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Effect of Sparing S1 Motion Segment on Spinopelvic-Sagittal Balance Relationship and its Impact on Pain and Functional Outcome: A Retrospective Cohort Study of Single Center Experience

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Abstract

Background: The relationship of the spine to the pelvis is the key determinant of the sagittal spinal alignment and is analyzed by the following parameters: The pelvic tilt (PT), the pelvic incidence (PI), the sacral slope (SS), lumbar lordosis (LL) and sagittal vertical axis (SVA). S1 instrumented fusion in cases of advanced degenerative spondylolisthesis affect different spinopelvic parameters thus requiring pre-operative comprehensive measurement of different parameters so as not to disrupt it postoperatively rendering it sagittally imbalanced thus more muscle strain to achieve balance is advocated resulting in back pain.

Aim of Study: To assess the effect of S1 motion segment sparing in the setting of degenerative spondylosis and its effect on spinopelvic-sagittal balance parameters and long-term pain and disability using VAS (visual analogue scale) and ODI (modified Oswestry disability index-Arabic version).

Material and Methods: 89 patients with multilevel lumbar canal stenosis underwent fusion surgery with or without S1 fixation were enrolled in the study. The patients were subsequently divided into 2 groups: S1 included (37 patients) and S1 sparing (52 patients); their clinical charts, radiological studies, and follow-up charts were retrieved and analyzed with special consideration on pre- and postsurgical parameters was done.

Results: The mean Post-operative (LL) in S1 sparing group (37.57±7.89) while in S1 included group (12.2±2.69). The mean Post-operative (SS, PT) in S1 sparing group (26.95±10.8, 19.5±6.37) while in S1 included group (21.2±5.24, 28.3±6.97). The mean immediate Post-operative (VAS) in S1 sparing group Dropped from (7.56±0.87) to (4.12±0.97) while in S1 included group (7.59±0.96), while 6-12 Months follow-up VAS was (4.12±0.97, 4.95±1.31) in S1 sparing, S1 included respectively.

Conclusions: S1 motion segment sparing in the setting of decompression and fusion of lower lumber spine seems to positively impact the post-operative lumber lordosis, pelvic tilt and sacral slope with respect to sagittal balance parameters, hence muscle strain and energy expenditure of the adjacent level decreased leading to better immediate as well as long term follow-up VAS, ODI scores compared to S1 inclusion.

Key Words: *Spinopelvic Parameters – Pain – Disability – Spine Fixation – S1 Inclusion – S1 Sparing.*

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Introduction

THE lumbosacral junction is a significant contributor to the motion of the lumbar spine segments. It is a point where weights are transferred from the axial spine to the appendicular skeleton through the pelvic girdle. This transitional zone holds a significant amount of focal axial weight stress that can reach up to 200 N in some circumstances, explaining the possible reason behind the very high prevalence of lower lumbosacral degenerative pathologies and the increased surgical management of this critical stress-holding motion segment **[1]**.

Due to the obliquity of the L5-S1 segment and the sacrum having less cortical bone reserve than other lumbar spine segments, when fusions are extended to S1, a strong lever arm forms that transmits axial weight, torsional, flexion, and extension forces to it. As a result, the cortical purchase of the S1 pedicle screw is lower than at other instrumented levels **[2,3,4]**.

Surgical management is indicated in many cases of advanced lumbosacral degenerative disease, especially when multiple levels are affected. In the majority of cases, the need for multilevel laminectomies, flavectomies, and medial facetectomies is necessary, raising the need for achieving fusion of these levels to restore normal lumbar spine alignment and prevent iatrogenic spondylolisthesis **[5,6]**.

Long-segment fixations (i.e., ≥4 levels) with sacral inclusion are more prone to failure than short-segment ones due to longer lever arm exertion by the proximal column on the distal sacral instrumentation **[7]**.

Lumbosacral fixation carries a high rate of complications, including pedicle screw loosening or pseudoarthrosis in up to 20–60%, frequently cited as a reason for reoperation. The first reason might be that the instrumentation at L5-S1 was under more stress due to inappropriate bony fusion from inadequate decortication and bone grafting **[8]**.

The debate over S1 screw loosening continues. There is still a lack of evidence that inserting iliac screws simply to prevent S1 screw loosening can lead to better clinical outcomes for patients. Iliac screws require extensive subfascial dissection, increasing the rate of complications such as implant prominence, deep infection, and poor wound healing. Additionally, several studies have shown increased rigidity of lumbosacral fixation techniques contributing to late sacroiliac joint arthritis and pain **[9]**.

The relationship of the spine to the pelvis is the key determinant of sagittal spinal alignment and is analyzed by parameters such as pelvic tilt (PT), pelvic incidence (PI), sacral slope (SS), lumbar lordosis (LL), and sagittal vertical axis (SVA). S1 instrumented fusion in cases of advanced degenerative spondylolisthesis affects different spinopelvic parameters, therefore requiring preoperative comprehensive measurement of different parameters to avoid postoperative disruption that could lead to sagittal imbalance and increased muscle strain, resulting in back pain **[10,11]**.

