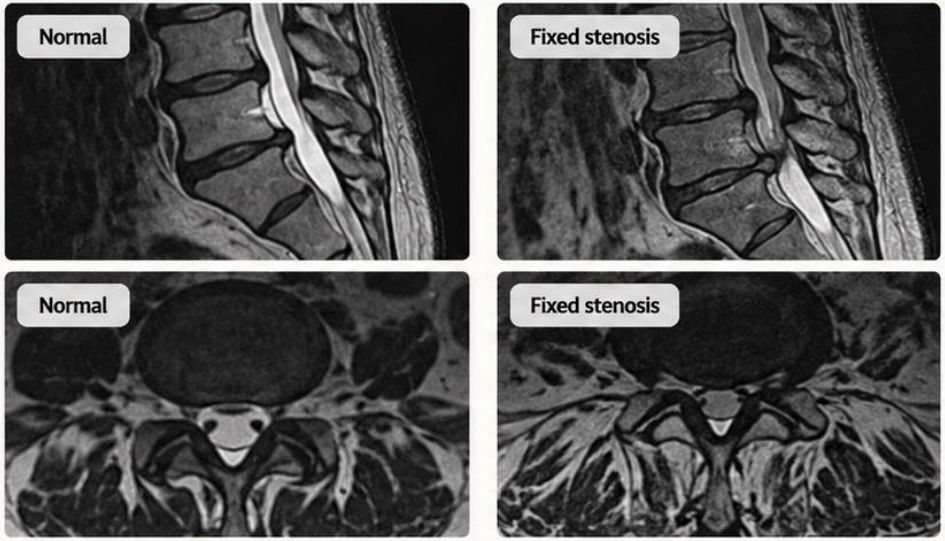
PHASE 6 OF 6 · TREATMENT WINDOW

6 Fixed stenosis — what to offer

The compression is now structural and no longer positional. This is the phase in which posture no longer helps.

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PATHOLOGY — IMAGING EXAMPLES



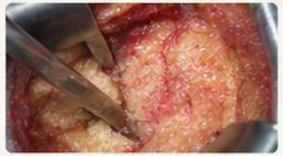
Sagittal (top) and axial (bottom) MR images showing normal vs. severe fixed stenosis with disc collapse, facet hypertrophy, and ligamentum flavum thickening.

REASONABLE OPTIONS AT THIS PHASE

1. **Neurosurgical or orthopedic spine consultation**
   This is the referral phase.



2. **Direct surgical decompression**
   Kirkaldy-Willis observed that decompression alone is generally sufficient once the segment has stiffened.



3. **Fusion (when indicated)**
   For patients with deformity, high-grade slip, or demonstrated instability.



4. **Neuromodulation (SCS)**
   For patients who are not surgical candidates or who have persistent pain after decompression.



What this is not: *This is not a target for indirect decompression or distraction. A fixed segment has no recoverable height to restore and no abnormal motion to arrest.*

Phase description and surgical implication per Yong-Hing & Kirkaldy-Willis 1983 [1]. Red-flag and referral considerations per Katz et al., JAMA 2022 [3]. Images: Splettstöser A et al., World J Radiol 2017;9(5):223-229, PMC5441455/, CC BY-NC 4.0.

FIRST-LINE MANAGEMENT

Exercise and physical therapy: what the evidence supports

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WHAT WE KNOW

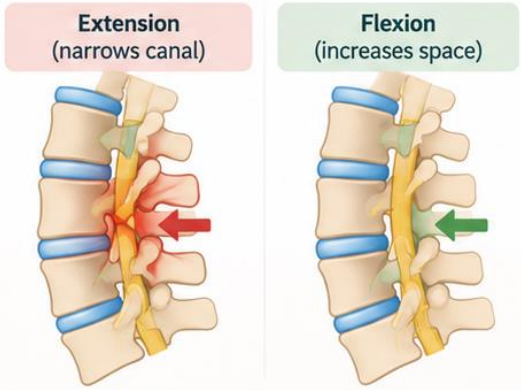
Exercise and physical therapy are recommended as first-line care, but the evidence base is more modest than the strength of that recommendation suggests. A Cochrane review found no clear superiority of any single non-operative approach and rated the overall evidence quality as low. In a randomized trial comparing surgery to structured physical therapy, patients who consented to either arm improved similarly in function at two years.

KEY TAKEAWAYS

- Still recommended as first-line care
- No single non-operative approach is clearly superior
- Structured PT can produce meaningful improvement

1 Flexion-based exercise

Core and hip strengthening in postures that reduce extension load are the most commonly studied approach.



2 Aerobic conditioning

Stationary cycling in a flexed position is often better tolerated than treadmill walking and preserves cardiovascular benefit.



OFTEN BETTER TOLERATED THAN:

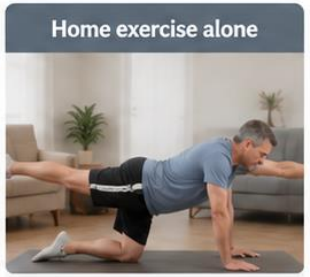
- Upright walking (treadmill) ✗
- Stationary cycling (flexed position) ✓

3 Supervised over unsupervised

Programs delivered with therapist supervision tend to show better adherence and modestly better outcomes than home exercise alone.



- ✓ Better adherence
- ✓ Modestly better outcomes



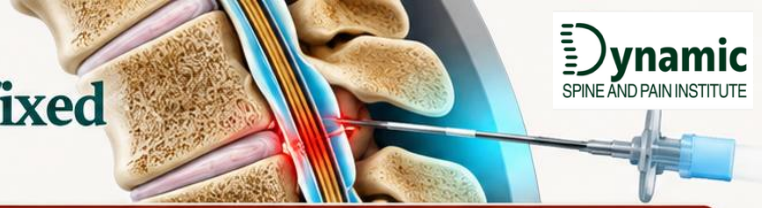
- ✗ Lower adherence
- ✗ Generally less improvement

Ammendolia et al., Cochrane Database Syst Rev 2013 [27]; Delitto et al., Ann Intern Med 2015 [28]; Kreiner et al., NASS guideline, Spine J 2013 [26].

FIRST-LINE MANAGEMENT

ESI works best before stenosis becomes fixed

Severity drives expected response more than injection route.



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THE PATIENT MOST LIKELY TO BENEFIT

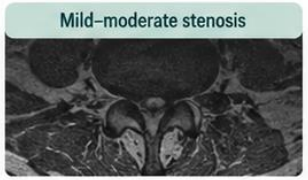
ESI can reduce inflammation, improve symptoms, and buy time.

Mild-to-moderate stenosis
Central or foraminal stenosis with concordant leg symptoms.

Positional symptoms
Neurogenic claudication or radicular pain with retained positional relieif (e.g., better with sitting or flexion).

Functional goal
Improve walking distance, standing tolerance, or participation in rehabilitation.

Use ESI appropriately
As a targeted, time-limited treatment for the inflammatory component.





WHEN ESI IS LESS LIKELY TO BE ENOUGH

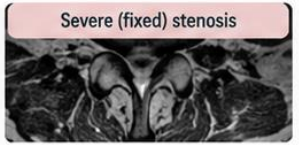
Fixed, non-positional compression is less likely to respond.

Severe or multilevel fixed compression
With reduced expected pain and function benefit.

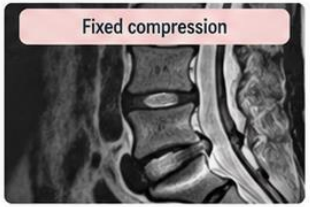
Constant, non-positional symptoms
Symptoms that persist regardless of position or progressive neurologic deficit.

Repeated brief response to ESI
Only temporary or minimal relief after a properly targeted injection.

Structural problem
That needs decompression, stabilization, or surgical evaluation.



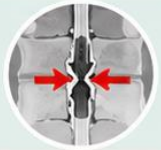




MATCH THE TOOL TO THE PATHOLOGY



ESI treats the inflammatory component of stenosis.



It does not reverse fixed compression.

FIRST-LINE MANAGEMENT

Choose the route to fit the anatomy

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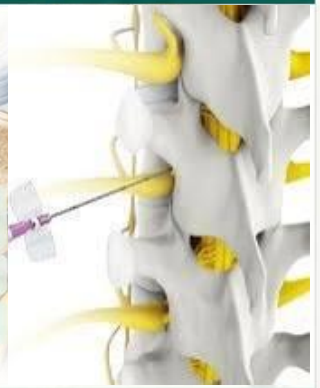
All three routes produced broadly similar overall relief; choose based on symptom distribution and levels involved.

1 TRANSFORAMINAL

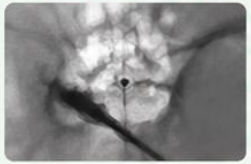
BEST FIT

Focal, single-level, usually unilateral radicular symptoms.

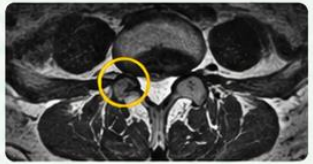
- Target the symptomatic nerve root and side
- Most selective route
- Lower injectate volume



TYPICAL IMAGING VIEW



Fluoroscopic (oblique)



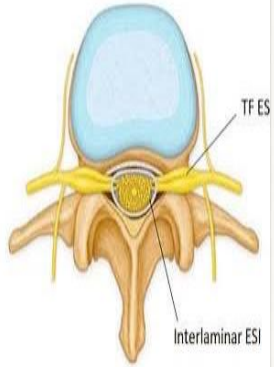
Axial MRI (foraminal stenosis)

2 INTERLAMINAR

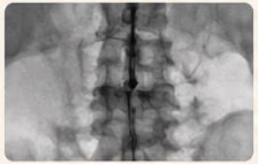
BEST FIT

Broader or multilevel central stenosis.

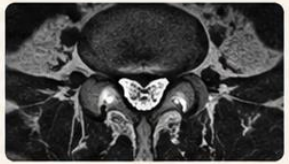
- Place at maximal stenosis or one level caudad
- Useful when pathology is less focal
- Covers bilateral symptoms



TYPICAL IMAGING VIEW



Fluoroscopic (AP)



Axial MRI (central stenosis)

3 CAUDAL

BEST FIT

Multilevel lower-lumbar pathology, especially L3–S1.

