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Dynamic stabilization for unilateral spinal pathologies: clinical efficacy and safety outcomes

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Abstract

Background Fusion operations using transpedicular screws and cages are commonly employed for spinal stabilization, but they present with drawbacks including increased rigidity and altered biomechanics. Complications such as adjacent segment disease, pseudoarthrosis, and implant failure are often associated with traditional rigid stabilization techniques. To address these challenges, unilateral dynamic stabilization has emerged as a novel approach for patients with unilateral spinal pathologies. This study aims to evaluate the safety, efficacy, and clinical outcomes of unilateral dynamic stabilization and bilateral dynamic stabilization methods.

Methods This retrospective study encompassed 43 spinal patients who underwent surgery between 2017 and 2020, with at least 2 years of clinical and radiological follow-up. Parameters including demographic data, underlying pathologies, surgical complications, screw malposition rates, perioperative data, and clinical and radiological outcomes were analyzed. Pre- and post-operative Visual Analogue Scale (VAS) and Oswestry Disability Index (ODI) scores were compared to assess surgical efficacy.

Results The mean age of the study population was 39.13 ± 14.11 years, with a mean clinical follow-up period of 29.7 months. Both unilateral and bilateral approaches demonstrated comparable outcomes in symptomatic and radiological criteria, yielding significant improvements in pain levels and functional capacity. Visual Analog Scale (VAS) and Oswestry Disability Index (ODI) scores exhibited significant reductions in pain. The unilateral approach exhibited shorter hospital stays, reduced surgical durations, and lesser blood loss compared to the bilateral approach.

Conclusions Unilateral dynamic stabilization presents promising results in terms of stability, improved clinical outcomes, and reduced operation time and cost for patients with unilateral spinal pathologies. This approach offers effective stabilization without compromising mobility and biomechanics. However, caution is warranted when applying unilateral dynamic stabilization for multiple-level operations, as it may entail an increased risk of instrumentation failure.

Keywords Unilateral, Dynamic stabilization, Fusion surgery, Short segment

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Introduction

Encountering patients with unilateral spinal pathologies is a common scenario in clinical practice. Infections of the posterior units, metastatic tumors, one sided degenerative diseases, traumatic fractures or some defects which can occur after the spinal surgery are some of the examples of the unilateral pathologies and they significantly decrease the quality of the life of the patient [1–3]. During the surgery and treatment of those pathologies, unilateral facet resection may be performed, however, it can create instability to the spine [4–6].

To treat the unstable spine, fusion operations by using transpedicular screws and cages are commonly performed. Thanks to instrumentation, disc height is restored, nerve roots are decompressed, stability can be acquired, and clinically satisfactory results can be obtained with high fusion ratio [6–8]. Due to instrumentation, segmental rigidity increases and thus, mobility reduces. This alters the kinematics and biomechanics of the spine. In several studies, it has been observed that to compensate the decrease in the mobility at the operated segment due to fusion, motion at the adjacent segment increases. That increase causes biomechanical stress which exceeds the normal range at adjacent segment to the fusion [6, 9, 10]. Also, decrease in the bone mineral content in the operated level can be also given as another disadvantage of the fusion systems which can also possibly end up with instability in the spine [11]. Moreover, traditional rigid stabilization systems are associated with complications such as pseudoarthrosis, adjacent segment disease and proximal junctional kyphosis.

To overcome the problems encountered with rigid fusion systems, dynamic systems with flexible pedicle screws and rods started to be used. Dynamic systems have several advantages over fusion systems. It controls the excessive movement of the unstable segment, distributes load and stress more equally and thus, prevents the degeneration of the adjacent segment [12]. Clinical studies also shown that dynamic system also at least comparable and, in some ways, superior to the traditional rigid fixation systems [13, 14]. However, it also has some drawbacks. Some studies observed higher reoperation rate, not significant difference with fusion systems in terms of effect on the adjacent segment degeneration and higher failure rates especially in some elderly patients and in the operations which require stabilization of the more than one segment [4, 9, 13].