Our study retrospectively assesses the effect of sparing vs. including S1 in fusion segments and the impact on different spinopelvic parameters in relation to sagittal balance parameters and long-term pain and disability using VAS (visual analogue scale) and ODI (Oswestry Disability Index-Arabic version) **[12]**.

Patients and Methods

Patient population & study design:

This is a single-center, comparative, retrospective cohort study conducted at our tertiary care center.

All cases of multilevel disco-ligamentous lumbar canal stenosis (LCS) that underwent fusion surgery with or without S1 fixation between January 2021 and February 2023 were enrolled in the study.

The inclusion criteria included all patients who had posterolateral fusion with posterior transpedicular screw-rod systems and recurrent cases managed with re-decompression and fixation. Exclusion criteria included morbid obesity (BMI over 35), advanced spondylolisthesis greater than grade III, traumatic spinal fractures, pathological fractures due to primary or metastatic tumors, spondylodiscitis, osteoporotic patients, and associated congenital anomalies (Fig. 1).

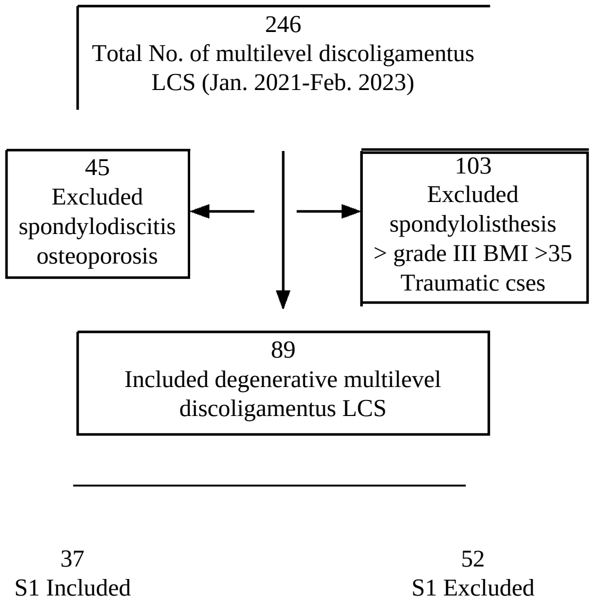

Fig. (1): Patients' stratification and selection.

89 patients met the inclusion criteria and were enrolled in the study. They were then divided into 2 groups: S1 fixation (37 patients) vs. S1 sparing fixation (52 patients). Clinical charts, radiological studies, operative notes, and follow-up results were retrieved and analyzed, with a focus on pre- and post-surgical parameters.

Radiological evaluation was conducted in a standing position for patients without neurological deficits. Surgimap© was used to assess various spino-pelvic parameters and their relationship with sagittal balance parameters. Spinopelvic parameters are geometric and anatomical measures that assess the alignment of the spine and pelvis. Pelvic incidence was measured by determining the angle between the line connecting the center of the femoral heads to the sacral promontory and a line perpendicular to the sacral plate. This is a morphological parameter that remains constant regardless of position.

Pelvic tilt was measured by determining the angle between the vertical line and the line connecting the midpoint of the sacral plate to the axis of the femoral heads. It indicates the position of the pelvis in relation to the femurs and changes with posture. Sacral slope was measured by determining the angle between the sacral plate and the horizontal plane. It changes with pelvic position and is linked to the orientation of the sacrum.

Lumbar lordosis refers to the curvature of the lower spine and is measured as the angle between the top and bottom of the lumbar spine. Ideally, lumbar lordosis should be proportional to pelvic incidence for optimal spinal alignment. The sagittal vertical axis was measured by a plumb line from the center of the C7 vertebral body to the posterior superior corner of the sacrum. This assesses the overall balance of the spine in the sagittal plane, with a larger distance indicating a forward shift in the body's center of mass (Fig. 2).

Fig. (2): Plain X-ray whole spine in standing position lateral view showing measurement of different spinopelvic parameters (PL=plumb line, LL=lumbar lordosis, SS=sacral slope, PT= pelvic tilt, PI=pelvic incidence, FH= femoral head, SVA=sagittal vertical axis).

Postoperatively, the patients were routinely followed-up immediately and at 6-12 months postoperation to record their functional and radiological results. Functional outcomes were measured using the VAS and mODI (modified Oswestry Disability Index - Arabic version). Documentation of surgical parameters was also completed, including blood loss and surgery length. At the final follow-up, a CT scan was performed to evaluate fusion, and patients were monitored at regular intervals with imaging and clinical evaluation.

Surgical procedure:

Patients were positioned in a neutral prone position using rolls to achieve a near-normal lumbar lordotic curve. Antiseptic solutions were applied to the skin for five minutes. C-arm fluoroscopy was used to navigate throughout the procedure steps. After determining the pedicle projections, the facet joint surfaces were prepared. Using a pedicle finder, a nest was carefully made in the vertebral body.

A round-tip probe was used to examine each hole. Under the guidance of C-arm fluoroscopy, transpedicular screws were inserted into these entry points according to pre-operative estimations.

Each screw was positioned so that its point reached a head of two-thirds of the length of the vertebral body. Rigid rods modeled after the lumbar curve were used to anchor the transpedicular screws.