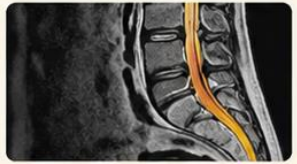
- Broad epidural access from the sacral hiatus
- Requires more volume
- Less anatomically selective



TYPICAL IMAGING VIEW



Fluoroscopic (lateral)



Sagittal MRI (multilevel stenosis)

Clinical takeaway: Severity and symptom–imaging concordance matter more than trying to identify a universally “superior” injectior route.

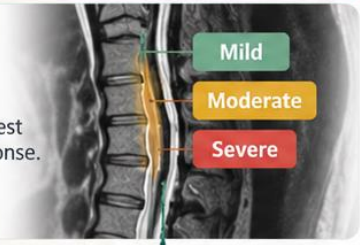
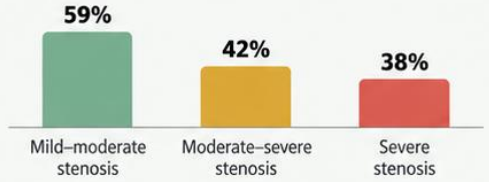
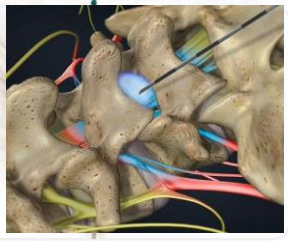
Wildeman I, Sarzetto F, Didari T, et al. Pain Physician. 2026;29:E337–E361. Route conclusions limited by heterogeneous, mostly small study groups.

FIRST-LINE MANAGEMENT

What determines ESI response in lumbar stenosis?

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The evidence hierarchy: candidate selection first, anatomy second, medication strategy third.

STUDY VARIABLE	WHAT THE META-ANALYSIS FOUND	PRACTICAL INTERPRETATION
1 STENOSIS SEVERITY This is the strongest predictor of response. 	**Pooled pain relief at 2–3 months** 	**Select the right severity of disease.** • Best results in mild–moderate, position-responsive disease. • Severe or fixed compression requires realistic expectations and consideration of a structural solution. • Use clinical and imaging findings to set expectations.
2 INJECTION ROUTE All three routes provide benefit, with no universally superior approach. 	**Interlaminar, transforaminal, and caudal injections** ✓ All provided benefit in patients with lumbar stenosis. ✓ No route was universally superior across the review. ✓ Route selection should be based on anatomy, symptom distribution, and levels involved.	**Match the route to the anatomy.** • Focal root symptoms favor transforaminal. • Broader or multilevel central stenosis favors interlaminar or caudal. • Consider patient anatomy, level(s) involved, and symptom distribution.
3 STEROID / DOSE Steroid type and dose influence duration of benefit, but results are mixed. 	**Betamethasone vs. Methylprednisolone** ✓ Betamethasone/depot steroids had more sustained benefit in some study groups. – Dose was not consistently linked to better outcomes. – Study groups were heterogeneous.	**Individualize the medication strategy.** • Consider a longer-acting steroid when appropriate. • Use the lowest effective dose. • Interpret comparisons cautiously due to heterogeneous study groups.

BOTTOM LINE: Treat dynamic, inflammatory symptoms; choose the route that reaches the anatomy; do not expect ESI to reverse fixed compression.

Wildeman I, Sarzetto F, Didari T, et al. Pain Physician. 2026;29:E337–E361. 24 studies; 33 groups; 1,350 patients. High heterogeneity; evidence should guide selection rather than create a rigid protocol.

FIRST-LINE MANAGEMENT

Facet-directed procedures, and closing out conservative care

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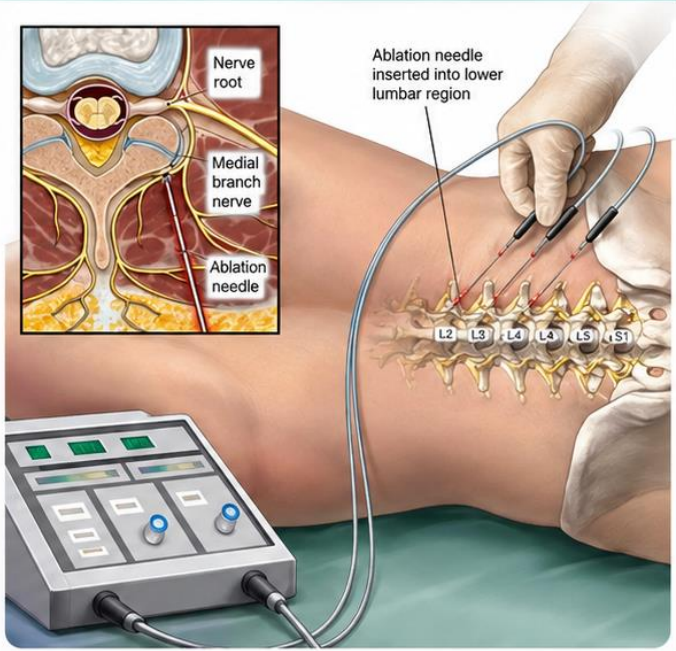
MEDICAL BRANCH BLOCKS AND RADIOFREQUENCY ABLATION

1. **TARGET THE FACET JOINTS**
   Target the facet joints directly when axial back pain, worse with extension and rotation, is the dominant complaint.

2. **USE DIAGNOSTIC BLOCKS**
   Diagnostic medial branch blocks should show meaningful, reproducible relief before proceeding to ablation.

3. **RADIOFREQUENCY ABLATION**
   Typically provides relief measured in months, not years, and is expected to be repeated.

4. **DOES NOT CHANGE ANATOMY**
   Neither procedure alters canal or foraminal dimensions and neither changes segmental mechanics.



SECTION SUMMARY

Conservative care is the right first step and often the only step needed, since the natural history of stenosis is frequently non-progressive.

Medial branch blocks and radiofrequency ablation can effectively treat facet-mediated pain within conservative care.

These procedures treat pain but do not change spinal anatomy and are typically repeated when pain returns.

SIGNAL THAT IT IS TIME TO MOVE ON

A recurring pattern — real relief from an injection or ablation that fades in weeks rather than months — is itself diagnostic information. It suggests the pain generator was correctly identified but the mechanical driver behind it was not addressed.

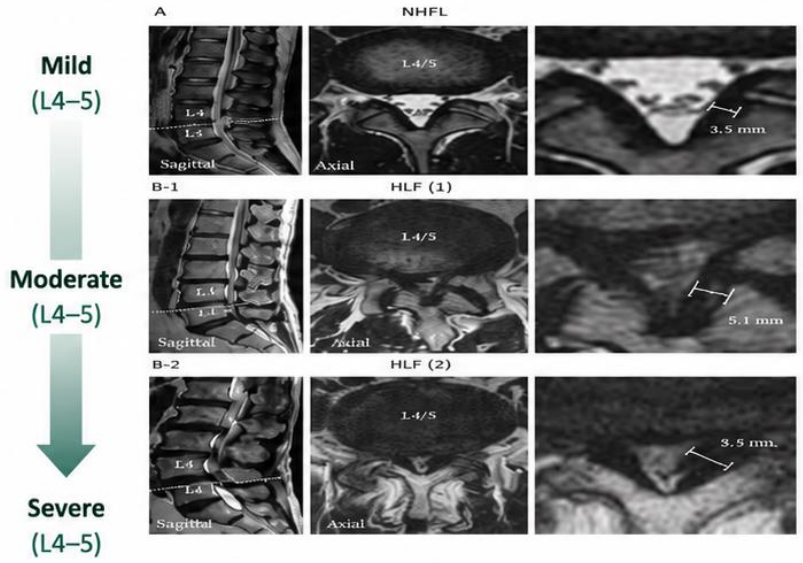
BOTTOM LINE: Facet-directed procedures are an effective part of conservative care for facet-mediated pain, provide temporary relief, and do not reverse stenosis or alter spinal anatomy.

MINIMALLY INVASIVE CARE: PILD

Percutaneous image-guided lumbar decompression: mechanism

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Targeted removal of hypertrophic ligamentum flavum and a portion of lamina to increase canal space — no implant, no fusion.



The ligamentum flavum hypertrophy PILD targets — visualized here on MRI at increasing thickness (tep to bottom).

WHAT THE PROCEDURE DOES

Debulks hypertrophic ligamentum flavum
Removes excess ligament and a portion of lamina causing central canal narrowing.

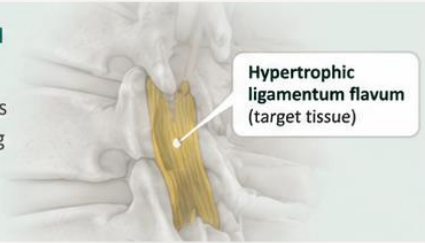
Posterior, central-canal procedure
Targets tissue rather than distracting or fusing the segment.

No implant is placed
The mechanics of the segment are otherwise unchanged.

Performed under fluoroscopic guidance
Minimally invasive, local-anesthesia option for appropriate patients.

WHERE IT SITS ON THE CONTINUUM

PILD is the tissue-removal answer to the buckled-ligament picture in dynamic stenosis (phase 4): it makes the canal bigger by taking material out, rather than by changing how the segment moves.



KEY TAKEAWAY: PILD is best for patients with neurogenic claudication from central canal stenosis due to hypertrophic ligamentum flavum, without instability, and who are seeking a minimally invasive option.