To address these challenges, we implemented a unique approach wherein unilateral dynamic stabilization (UDS) was utilized to manage patients with unilateral spinal pathologies. This study aims to evaluate the safety, efficacy, and long-term outcomes associated with unilateral dynamic stabilization and bilateral dynamic stabilization (BDS) methods. Additionally, we seek to assess the potential advantages and complications associated with two-level unilateral dynamic stabilization (2LUDS) and the efficacy of unilateral dynamic stabilization surgery as an alternative to bilateral dynamic stabilization surgeries, according to clinical and radiological outcomes.

Materials and methods

In this study, all procedures performed were in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all participants included in the study.

Spinal patients who were operated in our clinic between 2017 and 2021 and had at least 2 years of clinical and radiological follow-up been analyzed retrospectively. The study included 43 patients who underwent surgery for 2-level unilateral dynamic system, single-level unilateral dynamic system, and bilateral dynamic system procedures.

The patients were diagnosed following detailed neurological and radiological imaging examinations to determine the location of pain. Direct radiography, computed tomography (CT), and magnetic resonance imaging (MRI) were performed on all patients. Patients with 2-level foraminal stenosis underwent 2-level unilateral dynamic system procedure, while the remaining patients underwent single-level unilateral dynamic system procedure.

In decompressions requiring facet joint removal in unilateral and single level pathologies, the segment was considered unstable and unilateral dynamic stabilization was applied. In addition, in disc herniation cases with a high risk of recurrence (accompanying modic degeneration, large annular tear, accompanying socialization, obesity, etc.), unilateral dynamic stabilization was applied to the side where discectomy performed. Bilateral dynamic stabilization was performed in patients with severe central canal stenosis and bilateral decompression due to bilateral symptoms. As dynamic systems, Dynesys DSS (Zimmer Inc., Warsaw, IN, USA) [15], Safinaz DSS (Dynamic screw, Medikon Tipsan AS, Turkey) [16] and PEEK rod was used.

Demographic data, pathologies leading to the operation, surgical complications, screw malposition rates, perioperative operation data, and clinical and radiological follow-ups of the operated cases were examined. The patients' quality of life and pain scores were evaluated using the visual analog pain scale (VAS) and the Oswestry disability index (ODI) at preoperatively and postoperative third months, sixth months, first year, and annually.

The patient's anamnesis, recorded during routine clinical follow-ups, was compared with the initial complaints, and analyzed. Compared to the preoperative period,

Table 1 Pathologies of the patients

Preoperative diagnosis, *n*	Procedure applied, *n*
Paramedian disc herniation,5	UDS, 1
	BDS, 4
	2LUDS
2 level foraminal stenosis,9	UDS
	BDS,
	2LUDS, 9
Foraminal stenosis, 8	UDS, 2
	BDS, 6
	2LUDS
Central spinal stenosis, 11	UDS, 1
	BDS, 10
	2LUDS
Tumoural lesions, 6	UDS, 1
	BDS, 5
	2LUDS
Extra foraminal disc herniation, 4	UDS, 4
	BDS
	2LUDS

UDS: Unilateral Dynamic Stabilization

2LUDS: 2 Level Unilateral Dynamic Stabilization

BDS: Bilateral Dynamic stabilization

the patient was examined for improvement in both his physical examination and symptoms, and patients whose clinical symptoms improved were recorded as benefiting from the operation.

Operation technique and nuances

Decompression approaches varied according to the location, severity and type of pathology. Cases requiring extensive facet resection, cases requiring extensive laminectomy for intra/extradural tumour resection and discectomy cases with high risk of recurrence were considered unstable. In addition, uni/bilateral dynamic stabilization was performed after decompression in cases with preoperative clinical examination findings compatible with instability, hyperintensity of facet joints, accompanying listhesis and vacuum phenomenon on computed tomography.

Following the decompression of neural structures, the dynamic screws were inserted into the corresponding pedicles of the affected levels with Wiltse approach. The dynamic rods were then connected to the screws, providing stability while allowing controlled motion.

Throughout all procedures, meticulous attention was given to ensure appropriate placement of dynamic screws and rods, aiming for optimal stability and motion preservation. Intraoperative imaging, such as fluoroscopy or O-arm navigation, was employed to verify the accuracy of screw placement. Postoperative radiographic evaluations were conducted to assess the alignment and position of the instrumentation.