Additionally, in some cases, reduction, facetectomy, and osteotomy were performed to achieve the optimal lordotic curve of the lumbar spine. Microsurgical principles were applied in each case based on the pathology. Following facet and transverse process decortication, autogenous bone grafts were implanted, and screws were secured. Patients were mobilized with a lumbar corset reinforced by steel bars on the same day after surgery.

On the first day after the operation, full spine erect radiographs were taken. In necessary instances, a Lumbosacral CT scan was performed. Patients were advised to wear a lumbar brace for 3 months.

Data sources:

The patients' medical records from January 2021 to February 2023 were examined, and relevant data were extracted. The PACS system (patients' radiological investigations record) was reviewed for all patients with multilevel disco-ligamentous lumbar canal stenosis who underwent decompression and fixation with or without S1 fixation, as well as recurrent discs managed with re-decompression and fixation. A comprehensive review of the sample was conducted using the Ibn-Sina system for patient medical records to assess long-term post-operative pain and evaluate different spino-pelvic parameters in serial plain X-ray studies.

Ethical considerations:

The study protocol was approved by ethical committee "Local Institutional Review Board" (R.23.09.2331.R1), Faculty of Medicine, Mansoura University. All procedures for data collection were treated with confidentiality according to Helsinki Declarations of Biomedical Ethics.

Statistical analysis:

Once the data was collected and tabulated, descriptive statistics were used for continuous variables. All the measurements were made on radiographs by two independent experts who were blinded to the results and the mean of their readings was taken as the final value. Data was analyzed using Statistical package for Social Science (IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.). Chi-

Square test was used to examine the relationship between two qualitative variables. Student *t*-test was used to assess the statistical significance of the difference of parametric variable between two study group means. ANOVA with repeated measure test was used to assess the statistical significance of the difference of parametric variable between more two study periods. While Mann Whitney Test was used to assess the statistical significance of the difference of a non-parametric variable between two study groups. A *p*-value is considered significant if <0.05 at confidence interval 95%.

Results

There was a total of 89 cases, with the majority of patients being male (61.8%) and females accounting for 38.2%. The mean age was 41.8±13 years (range=19-62), and the average BMI was 27.3kg/m^2. The most prevalent pathologies observed were L4-5-S1 stenosis (49.4%) and L5-S1 spondylolisthesis (22.5%). Recurrent cases made up 29.2% of the cohort. Surgeries performed for all cases included decompression and fixation, with an average operation time of 120 minutes.

Complications were reported in 13.48% of cases, with an average follow-up duration of 13.7 months (Table 1).

Table (1): Demographic, clinical, surgical parameters among the studied cases.

	All Cohort (N = 89)
Age (years)	41.8±13 (1.38)
Sex:	
Male	55 (61.8%)
Female	34 (38.2%)
BMI (kg/m^2)	27.3±6.9 (0.73)
Pathology:	
L4-5-S1 Stenosis	44 (49.4%)
L5-S1 Spondylolithesis	20 (22.5%)
L3-4-5-S1 Stenosis	9 (10.1%)
L4-5 Spondylolithesis	7 (7.9%)
L3-4-5 Stenosis	6 (6.7%)
L3-4 Stenosis	3 (3.3%)
Recurrent cases	26 (29.2%)
Operation time (minutes)	120±26.2 (2.78)
Complications:	12 (13.48%)
Dural tear	5 (5.6%)
Wound dehiscence	2 (2.2%)
CSF leakage	1 (1.1%)
Root injury	1 (1.1%)
S1 Peudoarthrosis	1 (1.1%)
Screw neck fracture (SNF)	2 (2.2%)
S1 Included	37 (41.6%)
S1 Sparing	52 (58.4%)
Follow-up (months)	13.7±3.47 (0.37)

Numerical data was expressed by using Mean ± SD. (SE.).
Non-numerical data was expressed by using no. (%).

The entire patient sample was divided into two groups: S1 transpedicular fixation (41.6%-37 patients) and S1 sparing (58.4%-52 patients). There were no significant differences in age and sex between the two groups, but the BMI was significantly higher in the S1 included group (mean of 33.3kg/m^2) compared to the S1 sparing group (mean of 23.1kg/m^2). The mean operation time did not differ significantly between the groups. Complications were reported in 10.8% of S1 included cases and 18.91% of S1 sparing cases.

Postoperative complications were seen in 12 cases (13.48%): 5 cases of dural tear, 2 cases of wound dehiscence, 1 case of CSF leakage, 2 cases of screw neck fracture, 1 case of S1 pseudoarthrosis, and 1 case of root injury (Table 2).

Table (2): Comparison of S1 exclusion group versus S1 inclusion group regarding demographic, clinical and surgical parameters.