Image: Yamada K et al., Sci Rep 2021;11;23297, PMC8648848, CC BY 4.0, Fig 1. https://pmc.ncbi.nlm.nih.gov/articles/PMC8648848/

MINIMALLY INVASIVE CARE: PILD

Patient selection

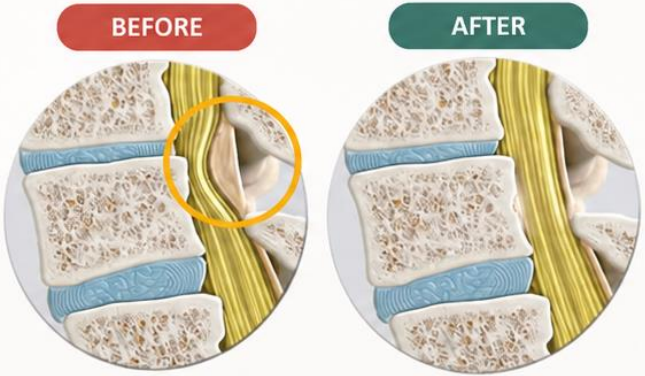
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THE PATIENT WHO DOES WELL

- **Neurogenic claudication** from central canal stenosis, with imaging showing hypertrophic ligamentum flavum as a major contributor
- **Symptoms persist** despite a fair trial of conservative care
- **No more than mild-to-moderate spondylolisthesis** (trials generally excluded grade II or higher)
- **No significant segmental instability** on flexion-extension imaging
- **A patient for whom an outpatient, local-anesthesia procedure** is preferable to a larger operation

HOW PILD WORKS

A percutaneous, fluoroscopically guided debulking of hypertrophic ligamentum flavum and a portion of lamina, performed without direct visualization of the working area.



Hypertrophic ligamentum flavum narrowing the canal

Debulked ligamentum flavum with increased canal space

WHERE PILD WILL DISAPPOINT

- **Foraminal or lateral recess stenosis** since this is a central-canal procedure
- **Lost disc height or foraminal height** nothing is restored
- **Meaningful segmental instability** since motion is unchanged
- **A patient who needs stabilization** not just more room

BOTTOM LINE: PILD is best for patients with neurogenic claudication from central canal stenosis due to hypertrophic ligamentum flavum, without instability, and who are seeking a minimally invasive option.

Selection criteria per Deer et al., Pain Med 2022 [11]; exclusion pattern consistent with the MOTION trial design.

MINIMALLY INVASIVE CARE: PILD

The MOTION trial: design

A rigorously designed RCT with objective, real-world outcome measures.

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STUDY DESIGN

A randomized controlled trial compared PILD plus conventional medical management against conventional medical management alone in patients with neurogenic claudication from lumbar spinal stenosis. Objective, real-world outcome measures were built into the protocol rather than relying on patient report alone.

PILD + Medical Management



VS

Medical Management Alone



RCT

RANDOMIZED CONTROLLED TRIAL

PILD plus medical management vs. medical management alone in patients with neurogenic claudication from lumbar spinal stenosis.

Primary endpoint

OBJECTIVE FUNCTIONAL OUTCOME

Oswestry Disability Index and objectively measured walking time (rather than patient report alone).



1 / 2 / 3 yr

DURABILITY ASSESSMENT

Outcomes reported at 1, 2, and 3 years in successive publications.

1 YEAR — 2 YEARS — 3 YEARS

Deer TR et al. The MOTION study. Pain Med. 2022;23(4):625-634 [11]; Deer TR et al. Pain Pract. 2024;24(1):109-119 [12]; Costandi SJ et al. Interv Pain Med. 2025;4(1):100561 [13].

MINIMALLY INVASIVE CARE: PILD

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The MOTION trial: results and durability

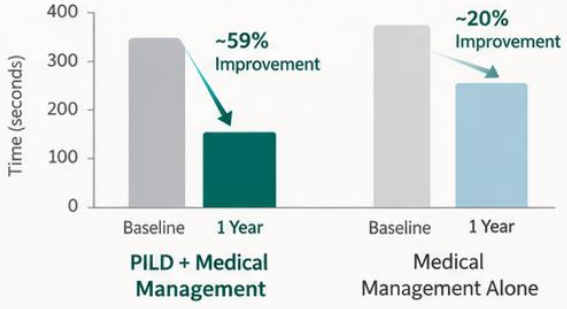
Sustained, meaningful improvement in function with low adverse events through 3 years.

1 YEAR — SIGNIFICANTLY GREATER IMPROVEMENT

PRIMARY OUTCOME

Significantly greater improvement in Oswestry Disability Index (ODI) and in objectively measured walking time versus medical management alone. [11]

OBJECTIVELY MEASURED WALKING TIME



2 YEARS — IMPROVEMENT SUSTAINED

DURABILITY

Improvement sustained; between-group difference favoring PILD persisted. [12]



3 YEARS — DURABILITY MAINTAINED WITH LOW ADVERSE EVENTS

LONG-TERM OUTCOMES

Durability maintained at longest reported follow-up; low rate of device- or procedure-related adverse events across the series. [13]



Deer TR et al. Pain Med. 2022;23(4):625-634 [11]; Pain Pract. 2024;24(1):109-119 [12]; Costandi SJ et al. Interv Pain Med. 2025;4(1):100561 [13].

MINIMALLY INVASIVE CARE: PILD

MiDAS ENCORE: PILD compared against epidural steroid injection

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A randomized controlled trial demonstrating superior and durable outcomes with PILD in neurogenic claudication due to lumbar spinal stenosis with ligamentum flavum hypertrophy.



STUDY DESIGN

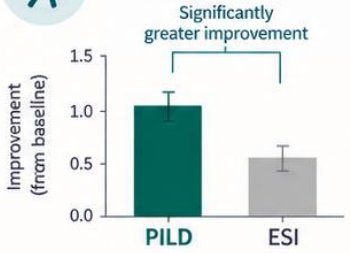
A randomized controlled trial compared **PILD against epidural steroid injection** in patients with neurogenic claudication from lumbar spinal stenosis with ligamentum flavum hypertrophy. PILD showed **significantly greater improvement** in the Zurich Claudication Questionnaire and numeric pain ratings compared with the injection arm, an effect that was maintained at two-year follow-up.

RCT | PILD vs. EPIDURAL STEROID INJECTION

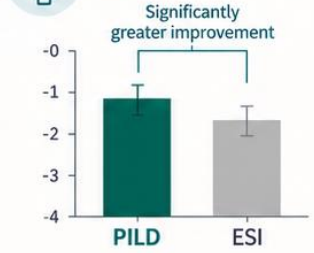
- Randomized controlled trial
- **PILD** versus epidural steroid injection
- Patients with neurogenic claudication due to lumbar spinal stenosis with ligamentum flavum hypertrophy
- Head to head comparison

ZCQ + NPRS | PILD FAVORED ON BOTH PRIMARY MEASURES

Zurich Claudication Questionnaire (ZCQ)



Numeric Pain Rating Scale (NPRS)



2 YEARS | DURABILITY OF THE TREATMENT EFFECT

Treatment effect maintained at two-year follow-up.



- Sustained improvement in function
- Sustained pain relief
- Low rate of device- or procedure-related adverse events

Benyamin RM, Staats PS; MIDAS ENCORE Investigators. Pain Physician. 2016;19(4):229-242 [14]; Staats PS et al. Reg Anesth Pain Med. 2018;43(7):789-794 [15].

MINIMALLY INVASIVE CARE: PILD

Coverage and the Medicare claims benchmark

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COVERAGE STATUS

MEDICARE NATIONAL COVERAGE DETERMINATION 150.13

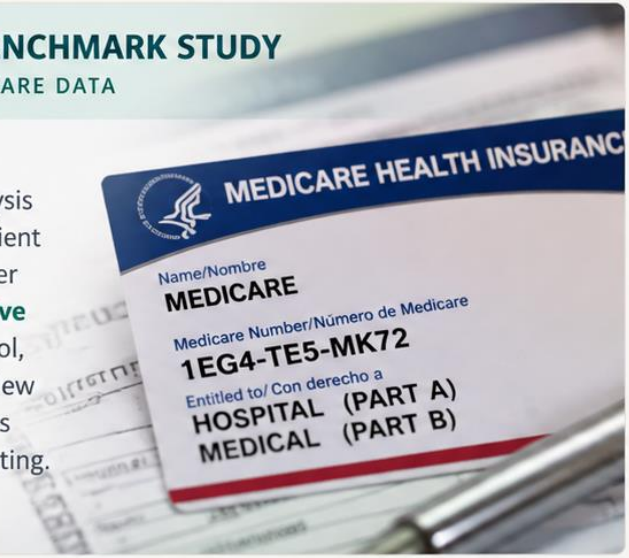
Under national coverage determination 150.13, **Medicare covers PILD for lumbar spinal stenosis through coverage with evidence development** for beneficiaries enrolled in an approved clinical study.

Commercial payer policies vary and have been revisited more than once as evidence has accumulated. **Verify current local coverage before scheduling.**

THE CLAIMS BENCHMARK STUDY

REAL-WORLD MEDICARE DATA

A 2-year Medicare claims analysis benchmarked PILD and outpatient laminectomy against each other using **real-world administrative data** rather than a trial protocol, providing a population-level view of how the procedure performs outside the controlled trial setting.



PRACTICAL NOTES

OUTPATIENT
Performed under local anaesthesia with sedation.

SAME-DAY DISCHARGE
Same-day discharge in most series.

NO IMPLANT
Tissue removal only, no hardware-related complications.

LOW ADVERSE EVENTS
Reported device- and procedure-related adverse events have been low across published series.

CMS NCD 150.13 [16]. Staats PS et al. Interv Pain Med. 2024;3:100412 [17].

Safety profile and section summary

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SAFETY PROFILE

FAVORABLE SAFETY PROFILE WITH LOW RATES OF ADVERSE EVENTS



NO IMPLANT

Avoids hardware-specific complication categories seen with spacers and fixation devices.

NO MIGRATION

No risk of implant migration.

NO IMPLANT-BONE INTERFACE

Eliminates risk of hardware-related revision.

LOW ADVERSE EVENT RATE

Reported adverse events across the MOTION and MiDAS series have been predominantly minor and procedure-related rather than device-related.

SECTION SUMMARY

PILD is a **well-studied, implant-free option** for central-canal, ligamentum-flavum-driven claudication with a **strong randomized evidence base**, both against medical management and against epidural steroid injection. Its limitation is scope: **it treats the central canal and nothing else**, and it leaves segmental mechanics untouched. Where the problem is foraminal, or where instability is driving the picture, PILD is the wrong tool even when it is technically well executed.



Synthesis of sources cited across this section [11-17].

