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# Imaging Controversies in Assessing Instability in Lumbar Degenerative Spondylolisthesis

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## Abstract

**Objectives:** To evaluate the controversies surrounding imaging modalities for diagnosing instability in lumbar degenerative spondylolisthesis (LDS) and their clinical implications for surgical decision-making.

**Methods:** A comprehensive review of conventional and advanced imaging techniques, including standing lateral and dynamic flexion-extension X-rays, MRI, and CT, was conducted. Their advantages, limitations, and reliability in detecting instability in LDS were analyzed based on existing literature.

**Results:** Conventional radiographs remain the primary tool for assessing instability but have limitations in detecting subtle cases. MRI and CT provide valuable insights into disc degeneration, facet joint integrity, and neural element compression but may not reliably quantify instability. The lack of a standardized imaging protocol contributes to ongoing debate.

**Conclusion:** Accurate imaging-based assessment of instability in LDS is essential for optimizing patient selection for surgical intervention. Further research is needed to establish standardized imaging criteria that enhance diagnostic accuracy and improve clinical outcomes.

***Keywords:*** *Degenerative Spondylolisthesis; Lumbar Instability; Low Back Pain; Radiological Assessment; Segmental Instability; Lumbar Spine*

## Abbreviations

LDS: Lumbar Degenerative Spondylolisthesis; LBP: Low Back Pain; MRI: Magnetic Resonance Imaging; CT: Computed Tomography; SPECT: Single Photon Emission Computed Tomography; PLC: Posterior Ligament Complex; SSL: Supraspinous Ligament; ISL: Iliolumbar Ligament; LF: Ligamentum Flavum; TLICS: Thoracolumbar Injury Classification and Severity Score; IAR: Instantaneous Axis of Rotation; AP: Anterior-Posterior; VP: Vacuum Phenomenon; 99mTc MDP: Technetium-99m Methylene Diphosphonate

## Introduction

Degenerative spondylolisthesis (LDS) of the lumbar spine is often linked to segmental instability, which can lead to consideration of lumbar fusion surgery [1]. However, the presence of (LDS) does not inherently indicate instability, as studies have shown no statistically

significant association between LDS and the occurrence of low back pain (LBP) [2,3]. This is because LBP may stabilize naturally over time [4-6]. Surgical decisions should account for the condition's natural progression, clinical symptoms, and co-relation with imaging findings rather than solely relying on the diagnosis of LDS.

Defining lumbar spine instability remains challenging due to inadequately established clinical criteria and ambiguities and controversies in radiologic assessments [7]. Despite various imaging modalities, no consensus exists on the most effective diagnostic approach, as most current methods fail to fully capture load-deformation characteristics crucial for assessing biomechanical instability. This review aims to assess the diagnostic accuracy of radiological markers indicative of instability, emphasizing the limitations of the methods and the controversies regarding their interpretation and clinical relevance. The findings are intended to enhance diagnostic accuracy and inform subsequent management strategies.

## Materials and Methods

A literature review was conducted across PubMed, Scopus, Web of Science, and Google Scholar databases, encompassing studies published up to December 2024. The search strategy utilized keywords such as "degenerative spondylolisthesis", "lumbar instability", "low back pain", "radiological assessment", "segmental instability", and "lumbar spine".

## Results and Discussion

The review focused on studies examining the use of radiological methods to diagnose lumbar instability in symptomatic patients with degenerative spondylolisthesis (LDS). Studies were assessed for quality based on design, methodology, clarity, and consistency. Data is narratively synthesized to compare techniques, criteria, prevalence, evidence, and controversies in diagnosing instability. Ethical review was not required as only published articles were used in this review.

### Definition and mechanisms of lumbar spinal instability

A spinal motion segment comprises two adjacent vertebrae, an intervertebral disc, ligaments, and joints, providing stability by limiting excessive movement. Lumbar spinal instability occurs when segmental stiffness is lost, resulting in abnormal motion under normal applied loads and an inability to maintain intervertebral neutral zones within physiological limits, potentially causing pain, deformity, and neurological risks [8-10].

### The pathodynamics of degenerative lumbar intervertebral instability: Mechanisms and stages

The reported prevalence of degenerative spondylolisthesis in the general population varies widely, ranging from 6% to 20%, depending on the population studied. Degenerative spondylolisthesis most commonly occurs at L4-L5 level with a higher prevalence in females (5.9%) compared to males (1.5%). This is due to high shear forces due to the stresses of upright posture and a more sagittal orientation of the facet joint at L4-L5. A more sagittal facet joint alignment increases the risk of vertebral slippage because although L5-S1 experiences higher shear forces, its more coronally oriented facets provide greater stability [11].

