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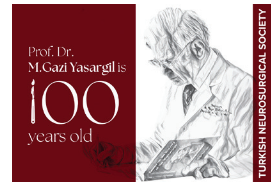

Original Investigation

Spine and Peripheral Nerves

Evaluation of Early Sagittal Balance Parameters in Patients Undergoing Bilateral Decompression with a Unilateral Approach in Lumbar Spinal Stenosis Surgery

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ABSTRACT

AIM: To observe the impact of the bilateral decompression with a unilateral approach technique, which is an effective and safe method in the surgical treatment of lumbar spinal stenosis (LSS) on the biomechanics of the spine in the early postoperative period and observe changes in sagittal balance parameters.

MATERIAL and METHODS: Forty-one patients who underwent bilateral lumbar decompression with a unilateral approach between March 2020 and March 2022 at our clinic were followed up prospectively for 1 year from the date of their operation, and their sagittal balance parameters were measured by performing whole-body radiography. The measurements were analyzed and recorded with Surgimap® (Nemaris, Inc. product, USA). Patients were divided into 3 groups (<50 mm, ≥50 mm- <100 mm, ≥100 mm) according to their Sagittal Vertical Axis (SVA) values in preoperative measurements. The groups' clinical parameters and sagittal balance parameters were compared as preoperative and postoperative.

RESULTS: Significant improvements were detected in the sagittal balance parameters of patients who underwent bilateral decompression with a unilateral approach in the LSS. SVA values decreased significantly from 64.8 mm preoperatively to 48.6 mm. We observed a significant increase in the lumbar lordosis angle from 41.7° to 45.9°. Functional improvements were observed with clinical pain control and an increase in walking distance in these patients. Furthermore, improvements were also observed in compensatory mechanisms along with improvements observed in sagittal alignment. Pelvic tilt and knee flexion angles decreased.

CONCLUSION: Bilateral decompression surgery with a unilateral approach, which is a minimally invasive approach in patients with lumbar degenerative stenosis, is an effective method that causes improvements in sagittal balance parameters and compensation mechanisms in these patients and ensures clinical improvement in these patients.

KEYWORDS: Hemilaminotomy bilateral decompression, Lumbar spinal stenosis, Minimally invasive surgery, Unilateral laminotomy, Sagittal balance

INTRODUCTION

It is estimated that the incidence of lumbar spinal stenosis (LSS) is between 3.9% and 11% of the population (14), and its prevalence increases in our aging population (7). In LSS, decompressive surgical treatment has been shown to be more effective than non-surgical treatments for eligible patients (21,24,32). Various decompressive surgical procedures, which differ in terms of the invasiveness of the intervention, are available nowadays. These range from minimally invasive segmental laminotomy, which preserves all posterior structures, to wide laminectomy with invasive facetectomy (23).

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Decompression with laminotomy and laminectomy, or instrumented fusion (IF) with decompression of the treated level are the most common surgical methods. A more radical and invasive approach, such as IF, is usually selected if pathological or iatrogenic destabilization of the spine is suspected (3).

The bilateral decompression technique with a unilateral approach preserves the bilateral facet joints and neural arch, allowing bilateral nerve decompression to be carried out. It minimizes postoperative instability and prevents scarring of nerve tissue with posterior elements (25). First described by Young in 1988 (33) and later modified by McCulloch, it is a microscopic technique that provides unilateral multifidus retraction and ipsilateral microdecompression and is characterized by contralateral microdecompression performed under midline posterior structures and has been employed with some modifications by the current authors since 1995.

The significance of sagittal balance has been better understood in recent years, and its assessment is now more frequently taken into account in surgical decisions. Its importance in spinal deformity and its relationship with clinical parameters have been clearly revealed (5,30). In contrast, few studies have researched changes in sagittal balance after isolated decompression surgery (9,15,23). Global sagittal balance is an inevitable subject that must be considered in the surgical treatment strategy for patients with LSS. Since the spinal canal widens with forward bending, the compensatory reduction in lumbar lordosis (LL) is likely to induce global sagittal imbalance (9). A forward-leaning posture leads to an increase in the sagittal vertical axis (SVA) and a decrease in LL, disrupting the global sagittal alignment. The increase in knee flexion, which is a compensatory mechanism, is another indicator of global sagittal imbalance (4,20).