MINIMALLY INVASIVE CARE: INTERSPINOUS DEVICES

Two families, one location, very different mechanics

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INTERSPINOUS SPACERS

BLOCK EXTENSION AND HOLD THE SEGMENT OPEN



Courtesy of Vertiflex®

- Placed between the spinous processes
- Blocks extension, holding the segment out of position
- No fusion, no bone removal — the device itself does the work
- Indefinite use as long as it remains in place

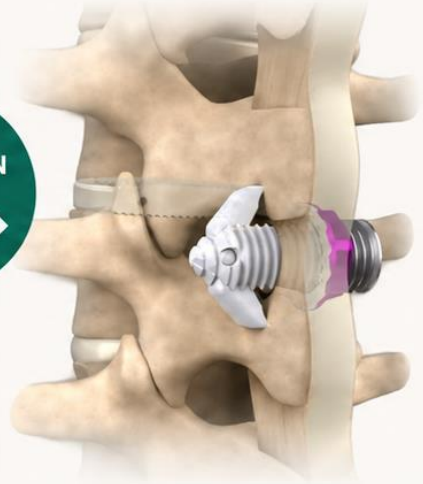
Largely unavailable today.
X-Stop was withdrawn; Superion was recalled.

Examples: X-Stop, Superion (Vertiflex), Coflex.

SAME LOCATION

INTERSPINOUS-INTERLAMINAR FIXATION DEVICES

PROVIDE IMMEDIATE FIXATION AND FUSE THE SEGMENT



- Placed between the spinous processes and lamina
- Distracts the segment, provides immediate fixation
- Fusion occurs over time — bone, not the implant, holds the segment open
- Changes the long-term mechanics through fusion

Example: Minuteman
(interspinous-interlaminar fixation and fusion).

KEY TAKEAWAY

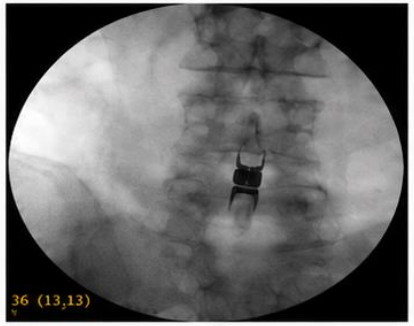
Both families are placed in the same general location, but they work very differently. Spacers are dynamic decompression devices that block extension. Interspinous-interlaminar fixation devices provide immediate fixation and achieve fusion.

FDA distinguishes dynamic decompression "spacers" from fixation/fusion devices, with different regulatory pathways and different levels of required clinical evidence.

INTERSPINOUS SPACERS

X-Stop and Superion: the predicate history

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(a)



AP (a) and lateral (b) fluoroscopy of an implanted Superion interspinous spacer.

THE DESIGN INTENT

X-Stop, approved in the early 2000s, was the predicate device: a titanium implant placed between the spinous processes to limit extension and hold the segment in a position that keeps the canal open, without removing bone or ligament.

Superion was developed as a next-generation spacer and was tested head-to-head against X-Stop as the active control.



391
PATIENTS RANDOMIZED
Superion vs. X-Stop, 29 US sites

Non-inferior
WAS THE FINDING
Superion performed comparably to X-Stop, not better.

2 years
FOLLOW-UP
in the pivotal randomized comparison.

Patel VV et al. Superion interspinous process spacer for intermittent neurogenic claudication. Spine. 2015;40(5):275-282 [19].
Image: Miller LE, Block JE. Pain Res Treat. 2012;2012:823509, PMC3289933, CC BY 3.0, Fig 2. https://pmc.ncbi.nlm.nih.gov/articles/PMC3289933/

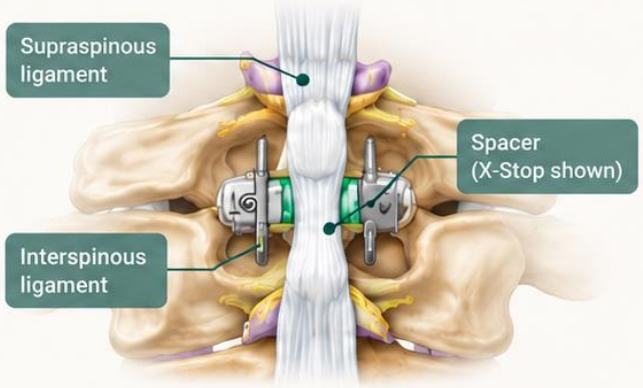
INTERSPINOUS SPACERS

The biomechanical problem: a spacer, not a fusion

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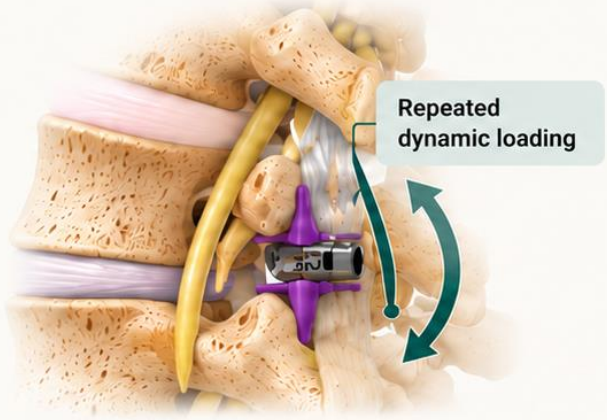
1 THE DESIGN TENSION

A stand-alone spacer has to hold position indefinitely without ever fusing. That places the entire **long-term mechanical burden** on two things: the bone-implant interface at the spinous process, and the posterior ligamentous tension band — the **supraspinous and interspinous ligaments.**



2 NO FUSION MEANS NO PERMANENT FIX

Because the device never fuses to bone, **every load cycle** — every time the patient stands, sits, or bends — passes through the same titanium-to-bone interface for as long as the implant is in place.



KEY TAKEAWAY

Interspinous spacers are designed to hold the segment open — not fuse it — which places continuous mechanical stress on the implant–bone interface and the posterior ligamentous tension band.

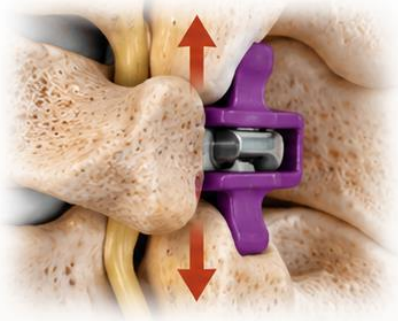
Gazzeri R et al. Failure rates and complications of interspinous process decompression devices. Neurosurg Focus. 2015;39(4):E14 [38].

INTERSPINOUS SPACERS

What cyclic loading without fusion produces over time

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1 Repetitive loading at the bone-implant interface



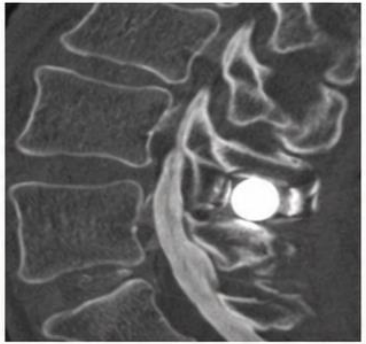
Titanium is far stiffer than the cancellous bone of the spinous process. Every cycle **concentrates stress at that junction** rather than distributing it the way a healed fusion mass would.

2 Subsidence and occult fracture



Case series and imaging studies describe **bony erosion, chronic fatigue fracture, and settling of** the posterior elements around the implant — often before the patient reports any change in symptoms.

3 Loss of the indirect decompression



Once the bone subsides or fractures around the device, the **distraction the implant was providing is lost.** The canal and foramen return toward their pre-treatment dimensions.

4 Recurrence, and often reoperation



Symptoms that had responded now return. Published series report reoperation rates for interspinous process devices ranging widely, **up to the high double digits in** some long-term cohorts.

KEY TAKEAWAY

Without fusion, cyclic loading can lead to bone resorption, loss of the initial decompression, symptom recurrence, and frequently the need for reoperation.

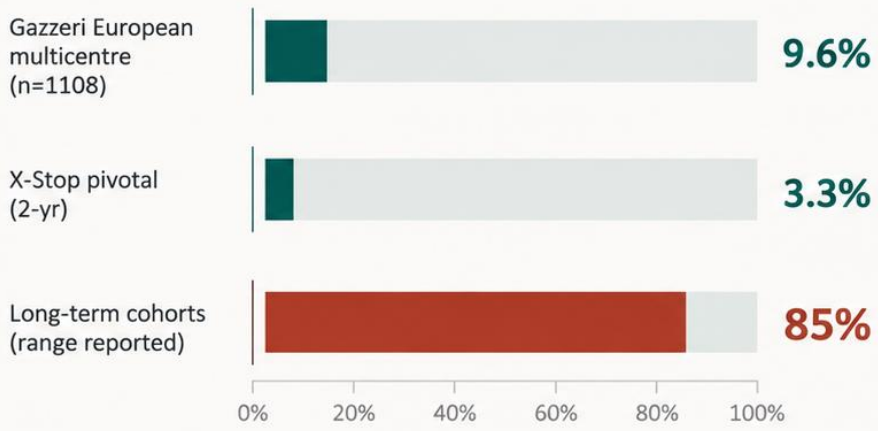
Miller JD et al., J Neurosurg Spine 2010 [35]; Kim DH et al., Spine 2011 [36] and Spine J 2012 [37]; Cianfoni A et al., AJNR 2012 [41]; Gazzeri R et al., Neurosurg Focus 2015 [38].

INTERSPINOUS SPACERS

What the real-world data showed

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REOPERATION RATE BY SERIES (%)



CONVERGENT EVIDENCE

- Higher fracture risk
- Migration
- Worsening symptoms

A pharmacovigilance analysis of the FDA MAUDE database found **statistically significant signals for fracture, migration, and worsening symptoms** across Coflex, Vertiflex, and X-Stop. A Medicare claims analysis found interspinous spacer patients had fewer major medical complications than decompression or fusion patients — but that dataset noted the supporting randomized trial was manufacturer-sponsored, and did not settle the revision-rate question. X-Stop was ultimately taken off the market; Superion was later recalled.

THE THROUGHLINE

None of this reflects a flawed concept — indirect decompression by *extension-blocking* is mechanically sound and the early trials proved it works acutely. The failure mode is durability: **a device asked to do a fusion's job without ever fusing**.