Table 2 Demographic data of the patients

		Number	%
Age, Mean ± SD		39.13 ± 14.11	
Gender	Female	17	39,5
	Male	26	60,5
System	UDS*(total)	18	42,0
	BDS*	25	58,0
	2LUDS	9	21,0

UDS: Unilateral Dynamic Stabilization

2LUDS: 2 Level Unilateral Dynamic Stabilization

BDS: Bilateral Dynamic stabilization

Table 3 Distribution of the levels of the operation

Level	Number	%
Thoracal (T4-T10)	2	4.65
Thoracolumbar (T10-L2)	3	6.98
Lumbar (L2-L5)	31	72.09
Lumbosacral (L5-S1)	7	16.28

Statistical analyses

All statistical analyses were performed using IBM SPSS 20.0 software (IBM Corp., Armonk, NY, USA). Data are reported as the mean ± SD for normally distributed continuous variables and as number and percentage for dichotomous variables. Data were compared using the chi-square test for categorical data and the t-test or analysis of variance for continuous data. A two-tailed $p < 0.05$ was considered to indicate significant differences.

Results

A total of 43 patients were included in this study, consisting of 8 cases with foraminal stenosis, 4 cases with extraforaminal disc herniation, 6 cases with intradural extramedullary tumors, 11 cases with central spinal stenosis, 5 cases with paramedian disc herniation, and the remaining cases with 2-level spinal stenosis (Table 1). The study population comprised 26 (60.5%) males and 17 (39.5%) females, with a mean age of 39.13 ± 14.11 years (ranging from 23 to 65 years) (Table 2).

The mean clinical follow-up was 29.7 months (range 24–40 months). Among the patients, 18 underwent the unilateral dynamic system procedure, while 25 underwent the bilateral dynamic system procedure. Within the unilateral group, 9 patients were treated for 2-level spinal stenosis. Locations of the operations were presented in Table 3.

Between the two groups, no significant differences were observed in terms of symptomatic and radiological criteria. We assessed the preoperative and postoperative Visual Analog Scale (VAS) and Oswestry Disability Index (ODI) scores at different time points: preoperative, 6th month, 12th month, and 24th month. Both the unilateral and bilateral dynamic system procedures showed similar outcomes in terms of symptom relief and radiological

Table 4 Clinical parameters of the patients

		Preop	6th Month	12th month	24 month	*p**
		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	
VAS	UDS*	6,88±,78	2,36±,95	1,04±,93	0,96±,93	< 0,001
	2LUDS*	6,90±,78	2,33±,95	1,01±,93	0,99±,93	< 0,001
	BDS*	6,94±,78	2,39±,95	1,02±,93	0,93±,93	< 0,001
ODI	UDS	67,52 ± 6,74	26,96 ± 8,68	10,64 ± 11,21	9,52 ± 10,07	< 0,001
	2LUDS	69,12 ± 6,74	25,19 ± 8,68	12,51 ± 11,21	9,10 ± 10,07	< 0,001
	BDS	63,84 ± 6,74	28,73 ± 8,68	11,83 ± 11,21	11,31 ± 10,07	< 0,001

UDS: Unilateral Dynamic Stabilization

2LUDS: 2 Level Unilateral Dynamic Stabilization

BDS: Bilateral Dynamic stabilization

improvement (Table 4). The mean VAS score before the surgery was 6.88 ± 0.78, indicating a high level of pain. However, at the 6th month follow-up, there was a significant improvement in pain levels with a mean VAS score of 2.36 ± 0.95. This improvement was sustained at the 12th month with a mean VAS score of 1.04 ± 0.93, and further improved at the 24th month with a mean VAS score of 0.96 ± 0.93. These findings demonstrate a significant reduction in pain levels following the surgery, which persisted throughout the follow-up period ($p < 0{,}001$).