	S1 Sparing (N = 52)	S1 Included (N=37)	*p*
Age (years)	42.8±12.6 (1.74)	40.5±13.7 (2.25)	0.419
Sex:			
Male	34 (65.4%)	21 (56.8%)	0.409
Female	18 (34.6%)	16 (43.2%)	
BMI (kg/m^2)	23.1±4.92 (0.68)	33.3±4.31 (0.71)	<0.001*
Pathology:			
L4-5-S1 Stenosis	29 (55.8%)	15 (40.5%)	<0.001*
L5-S1 Spondylolithesis	0 (0.0%)	20 (54.1%)	
L3-4-5-S1 Stenosis	9 (17.3%)	0 (0.0%)	
L4-5 Spondylolithesis	7 (13.5%)	0 (0.0%)	
L3-4-5 Stenosis	5 (9.6%)	1 (2.7%)	
L3-4 Stenosis	2 (3.8%)	1 (2.7%)	
Recurrent	12 (23.1%)	14 (37.8%)	0.131
Operation time (minutes)	119±28.6 (3.97)	122±22.7 (3.73)	0.602
Complications	5 (9.6%)	7 (18.91%)	1.000

Numerical data was expressed by using Mean ± SD. (SE.).
Non-numerical data was expressed by using no. (%).
X^2: Chi Square, *t*: Student *t*-test, U: Mann Whitney,
P: Comparing Non S1 and SI, *: Significant.

There were 26 recurrent cases, with 12 cases having no S1 fixation and 14 with S1 inclusion. Patients had a significant history of previous canal decompression surgeries and were managed operatively based on clinical complaints and evidence of progressive iatrogenic spondylolisthesis on dynamic standing flexion and extension X-rays.

Spinopelvic parameters:

In the S1 sparing group, the mean preoperative pelvic incidence (PI) was 55, while in the S1 included group, it was significantly higher at 62.9 (*p*<0.001). The mean value of preoperative lumbar lordosis (LL) in the S1 included group was 12.2, while in the S1 sparing group it was 11.45, with no statistically significant difference between the two groups (p<0.005). Regarding preoperative sagittal vertical axis (SVA), it was 7.2 in the S1 included group and 7.42 in the S1 sparing group. The pelvic tilt (PT) was (21±5.12) in the S1 included group and (21.4±5.87) in the S1 sparing group. The sacral slope (SS) was (34.1±9.79, 41.9±6.34) in the S1 included versus S1 sparing groups, respectively.

The immediate post-operative PI was 28.1 for the S1 sparing group and 25.4 for the S1 included group, both significantly lower than the preoperative values (p_1<0.001, p_2<0.001). LL in the S1 included group was 25, while in the S1 sparing group it was 36 with a statistically significant difference between the two groups (p<0.005). The SVA was (5.23, 7) in the S1 included versus S1 sparing groups, respectively. The SS was (21.2±5.24, 26.95±6.14) in the S1 included versus S1 sparing groups, respectively. The PT was (25.3±6.97, 21.5±10.4) in the S1 included versus S1 sparing groups, respectively.

At 6-12 months follow-up, the PI in the S1 included group was (55.4±7.42) while in the S1 sparing group it was (44±0). LL in the S1 included group was 25, while in the S1 sparing group it was 30, with no statistically significant difference. The SVA was (3±.6, 4.52±.7) in the S1 included versus S1 sparing groups, respectively. The SS was (21.2±5.24, 26.95±10.8) in the S1 included versus S1 sparing groups, respectively. The PT was (28.3±6.97, 19.5±6.37) in the S1 included versus S1 sparing groups, respectively (Table 3, Figs. 3,4,5).

Table (3): Comparison of S1 exclusion group versus S1 inclusion group regarding spinopelvic parameters in preoperative, immediate postoperative and follow-up.

	S1 Sparing		S1 Included		p_3
	N = 52	p_1	N=37	p_2	
PI:					
Preoperative	55±0 (0)	<0.001*	62.9±6.68 (1.10)	<0.001*	<0.001*
Immediate postp.	48.45 (1.31)		50.4±7.42 (1.22)		0.150
Follow-up	44±0 (0)		55.4±7.42 (1.22)		<0.001*
PT:					
Preoperative	21.4±5.87 (0.81)	<0.001*	21.0±5.12 (0.84)	<0.001*	0.713
Immediate postp.	21.5±10.4 (1.44)		25.3±6.97 (1.15)		0.379
Follow-up	19.5±6.37 (0.88)		28.3±6.97 (1.15)		<0.001*
SS:					
Preoperative	34.1±9.79 (1.36)	<0.001*	41.9±6.34 (1.04)	<0.001*	0.028*
Immediate postp.	26.95±6.14 (0.85)		21.2±5.24 (0.86)		0.468
Follow-up	26.95±10.8 (1.49)		21.2±5.24 (0.86)		<0.001*
LL:					
Preoperative	11.45±3.14 (0.76)	<0.001*	12.2±2.69 (1.24)	<0.001*	0.014*
Immediate postp.	36.25±8.15 (1.12)		25.23±1.66 (0.89)		0.258
Follow-up	37.57±7.89 (1.58)		25.69±1.84 (1.05)		<0.001*
SVA:					
Preoperative	7.42±2.13 (1.01)	<0.001*	7.2±2.0 (1.28)	<0.001*	0.035*
Immediate postp.	5.23±1.46 (0.69)		7±1.39 (1.00)		0.396
Follow-up	4.52±1.0 (0.82)		3±0.6 (0.66)		<0.001*

Non-numerical data was expressed by using no. (%). Numerical data was expressed by using Mean ± SD. (SE.), t: Student. t-test, U: Mann Whitney, $p1$: Comparing preoperative to immediate postoperative and follow-up periods in S1 sparing group, $p2$: Comparing preoperative to immediate postoperative and follow-up periods in S1 included group, $p3$: Comparing, S1 sparing to S1 included groups, *: Significant.

