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Opinion

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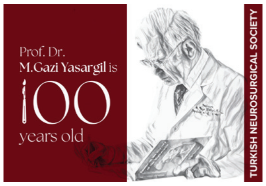


# Dynamic Stabilization: A Game-Changer in Disc Herniation Surgery

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## ABSTRACT

**AIM:** To evaluate the effectiveness of dynamic stabilization as an alternative to traditional fusion surgery for the treatment of lumbar disc herniation and degenerative disc disease, focusing on its impact on segmental stability and patient outcomes.

**BACKGROUND:** Back pain is a prevalent global health issue, often caused by abnormal load distribution rather than movement. Key diagnoses such as lumbar disc herniation and degenerative disc disease are linked to spinal instability. While classical surgical methods like discectomy and fusion have been standard, they often result in limited patient satisfaction and complications like adjacent segment degeneration.

**Lumbar Disc Herniation:** Disc herniation involves the nucleus pulposus tearing the annulus fibrosus, causing pain through structural disruption or nerve root compression. Most cases resolve spontaneously, but a subset requires surgical intervention. Success of surgery depends on accurate assessment of segmental stability and patient-specific factors.

**Segmental Stability:** Stability is crucial for preventing pain and neurological deficits. It depends on three subsystems: osteoligamentous, musculotendinous, and neural control. When one subsystem is compromised, instability occurs. Indicators for stabilization include insufficient muscle support, hypermobility, significant annular defects, and the presence of disc herniation with anterolisthesis or Modic changes.

**Dynamic Stabilization:** Unlike rigid fusion, dynamic stabilization uses flexible materials to maintain physiological spinal movement and distribute loads. Initial systems aimed only for minor instability, but advancements now support movement preservation. Clinical outcomes show reduced adjacent segment stress and potential disc regeneration.

**CONCLUSION:** Dynamic stabilization offers a promising alternative to fusion surgery by providing controlled stabilization and preserving spinal mobility. It addresses the limitations of fusion surgery, such as high complication rates and patient dissatisfaction, making it a significant advancement in the surgical treatment of lumbar disc herniation and degenerative disc disease.

**KEYWORDS:** Dynamic, Stabilization, Disc disease, Fusion surgery, Spinal

## BACK PAIN - GENERAL INFORMATION

With up to 80% of the population experiencing back pain at least once in their lifespan, it is one of the most prevalent complaints for hospital admissions worldwide. The underlying cause of back pain is frequently abnormal load distribution rather than abnormal movements. Most patients complain of postural or positional pain as the predominant symptom. Therefore, there has been growing consensus that the most optimal surgical outcomes can be obtained by achieving physiological load transmission during treatment.

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Two primary diagnoses are identified as surgically significant when the differential diagnosis of back pain is considered: lumbar disc herniation and degenerative disc disease. The fundamental pathophysiological process that underlies these diagnoses is spinal instability. Knutsson initially identified instability linked to intervertebral disc degeneration in 1944 and described the abnormal flexion-extension displacement on direct radiographs in patients with disc degeneration (10). Disc degeneration can be graded using Pfirrmann criteria. The entire spine may be affected by the formation of synovial cysts and osteophytes, gas leakage into the disc, a reduction in spinal height due to osteoporosis, tropism of the facet joint, deterioration of ligament quality, and deformity as the degeneration progresses.

**Lumbar Disc Herniation**

Lumbar disc herniation occurs when the annulus fibrosus is torn by the nucleus pulposus, causing protrusion. This protrusion subsequently irritates or compresses the spinal cord or nerve roots. Upon analyzing the pathophysiology of disc herniation, it is evident that the water content, which typically constitutes 80%–85% of the disc, decreases, suggesting that it is a degenerative process. Based on the degree of disc degeneration, the isotropic properties and load transmission of the intervertebral disc vary. Disc injury may occur with rotational or axial loads, or a combination of both. Rotational loads induce circumferential annular tears, which do not produce as much pain as the tears proceed from inside to outside. The vertical tears that result from axial loading cause pain. The outer layers of the annulus have abundant nociceptive receptors. When the tears travel from the center to the periphery and reach these layers, the receptors are affected, leading to pain perception. The pain that has been observed thus far is exclusively associated with the disruption of the disc's structure and is generally referred to as discogenic pain. Pain induced by compression of nerve roots by nucleus pulposus fragments is called radicular pain.