Disc degeneration typically begins around the age of 30. It leads to disc collapse and pathological alterations in the vertebrae, ligaments, and spinal canal [12]. These changes can potentially lead to spondylolisthesis however there is no significant link between disc degeneration and abnormal motion. Studies linking disk degeneration to instability, have reported conflicting findings [13,14]. Lumbar instability in LDS progresses through stages of dysfunction, instability, and stabilization, which can be identified as multidirectional shifts or rotations on imaging [5]. Changes in intervertebral mobility across stages highlight the dynamic nature of lumbar instability, therefore, the radiological presence of spondylolisthesis does not always indicate active instability [5,12].

## Radiographic assessment of lumbar instability

Indirect radiographic signs suggesting instability include moderate disc degeneration, traction spurs, the intervertebral vacuum phenomenon (VP), and transitional vertebrae. Since they can also be observed in healthy individuals or in conjunction with other conditions, their diagnostic value remains uncertain [5,15,16].

The presence of intradiscal gas on X-rays, CT scans and MRI, known as the vacuum phenomenon, was first described by Knutsson in 1944. It is widely regarded as a sign of segmental instability and may correlate with axial pain. However, this phenomenon has also been observed in asymptomatic individuals and other conditions which include degenerative disc disease, osteoporotic vertebral fractures and rarely, spinal infections and malignancies such as multiple myeloma. The presence of intradiscal gas is a crucial factor in planning spinal fusion surgery. Since it signifies segmental instability, it may impact the extent of fusion required [17]. Therefore, clinical correlation is essential when interpreting this finding [18].

The presence of traction spurs on radiographs has also been linked to instability. It is speculated that abnormal motion or stress on the outermost annular fibres at the affected spinal segment leads to the formation of these horizontally oriented bony outgrowths at the vertebral margin. Traction spurs typically reflect early-stage disc degeneration, temporary dysfunction. Their presence alongside claw osteophytes, suggests that they may be part of the same degenerative process. They can be useful in preoperative evaluations and post-fusion assessments but cannot be considered definitive markers of instability [18]. Their exact role and significance in diagnosing lumbar instability remain controversial.

## Dynamic imaging: Debates on the best position to reveal lumbar instability

Lumbar spine's movement during physiological flexion and extension has been studied using various methods, but no consistent pattern of motion of each individual segment during these movements has been observed [19]. Mimura (1990) utilized bi-plane X-ray analysis to study motion patterns of the spine. They observed that rotational motion at each segment in the normal lumbar spine ranged from 2 to 3 degrees. In LDS, degeneration disrupts the instantaneous axis of rotation. This leads to complex biomechanical changes, with increased flexion and rotation. This potentially contributes to instability and symptoms [20]. Gertzbein., *et al*. (1985) in a cadaveric study also demonstrated that degeneration leads to complex movement patterns in the spine, causing erratic motion due to changes in the instantaneous axis of rotation (IAR), leading to instability and back pain [21].

Knutsson in 1944 introduced erect flexion-extension radiographs. This represented a groundbreaking advancement in the diagnosis of spinal instability. Flexion and extension X-rays evaluate translation (e.g. anterolisthesis or retrolisthesis) and angular motion. Excessive or abnormal movement suggests instability [17].

Pope and Panjabi in 1985 theorised that reduced stiffness may increase vertebral motion which can contribute to instability and back pain [22]. This prompted researchers to investigate various radiographic positions, to identify abnormal motion indicative of instability.

Erect X-ray radiography at present is the most widely utilized method by spine surgeons to reveal increased segmental motion, primarily due to its simplicity, accessibility, and low cost [17,23]. However, the accuracy and reliability of erect flexion-extension radiographs is a debatable topic, as it relies on patient cooperation, movement, measurement precision and technique. Few studies have advocated side-lying full flexion-extension X-ray. The argument is that this position reduces muscle bracing and pain, potentially revealing instability more clearly [24,25]. Conversely, still, other studies contested the view that intervertebral motion decreases in a recumbent position due to the absence of body weight, suggesting standing radiographs may better detect instability [26,27]. Still others have suggested supine-prone, and dynamic seated postures [28].