Gazzeri R et al., Neurosurg Focus 2015 [38]; Aggarwal N, Chow R, Anesth Pain Med 2021 [39]; Deyo RA et al., Spine 2013 [40].

THE DESIGN LESSON

What a durable device needs to do differently

The lesson from the spacer generation is specific, not general: indirect decompression and posterior stabilization work.

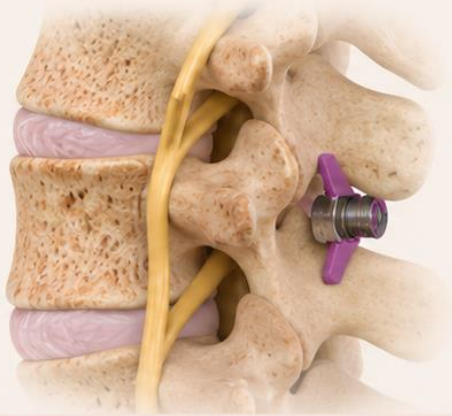
What failed was asking an unfused implant to bear cyclic load indefinitely against a bone interface it was never going to become part of.

A device that distracts the segment, fixes it immediately, and then fuses removes that failure mode entirely — once fusion occurs, bone is the long-term stabilizer, not titanium against titanium-to-bone contact.

That is the design principle behind interspinous-interlaminar fixation — the next section.

INTERSPINOUS SPACER

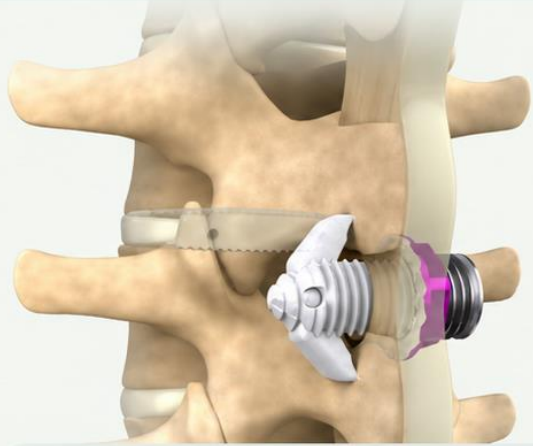
TEMPORARY DISTRACTION, NO FUSION



- Holds the segment open, but never fuses.
- Cyclic loading concentrates stress at the bone-implant interface.
- Associated with subsidence, bone fracture, loss of decompression, and high reoperation rates.

INTERSPINOUS-INTERLAMINAR FIXATION DEVICE (FUSION)

IMMEDIATE FIXATION, LONG-TERM STABILITY

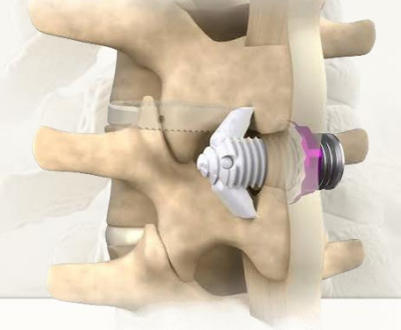


- Distracts the segment and provides immediate fixation.
- Once fusion occurs, bone is the long-term stabilizer — not titanium against titanium-to-bone contact.
- Removes the failure mode seen with spacers by achieving fusion.

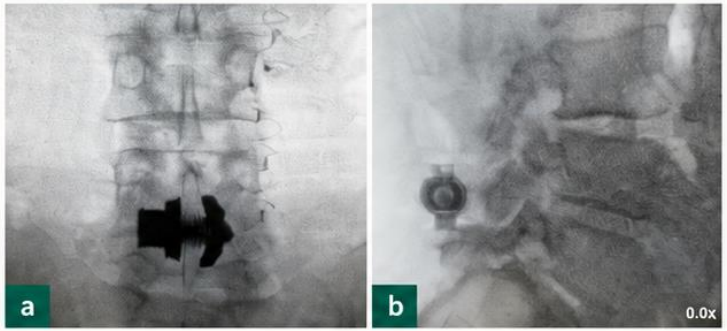
INTERSPINOUS-INTERLAMINAR FIXATION

Mechanism: distract, fix, fuse

A simple concept. A powerful result.



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Actual fluoroscopy of an implanted interspinous-interlaminar fixation device: AP (a) and lateral (b) views.

1 Distract

The implant separates the spinous processes and laminae, indirectly opening the central canal and foramen at the treated level.

2 Fix

Immediate mechanical fixation arrests abnormal segmental motion from the moment of implantation — the patient is stabilized before any biologic healing occurs.

3 Fuse

Bone graft placed with the device drives arthrodesis. Once fused, the construct is bone, not hardware — the long-term stabilizer is no longer dependent on the implant-bone interface.

THE RESULT

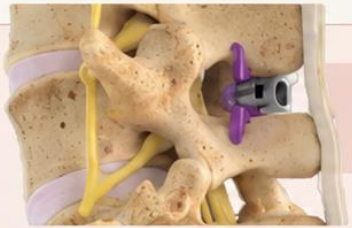
Stability today. Long-term fusion tomorrow.

Mechanism as described in Baranidharan G et al., J Pain Res 2024 [42]. Images: Soto E, Esposito MF, J Pain Res 2025;18:4431-4441, PMC12399849, CC BY-NC 4.0, Fig 1; Park S-M et al., Asian Spine J 2026, PMC13329252, CC BY-NC 4.0, Fig 3.

INTERSPINOUS-INTERLAMINAR FIXATION

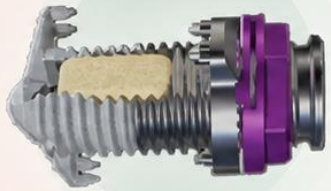
The contrast that matters: bone becomes the stabilizer

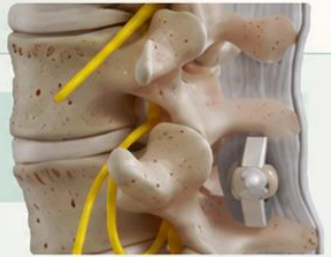
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A STAND-ALONE SPACER

- Holds position for as long as the titanium-bone interface holds
- Every load cycle, for the life of the implant, passes through that same junction
- **No fusion** means no permanent transfer of the mechanical job away from the device
- **Failure mode:** subsidence, fracture, loss of the decompression it created





A FIXATION DEVICE THAT FUSES

- Holds position mechanically from day one, while bone graft matures
- Once fused, the spinous processes and laminae are **bridged by living bone**
- The mechanical job transfers from **hardware to skeleton** — the definition of a successful fusion
- Failure mode becomes **pseudarthrosis**, the same failure mode every fusion procedure shares, and one that is well studied and detectable on imaging

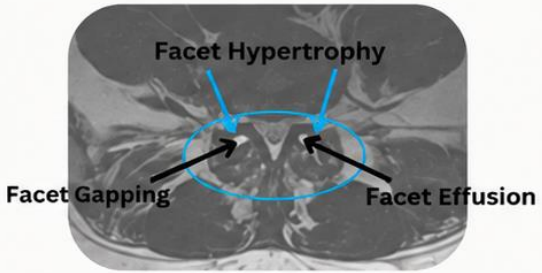
DIFFERENT DESIGNS. DIFFERENT MECHANICS. DIFFERENT OUTCOMES.

THE GOAL IS LASTING STABILITY — AND THAT REQUIRES BONE, NOT JUST HARDWARE.

INTERSPINOUS-INTERLAMINAR FIXATION

Patient selection

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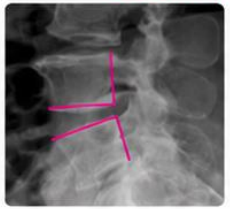


("gator eyes")

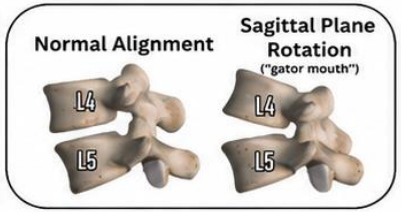
Can Achieve Positional Relief of Symptom



Sagittal Plane Rotation


Lateral Extension X-Ray


Lateral Flexion X-Ray



THE PATIENT WHO DOES WELL

- Neurogenic claudication with genuine relief in flexion — the canal can still be opened
- Moderate stenosis with demonstrated segmental motion on flexion-extension imaging
- Low-grade degenerative spondylolisthesis
- Adequate spinous process bone stock
- Symptoms persisting despite a fair trial of conservative care
- A patient for whom the mechanical driver — not just the compression — needs to be addressed

PRACTICAL ADVANTAGES OF THE APPROACH

- Small posterior incision; no laminectomy and no midline muscle stripping
- Short operative time with minimal blood loss
- Typically outpatient, with a rapid return to normal activity
- Suitable where a large open procedure carries meaningful perioperative risk
- Does not preclude a later open decompression or fusion if the disease progresses

Selection criteria consistent with the Baranidharan et al. 2024 RCT population [42].

THE EVIDENCE: BARANIDHARAN ET AL., 2024

Study design — the strongest evidence in this device category

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DESIGN

An early-stage, multicentre, prospective, randomized controlled trial, approved by the Health Research Authority, with a planned five-year follow-up. Forty-eight participants were randomly assigned to interspinous fixation device (Minuteman) or standard open direct surgical decompression. Two-year results are reported here.

N = 48

randomized, multicentre, prospective RCT — rare for this device category

6 endpoints

VAS leg and back pain, ODI, Zurich Claudication Questionnaire, walking distance, sit-to-stand reps

5-yr planned

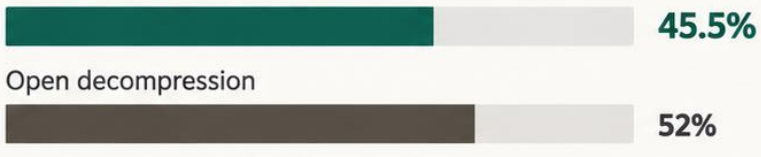
two-year results are an interim report of a longer trial

Baranidharan G, Bretherton B, Feltbower RG, et al. 24-month outcomes of indirect decompression using a minimally invasive interspinous fixation device versus standard open direct decompression for lumbar spinal stenosis: a prospective comparison. J Pain Res. 2024;17:2079-2097 [42].