The objective of the present study is to assess changes in global sagittal balance following bilateral decompression surgery with a posterior unilateral approach, which is a fusionless and minimally invasive method, in symptomatic LSS patients. Furthermore, our study is the first in the literature researching the relationship of bilateral decompression, especially with the unilateral approach, with global sagittal balance and changes in global compensatory mechanisms.

MATERIAL and METHODS

This study was approved by the Institutional Review Board (IRB) of Erciyes University in March 2020 (Approval No: 2020/183).

Study Design

In the current study, 41 patients who underwent bilateral lumbar decompression with a unilateral approach between March 2020 and March 2022 at Erciyes University, Faculty of Medicine, Neurosurgery Clinic were followed up prospectively for 1 year from the date of surgery, and canal stenosis was evaluated by performing preoperative lumbar MRI on these patients, the differential diagnosis of listhesis was established by taking dynamic radiographs, and the findings were examined with sagittal and coronal balance evaluation by taking the PA and lateral radiographs of the whole body. One year after the surgery, they were called for control again, their clinical examination was performed, whole-body radiographs were taken, sagittal balance parameters were measured, and evaluation was carried out by comparing them preoperatively and postoperatively.

Inclusion Criteria

The inclusion criteria are as follows: 1) patients who had symptoms for more than 3 weeks due to lumbar degenerative disease but did not respond to conservative treatment; 2) patients with proven lumbar spinal stenosis on MRI; 3) the presence of clinical and active complaints compatible with radiology; 4) the presence of spondylolisthesis not exceeding Grade 1.

Exclusion Criteria

The exclusion criteria are as follows: 1) Advanced spondylolisthesis according to the Meyerding classification (Grade>1); 2) Instrumented patients; 3) Patients with scoliosis (Cobb angle >20°); 4) Any previous lumbar surgery; 5) Non-degenerative LSS conditions (trauma, advanced osteoporosis, infection, tumor, congenital condition, etc.), 6) Spinal instability

Radiological Parameters

Sacropelvic and spinal parameters such as LL, SVA and pelvic balance parameters such as sacral slope (SS), pelvic tilt (PT), pelvic incidence (PI), and knee flexion angle (DFA) were measured using the Cobb technique in the PA and lateral spine scoliosis radiographs of all patients in the preoperative period and postoperative 1st year. Spine surgeons and radiologists evaluated these measurements (1).

To ensure healthy visualization of the spine, radiographs were taken while patients were standing in an upright position, with the arms in flexion, and the fingers at the level of the clavicle. The patients were told to stand upright and look straight ahead during imaging (16).

The patients were divided into 3 groups according to the degree of sagittal imbalance. In general, SVA values on preoperative radiographs were used to define balance (26, 29). The threshold value of 50 mm for SVA measurements was based on previous studies on other spinal deformities (27). The first group (Group 1) consisted of patients with normal sagittal balance with an SVA value of <50 mm, the second group (Group 2) consisted of patients with minor sagittal imbalance with an SVA value of ≥50 mm and <100 mm, and the third group (Group 3) comprised patients with major sagittal imbalance with an SVA value ≥100 mm. We compared radiological parameters and clinical outcomes according to these groups

Clinical Parameters

Age, sex, and the level or levels of the narrow spinal canal at which the surgery was performed were recorded for all patients. The visual analog scale (VAS) was used to evaluate pain intensity in the lower back and legs. Moreover, all patients filled out the Zurich Claudication Questionnaire (ZCQ), which measures the combination of physical function, severity of symptoms, and patient satisfaction. The questionnaire consists of two sections: ZCQ Symptom Frequency (ZCQ-SF) and ZCQ Physical Function (ZCQ-PF). The ZCQ represents an inquiry questionnaire used to measure symptom severity in LSS. A high score from this questionnaire indicates a multiplicity of symptoms (31).