Lumbar disc herniation can manifest at any level; however, it is frequently encountered at the L4–L5 or L5–S1 levels. Disc degeneration is the most prevalent cause of herniation, with sudden traumas ranking second. Patients may present with back pain as well as lower limb pain, tingling sensation, or weakness. Motor deficit, urinary or fecal incontinence, sexual dysfunction, and saddle anesthesia are symptoms that necessitate more urgent intervention.

Most lumbar disc herniations are painless, and 80%–90% of symptomatic patients experience spontaneous healing within 6–12 weeks without any treatment. In a limited number of patients, surgical treatment is required. Conventionally, discectomy and laminotomy are performed. However, not all patients who undergo surgery benefit from these methods. In some cases, the disc may reherniate, and in others, the patient's pain may persist despite everything being normal radiologically. To predict the success of surgery, it is necessary to review the patient's history, examination, and tests meticulously and prepare an individualized strategy.

**Segmental Stability**

To determine the lumbar disc herniation patients who can benefit from surgery, it is necessary to examine the concept of segmental stability. Panjabi described a second component, which he called the elastic zone, in addition to a neutral zone, that is included in the total physiological range of motion (13). The neutral zone is a column that is situated in the middle of the vertebrae and is formed by the area near 1/3 of the posterior part of the functional unit. In all planes of the spine, the neutral zone forms the column with the least physiological movement. If movement increases in this column, it indicates that the functional unit is unstable. Neutral zone movement is the movement performed by the most stable portion of the segment, which is characterized by minimal resistance. The elastic zone is the segment surrounding the neutral zone, where the resistance to movement is at its highest. Segmental stability ensures that there is no pain, neurological deficit, or deformity in the spinal neutral zone during routine functional activity.

Panjabi defined segmental instability as "an abnormal movement of one vertebra on the other in a motion segment and 'widening of the neutral zone'" (13-15). Segmental instability may manifest at one or more levels. The functionality of this system is contingent upon three fundamental subsystems: the osteoligamentous subsystem (including the vertebra, disc, joint, and ligament, and is referred to as the passive system); the musculotendinous subsystem (including the muscles, which is called the active system); and the neural control subsystem (including the brain and spinal cord). The physiological function of the spine is maintained, and a pain-free range of motion is enabled by the healthy formation of the aforementioned subsystems. Instability arises when one of these subsystems is disrupted and the other subsystems are unable to compensate.

**When Should Stabilization Be Performed?**

If the patient exhibits signs such as painful black discs, degenerative anterior or posterior listhesis (which is a sign of advanced degeneration), a traction spur, facet tropism, osteophyte formation, or annular tear (regardless of whether it is associated with disc herniation), these may all indicate insufficiency of the osteoligamentous system. Consequently, if the osteoligamentous system is compromised and the musculotendinous system is unable to compensate due to pain or the patient's inability to engage this system, solely performing nerve decompression may not be beneficial.

Stabilization should be addressed prior to surgery when clinical signs of segmental instability manifest in a patient. These clinical signs include:

Insufficiency of the muscular compartment (Figure 1): This indicates inadequate paravertebral muscle support, which is primarily caused by a sedentary lifestyle. An MRI-based evaluation of the patient's abdominal, paravertebral, and thoracolumbar muscle compartments, as well as their body composition, can provide valuable insight. As muscles age, they exhibit a propensity to undergo fatty degeneration.