Lateral X-rays are valuable in evaluating vertebral translation and rotation as markers of spinal instability, but the independent assessment of these movements remains contentious. Wood., *et al*. demonstrated that flexion-extension X-rays in the lateral decubitus position revealed more abnormal translation than erect radiographs, though dynamic angulation was unaffected by patient positioning. They recommended lateral decubitus X-rays for optimizing motion assessment in spondylolisthesis [24]. Cabraja., *et al*. found that recumbent radiography better identified sagittal translation, while standard erect flexion-extension imaging was superior for detecting sagittal rotation [29]. To the debate, Paris introduced the concept of hypermobility as distinct from instability. They argued that radiographs fail to capture true functional motion. Spinal palpation better detects irregular movements such as vertebral slips or vertebral positional changes [30]. Their findings highlight the importance of clinical assessments in diagnosing spinal instability, perhaps even outweighing radiographic imaging. Soini., *et al*. (1991) also challenged the diagnostic utility of flexion-extension radiography in identifying lumbar spine instability. They studied the relationship between disc degeneration and spinal motion using plain radiography, flexion-extension radiography, and discography and found no significant association between disc degeneration and abnormal angular movement, indicating that disc degeneration does not necessarily result in instability [13]. These contrasting perspectives highlight the ongoing debate about instability and the lack of consensus in the field.

Lateral instability in the coronal plane has received less attention in research despite being linked to more severe symptoms and reduced lumbar lordosis angles. Wang., *et al*. highlighted the limitations of conventional assessments and advocated for the inclusion of right and left-bending radiographs to provide a more comprehensive evaluation [31]. This recommendation underscores the ongoing debate over the adequacy of existing diagnostic methods for capturing the full spectrum of spinal instability.

### Defining segmental instability: Criteria, variability, and clinical implications

Is sagittal rotation or sagittal translation alone sufficient to define segmental instability, or should both be present to consider a segment as unstable?

A 1990 study involving 40 asymptomatic male volunteers aged 19 to 43 examined physiologic lumbar spine motion using weight-bearing lateral flexion-extension radiographs. The study found that dynamic anterior-posterior (AP) translation was a more accurate indicator of lumbar segmental instability than static measurements. 42% of the study participants showed static olisthesis over 3.0 mm. Lumbar angular rotation ranged from 7.7 to 9.4 degrees in normal individuals, with the greatest motion observed at L4-L5 and L5-S1. The study concluded that a dynamic translation greater than 3 mm or more than 8% of vertebral width on flexion-extension radiographs should be considered a marker of lumbar segmental instability, a criterion which is still widely accepted [32]. However, as the study included only young male subjects, it raises questions about the applicability of these criteria to older individuals and females, who are more frequently affected by degenerative spondylolisthesis.

A systematic review highlighted variability in Diagnostic criteria for defining instability, 24% studies used dynamic sagittal translation alone, 26% included both dynamic translation and angulation, and 8% relied on narrative definitions [33]. Chatprem., *et al*. in their study used the criteria for lumbar instability, requiring either rotational or translational instability in two segments, or both in one. Instability is his study was defined by sagittal translation > 4.5 mm and rotational movement exceeding 15° at L1-2, 20° at L4-5, and 25° at L5-S1 during flexion and extension [25]. Posner., *et al*. recommended measuring horizontal displacement as a percentage of the upper vertebral body's width, rather than using absolute displacement values. This approach accounts for variations in X-ray magnification caused by differing distances between the X-ray tube, patient, and imaging plate, thereby enhancing measurement accuracy. Based on their experimental laboratory study using cadavers, Posner., *et al*. proposed that a spinal segment can be defined as unstable if translation exceeds > 6% (± 2%) of the vertebral width from L1-L2 to L4-L5, or > 4% (± 4%) at L5-S1. Additionally, sagittal rotation exceeding 6° (± 4°) from L1-L2 to L4-L5, or 5° (± 7°) at L5-S1, also indicates instability [34]. These values are closely aligned with those employed in clinical studies to guide the selection of candidates for lumbar fusion treatment [35,36].

Despite multiple studies, there is no universal consensus on diagnostic thresholds for segmental instability. Common values, such as 10° for sagittal rotation and 4 mm for translation, remain arbitrary and unstandardized [37]. This highlights the need for further research to establish clear guidelines and improve diagnostic accuracy.