Regarding the ODI scores, the mean score prior to the surgery was 67.52 ± 6.74, indicating a high level of disability. However, at the 6th month follow-up, there was a significant improvement in functional capacity with a mean ODI score of 26.96 ± 8.68. This improvement further progressed at the 12th month with a mean ODI score of 10.64 ± 11.21 and remained stable at the 24th month with a mean ODI score of 9.52 ± 10.07. These results demonstrate a substantial improvement in functional capacity following the surgery, which was maintained over the long-term follow-up.

Among the cases analyzed, there were 1 (4%) subcutaneous hematoma and 1 (4%) superficial infection observed in the bilateral dynamic system group. Additionally, a total of 3 patients (12%) experienced neuropathic pain persisting for approximately 6 months after surgery, consisting of 1 patient who underwent foraminal stenosis decompression and 2 patients with adjacent segment disease. In the unilateral dynamic system group, 1 patient (11%) exhibited screw loosening in control imaging among the two-level unilateral dynamic system group, however patient was asymptomatic and did not require reoperation (Fig. 44). Notably, no rod fractures were observed during the 2-year follow-up period. No patient required reoperation in all groups during 2-year followup period. Patients in the unilateral dynamic system group had shorter surgical durations compared to the bilateral dynamic system group, 2LUDS: 61 min ± 13 min, 1LUDS: 49 min ± 15 min, BDS: 110 min ± 35 min. Similarly average blood loss is lower in unilateral dynamic stabilization compared to bilateral dynamic stabilization group, 2LUDS: 158.94 ml ± 52.27 ml, 1LUDS: 114.72 ml ± 33.84 ml, BDS: 221.1 ml ± 74.60 ml. Selected cases from this series are illustrated in Figs. 1, 2, 3 and 4.

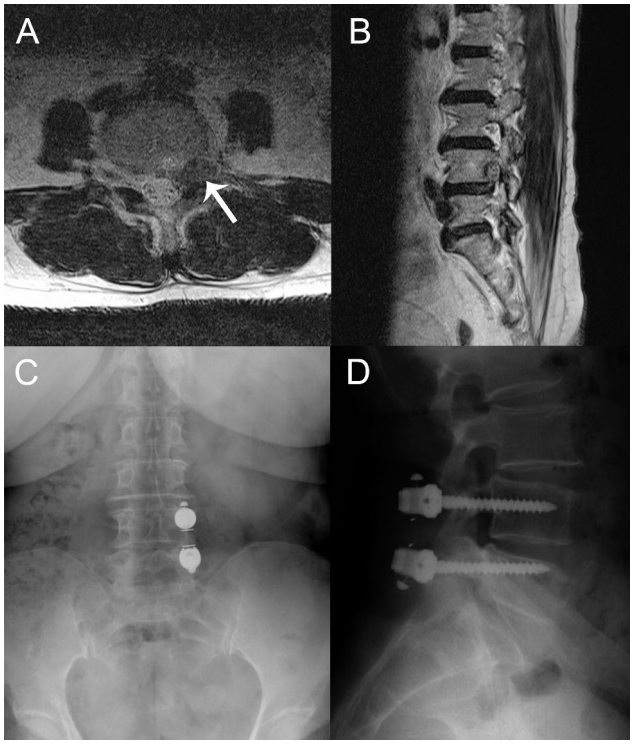


Fig. 1 Patient with wide-based annular tear and left L4 disc herniation that extended to far-lateral region. Discectomy and unilateral dynamic stabilization with Safinaz screw and PEEK rod was performed at L4-L5. Preoperative (**A**) axial and (**B**) sagittal T2W MRI, postoperative (**C**) anteroposterior and (**D**) lateral X-Rays. Arrow indicates extraforaminal disc herniation

Discussion

Facet joints are biomechanically important elements of the spine. They involve in movement process of the spine, contribute the equal distribution of the load, and provides stability. Facetectomy which is performed for the spinal pathologies reduces the stability of the spine and alters the biomechanics of the spine [17]. In their study, Karakoyun et al. have showed that while performing