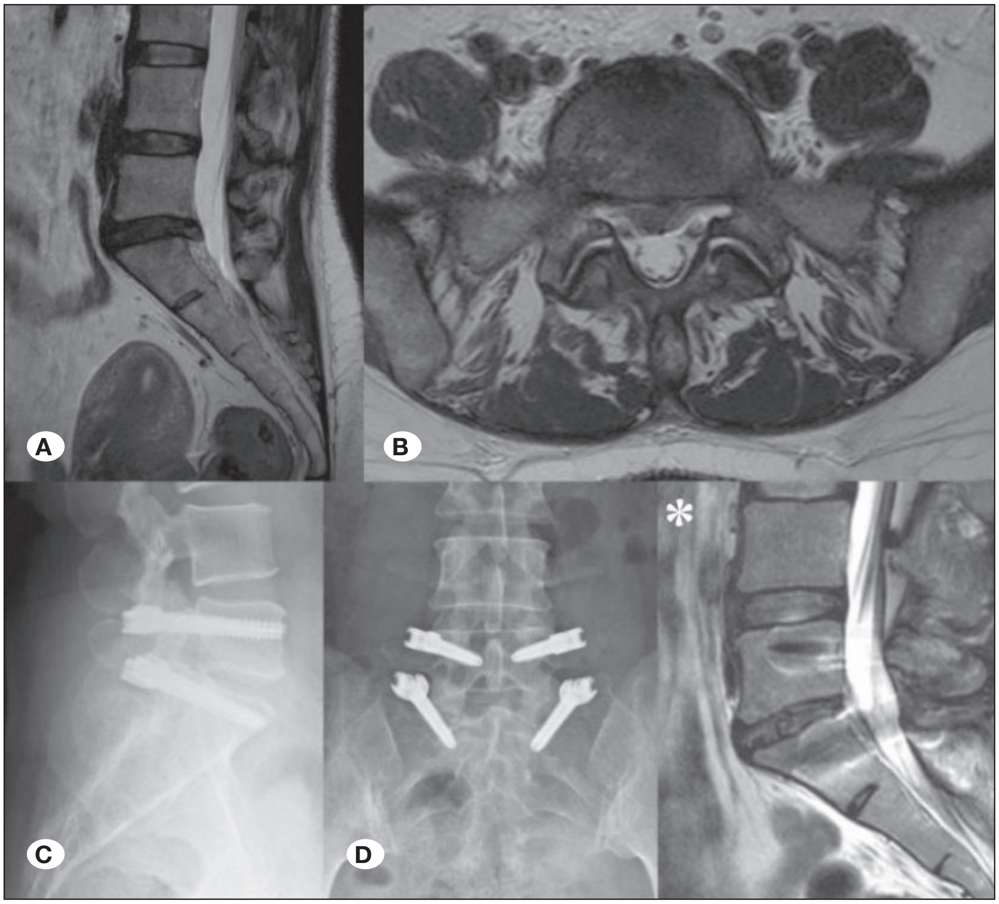


**Figure 1:** 50-year-old female patient comes with back pain and dysesthesia in her left leg. Dynamic stabilization was performed with dynesys system at L5-S1 levels in the patient with weak muscle support. **A, B)** Sagittal and axial T2-weighted MRI showing an L5-S1 disc herniation, respectively. Postoperative scoliosis X-ray displaying the lateral **(C)** and anteroposterior **(D)** view, respectively. *Postoperative 1-year follow-up sagittal T2-weighted MRI image.

Hypermobility: It refers to the increase in joint flexibility. For instance, hypermobility in the upper segment and early disc degeneration may occur in patients with sacralization or when spontaneous fusion occurs in the lower segment due to degeneration.

Disc herniation with anterolisthesis or retrolisthesis (Figure 2): Listhesis refers to the anterior or posterior displacement of one vertebra relative to the caudal one. This indicates that the internal structure of the disc has deteriorated to the extent that a motion segment is unable to maintain its integrity. The likelihood of reherniation is particularly high in unstable segments that have been further compromised by subtotal discectomy.

Presence of significant annular defects (Figure 3) (such as in Carragee types 2 and 4, especially if >1 cm): The Carragee classification system categorizes lumbar disc herniations according to annular integrity and the presence of extruded/sequestered disc fragments (3). These are defined as follows:

Type 1: Fragmented-fissure herniation,

Type 2: Fragmented defect herniation,

Type 3: Fragment-contained herniation,

Type 4: No fragment contained herniation.