### MRI in lumbar instability: Findings, controversies and limitations

MRI studies suggest that while degenerative disc disease and facet joint osteoarthritis affect motion segment stability, their relationship with vertebral instability remains unclear. Murata., *et al*. found no significant correlation between MRI findings of disc degeneration and instability on flexion-extension radiography [14]. Min., *et al.* observed that disc and facet degeneration increase translational motion but limit excessive angular motion [38]. Fujiwara., *et al.* associated anterior translation ≥ 3 mm with disc and facet degeneration [39].

Facet joint oedema and effusions, particularly large effusions (1-1.5 mm) at the L4-L5 level, are strong indicators of instability in lumbar degenerative spondylolisthesis (LDS). When LDS is not apparent on supine MRI in the presence of facet effusion, stress-loading flexion-extension X-rays are recommended to assess the presence of dynamic instability [40,41]. However, the presence of facet joint effusion is not always associated with instability. A study reported that 7% of patients with facet fluid signals on MRI did not exhibit instability on lateral radiographs, while 17% of patients with instability on lateral radiographs showed no fluid signal on MRI. These findings suggest that both radiographic and MRI evaluation are necessary for clinical decision-making [42].

MRI is widely used to evaluate spinal canal narrowing and ligament integrity. In patients who report standing or upright positional pain supine MRI may not fully capture the extent of angulation or instability in degenerative conditions [14]. Positional MRI studies have demonstrated that posture significantly influences the dural sac's cross-sectional area at the intervertebral disc level. The smallest values are observed in the supine position. When transitioning from a supine to a standing position, the lumbar dural sac volume expands due to increased cerebrospinal fluid pressure, resulting in a larger cross-sectional area. Erect Dynamic MRI, and axial-loaded MRI, which simulates an upright posture through pelvic loading, have shown superior accuracy in detecting olisthesis and correlating lumbar stenosis symptoms with changes in the dural sac area under load [38,43-45]. Weishaupt., *et al*. also found that neural foramina size varies with body position, reinforcing the concept of dynamic foraminal stenosis. Positional MRI can be valuable for diagnosis, as pain level changes are closely associated with foraminal narrowing [46].

Facet synovial cysts are associated with degenerative spinal conditions like osteoarthritis, degenerative disc disease, and spondylolisthesis, but their pathogenesis and association with spinal instability remain debated, with uncertainty about which condition precedes or contributes to the other [47,48]. While some suggest facet joint instability contributes to its development, their role as definitive markers of instability is controversial [49]. Doyle and Merrilees found a higher incidence and severity of facet joint arthritis and degenerative spondylolisthesis in patients with synovial cysts compared to those without [47]. A meta-analysis found spondylolisthesis with synovial cyst herniation in 42.5% to 45% of cases, with affected patients significantly more likely to undergo initial fusion surgery (odds ratio 11.5, *P* < 0.0001) and face a higher risk of reoperation (odds ratio 2.0, *P* = 0.088) due to lumbar instability [50].

Facet joint opening and subchondral sclerosis on MRI are also recognized as strong indicators of segmental instability, with joint opening being the most predictive marker. Facet degeneration can lead to anterior subluxation, which is detectable on weight-bearing lateral X-rays, whereas supine MRI may reveal a facet gap as the spine shifts backwards when unloaded. Facet degeneration typically develops up to 20 years after disc degeneration, making it neither an early nor a reliable marker of instability [51].

The posterior ligament complex (PLC) is utilized in the thoracolumbar injury classification and severity (TLICS) Score system to assess spinal fracture stability. This may also play a role in diagnosing chronic lumbar instability in LDS. High-intensity signals in the interspinous ligaments indicate segmental instability whereas advanced degeneration of the supraspinous ligament (SSL) should prompt

further evaluation for lumbar instability [52]. Degeneration and alterations in the iliolumbar ligament (ISL) and ligamentum flavum (LF) are regarded as less reliable indicators of instability [52,53].