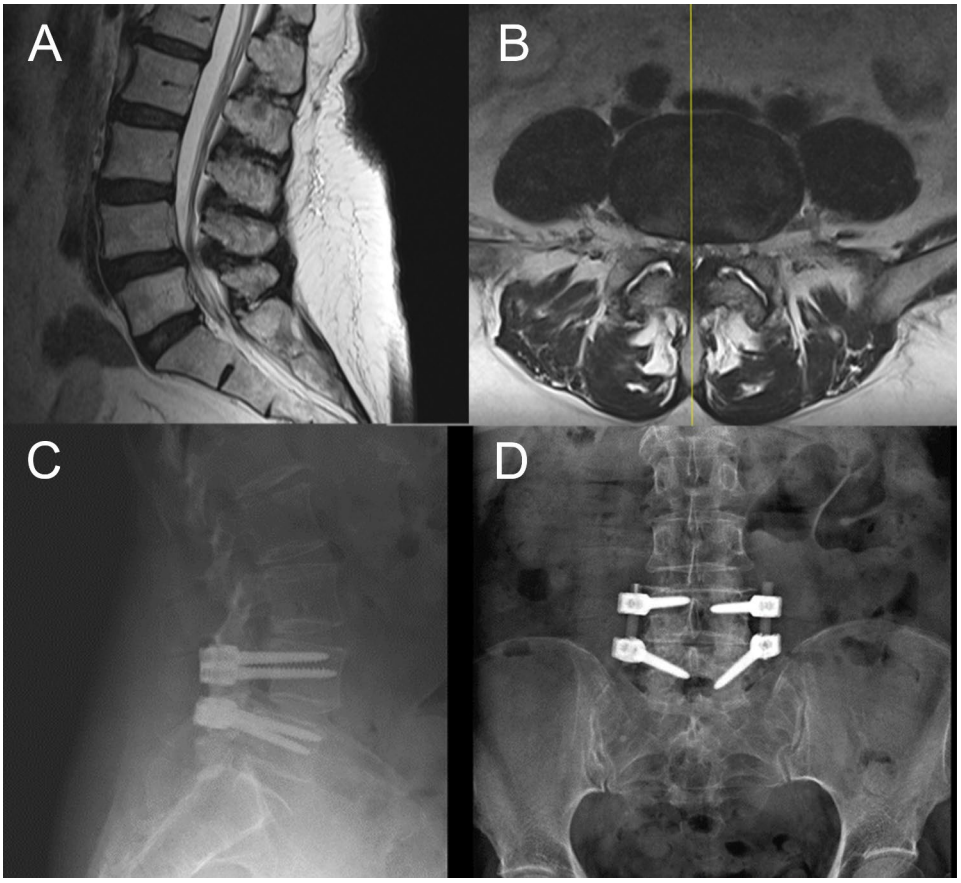


Fig. 2 Patient with lumbar spinal stenosis (Schizas Grade C, Lee Grade 3) presented with neurogenic claudication and lower back pain. Decompression and bilateral dynamic stabilization at L4-L5 were performed. Safinaz screw a PEEK rod were used for dynamic stabilization. (**A**) preoperative sagittal T2W MRI, (**B**) preoperative axial T2W MRI postoperative standing (**C**) lateral and (**D**) anteroposterior X-Rays

lateral bending and flexion tests, facetectomy operation caused a reduction in the yield moved and stiffness, increase in the flexion and lateral bending angles have been also observed which as a result created instability to the spine [9]. Abumi et al. showed that even the removal of the supraspinous/interspinous ligament did not alter range of motion, on the other hand, total facetectomy created instability to the spine [18]. Cusick et al. also demonstrated that even posterior ligaments are not removed, after total facetectomy, spinal instability was observed [19]. Thus, in the most of the facetectomy cases, stabilization is required.

Fusion surgery can be done unilaterally or bilaterally. Several studies investigated safety and efficacy of the unilateral and bilateral pedicle stabilization with rigid systems and compared their clinical outcomes. Kabins et al. reported that clinical outcomes of the unilateral fixation are similar to bilateral fixation at L4-L5 levels [20]. In their prospective, randomized study comparing unilateral and bilateral pedicle screw fixation, Suk et al. reported that there is no significant difference between the groups in terms of blood loss, operation time or complication rates. They concluded that unilateral pedicle fixation can be used effectively for the surgery of unilateral vertebral pathologies instead of bilateral pedicle fixation [21]. Xie et al. also compared unilateral and bilateral pedicle screw fixation with interbody fusion which was performed with cages. They also showed that unilateral fixation is a safe and preferable procedure which can be used as an alternative to the bilateral fixation [22].