Types 1 and 3 lumbar disc herniations typically necessitate only fragmentectomy because the defect is relatively minor, allowing for spontaneous repair without compromising the osteoligamentous subgroup. The probability of an unstable segment forming after surgery is small, and recurrence rates are also low. Conversely, types 2 and 4 lumbar disc herniations involve substantial damage to the osteoligamentous system, and aggressive discectomy may aggravate this, increasing the likelihood of postoperative segmental instability and recurrent herniation (up to 27%–30%). Hence, we designate these groups as the most severe in lumbar disc herniation.

The coexistence of disc herniation with Modic type 1 and 2 degeneration (Figure 4): This classification was described by Dr. Michael Modic by 1988 (11). These are defined as follows:

Type 0: normal disc and vertebral body morphology

Type 1: bone marrow edema and hypervascularization in the corpus

Type 2: fatty tissue replacement of red bone marrow in the corpus

Type 3: subchondral bone sclerosis

Types 1 and 2 are characterized by edema and fatty degeneration, respectively, leading to nutritional disturbances within the nucleus. This causes a decline in the metabolic process responsible for maintaining nucleus integrity. The risk of hernia-

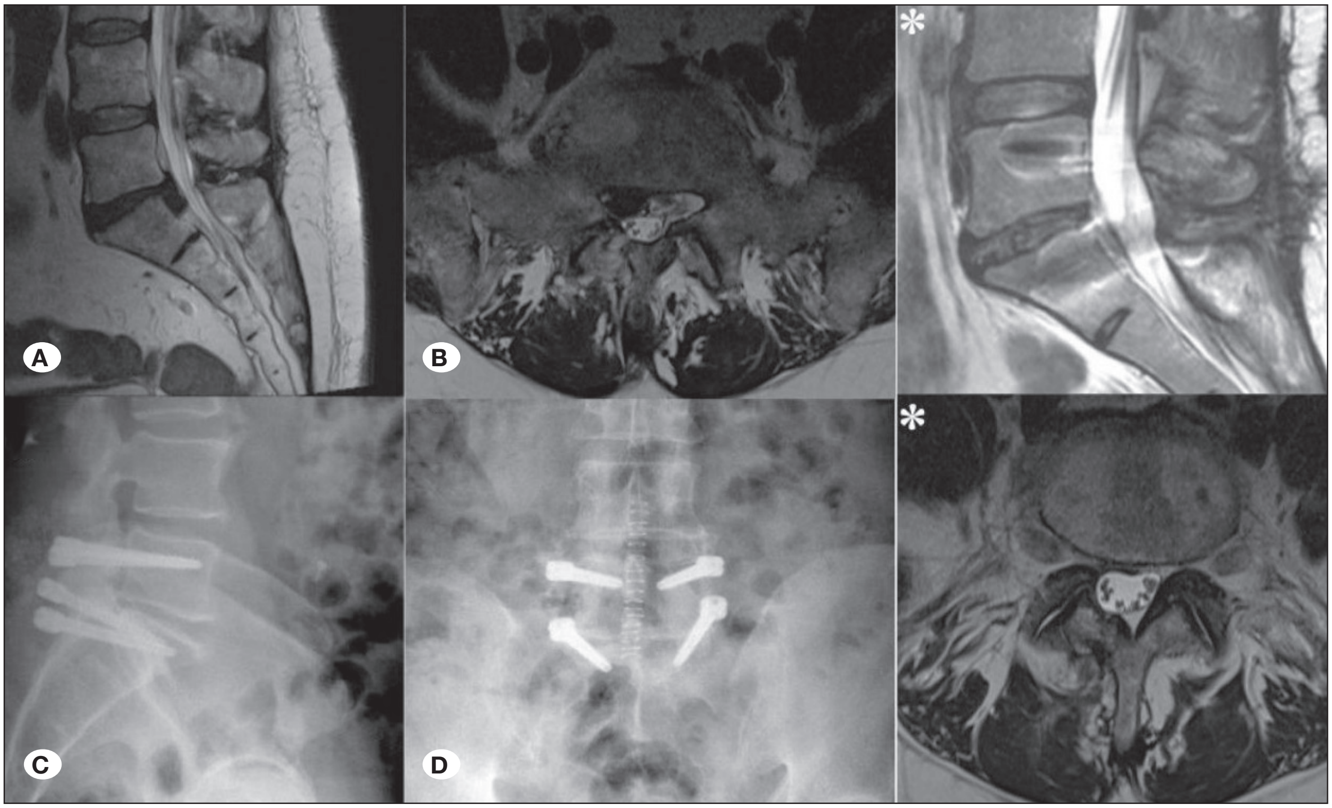


**Figure 2:** 59-year-old male patient visited to the clinic with back and right hip pain. Recurrent hernia and retrolisthesis were observed in his MRI. Microdiscectomy and dynamic stabilization was performed with dynesys system at L5-S1. **A,B)** Sagittal and axial T2-weighted MRI showing an L5-S1 listhesis and disc herniation, respectively. **C,D)** Postoperative scoliosis X-ray displaying the sagittal and coronal view, respectively. * Postoperative 1-year follow-up sagittal and axial T2-weighted MRI.