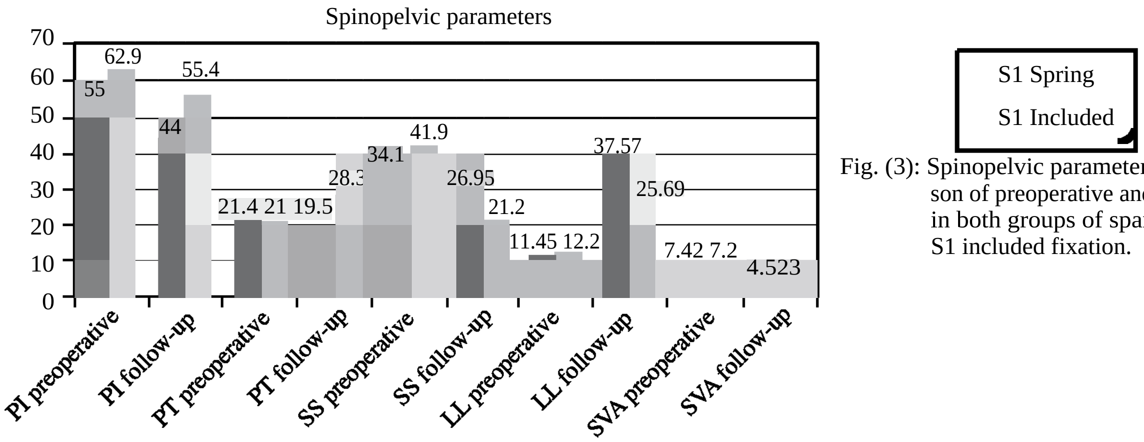

Fig. (3): Spinopelvic parameters comparison of preoperative and follow-up in both groups of sparing versus S1 included fixation.

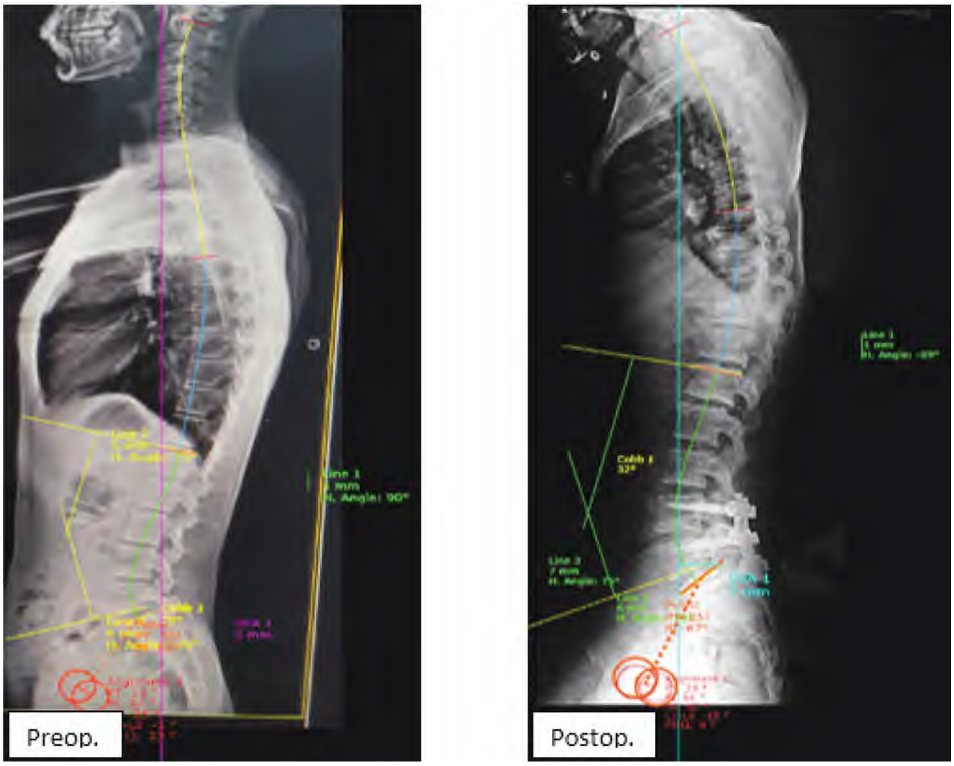

Fig. (4): Pre and postoperative radiological evaluation of spinopelvic parameters in S1 included fixation.