Surgical Technique

All surgeries were performed under general anesthesia and in the prone position. A midline skin incision of about 2-3 cm was made on the side where the patient's complaints were dominant and on the side with more stenosis on lumbar CT or MR images in patients without side findings, according to the distance number to be decompressed. The lumbosacral fascia was opened from the midline. After the subperiosteal stripping of the paravertebral muscles, a Williams or Taylor retractor was placed on the surgical field and the paravertebral muscles were retracted. If a Taylor retractor is used, a weight of 500 g – 1 kg is hung on the retractor (in practice, it is ensured by hanging 1000 cc normal saline). The hemilaminotomy and foraminotomy were performed using a microscope and a high-speed drill. The hypertrophic ligamentum flavum was excised using a Kerrison rongeur, and the lateral recess was opened using a Kerrison and high-speed drill from below by performing a partial mesial facetectomy in a way preserving the facet joint.

Afterward, the operating table was tilted to the opposite side, and the angle of the microscope was changed to face the other side. As a result, an angle of about 60 – 70 degrees is achieved with these maneuvers. Thus, a very good image is acquired for the other side. The ligamentum flavum was excised up to the margin of the thecal sac and pedicle of the contralateral side with a Kerrison rongeur. The bottom of the spinous process was taken with a high-speed drill and a curved Kerrison rongeur. Thus, the opposite foramen and lateral recesses became visible under the microscope. The under of contralateral lamina is partially removed, if marked hypertrophic bone spurs arising from the facet joints and impinging on the dural sac. Likewise, decompression was provided the opposite side (Figure 1). If necessary, the same procedure can be applied to an upper and a lower levels. If considered sufficient, only hemipartial laminectomy should be performed. Thus, hemilaminectomy was performed only in necessary cases. In this way, both sides were decompressed under the microscope, and the surgery was terminated (Figure 2).

Statistical Analysis

Statistical analysis was conducted using a package program SPSS (IBM SPSS Statistics 24). Frequency tables and descriptive statistics were used in the interpretation of the results.

Parametric methods were employed for the measurement values suitable for normal distribution. In accordance with parametric methods, the "Paired Sample" test (t-table value) was used to compare two dependent groups with measurement values, and the "ANOVA" test (F-table value) method was used to compare three or more independent groups.

Non-parametric methods were employed for the measurement values not conforming to the normal distribution. In accordance with non-parametric methods, the "Wilcoxon" test (Z-table value) was used to compare two dependent groups with measurement values, and the "Kruskal-Wallis H" test (χ 2 -table value) method was employed to compare three or more independent groups. "Pearson-χ 2 crosstabs" were used to examine the relationships between two qualitative variables.

RESULTS

Patient Population

The present study included 41 patients who met our inclusion criteria and were followed up for 12 months. The mean age of the patients at the time of surgery was 62.8 (±7.9) years. Twenty-one (52%) patients were male, and 20 (48%) were female. LSS was at a single level in most patients (44%). The most frequently operated vertebral level was L4-L5 (49%). Table I contains demographic data.

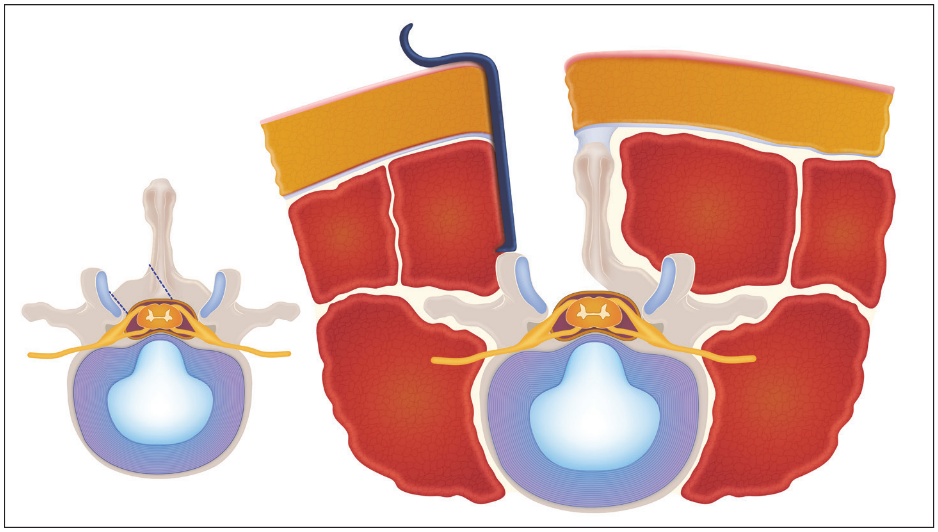

Figure 1: The bilateral lumbar decompression with a unilateral approach technique.