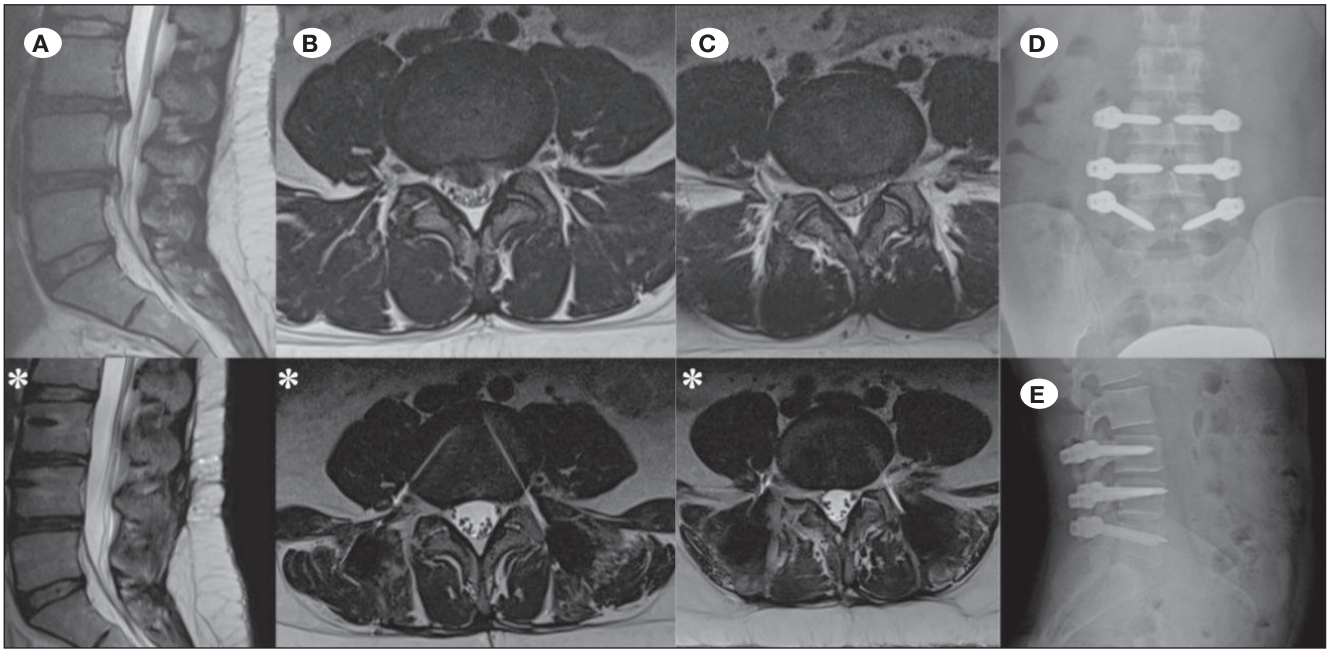


**Figure 3:** 25-year-old female patient visited to the clinic with back pain. 22 mm anular defect was observed in her MRI. Microdiscectomy and dynamic stabilization was performed with safinaz screw and peek rod at L3-4-5. **A,B,C)** Sagittal and axial T2-weighted MRI showing L3-4 and L4-5 disc herniations, respectively. **D, E)** Postoperative scoliosis X-ray displaying the coronal and sagittal view, respectively. * Postoperative 1-year follow-up sagittal and axial T2-weighted MRI.

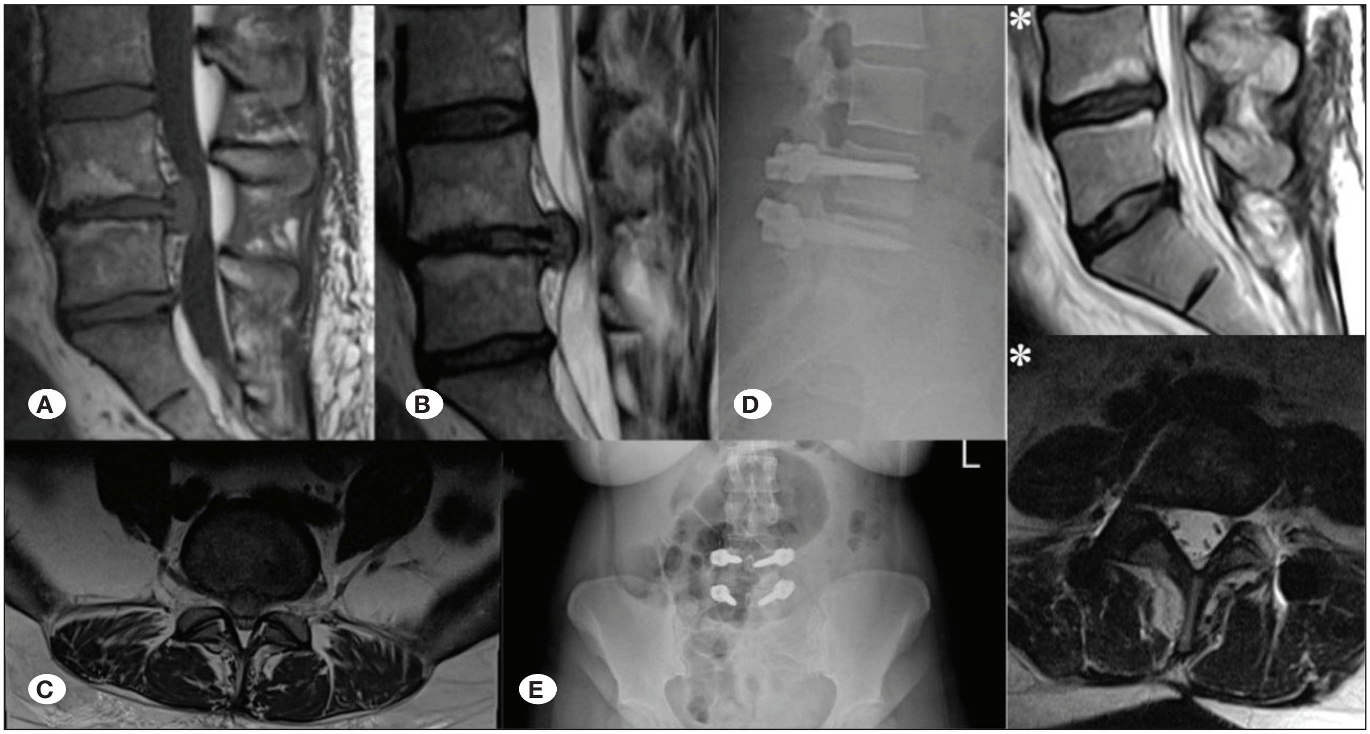


**Figure 4:** 42-year-old female patient visited to the clinic with back and left leg pain. Modic type 2 change was detected in her MRI. Microdiscectomy and dynamic stabilization was performed with safinaz screw and peek rod at L4-L5. **A, B)** Sagittal T1-T2 weighted MRI showing modic type 2 change at L4-L5 level. **C)** Axial T2-weighted MRI showing L4-5 disc herniation. **D, E)** Postoperative scoliosis X-ray displaying the sagittal and coronal view, respectively. ***** Postoperative 1-year follow-up sagittal and axial T2-weighted MRI.