THE EVIDENCE: BARANIDHARAN ET AL., 2024

Results — pain and disability

ODI REDUCTION
(% FROM BASELINE)



LEG PAIN REDUCTION (VAS)
(% FROM BASELINE)



READING THE COMPARISON

Improvement with the interspinous fixation device was **comparable** to open decompression across both measures.

Baranidharan G et al., J Pain Res 2024;17:2079-2097 [42]. Figures approximate the range of reduction reported across the 8-week, 6-, 12-, and 24-month follow-up points; both reductions were statistically significant from baseline in each arm.

THE EVIDENCE: BARANIDHARAN ET AL., 2024

Results — function and mobility

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1 Zurich Claudication Questionnaire



Improved in both arms across all follow-up points, with the interspinous fixation device group tracking closely with the open decompression group at 12 and 24 months.

2 Walking distance



Increased in both groups from baseline; comparable gains sustained through 24 months.

3 Sit-to-stand repetitions in one minute



A functional, objective measure of lower-extremity endurance — **improved comparably in both arms**, reinforcing that the gains were not pain-score artifacts.

These are objective, activity-based measures *— not just how the patient rates their pain, but what they can physically do.*

Baranidharan G et al., J Pain Res 2024;17:2079-2097 [42].

THE EVIDENCE: BARANIDHARAN ET AL., 2024

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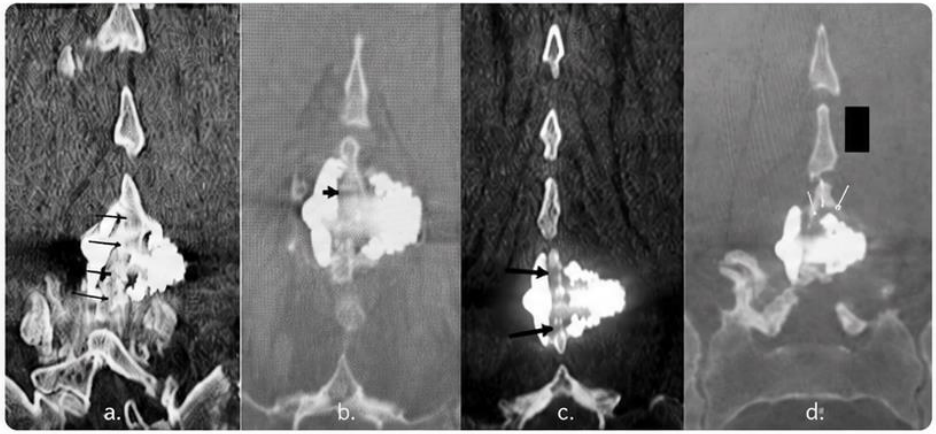
Perioperative advantages, and the fusion rate

Less
blood loss versus open decompression

Shorter
operating room time versus open decompression

89%
of evaluated patients achieved successful fusion

Comparable
reoperation experience between the two arms in this trial



WHY THE FUSION RATE MATTERS MOST

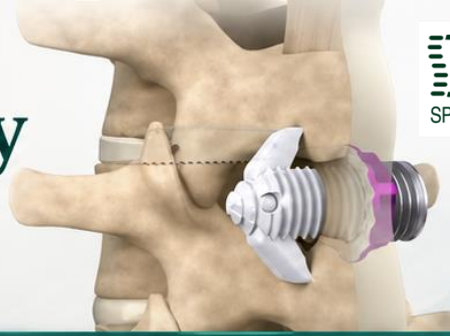
The 89% fusion rate is the number that validates the design principle from two sections ago. It means the mechanical job is, in most patients, successfully transferring from the implant to bone — which is precisely the failure mode that limited the stand-alone spacer generation.

Baranidharan G et al., J Pain Res 2024;17:2079-2097 [42]. Fusion CT image: Park S-M et al., Asian Spine J 2026, PMC13329252, CC BY-NC 4.0, Fig. 3.

MINIMALLY INVASIVE STABILIZATION

Minuteman: five-year durability in selected lumbar stenosis

A prospective multicenter randomized study of indirect decompression, fixation, and fusion.



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THE FIVE-YEAR IFD STORY:

durable clinical improvement + reduced procedural burden + evidence of fusion

66%
LESS LEG PAIN
Mean VAS-leg improvement at 5 years

60%
LESS BACK PAIN
Mean VAS-back improvement at 5 years

53%
LESS DISABILITY
Mean ODI improvement at 5 years

91%
LESS ANALGESIC USE
Relative reduction from baseline at 5 years

RIGHT PATIENT PROFILE

One- or two-level stenosis with positional symptoms, low-grade degenerative change, and unsuccescful conservative care.

CLINICAL PROMISE

A minimally invasive option that addresses both dynamic compression and posterior-segment stability.

Baranidharan G, et al. Interventional Pain Medicine. 2026;5:100814. Prospective multicenter randomized study; IFD cohort n~18.

FIVE-YEAR PATIENT OUTCOMES

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Durable relief that translates into meaningful clinical response

Most IFD participants achieved clinically important improvement across pain, disability, and claudication-function measures.



73%
LEG-PAIN MCID

Reached clinically important leg-pain improvement



83%
BACK-PAIN MCID

Reached clinically important back-pain improvement



83%
ODI MCID

Reached clinically important disability improvement



75%
ZCQ MCID

Reached clinically important claudication-function improvement



PATIENT- AND CLINICIAN-REPORTED IMPROVEMENT

87% average patient global improvement • 84% average clinician global improvement across study follow-up



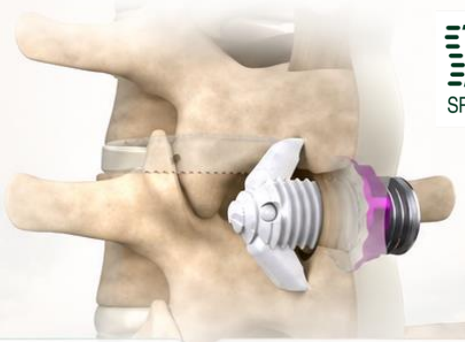
At five years, **73%** had mild-to-no leg pain and **83%** had mild-to-no back pain.

Baranidharan G, et al. Interventional Pain Medicine. 2026;5:100814. Prospective multicenter randomized study; IFD cohort n~18.

MINIMALLY INVASIVE ADVANTAGE

A smaller procedural footprint than open decompression

Every measured perioperative endpoint favored Minuteman in this study.



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80%
LESS BLOOD LOSS
23.8 vs 116.1 mL

57%
SHORTER SKIN-TO-SKIN
35.7 vs 83.7 minutes

37%
SHORTER THEATRE TIME
76.8 vs 122.4 minutes

41%
SHORTER LENGTH OF STAY
0.78 vs 1.32 days

Less tissue disruption, less blood loss, less time in the operating room, and a shorter hospital stay.

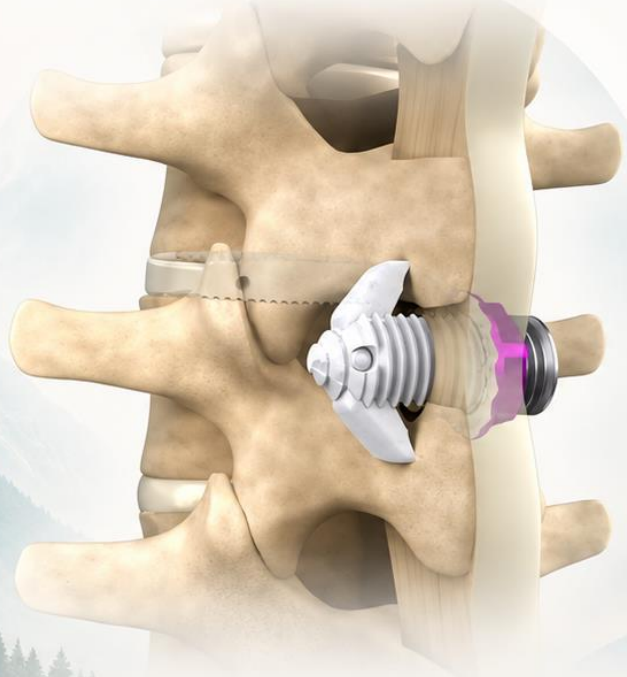
For a stenosis patient who needs more than injections but may benefit from a smaller procedure, **this is the practical value proposition.**

Baranidharan G, et al. Interventional Pain Medicine. 2026;5:100814. Prospective multicenter randomized study; IFD cohort n~18.

FIXATION PLUS FUSION

Minuteman is more than an interspinous spacer

The construct is designed to distract, rigidly fix, and create a posterior fusion bed through a minimally invasive lateral approach.



89%
FUSION

8 of 9 CT-assessed IFD participants were graded fused. Median CT timing: 39 months.

0
DEVICE MIGRATIONS

No reported device failure, malfunction, or migration during follow-up.

THE LONG-TERM DIFFERENTIATOR

A minimally invasive construct designed to stabilize and fuse the treated segment—not simply hold it open.

In this study, three removals were for recurrent/residual symptoms; the explanted devices showed bony integration.

Baranidharan G, et al. Interventional Pain Medicine. 2026;5:100814. Prospective multicenter randomized study; IFD cohort n~18.

CLINICAL TAKEAWAY

Where Minuteman fits in the treatment window

A durable minimally invasive option when decompression is needed but the pathology remains position-responsive and mechanically addressable.

1 Symptoms persist



Claudication / leg pain despite conservative care.

2 Confirm the phenotype



One or two levels • flexion relief • low-grade degenerative change.

3 Treat the mechanism



Indirect decompression + fixation + fusion.

4 Aim for durable function



Pain relief • less disability • less analgesic use.

THE PRODUCT-FORWARD MESSAGE

For appropriately selected lumbar stenosis, Minuteman delivered five-year durability with a substantially smaller procedural footprint.

Appropriate selection remains essential: the study excluded high-grade slip, scoliosis, osteoporosis/osteopenia, prior lumbar surgery, fixed deficits, and bowel/bladder disease.