Stabilization of the spine with rigid systems is commonly performed during clinical practice after spinal facetectomy procedures. Bilateral stabilization is commonly used in the routine practice, on the other hand, unilateral instrumentation gained acceptability in recent years, and it has several advantages compared to facetectomy without fusion. After instrumentation, there is no need for the external immobilization, fusion rates increase and allows to early ambulation of the patient [23]. On the other hand, there are several disadvantages of spinal stabilization systems. Firstly, reduction in bone mineral content is not only observed at operated segment, but it also observed at the adjacent segment in dog models [11]. Secondly, due to increased stiffness of the operated

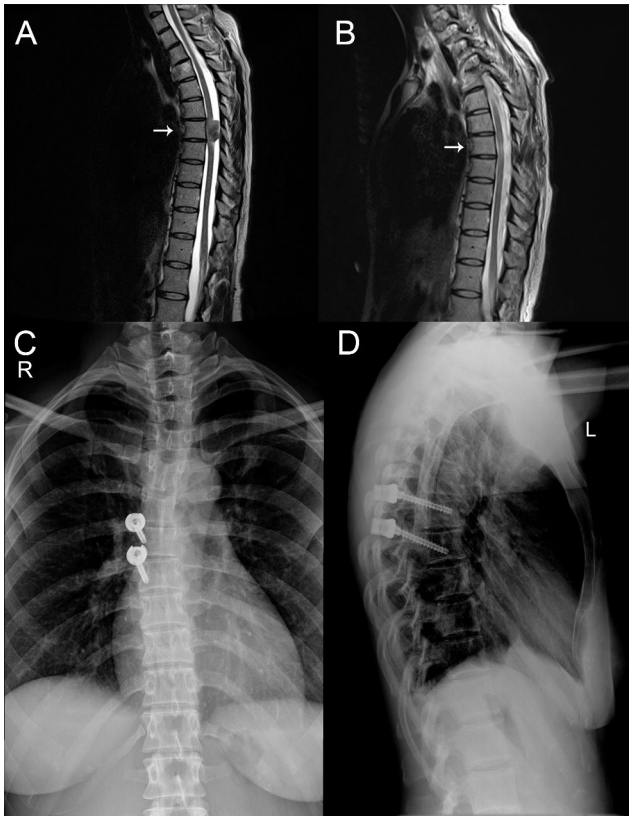


Fig. 3 The patient with a Schwannoma located at the T7-T8 level underwent surgery. (**A**) preoperative and (**B**) postoperative sagittal T2W MRI showing gross total resection. Postoperative (**C**) anteroposterior and (**D**) lateral X-Rays showing Unilateral dynamic stabilization with Safinaz and PEEK rod at T7-T8. Arrow indicates T7 vertebral body

segment, degeneration of the adjacent segment is also observed. Non-fusion systems such as dynamic stabilization decreases the adjacent segment degeneration, partially protects the motion of the operated segment, and reduction in the bone-fusion related complications [24]. However, as mentioned before, dynamic stabilization also has some drawbacks [25, 26]. There are also studies who observed higher reoperation rate, not significant difference with fusion systems in terms of effect on the adjacent segment degeneration and higher failure rates especially in some elderly patients and in the operations which require stabilization of the more than one segment [27].

In this study, we evaluated the efficacy of unilateral dynamic stabilization and bilateral dynamic stabilization in terms of clinical outcomes and complications. To our knowledge, the comprehensive analysis of effectiveness of both unilateral and bilateral dynamic stabilization methods together has not been previously conducted. It was aimed to obtain adequate but not exaggerated stabilization for the patients who undergone unilateral facetectomies and we have found several advantages of that approach. Firstly, to perform this procedure, unilateral muscle dissection is enough, thus, risk of the post-surgical late atrophy of the oppositely located paravertebral muscle is eliminated. Also, since contralateral site is not operated, possible complications that can be encountered during that operation is eliminated. Operation time and hospital stay time decreased. Finally, since only one side operated, cost of the operation is reduced.