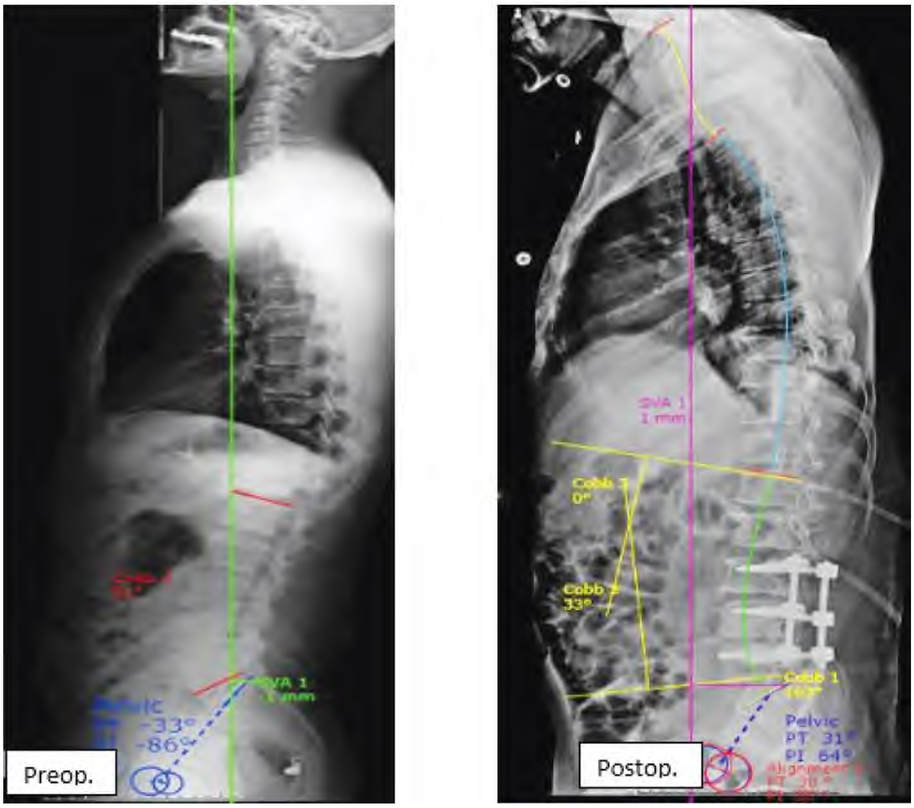

Fig. (5): Pre and postoperative radiological evaluation of spinopelvic parameters S1 spared segment. Noted the compensatory tilting of S1 segment led to increased pelvic tilt, lumber lordosis and compensatory balance.

Pain and functional indices:

Analysis and comparison of pain indices in both groups preoperatively, immediately postoperatively, and at follow-up reveal significant differences in visual analog scale (VAS) and Oswestry Disability Index (ODI) between the S1 sparing and S1 included groups (p_3=<0.001).

The immediate post-operative VAS scores decreased to 6.52 for the S1 sparing group and 6.30 for the S1 included group (p_1<0.001, p_2<0.001). The follow-up VAS scores further decreased to 4.35 for the S1 sparing group and 5.24 for the S1 included group (p_1<0.001, p_2<0.001). Comparison between both groups revealed no significant differences regarding immediate postoperative changes (p_3=0.339), but the S1 sparing group showed a statistically significant decrease in VAS at follow-up compared to the S1 included group (p_3<0.001).

Regarding ODI, the immediate post-operative modified ODI scores decreased moderately in the S1 included group (p_2=0.020) and non-significantly in the S1 sparing group (p_1=0.138). Comparison between both groups revealed no significant differences regarding immediate postoperative changes (p_3=0.397), but the S1 sparing group showed significant improvement in ODI at follow-up compared to the S1 included group (p_3<0.001).

The FABER test (flexion, adduction, and external rotation) showed significant differences between the two groups, with 11 patients out of 33 showing improvement in the S1 sparing group while there was no improvement in the S1 included group (statistically significant p_3=0.019) (Table 4, Fig. 6).

Table (4): Comparison of S1 exclusion group versus S1 inclusion group regarding pain indices in preoperative, immediate postoperative and follow-up.

	S1 Sparing		S1 Included		p_3
	N = 52	p_1	N=37	p_2	
VAS:					
Preoperative	7.56±0.87 (0.12)	<0.001*	7.59±0.96 (0.16)	<0.001*	0.851
Immediate postp.	4.52±1.35 (0.19)		5.24±1.31 (0.22)		0.441
Follow-up	4.12±0.97 (0.13)		4.95±1.31 (0.22)		<0.001*
mODI:					
Preoperative	27.4±7.73 (1.07)	0.138	25.1±7.61 (1.25)	0.020*	0.160
Immediate postp.	24.4±7.04 (0.98)		23.3±7.39 (1.21)		0.461
Follow-up	27.4±7.89 (1.09)		23.3±7.39 (1.21)		0.016*
FABER (+ve):					
Preoperative	33 (63.5%)	1.000	21 (56.8%)	1.000	0.523
Immediate postp.	32 (61.5%)		21 (56.8%)		0.651
Follow-up	22 (42.3%)		21 (56.8%)		0.019*

Numerical data was expressed by using Mean ± SD. (SE.), *t*: Student *t*-test, U: Mann Whitney.

p1: Comparing preoperative to immediate postoperative and follow-up periods in S1 sparing group.

p2: Comparing preoperative to immediate postoperative and follow-up periods in S1 included group.

p3: Comparing S1 sparing to S1 included groups, *: Significant.