Baranidharan G, et al. Interventional Pain Medicine. 2026;5:100814. Prospective multicenter randomized study; IFD cohort n~18.

THE EVIDENCE: INTERSPINOUS-INTERLAMINAR FIXATION

The rest of the published record

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Skoblar et al., 2023

Prospective, single-centre CT fusion study, 43 patients / 69 levels [43]

92.8% of levels **fused**; 4 asymptomatic spinous process fractures, no device failure or reoperation.

Sclafani et al., 2014

Retrospective outcomes, polyaxial interspinous fusion system [44]

Early clinical outcomes series supporting the fixation-and-fusion approach.

Falowski et al., 2021

Multicentre retrospective safety/efficacy review, 32 patients [46]

0% adverse event rate reported; no reoperation or device removal in this series.

Soto & Esposito, 2025

Single-centre retrospective, lateral transverse approach, 45 patients [45]

Pain reduction sustained through 3 months; consistent with the RCT direction of effect.

Consistently observational, but consistently pointing the same direction as the randomized data — and notably **free of the fracture-and-subsidence pattern** seen in the spacer literature.

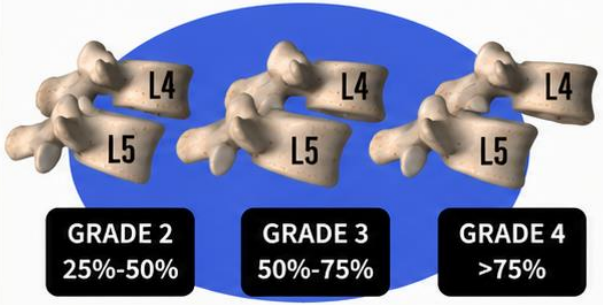
Skoblar M et al., J Pain Res 2023;16:2909-2918 [43]; Sclafani JA et al., Int J Spine Surg 2014;8:26 [44]; Falowski SM et al., J Pain Res 2021;14:1525-1531 [46]; Soto E, Esposito MF, J Pain Res 2025;18:4431-4441 [45].

MINUTEMAN™ INTERSPINOUS FIXATION DEVICE

Contraindications

The Minuteman device is not indicated for patients with the following:

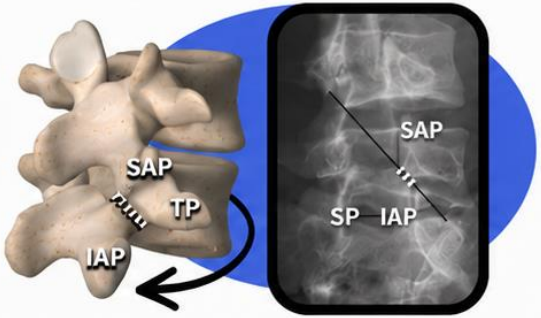
SIGNIFICANT SPONDYLOLISTHESIS



VERTEBRAL FRACTURES



PARS FRACTURE



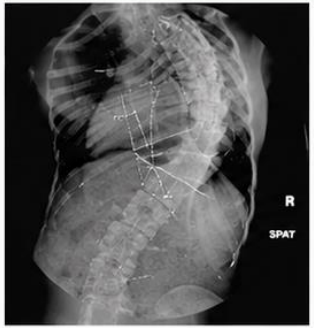
VERTEBRAL TUMOR



SPINOUS PROCESS FRACTURE



SCOLIOSIS COBB ANGLE >25 DEGREES



KNOWING THE LIMITS

When to refer for a spine surgical opinion

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URGENT

REFER NOW

- **Cauda equina syndrome:** saddle anaesthesia, urinary retention or incontinence, bilateral progressive deficit.
- **Progressive or non-recovering motor weakness,** including foot drop.
- **Suspected fracture, malignancy, or infection.**

STRUCTURAL

REFER FOR SURGICAL OPINION

- **Symptoms constant and no longer relieved** by flexion or sitting.
- **High-grade spondylolisthesis, deformity, or scoliosis.**
- **Severe multilevel stenosis,** or stenosis with a fixed bony block.
- **Recurrence after an appropriately selected minimally invasive procedure.**
- **Disabling symptoms despite documented, adequate conservative and interventional care.**

Red-flag and referral considerations per Katz JN et al. Diagnosis and management of lumbar spinal stenosis: a review. JAMA. 2022;327(17):1688-1699 [3].

KNOWING THE LIMITS

What the surgical evidence actually shows

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FUSION ADDED TO DECOMPRESSION — THE CASE FOR

In **66 patients** with grade I degenerative spondylolisthesis and stenosis, laminectomy plus instrumented fusion gave a slightly greater but **clinically meaningful gain** in physical quality of life than laminectomy alone. Disability scores did not differ significantly at two years. Reoperation was **14% with fusion and 34% without.**

FUSION ADDED TO DECOMPRESSION — THE CASE AGAINST

In **247 patients** with stenosis with or without degenerative spondylolisthesis, adding fusion **did not improve outcomes at two or five years,** while increasing blood loss, operative time, hospital stay, and cost.

HOW TO RECONCILE THEM

The trials enrolled different populations, which is why **patient selection has become the central question.** Preoperative motion metrics — vertical instability and dynamic slip in particular — may identify who benefits from fusion; a prospective study using a standardized instability measure changed roughly a third of surgical plans.

Ghogawala Z et al., N Engl J Med 2016;374:1424-1434 [21]; Forsth P et al., N Engl J Med 2016;374:1413-1423 [22]; Hipp JA et al., N Am Spine Soc J 2025 [8]; Reijmer JFH et al., Spine 2024 [24].

PUTTING IT TOGETHER

The toolbox, side by side

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1 **Stage 1** Disc Degeneration
2 **Stage 2** Micromotion Instability
3 **Stage 3** Angular Imbalance
4 **Stage 4** Dynamic Stenosis
5 **Stage 5** Vertical Collapse
6 **Stage 6** Fixed Stenosis

Conservative & injections

BEST FOR
Any phase, especially 1–3

INVASIVENESS
Low

STRENGTH
Repeatable, low-risk, often sufficient

WATCH FOR
Does not address fixed mechanical or structural problems.

PLD

BEST FOR
Central canal, phase 4

INVASIVENESS
Low–moderate

STRENGTH
Strong RCT base; no implant

WATCH FOR
Central canal only; motion unchanged.

Interspinous fixation

BEST FOR
Phases 2–5, motion + compression

INVASIVENESS
Moderate

STRENGTH
Addresses compression and motion together; RCT vs. open surgery

WATCH FOR
Requires adequate bone stock; smaller evidence base than open fusion.

Open decompression ± fusion

BEST FOR
Phase 5–6, fixed/structural

INVASIVENESS
Higher

STRENGTH
Definitive for fixed compression and deformity

WATCH FOR
Larger operation; longer recovery.

Summary view synthesizing the categories discussed in this presentation.
Not a substitute for individualized clinical judgement.

PUTTING IT TOGETHER

A practical sequence for the patient in front of you

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1 **Establish that the syndrome is clinical, not radiographic**

Neurogenic claudication, positional relief, walking and standing limitation, and an examination consistent with the imaged level.



2 **Give conservative care a documented, fair trial**

Structured exercise, analgesia, activity modification, and injections where indicated. Record function, not just elapsed weeks.

3 **Ask whether the narrowing is positional**

Does flexion, sitting, or leaning on a cart reliably relieve the legs? Retained positional relief means the canal can still open.

If yes: consider PILD where hypertrophic ligamentum flavum dominates, or interspinous fixation where mechanics are contributing.



4 **Ask whether the mechanics are driving recurrence**

Standing flexion-extension imaging characterizes the slip and its dynamic component. When relief from an injection or a decompression is real but repeatedly temporary, the pain generator was correctly identified and the mechanical driver was not addressed.



5 **Refer when the disease has moved past the interventional window**

Constant, non-positional symptoms; objective neurologic deficit; high-grade slip or deformity; severe multilevel or fixed bony stenosis; or failure after an appropriately selected minimally invasive procedure.



Sequence synthesized from the sources cited throughout this presentation; offered as a teaching aid, not a validated clinical decision rule.

IN SUMMARY

Six points to take back to clinic

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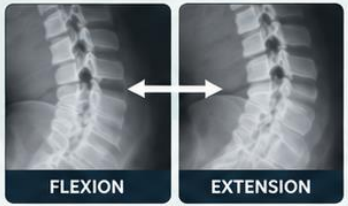
1 Stenosis is a clinical syndrome.

The history makes the diagnosis; imaging confirms the level.



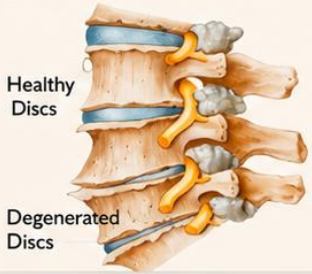
2 Instability is real but poorly measured.

A guarded, painful patient can produce a falsely reassuring flexion-extension film.



3 The phase of degeneration determines the answer.

Biologic problems need biologic treatment; mechanical problems need mechanical ones.



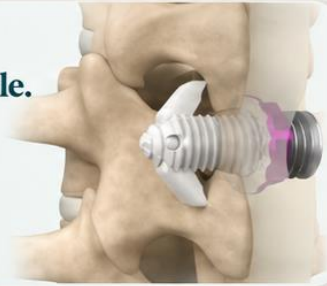
4 PILD earns its place with strong randomized data — for the central canal.

It does not touch the foramen or segmental motion.



5 Fusion, not the spacer, is what makes a device durable.

The stand-alone spacer generation failed at the bone-implant interface; fixation-and-fusion devices transfer the job to bone.



6 Knowing the limits is what makes the recommendation credible.

Recognizing who should be referred onward matters as much as recognizing who can be treated in clinic.