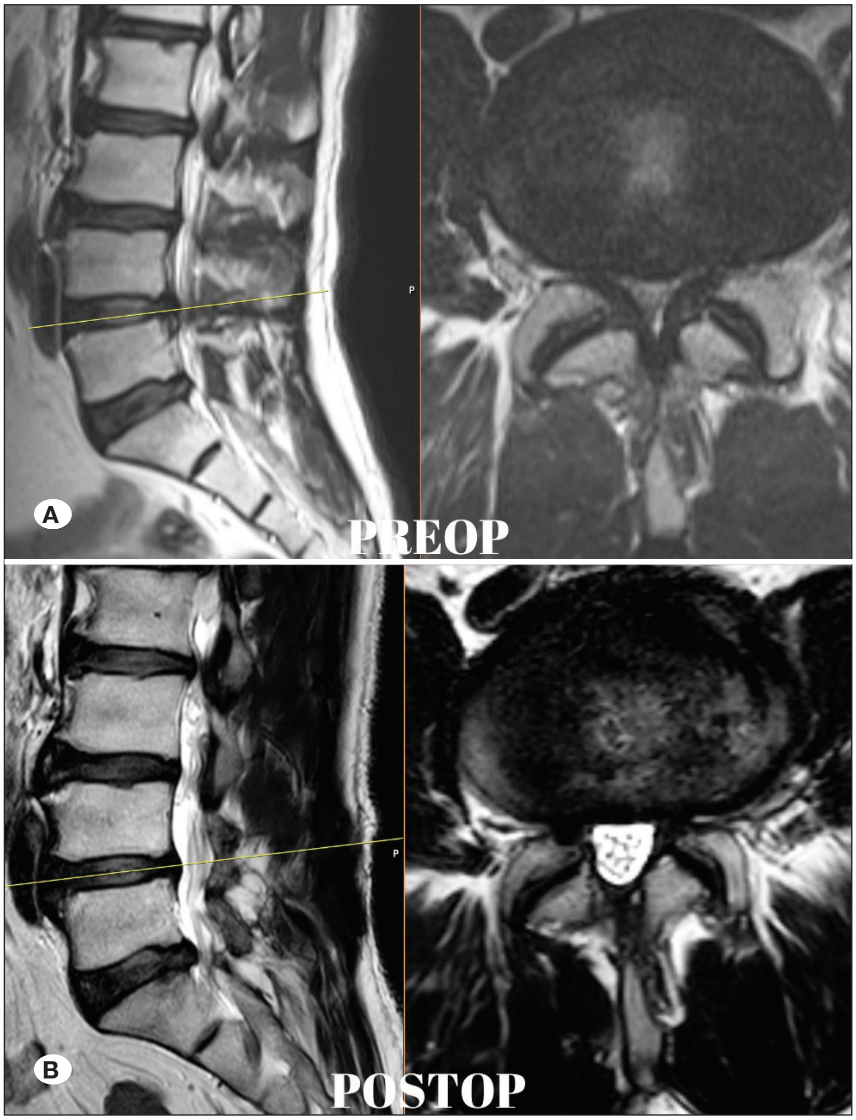

Figure 2: Preoperative **(A)** and postoperative **(B)** axial and sagittal magnetic resonance images. The lumbar spinal canal was evidently decompressed, including the decompressed side and the opposite side.