In our previous work [5], we introduced unilateral dynamic stabilization as a promising technique for addressing unilateral spinal pathologies. Karakoyun et al. demonstrated the efficacy of unilateral dynamic rod stabilization in protecting segmental movements and providing sufficient stability for patients undergoing unilateral facetectomy [6]. Additionally, their study on cadavers with unilateral spinal pathologies highlighted the safe and effective clinical outcomes achieved with unilateral dynamic pedicle screw fixation at the L4-L5 level [9].

Evaluating patients with unilateral spinal pathologies undergoing either unilateral or bilateral dynamic stabilization revealed that unilateral stabilization is a safe and effective option for single-level pathologies, with no significant differences observed in terms of ODI scores, VAS scores, or radiological examinations. However, for multilevel stabilizations, bilateral stabilization yielded better results in terms of complications. Our findings suggest that both unilateral and bilateral dynamic stabilization procedures are safe and effective in treating various pathologies, including foraminal stenosis, extraforaminal disc herniation, intradural extramedullary tumors, and two-level spinal stenosis. There were no significant differences between the two approaches in terms of symptomatic and radiological outcomes. Both techniques resulted in significant improvements in symptom relief and functional disability, as evidenced by reductions in VAS and ODI scores.

Similar to bilateral dynamic stabilization, single-level dynamic stabilization produced low complication rates and comparable clinical outcomes; thus, underlying its application in single-level operations to be a safe and effective alternative technique for unilateral spinal pathologies. However, when Unilateral Dynamic Stabilization was utilized for multiple level operations, we observed instance of instrumentation failure. It may be due to the increased stress exerted on the construct when multiple levels are involved. Additionally, achieving optimal fixation with unilateral dynamic screw stabilization becomes more challenging as the number of levels increases, potentially compromising the proper placement of the construct. These findings emphasize that while unilateral dynamic stabilization is a viable for single-level operations, caution should be exercised when considering its use for multiple levels due to the increased risk of instrumentation failure.