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References

1. Yong-Hing K, Kirkaldy-Willis WH. The pathophysiology of degenerative disease of the lumbar spine. *Orthop Clin North Am.* 1983;14(3):491-504.
2. Kalichman L, Cole R, Kim DH, et al. Spinal stenosis prevalence and association with symptoms: the Framingham Study. *Spine J.* 2009;9(7):545-550.
3. Katz JN, Zimmerman ZE, Mass H, Makhni MC. Diagnosis and management of lumbar spinal stenosis: a review. *JAMA.* 2022;327(17):1688-1699.
4. Ravindra VM, Senglaub SS, Rattani A, et al. Degenerative lumbar spine disease: estimating global incidence and volume. *Global Spine J.* 2018;8(8):784-794.
5. Kirkaldy-Willis WH, Wedge JH, Yong-Hing K, Reilly J. Pathology and pathogenesis of lumbar spondylosis and stenosis. *Spine.* 1978;3(4):319-328.
6. Chou SH, Lin SY, Shen PC, et al. Pain control affects the radiographic diagnosis of segmental instability in patients with degenerative lumbar spondylolisthesis. *J Clin Med.* 2021;10(17):3984.
7. Pollintine P, Dolan P, Tobias JH, Adams MA. Intervertebral disc degeneration can lead to "stress-shielding" of the anterior vertebral body. *Spine.* 2004;29(7):774-782.
8. Hipp JA, Currier BL, Grieco TF, van Susante JLC. Identifying preoperative radiographic metrics to guide surgical selection in lumbar spondylolisthesis and stenosis. *N Am Spine Soc J.* 2025;24:100784.
9. Hipp JA, Guyer RD, Zigler JE, Ohnmeiss DD, Wharton ND. Development of a novel radiographic measure of lumbar instability and validation using the facet fluid sign. *Int J Spine Surg.* 2015;9:37.
10. Friedly JL, Comstock BA, Turner JA, et al. A randomized trial of epidural glucocorticoid injections for spinal stenosis. *N Engl J Med.* 2014;371(1):11-21.
11. Deer TR, Costandi SJ, Washabaugh E, et al. The MOTION study: a randomized controlled trial with objective real-world outcomes for lumbar spinal stenosis patients treated with the mild procedure - one-year results. *Pain Med.* 2022;23(4):625-634.
12. Deer TR, Chafin TB, Costandi SJ, et al. The MOTION study: two-year results of a real-world randomized controlled trial of the mild procedure for treatment of lumbar spinal stenosis. *Pain Pract.* 2024;24(1):109-119.
13. Costandi SJ, Deer TR, Chafin TB, Kim C. Three-year results of the MOTION randomized controlled trial for treatment of lumbar spinal stenosis using the percutaneous mild procedure. *Interv Pain Med.* 2025;4(1):100561.

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References (continued)

14 Benyamin RM, Staats PS; MiDAS ENCORE Investigators. MILD is an effective treatment for lumbar spinal stenosis with neurogenic claudication: MiDAS ENCORE randomized controlled trial. *Pain Physician*. 2016;19(4):229-242.

15 Staats PS, Chafin TB, Golovac S, et al. Long-term safety and efficacy of minimally invasive lumbar decompression procedure for the treatment of lumbar spinal stenosis with neurogenic claudication: 2-year results of MiDAS ENCORE. *Reg Anesth Pain Med*. 2018;43(7):789-794.

16 Centers for Medicare & Medicaid Services. National Coverage Determination 150.13: percutaneous image-guided lumbar decompression for lumbar spinal stenosis. Medicare Coverage Database. Verify current status before scheduling.

17 Staats PS, Dorsi MJ, Reece DE, Strand NH, Poree L, Hagedorn JM. Percutaneous image-guided lumbar decompression and outpatient laminectomy for the treatment of lumbar spinal stenosis: a 2-year Medicare claims benchmark study. *Interv Pain Med*. 2024;3:100412.

18 Nunley PD, Patel VV, Orndorff DG, Lavelle WF, Block JE, Geisler FH. Five-year durability of stand-alone interspinous process decompression for lumbar spinal stenosis. *Clin Interv Aging*. 2017;12:1409-1417.

19 Patel VV, Whang PG, Haley TR, et al. Superior interspinous process spacer for intermittent neurogenic claudication secondary to moderate lumbar spinal stenosis: two-year results from a randomized controlled FDA-IDE pivotal trial. Spine. 2015;40(5):275-282.

20 Edinoff AN, Kaufman S, Alpaugh ES, et al. A comprehensive review of novel interventional techniques for chronic pain: spinal stenosis and degenerative disc disease. Adv Ther. 2021;38(9):4628-4645.

21 Ghogawala Z, Dziura J, Butler WE, et al. Laminectomy plus fusion versus laminectomy alone for lumbar spondylolisthesis. *N Engl J Med*. 2016;374(15):1424-1434.

22 Forsth P, Olafsson G, Carlsson T, et al. A randomized, controlled trial of fusion surgery for lumbar spinal stenosis. *N Engl J Med*. 2016;374(15):1413-1423.

23 Weinstein JN, Tosteson TD, Lurie JD, et al. Surgical versus nonsurgical therapy for lumbar spinal stenosis. *N Engl J Med*. 2008;358(8):794-810.

24 Reijmer JFH, de Jong LD, Kempen DHR, Arts MP, van Susante JLC. Clinical utility of an intervertebral motion metric for deciding on the addition of instrumented fusion in degenerative spondylolisthesis. *Spine*. 2024;49(6):E355-E360.

25 Blumenthal C, Curran J, Benzel EC, et al. Radiographic predictors of delayed instability following decompression without fusion for degenerative grade I lumbar spondylolisthesis. *J Neurosurg Spine*. 2013;18(4):340-346.

26 Kreiner DS, Shaffer WO, Baisden JL, et al. An evidence-based clinical guideline for the diagnosis and treatment of degenerative lumbar spinal stenosis (update). *Spine J*. 2013;13(7):734-743.

References (continued)

27 Ammendolia C, Stuber KJ, Rok E, et al. Nonoperative treatment for lumbar spinal stenosis with neurogenic claudication. *Cochrane Database Syst Rev.* 2013;(8):CD010712.

28 Delitto A, Piva SR, Moore CG, et al. A surgery versus nonsurgical treatment of lumbar spinal stenosis: a randomized trial. *Ann Intern Med.* 2015;162(7):465-473.

29 Suri P, Rainville J, Kalichman L, Katz JN. Does this older adult with lower extremity pain have the clinical syndrome of lumbar spinal stenosis? *JAMA.* 2010;304(23):2628-2636.

30 Boden SD, Davis DO, Dina TS, Patronas NJ, Wiesel SW. Abnormal magnetic-resonance scans of the lumbar spine in asymptomatic subjects. *J Bone Joint Surg Am.* 1990;72(3):403-408.

31 Spina N, Schoutens C, Martin BI, Brodke DS, Lawrence B, Spiker WR. Defining instability in degenerative spondylolisthesis: surgeon views. *Clin Spine Surg.* 2019;32(10):E434-E439.

32 Infusua A, An HS, Lim TH, Hasegawa T, Haughton VM, Nowicki BH. Anatomic changes of the spinal canal and intervertebral foramen associated with flexion-extension movement. *Spine.* 1996;21(21):2412-2420.

33 Willen J, Danielson B. The diagnostic effect from axial loading of the lumbar spine during computed tomography and magnetic resonance imaging in patients with degenerative disorders. *Spine.* 2001;26(23):2607-2614.

34 Genevay S, Atlas SJ. Lumbar spinal stenosis. *Best Pract Res Clin Rheumatol.* 2010;24(2):253-265.

35 Miller JD, Miller MC, Lucas MG. Erosion of the spinous process: a potential cause of interspinous process spacer failure. *J Neurosurg Spine.* 2010;12(2):210-213.

36 Kim DH, Tantorski M, Shaw J, et al. Occult spinous process fractures associated with interspinous process spacers. *Spine.* 2011;36(16):E1080-E1085.

37 Kim DH, Shanti N, Tantorski ME, et al. Association between degenerative spondylolisthesis and spinous process fracture after interspinous process spacer surgery. *Spine J.* 2012;12(6):466-472.

38 Gazzeri R, Galarza M, Alfieri A. Failure rates and complications of interspinous process decompression devices: a European multicenter study. *Neurosurg Focus.* 2015;39(4):E14.

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References (continued)

39 Aggarwal N, Chow R. Real world adverse events of interspinous spacers using Manufacturer and User Facility Device Experience data. *Anesth Pain Med*. 2021;16(2):177-183.

40 Deyo RA, Martin BI, Ching A, et al. Interspinous spacers compared with decompression or fusion for lumbar stenosis: complications and repeat operations in the Medicare population. *Spine*. 2013;38(10):865-872.

41 Cianfoni A, Pons M, Isalberti M, et al. Posterior vertebral arch cement augmentation (spinoplasty) to prevent fracture of spinous processes after interspinous spacer implant. *AJNR Am J Neuroradiol*. 2012;33(3):522-527.

42 Baranidharan G, Bretherton B, Feltbower RG, et al. 24-month outcomes of indirect decompression using a minimally invasive interspinous fixation device versus standard open direct decompression for lumbar spinal stenosis: a prospective comparison. *J Pain Res*. 2024;17:2079-2097.

43 Skoblar M, Hedman T, Rogers AJ, Jasper GP, Beall DP. Instrumented posterior arthrodesis of the lumbar spine: prospective study evaluating fusion outcomes in patients receiving an interspinous fixation device for the treatment of degenerative spine diseases. *J Pain Res*. 2023;16:2909-2918.

44 Sclafani JA, Liang K, Ohnmeiss DD, et al. Clinical outcomes of a polyaxial interspinous fusion system. *Int J Spine Surg*. 2014;8:26.

45 Soto E, Esposito MF. Safety and efficacy of interspinous fixation device via lateral transverse approach in patients with lumbar spinal stenosis: a single center, retrospective, observational study. *J Pain Res*. 2025;18:4431-4441.

46 Falowski SM, Mangal V, Pope J, Patel A, Coleman M, Kendall D, Brouillette R, Fishman MA. Multicenter retrospective review of safety and efficacy of a novel minimally invasive lumbar interspinous fusion device. *J Pain Res*. 2021;14:1525-1531.

47 US Food and Drug Administration. X STOP Interspinous Process Decompression System: Summary of Safety and Effectiveness Data, PMA P040001.

48 Trade press report: Boston Scientific initiated a field action affecting the Superion Indirect Decompression System; widely reported in spine-industry trade press, 2025. Verify current device status with the manufacturer before referencing clinically.

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