General Preoperative and Postoperative Radiographic Results

Table II contains the radiographic parameters evaluated in the preoperative period and at the 12th month as the average of the overall patient total. The SVA measurement decreased significantly in postoperative evaluations (preoperative SVA: 64.8 ± 47.8; postoperative SVA: 48.6 ± 42.2; p<0.001) (Figure 1). LL increased significantly from 41.7 ± 19 preoperatively to 45.9 ± 18.6 in the final follow-up (p<0.001). PT decreased from 19.8 ± 7.9 preoperatively to 17.3 ± 7.9, and pelvic retroversion improved (p<0.001). SS increased significantly from 32.8 ± 10.5 preoperatively to 35.1 ± 11 (p<0.001). The knee flexion angle (KFA), another compensatory mechanism, decreased from its preoperative value of 12.6 ± 6.3 to 9.9 ± 5.4 postoperatively, and this decrease was found to be statistically significant (p< 0.001).

Clinical Preoperative and Postoperative Results

Table II presents the overall clinical outcomes. In the VAS evaluation performed for low back and leg pain, the mean value of 7.1 ± 0.8 preoperatively decreased statistically significantly to 2.3 ± 1.3 (p<0.001). The mean ZCQ score also improved (from 3.1 ± 0.4 to 2 ± 0.6 for physical function; from 2.4 ± 0.3 to 1.6 ± 0.4 for symptom severity). Considering all these results, we observed a significant improvement in the postoperative conditions of patients compared to their preoperative conditions and a significant decrease in their complaints.

Preoperative and Postoperative Radiographic Results Between the Groups According to SVA

Table III shows differences in radiographic parameters between the groups. The preoperative mean SVA value of 23.9 ± 12 mm decreased to 15.9 ± 8.9 mm postoperatively in the balance group and from 63.5 ± 11.4 mm preoperatively to 41.2 ± 16.5 mm postoperatively in the minor imbalance group, whereas it decreased from 133.1 ± 25 mm preoperatively to 110 ± 24.9 mm postoperatively in the major imbalance group (p<0.001).

The lowest LL value was detected in the major imbalance group. An increase in the postoperative LL value was observed in all three groups, but this value was not statistically significant. An increase in the PT value was found in all groups. SS was revealed to increase in all groups. However, these values were not statistically significant. The KFA value, another compensatory mechanism, decreased in all groups. The greatest decrease in the KFA value was detected in the major imbalance group.

A significant decrease was detected in the SVA value in all three groups. The minor imbalance group was the group with the highest decrease. The value in this group decreased to 43.2 ± 16.5 on average and reached the balance group values. The greatest residual imbalance was observed in the major imbalance group. Nevertheless, significant improvements were observed in the compensatory mechanisms of PT, SS, and KFA in this group. Whereas improvement in LL was determined in all groups, the most significant improvement was observed in the major imbalance group.

DISCUSSION

Wide total laminectomy and partial or complete facetectomy are performed in the traditional surgical treatment of LSS (17). This traditional surgical procedure ensures neural decompression and leads to the complete removal of the posterior column, which is involved in spinal stabilization. Furthermore, the wide subperiosteal stripping of the paravertebral muscles causes the prolongation of the surgery duration in patients, exposure of the patient to more anesthetic agents, more intraoperative bleeding, and more postoperative pain. The purpose of surgical treatment in cases of LSS is to decompress the neural elements and preserve spinal stability. Minimally invasive surgical methods gain importance not to cause postoperative instability in the removal of bone and soft tissues for decompression (2,12). Damage to the midline supraspinous and interspinous ligament complex causes a loss of stabilization. This increases the risk of spinal instability (13).