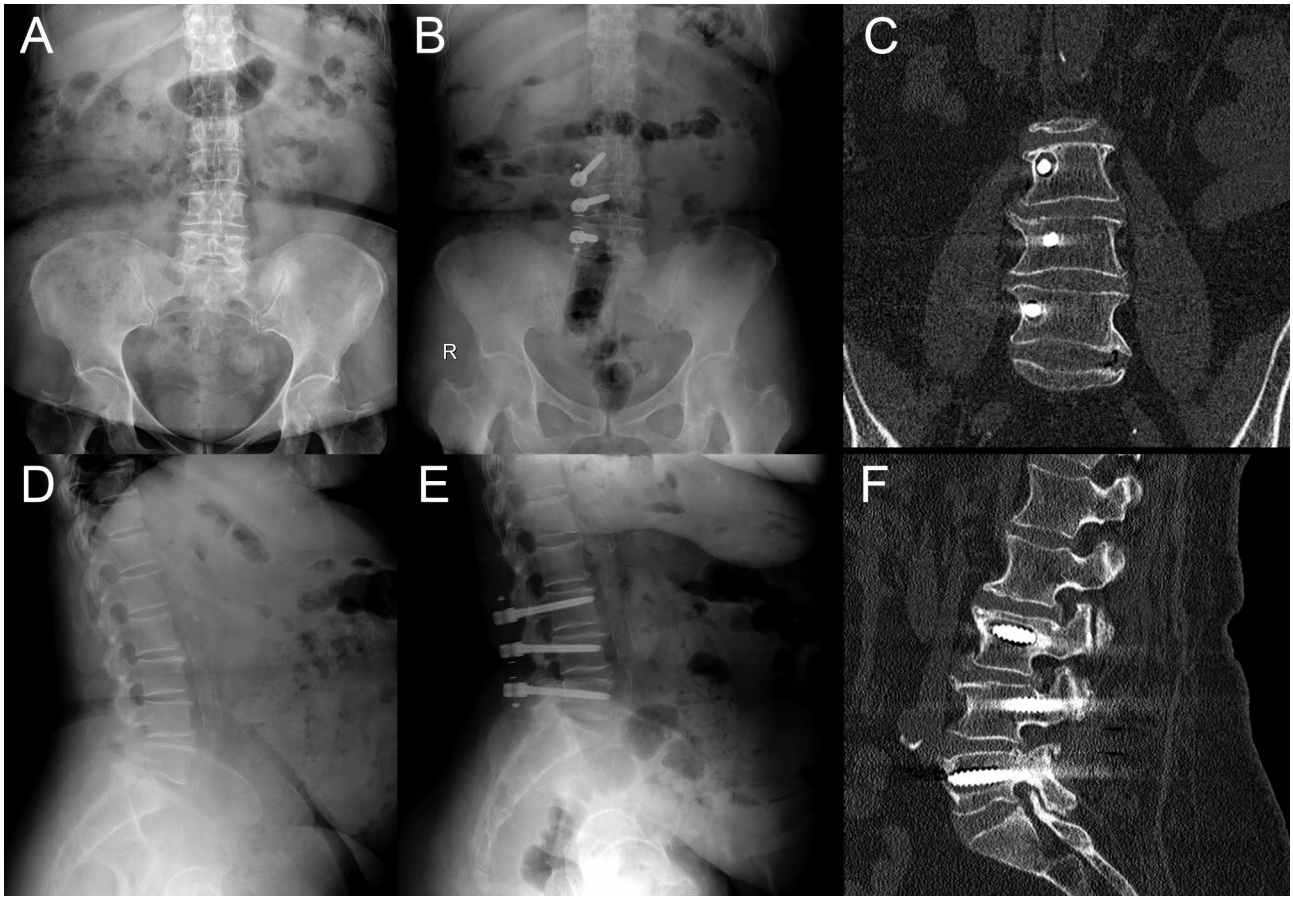


Fig. 4 Patient with two-level foraminal stenosis on right L3-L4 and L4-L5 levels presented with lower back pain, right sciatalgica and neurological deficit. Two level hemilaminectomy and unilateral dynamic stabilization was performed with Safinaz and PEEK rod. Preoperative (**A**) anteroposterior and (**D**) lateral standing X-Rays, postoperative (**B**) anteroposterior and (**E**) lateral standing X-Rays. Postoperative (**C**) coronal and (**F**) sagittal CT images at 12th month showing marked screw loosening at L3 and L5

There are several limitations of this study. Firstly, the retrospective nature of the study design introduces inherent biases and limitations. Secondly, the relatively small sample size of the study population may limit the generalizability of the findings. Furthermore, the follow-up period of the study may not capture long-term complications or changes in patient outcomes over time. Lastly, the heterogeneity of the patient groups in terms of disease types and severity limits the ability to evaluate the comparative effectiveness of unilateral versus bilateral dynamic stabilization in specific patient subgroups. Further prospective studies with larger cohort and patient categorization is needed to better understand the efficacy of unilateral dynamic stabilization in treating unilateral spinal pathologies.

Conclusion

Unilateral dynamic systems are safe and efficient for treating unilateral spinal pathologies for the single level, there was not any significant difference between patients in terms of ODI scores, VAS scores and radiological examinations when compared to patients who undergone bilateral dynamic stabilization. Advantages includes lesser complications since contralateral site is not operated, reduction in operation time, hospital stay time and cost. However, instances of instrumentation failure were observed in patients who underwent unilateral dynamic stabilization for multi-level operations. Future studies with more homogeneous patient groups will be needed to validate these findings and further refine surgical indications.

Author contributions

All authors contributed to the study conceptionand design. Material preparation, data collection, and analysis were performed by all authors. The first draft of the manuscript was written by Mehmet Yigit Akgun, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data availability
The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
This study was conducted in accordance with the Declaration of Helsinki and approved by the local ethics committee. [Institutional Review Board of Koc University Hospital (2022.021.IRB.016)]. Informed consent obtained from all the individual participants in this study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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