### The role of computed tomography in diagnosing lumbar instability

Computed tomography (CT) is better than standard radiography in detecting lumbar instability. It provides high-resolution imaging of disc degeneration, spinal canal narrowing, and facet joint hypertrophy. It is particularly effective in identifying the vacuum facet phenomenon, a strong indicator of segmental instability in degenerative spondylolisthesis [54]. CT myelography is the preferred method for confirming spinal canal narrowing or nerve root compression when MRI is not feasible. Plain CT can serve as an alternative when CT myelography is not possible. Functional CT, including the "twist test", can detect abnormal vertebral motion. It may also reveal a gap in the facet joint space or a vacuum phenomenon [5]. However, its use is limited by radiation exposure, and the reliability of these findings in distinguishing normal from unstable spines remains uncertain [23]. Consistency and standardized protocols, which are crucial for accurate CT-based assessments of lumbar instability, are currently lacking.

Single photon emission computed tomography (SPECT) is increasingly being recognized as a valuable tool for detecting spinal instability and guiding interventions in chronic low back pain. Its integration with three-dimensional (3D) data acquisition enhances spatial resolution, and when combined with CT, it allows for precise pain localization and detailed identification of associated pathologies like discogenic backpain, facet joint disease and pars defects. Compared to plain radiographs and conventional bone scans, SPECT, particularly with 99mTc MDP, offers greater sensitivity. It is especially beneficial for patients with implants, as it minimizes artifacts from surgical metalwork. However, its use in younger individuals with benign conditions should be approached with caution due to increased radiation exposure. To reduce this risk, low-dose CT protocols should be considered [55].

## Conclusion

Radiological evidence of spondylolisthesis does not necessarily indicate active instability. Studies have found no strong correlation between spondylolysis or spondylolisthesis on CT and the occurrence of low back pain (LBP), suggesting these conditions are not the primary causes of LBP in the general population.

Imaging plays a crucial role in confirming instability in lumbar degenerative spondylolisthesis (LDS) and assessing its severity. Standing lateral radiographs are reliable for diagnosing LDS, while flexion-extension X-rays help evaluate lumbar instability. MRI is the preferred modality for detecting spinal stenosis in patients with neurological symptoms, whereas CT and SPECT serve as an alternative when MRI is not feasible or inconclusive. However, despite its importance in diagnosis and treatment planning, imaging has limitations in establishing a direct link between radiological findings and functional instability.

## Declaration of Interests

No competing interests to declare.

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## Ethical Considerations

Not required.

## Bibliography

1. Bridwell KH., *et al*. "The role of fusion and instrumentation in the treatment of degenerative spondylolisthesis with spinal stenosis". *Journal of Spinal Disorders* 6.6 (1993): 461-472.
2. Hasegawa K., *et al*. "Lumbar degenerative spondylolisthesis is not always unstable: clinicobiomechanical evidence". *Spine (Phila Pa 1976)* 39.26 (2014): 2127-2135.
3. Herkowitz HN. "Spine update. Degenerative lumbar spondylolisthesis". *Spine (Phila Pa 1976)* 20.9 (1995): 1084-1090.
4. Vibert BT., *et al*. "Treatment of instability and spondylolisthesis". *Clinical Orthopaedics and Related Research* 443 (2006): 222-227.
5. Kirkaldy-Willis WH and Farfan HF. "Instability of the lumbar spine". *Clinical Orthopaedics and Related Research* 165 (1982): 110-123.
6. Kalichman L., *et al*. "Spondylolysis and spondylolisthesis: prevalence and association with low back pain in the adult community-based population". *Spine (Phila Pa 1976)* 34.2 (2009): 199-205.
7. Hasegawa K., *et al*. "What are the reliable radiological indicators of lumbar segmental instability?" *Journal of Bone and Joint Surgery - Series B* 93B.5 (2011): 650-657.
8. Hayes MA., *et al*. "Roentgenographic evaluation of lumbar spine flexion-extension in asymptomatic individuals". *Spine (Phila Pa 1976)* 14.3 (1989): 327-331.
9. Stokes IAF and Frymoyer JW. "Segmental motion and instability". *Spine (Phila Pa 1976)* 12.7 (1987): 688-691.
10. Panjabi MM and White III AA. "Clinical biomechanics of the spine: biomechanically relevant anatomy". Published online (1978): 1-35.
11. Saremi A., *et al*. "Evolution of lumbar degenerative spondylolisthesis with key radiographic features". *The Spine Journal* 24.6 (2024): 989-1000.
12. Axelsson P and Karlsson BS. "Intervertebral mobility in the progressive degenerative process. A radiostereometric analysis". *European Spine Journal* 13.6 (2004): 567-572.
13. Soini J., *et al*. "Disc degeneration and angular movement of the lumbar spine: comparative study using plain and flexion-extension radiography and discography". *Journal of Spinal Disorders and Techniques* 4.2 (1991): 183-187.
14. Murata M., *et al*. "Lumbar disc degeneration and segmental instability: a comparison of magnetic resonance images and plain radiographs of patients with low back pain". *Archives of Orthopaedic and Trauma Surgery* 113.6 (1994): 297-301.
15. Macnab I. "The traction spur. An indicator of segmental instability". *Journal of Bone and Joint Surgery, American Volume* 53.4 (1971): 663-670.
16. Kirkaldy-Willis WH., *et al*. "Pathology and pathogenesis of lumbar spondylosis and stenosis". *Spine (Phila Pa 1976)* 3.4 (1978): 319-328.
17. Knutsson F. "The instability associated with disk degeneration in the lumbar spine". *Acta Radiologica* 25.5-6 (1944): 593-609.
18. Tsukamoto M., *et al*. "Traction spurs in the lumbar spine: A historical overview and future perspectives". *Spine Surgery and Related Research* 8.4 (2024): 354-361.