Table I: Demographic Data

Characteristic	**Value**
Number of Cases	41
Mean age (years) (±std. dev.)	62.8 (±7.9)
Age Groups (years)	
≤54	6
55-64	17
≥64	18
Sex, M/F	21/20
Decompression segments (no. cases)	
1	18
2	15
3	6
4	2
Decompression level (no. cases)	
L2-3	7
L3-4	22
L4-L5	37
L5-S1	9

***M:** male, **F:** female.*

Table II: Preoperative and Postoperative Sagittal Parameters and Clinical Outcomes

	Pre-op	**Post-op**	**Difference Between Preop and Post-op (p-value)**
SVA, mm	64.8 ± 47.8	48.6 ± 42.2	**<0.001**
LL, °	41.7 ± 19	45.9 ± 18.6	**<0.001**
PT, °	19.8 ± 7.9	17.3 ± 7.9	**<0.001**
PI, °	50.5 ± 12.5	50.4 ± 12.7	0.81
SS, °	32.8 ± 10.5	35.1 ± 11	**<0.001**
PI-LL, °	7.6 ± 14.6	4.4 ± 13.2	**<0.001**
KFA, °	12.6 ± 6.3	9.9 ± 5.4	**<0.001**
ZCQ (Physical Function)	3.1 ± 0.4	2 ± 0.6	**<0.001**
ZCQ (Symptom Severity)	2.4 ± 0.3	1.6 ± 0.4	**<0.001**
VAS	7.1 ± 0.8	2.3 ± 1.3	**<0.001**

*Pre-op indicates preoperative; **Post-op:** Postoperative; **SVA:** Sagittal vertical axis; **LL:** Lumbar lordosis; **PT:** Pelvic tilt; **SS:** Sacral slope; **PI-LL:** Pelvic incidence minus lumbar lordosis; **KFA:** Knee flexion angle; **ZCQ:** Zurich Claudication Questionnaire; **VAS:** Visual analog scale*

Table III: Comparison of Sagittal Parameters Between Groups According to Preoperative SVA Values

Radiologic Parameters	Group SVA <50 (n=17)	Group SVA ≥50 mm <100 (n=13)	Group SVA ≥100 (n=17)	p-value
SVA, mm				
Pre-op	23.9 ± 12	63.5 ± 11.4	133.1 ± 25	**<0.001**
Post-op	15.9 ± 8.9	41.2 ± 16.5	110 ± 24.9	**<0.001**
LL, °				
Pre-op	47.2 ± 19.5	43.1 ± 18.9	31 ± 14.7	0.09
Post-op	50.7 ± 17.4	47.4 ± 18	36.5 ± 19	0.2
PT, °				
Pre-op	18.3 ± 8.7	22.2 ± 7.8	19.6 ± 6.7	0.3
Post-op	16.6 ± 8.3	19.3 ± 8.2	16.4 ± 7.1	0.3
PI, °				
Pre-op	50.5 ± 14.2	50.5 ± 13.5	50.3 ± 9	0.8
Post-op	50.6 ± 14.5	50.4 ± 13.6	50.2 ± 8.9	0.8
SS,°				
Pre-op	32.9 ± 9.8	31.9 ± 13.7	33.5 ± 8.2	0.4
Post-op	35.6 ± 10.9	33.5 ± 13.8	36 ± 8.5	0.4
KFA,°				
Pre-op	10 ± 4.8	11.1 ± 4.4	18.3 ± 7	**0.01**
Post-op	8.2 ± 3.9	9.2 + 4.5	13.5 ± 7.1	0.1

***SVA:** Sagittal vertical axis, **Pre-op:** Preoperative, **Post-op:** Postoperative, **LL:** Lumbar lordosis, **PT:** Pelvic tilt, **PI:** Pelvic incidence, **SS:** Sacral slope, **KFA:** Knee flexion angle.*

Sagittal imbalance represents a major cause of low back pain among low quality of life and spinal deformities (10). It is a risk factor for mechanical failure and poor outcomes following corrective surgery (19). Hence, it is essential to consider SVA when planning surgery (19,28). It is definitely known that abnormal preoperative and/or postoperative sagittal balance parameters influence the clinical outcomes of surgery. Studies have demonstrated that spinal fusion in degenerative lumbar diseases may have harmful effects on the spine, such as a decrease in SS and LL (11,18,22). The failure to provide LL properly after fusion causes abnormal PT development, which leads to chronic low back pain.

The current research is the first prospective study specifically investigating changes in global sagittal balance parameters, including compensatory mechanisms, in bilateral decompression surgery with a unilateral approach, which is a minimally invasive method. As seen in this study, regardless of the preoperative sagittal balance alignment, a minimally invasive surgery without fusion performed for LSS pathology within indications can cause an improvement in postoperative sagittal balance alignment (Figure 3). Bilateral decompression surgery with a unilateral approach is a safe and preferable method because it improves both clinical and radiological outcomes.