tion recurrence is high in a structurally compromised disc, and it is also elevated after surgery due to continued impairment of metabolism. Furthermore, the surgeries that are implemented as treatment can themselves cause disc destruction. During subtotal discectomy, viable disc tissue is removed along with diseased disc fragments, which may induce degeneration and lead to instability.

A recurrence rate of 78% is observed in cases where the aforementioned conditions are present, and the likelihood of success following microdiscectomy is low, particularly if three or more conditions are present. Therefore, discectomy may be insufficient in this patient group, necessitating consideration of additional stabilization.

Establishing the sufficiency of microdiscectomy as a standalone procedure is essential. If disc herniation develops on a normal anatomical backdrop or if Carragee type I and III annular tears are present—indicating a minor tear with a high chance of spontaneous repair—the recurrence probability is significantly reduced. Additionally, in cases where loose fragments are present, fragmentectomy without discectomy may frequently be sufficient to remove the loose fragments.

**Types of Stabilization**

It is crucial to ascertain the preferred form of stabilization when a stabilization decision is made. Although the classic gold standard fusion surgery is feasible, dynamic stabilization, which is the primary focus of this article, should also be considered. In fusion surgery, vertebrae are stabilized using rigid screw and rod systems, causing the vertebrae to fuse and behave almost like a single bone, thus losing its mobility.

Spinal fusion, first described by Albee and Hibbs, was initially employed for treating Pott's disease and spinal deformities (1,7). Spinal fusion has become a prevalent surgical treatment for other spinal pathologies, including chronic low back pain, disc herniation, spondylolisthesis, facet arthropathy, and spinal stenosis. Rigid stabilization and fusion are definitive surgical treatments for conditions causing acute instability, such as trauma, spondylolisthesis, or tumors. Despite the global consensus on fusion surgery and reports of radiological outcomes that are up to 100% successful, patient satisfaction and clinical outcomes have not met expectations.

A meta-analysis that systematically evaluated the lumbar spinal fusion outcomes reported that success rates vary between 16% and 95% (average 70%). Additionally, rigid spinal implants elevate stress on adjacent segments, resulting in the prevalent problem of adjacent segment degeneration. Furthermore, fusion surgery has several significant drawbacks, including pain, wound issues, infections due to prolonged operation duration, pseudarthrosis, and implant fatigue failure. Dynamic stabilization has emerged as an alternative to fusion surgery in cases of instability, considering all of these factors.

In cases where stabilization is necessitated due to segmental instability caused by the aforementioned reasons, completely freezing movement has been deemed an excessive measure.

In these patients, the instability is chronic; therefore, dynamic stabilization should be conducted to provide the spine with some support.

**Dynamic Stabilization: General Information**

In comparison to conventional fusion surgery, dynamic stabilization employs more flexible materials, which facilitates the spine's physiological movement. Additionally, it endeavors to alleviate pain by distributing the load between the anterior and posterior elements of the spine. At the 2nd Eurospine Congress in Rome, Graf presented non-fusion dynamic stabilization using pedicle screws named after him and later published the results (6). Both Graf's initial dynamic stabilization concept with the Graf ligament and the concept of movable screw heads first introduced by Von Strempel (17) were not intended to maintain spine movement. They defined the dynamic pedicle screw system as a simple stabilization system that can be employed only in cases of minor instability.

Fernström introduced the concept of maintaining movement in addition to stabilization (5). Sengupta stated that pain could be alleviated, and adjacent segment degeneration could be prevented by greater physiological load transfers (16). Additionally, he observed that the damaged disc may regenerate if normal movement and load transmission are achieved, provided that the degeneration has not advanced significantly.