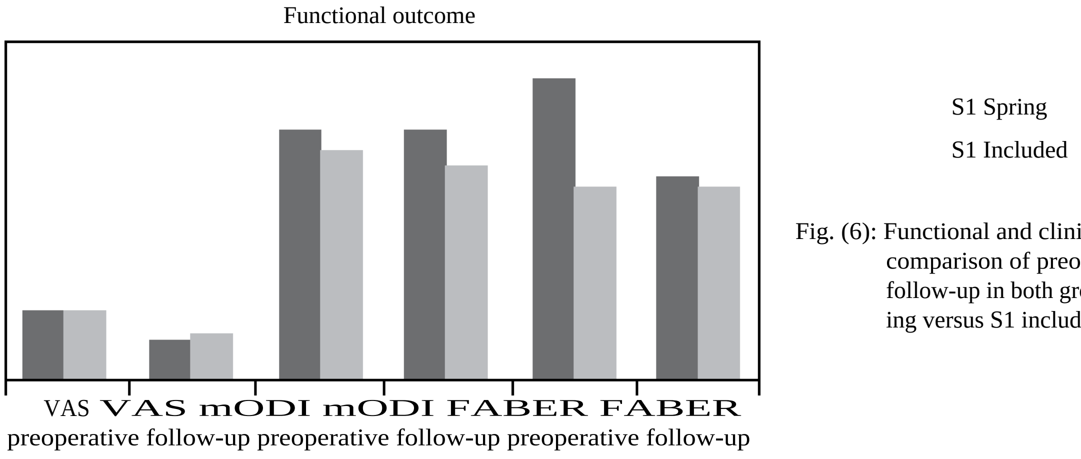

Fig. (6): Functional and clinical outcome comparison of preoperative and follow-up in both groups of sparing versus S1 included fixation.

Discussion

Lumbar spinal stenosis is a common neurosurgical problem, and the overall prevalence varies among studies. It has been reported that the prevalence reaches approximately 11% in the general population.

The point prevalence of LSS in Egypt is not well studied; however, many patients are diagnosed clinically and radiologically with LSS daily *[13]*.

Based on the nature of the lower lumbar spine, it is responsible for the highest mobility of the spine as well as a site for compensation for axial load. Referring to the principles of spinal biomechanics, the lower 3 lumbar vertebrae L4-5, L5-S1 carry the highest proportion of the axial load exerted upon the lumbar spine. It represents the transition zone between the spine and the appendicular skeleton (hips, knee) joints *[6]*.

Furthermore, it is a common site for degeneration as a response to substantial axial load leading to disc degeneration, facet and ligamentous hypertrophy, resulting in spinal stenosis. Surgically treating cases of advanced lumbar canal stenosis usually requires generous decompression of the lateral recess as well as discectomies and foraminotomies and occasionally facetectomies, rendering this high load-bearing segment theoretically unstable *[14,15,16]*.

The S1 segment of the lumbar spine is a greater contributor to the mobility of the lower lumbar segment and a common station for pelvic compensation in response to axial load and degeneration.

This leads to specific changes in spinopelvic parameters to regain sagittal balance, reducing axial skeletal strain. It carries the burden of resisting heavy axial load, resulting in subsequent degenerative changes, and is frequently included in aggressive surgical decompression *[15]*. The question of "iatrogenic instability is raised every time after surgical decompression, to fix or not is a question and to include S1 or not?" is another challenging question.

Our study aims to answer this question through a retrospective analysis of many patients who underwent surgical decompression and fusion with the inclusion of the S1 segment in fusion and with sparing it. We assessed different pre- and post-operative changes in spinopelvic parameters as well as pain using the visual analogue scale (VAS) and long-term follow-up using the Oswestry disability index (ODI).

Sagittal Balance is a dynamic process responsible for balancing the spine. With aging, some of this balance can be lost, resulting in compensation that sometimes produces pain and disability. There are multiple radiological parameters that can help in assessing sagittal balance, with the sagittal vertical axis (SVA), T1 pelvic angle (TPA), lumbar lordosis (LL), pelvic tilt (PT), sacral slope (SS), and pelvic incidence (PI) being the most frequently used. It is a morphological parameter that influences the others and serves as a reference under sagittal imbalance conditions. It helps us to discriminate between balanced, imbalance but compensated, or imbalanced decompensated patients, guiding both diagnosis and therapeutic decision-making. It is important to reinforce that radiographic analysis should be carried out in both planes (coronal and sagittal), complementing the clinical evaluation *[17,18]*.

When fusions are extended to S1, a strong lever arm is formed, transmitting the axial weight, torsional, flexion, and extension forces to it. These forces exert on the L5-S1 motion segment in the context of the obliquity of the L5-S1 segment, further transmitting axial load to adjacent hip and sacroiliac joints *[6,19]*.

In our study, there was a significant contribution to functional outcomes in cases where the S1 segment was spared in fusion. This was noticed in the post-op follow-up period in the form of achieving a normal range of the lumbar lordotic angle. In relation to the SVA, making the principle of the cone of economy more prone to be achieved. We can explain by sparing the S1 segment in fusion as a principal contribution to lower lumbar spine motion leading to compensatory retroversion of the sacral segment, thus decreasing the energy expenditure from the upper lumbar, dorsal, and cervical segment musculature leading to better tolerance of the post-operative period in terms of axial muscle pain, as well as the resultant hip and knee compensation to achieve a balanced spine. These results align with Shetty et al., where there was a significant correlation between maintaining the lumbar lordosis and good functional outcome. The restoration of this lordosis has definite biomechanical advantages and improves the functional outcome of patients *[20,21]*.