Little is known about the mechanism underlying the reactive improvement in global sagittal alignment. Endo et al. demonstrated a decrease in the degree of LL and an increase in SVA value in patients with lumbar disc herniation (8). Moreover, they stated that the change was secondary to the analgesic response and probably did not originate from structural deformity. Endo et al. revealed that pelvic back tilt and trunk forward bend were observed in patients with LCS (8). This forward-leaning posture increases the diameter of the spinal canal and alleviates the symptoms of neurogenic claudication. The said posture leads to anterior sagittal imbalance and an increase in SVA value. Fuji et al. suggested that compensatory forward-leaning posture, developing due to LSS, improved after decompression, which improved the global sagittal balance alignment by causing an increase in LL (9).

Hikata et al. showed that sagittal imbalance values normalized in 52% (23 out of 44) patients with SVA values ≥ 50 mm and undergoing decompression by spinous process splitting in 12-month follow-ups (15). Permanent sagittal imbalance was detected in the follow-up of patients with an SVA value of ≥ 80 mm. In our study, the patients were followed up for 12 months postoperatively, and the postoperative SVA value of the patients with a mean SVA value of 64.8 mm decreased to 48.6 mm. The patients' LL increased. A decrease in pelvic retroversion (PT) was revealed, and the preoperative PT decreased from 19.8° to 17.3°. The PI-LL value approached the normal balance by decreasing from 7.6 to 4.4. Knee flexion angles, a compensatory response developing preoperatively in patients, decreased from 12.6° to 9.9°. These results demonstrate that there are improvements in the forward-leaning posture, which is likely to be reactive, following bilateral decompression with a unilateral approach and adequate decompression, the com-