Dynamic stabilization is designed to maintain movement at the affected spinal segment and control abnormal movement, as well as to eradicate pain by facilitating a more physiological load transmission between the anterior and posterior spinal components. When subjected to postural changes, dynamic systems enable anatomical modification of the mobile segment. Depending on the extent of disc damage, the distance under the dynamic system may lead to the disc either returning to a normal state, remaining unchanged, or fusing if severely damaged; however, the patient will undergo this process without pain, indicating that the body itself determines the outcome of the impaired segment.

Dynamic screws (such as COSMIC, Safinaz, etc.) and dynamic rods (such as PEEK, dream, etc.) are used in dynamic stabilization. Dynesys is also one of the dynamic stabilization systems. Dynesys employs dynamic transpedicular screws and elastic spacers. In the dynamic stabilization system, the combination of dynamic screws and dynamic rods achieves results closest to an intact spine during flexion, extension, and right and left lateral bending. When investigating the average range of motion (ROM) values in the L4–L5 segment, it is noted that the dynamic combination yields results comparable to those of an intact spine.

Stabilization that is comparable to that of a rigid system is obtained when dynamic screws are employed in conjunction with a rigid rod from a biomechanical perspective (2,18). However, when a dynamic screw is used with a more flexible rod, such as the Peek rod, e.g., the Talin flexible rod used in biomechanical studies, the range of motion of the stabilized segment approaches that of a normal motion segment (4,12). Patients who are stabilized in this fashion experience highly favorable clinical outcomes, and the stress on adjacent segments is invariably diminished.

Various factors, predominantly structural, can cause mobile spinal segments in humans to differ from one another. The extent of degeneration of the structures that comprise the mobile segment is also quite important. Some of the questions that are still being investigated include the ideal rod tension in a mobile segment, the extent to which the normal physiological range of motion in all directions is influenced by age, height, and muscle volume, and the extent to which ethnic factors influence these processes.

Hypermobility does not necessarily imply that the mobile segments are unstable. This is especially evident in gymnasts. Thus, the expectation that the characteristics of the mobile segment, which vary from person to person, can be replicated using a single rod is not feasible.

In terms of the complications of dynamic stabilization, in the absence of severe osteoporosis, the loosening rate is 4% per level, irrespective of age. Subtotal discectomy is not necessary for dynamic stabilization; removal of the necrotic tissues is sufficient. Dynamic stabilization, when performed along with discectomy during the initial stages of degeneration, allows the disc a chance to recover and facilitates mobility in the functional segment. In the advanced stages of degeneration, it ensures that the vertebrae fuse in a significantly more regulated manner.

## CONCLUSION

Considering all these factors, dynamic stabilization can be regarded as a viable alternative to conventional fusion surgery (8,9). It offers controlled stabilization by permitting physiological movement and has significantly fewer classical complications of fusion surgery. Although the optimal dynamic stabilization materials have not yet been identified, the long-term outcomes of surgeries performed with existing materials are being examined, and ongoing research is continuing to advance the field.

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**Availability of data and materials:** The datasets generated and/or analyzed during the current study are available from the corresponding author by reasonable request.

**Disclosure:** The authors declare no competing interests.

**Ethics approval:** This study was conducted in accordance with the Declaration of Helsinki. Since the present study was an interpretative review and statistical data were not used, ethics committee approval was not obtained.

**Consent to participate:** Informed consent obtained from all the individual participants in this study.

**Consent for publication:** No individual person's data were included in this study.

**AUTHORSHIP CONTRIBUTION**

Study conception and design: ND, MYA, TO, MS, OT, AFO

Data collection: ND, MYA, TO, MS, OT, AFO

Analysis and interpretation of results: ND, MYA, TO, MS, OT, AFO

Draft manuscript preparation: MYA, ND

Critical revision of the article: ND, MYA, TO, MS, OT, AFO

All authors (ND, MYA, TO, MS, OT, AFO) reviewed the results and approved the final version of the manuscript.

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