19. Caelers I., *et al*. "The variability of lumbar sequential motion patterns: observational study". *JMIR Biomedical Engineering* 8 (2023): e41906.

20. M Mimura. "[Rotational instability of the lumbar spine--a three-dimensional motion study using bi-plane X-ray analysis system]". *Nihon Seikeigeka Gakkai Zasshi* 64.7 (1990): 546-559.

21. Gertzbein SD., *et al*. "Centrode patterns and segmental instability in degenerative disc disease". *Spine* 10.3 (1985): 257-261.

22. Pope MH and Panjabi M. "Biomechanical definitions of spinal instability". *Spine (Phila Pa 1976)* 10.3 (1985): 255-256.

23. Nizard RS., *et al*. "Radiologic assessment of lumbar intervertebral instability and degenerative spondylolisthesis". *Radiologic Clinics of North America* 39.1 (2001): 55-71.

24. Wood KB., *et al*. "Radiographic evaluation of instability in spondylolisthesis". *Spine (Phila Pa 1976)* 19.15 (1994): 1697-1703.

25. Chatprem T., *et al*. "A diagnostic tool for people with lumbar instability: a criterion-related validity study". *BMC Musculoskeletal Disorders* 22.1 (2021): 976.

26. Pennal GF., *et al*. "Motion studies of the lumbar spine: a preliminary report". *The Journal of Bone and Joint Surgery. British Volume* 54.3 (1972): 442-452.

27. Penning L., *et al*. "Inability to prove instability. A critical appraisal of clinical-radiological flexion-extension studies in lumbar disc degeneration". *Diagnostic Imaging in Clinical Medicine* 53.4 (1984): 186-192.

28. D'Andrea G., *et al*. ""Supine-prone" dynamic X-ray examination: new method to evaluate low-grade lumbar spondylolisthesis". *Journal of Spinal Disorders and Techniques* 18.1 (2005): 80-83.

29. Cabraja M., *et al*. "The analysis of segmental mobility with different lumbar radiographs in symptomatic patients with a spondylolisthesis". *European Spine Journal* 21.2 (2012): 256-261.

30. Paris S V. "Physical signs of instability". *Spine (Phila Pa 1976)* 10.3 (1985): 277-279.

31. Wang X Wen., *et al*. "Analysis of lumbar lateral instability on upright left and right bending radiographs in symptomatic patients with degenerative lumbar spondylolisthesis". *BMC Musculoskeletal Disorders* 23.1 (2022): 1-7.

32. Boden SD and Wiesel SW. "Lumbosacral segmental motion in normal individuals: Have we been measuring instability properly?" *Spine (Phila Pa 1976)* 15.6 (1990): 571-576.

33. Elmose SF., *et al*. "Radiological definitions of sagittal plane segmental instability in the degenerative lumbar spine - a systematic review". *Global Spine Journal* 13.2 (2022): 523-533.

34. Posner I., *et al*. "A biomechanical analysis of the clinical stability of the lumbar and lumbosacral spine". *Spine (Phila Pa 1976)* 7.4 (1982): 374-389.

35. Yone K and Sakou T. "Usefulness of Posner's definition of spinal instability for selection of surgical treatment for lumbar spinal stenosis". *Journal of Spinal Disorders* 12.1 (1999): 40-44.