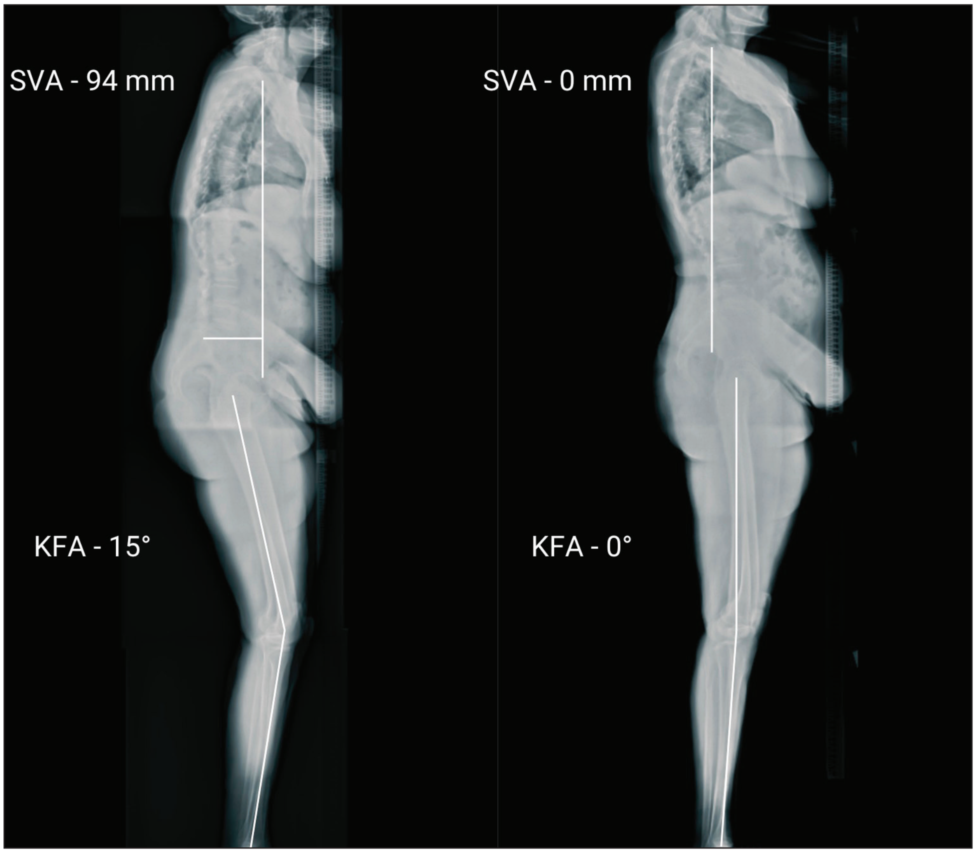

Figure 3: An example of change in the preoperative and postoperative sagittal alignment. SVA decreased from 94 mm preoperatively to 0 mm. Pelvic tilt decreased. An increase in the sacral slope was observed. The knee flexion angle decreased from 15° to 0°.

pensatory mechanisms developing against this imbalance are disrupted, and these responses also decrease.

Madkouri et al. prospectively followed up 72 patients with LSS after they operated them with bilateral laminotomy surgery and evaluated the patients by taking their lateral radiographs in the 1st year postoperatively. They showed that patients with preoperative SVA values of 72 mm had postoperative SVA values of 48.3 mm, and preoperative LL increased from 41˚ to 46˚. In this study, the researchers stressed that the preoperative SVA values of patients with postoperative residual imbalance were >100 mm (23). In our study, the most significant change in sagittal imbalance was observed in the group with an SVA value between 50 mm and 100 mm. The SVA value, which was 63.5 mm preoperatively, decreased to 41.2 mm postoperatively in this group. Although postoperative residual imbalance remained in the major imbalance group with an SVA value greater than 100 mm, clinical improvement and postural improvements were observed in these patients.

We see that the compensatory mechanisms regress globally along with sagittal balance improvements of the spine after lumbar spinal stenosis surgery. Pelvic retroversion and knee flexion angles are reflex mechanisms, and the recovery of the underlying pathology causes reversals in these mechanisms.

Sagittal balance alignment outcomes in LSS patients can be examined more clearly by increasing the number of cases, which is the limiting factor in our study, and providing longer-term follow-ups.

CONCLUSION

We think that the importance of the sagittal balance concept has recently increased in making surgical decisions, and it is essential to recommend caution in interpreting sagittal parameters. The evaluation of sagittal balance parameters should become routine in degenerative spinal surgeries.

Degenerative LSS surgery patients mostly consist of older age, therefore, operating these patients with fusion surgeries increases the risk of complications, prolongs hospital stay, and increases intraoperative bleeding (6).

The present study revealed that global sagittal alignment could be improved after decompression without fusion in a significant part of cases. These results may prevent us from treating a significant part of patients with major surgery. Considering the results in our series of LSS patients treated using a minimally invasive method, we see that this method is reliable and successful. We observed that clinical and functional improvements were achieved in our patients using this method, and it also caused improvements in global sagittal balances and reversals in their compensatory mechanisms.

Our prospective study demonstrated improvements in sagittal balance and LL after surgery even in patients with preoperative SVA >100 mm among cases who underwent bilateral decompression with a unilateral approach in LSS surgery. These improvements showed that sagittal imbalance might be a reflex against pain in these patients, and successful results could be achieved in case of eliminating this cause with a minimally invasive surgical approach. In some patients, this sagittal imbalance may not be a major change due to its structural development. However, even in these patients, a minimally invasive surgery relieves patients clinically, relieves pain, and increases walking distance.

Some limitations of this study should be noted. First, patients were followed up for 1 year. Therefore, the outcomes are not generalizable to long term. Second, the number of patients is low.

In the light of these results, the studies with wider patients population will show the most accurate results in the future.

Declarations

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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.

AUTHORSHIP CONTRIBUTION

Study conception and design: BY, AK
Data collection: BY, AS
Analysis and interpretation of results: BY, NAD
Draft manuscript preparation: BY, SO
Critical revision of the article: BY, AK
Other (study supervision, fundings, materials, etc...): AK
All authors (BY, AS, NAD, SO, AK) reviewed the results and approved the final version of the manuscript.

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