36. Nachemson AL., *et al*. "Mechanical properties of human lumbar spine motion segments. Influence of age, sex, disc level, and degeneration". *Spine (Phila Pa 1976)* 4.1 (1979): 1-8.

37. Morgan FP and King T. "Primary instability of lumbar vertebrae as a common cause of low back pain". *The Journal of Bone and Joint Surgery. British Volume* 39-B.1 (1957): 6-22.

38. Min HK., *et al*. "Kinetic magnetic resonance imaging analysis of abnormal segmental motion of the functional spine unit". *Journal of Neurosurgery: Spine* 10.4 (2009): 357-365.

39. Fujiwara A., *et al*. "The relationship between facet joint osteoarthritis and disc degeneration of the lumbar spine: an MRI study". *European Spine Journal* 8.5 (1999): 396-401.

40. Schinnerer KA., *et al*. "MR findings of exaggerated fluid in facet joints predicts instability". *Journal of Spinal Disorders and Techniques* 21.7 (2008): 468-472.

41. Junfeng M., *et al*. "Correlation between facet joint effusion in magnetic resonance imaging and lumbar stability after interspinous and degenerative lumbar spondylolisthesis". *Chinese Journal of Tissue Engineering Research* 23.24 (2019): 3845.

42. Cho IY., *et al*. "MRI findings of lumbar spine instability in degenerative spondylolisthesis". *Journal of Orthopaedic Surgery (Hong Kong)* 25.2 (2017): 2309499017718907.

43. Tarantino U., *et al*. "Lumbar spine MRI in upright position for diagnosing acute and chronic low back pain: statistical analysis of morphological changes". *Journal of Orthopaedics and Traumatology* 14.1 (2013): 15-22.

44. Mahato NK. "Load-bearing shifts in laminar and ligament morphology: comparing spinal canal dimensions using supine versus upright lumbar MRI in adults without back pain". *Indian Journal of Radiology and Imaging* 33.3 (2023): 344-350.

45. Kanno H., *et al*. "Dynamic change of dural sac cross-sectional area in axial loaded magnetic resonance imaging correlates with the severity of clinical symptoms in patients with lumbar spinal canal stenosis". *Spine (Phila Pa 1976)* 37.3 (2012): 207-213.

46. Weishaupt D., *et al*. "Positional MR imaging of the lumbar spine: does it demonstrate nerve root compromise not visible at conventional MR imaging?" *Radiology* 215.1 (2000): 247-253.

47. Doyle AJ and Merrilees M. "Synovial cysts of the lumbar facet joints in a symptomatic population: prevalence on magnetic resonance imaging". *Spine (Phila Pa 1976)* 29.8 (2004): 874-878.

48. Bydon A., *et al*. "Recurrent back and leg pain and cyst reformation after surgical resection of spinal synovial cysts: systematic review of reported postoperative outcomes". *The Spine Journal* 10.9 (2010): 820-826.

49. Mattei TA and Rodriguez AH. "True synovial cysts of the lumbar spine: an epiphenomenon of instability of the functional spine unit?" *Neurosurgical Review* 36.3 (2013): 495-500.

50. Ramhmdani S., *et al*. "Synovial cyst as a marker for lumbar instability: a systematic review and meta-analysis". *World Neurosurgery* 122 (2019): e1059-e1068.

51. Rihn JA., *et al*. "Does lumbar facet fluid detected on magnetic resonance imaging correlate with radiographic instability in patients with degenerative lumbar disease?" *Spine (Phila Pa 1976)* 32.14 (2007): 1555-1560.

52. Jiang J., *et al*. "High intensity in interspinous ligaments: a diagnostic sign of lumbar instability and back pain for degenerative lumbar spondylolisthesis". *BMC Musculoskeletal Disorders* 25.1 (2024): 949.

53. Huang Y., *et al*. "The relationship between MRI findings of posterior ligamentous complex and lumbar instability in degenerative spondylolisthesis". *International Journal of General Medicine* 17 (2024): 2279-2287.

54. Sun ZM., *et al*. "Vacuum facet phenomenon in computed tomography imaging: a sign of instability in degenerative spondylolisthesis?" *World Neurosurgery* 129 (2019): e393-e400.

55. Shur N., *et al*. "Radiological and radionuclide imaging of degenerative disease of the facet joints". *Indian Journal of Nuclear Medicine* 30.3 (2015): 191-198.

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