In our study, the immediate post-operative sacral slope was significantly higher in the S1 spared group compared to the S1 included group, whereas PT was lower in the S1 spared group compared to the inclusion group. This indicates the freedom of movement of the non-fixed S1 segment leading to spinopelvic compensation to achieve sagittal alignment. These results show the effect of sacral slope and pelvic tilt on restoring lumbar lordosis, supported by the same results of Liow et al., study in which they assessed 63 patients with degenerative spondylolisthesis and the effect of sacral slope and lumbar lordosis on functional outcomes *[21,22,23]*.

In fact, we can assume that S1 segment sparing led to better spinopelvic compensatory biomechanics in terms of increasing sacral slope and decreasing pelvic tilt leading to a better outcome. Our study showed better immediate and long-term follow-up in the S1 sparing group compared to the S1 included group in the form of lower immediate post-op VAS scores. The mean Immediate post-op VAS score in the S1 spared group dropped significantly compared to the S1 included group. These results follow the landmark article examining the relationship between sagittal alignment and clinical status by Glassman et al. *[17]*. The spine, pelvis, and lower limb areas are involved in compensation to balance the axis of gravity. Any failure to compensate and maintain the normal sagittal balance of the body leads to poor clinical outcomes. Positive sagittal balance has a strong correlation with poor health-related scores, and the proper restoration of sagittal plane alignment is critical for improving the clinical outcomes in patients with deformities *[20,24,25]*.

Our study highlights the value of sparing the S1 segment and its effect on better immediate as well as long-term follow-up, achieving better lumbar lordosis. It was significantly higher in the setting of S1 sparing compared to inclusion, which in turn reflects upon sagittal alignment and less muscle strain of the adjacent lumbar levels. The lordosis of the lumbar spine is due to the last two vertebrae and disc spaces. When there is involvement of these vertebrae by the disease process, the lordosis decreases drastically, and the sagittal balance is also compromised, as reflected by Barrey et al., highlighting the value of S1 sparing and its effect on achieving better lumbar lordosis *[26,27]*.

Limitation of the study:

Our study didn't include the details of the correlation between pelvic parameters and the overall sagittal alignment due to the lack of preoperative full-length whole spine from occiput to mid-femur X-rays in standing in many cases. Also, some of our patients were unfamiliar with ODI responses, while others had insufficient data records. Further, larger sample size studies should be planned to study the sagittal spinal alignment and its effect on the functional outcomes.

Conclusion:

S1 motion segment sparing in the setting of decompression and fusion of the lower lumbar spine seems to positively impact the post-operative lumbar lordosis, pelvic tilt, and sacral slope with respect to sagittal balance parameters. Hence, muscle strain and energy expenditure of the adjacent level decreased, leading to better immediate as well as long-term follow-up VAS, ODI scores compared to S1 inclusion.

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تأثير تجنيب تثبيت الفقرة الأولى العجزية على العلاقة بين توازن العمود الفقرى مع الحوض والتوازن السهمى للعمود الفقرى وتأثيره على الالم والمحصلة الوظيفية: دراسة ذات منظور رجعى لتجربة المركز الوحيد

يهدف البحث الي تقييم تأثير تجنيب تثبيت الفقره العجزية الاولى فى حالات داء الفقار التنكسية وتأثيره على العلاقة بين توازن العمود الفقرى مع الحوض و التوازن السهمى للعمود الفقرى وتأثيره على الألم والمحصلة الوظيفية والإعاقة على المدى الطويل باستخدام المقياس التناظرى البصرى ومؤشر إعاقة أوسويستري المعدل – النسخة العربية.

تم تسجيل ٨٩ مريضاً يعانون من اختناق في القناة العصبية الشوكية بالمنطقة القطنية متعددة المستويات خضعوا لجراحة تثبيت الفقرات مع أو بدون تثبيت الفقره الاولى العجزية فى الدراسة. وتم فيما بعد تقسيم المرضى إلى مجموعتين: تثبيت الفقره العجزية الاولي فى (٣٧ مريضاً) والمجموعة الاخرى لم يتم تثبيت الفقره العجزية الاولى فى (٥٢ مريضاً).

تم استرجاع ومراجعة سجلات المرضى الطبية شاملة الخرائط السريرية والدراسات الإشعاعية وخرائط المتابعة وتحليلها مع التركيز على قياسات تحليل الالم والوظيفة والتوازن السهمى السابقة واللاحقة للجراحة.

شملت متوسط درجة القعس القطنى فى مجموعة عدم تثبيت الفقرة الأولى العجزية بعد الجراحة 37,57±7,89 درجة بينما كانت درجة القعس القطنى فى مجموعة تثبيت الفقرة الأولى العجزية 12,2±2,69 درجة.

كانت متوسط درجة المنحدر العجزى وإمالة الحوض فى مجموعة عدم تثبيت الفقرة الأولى العجزية بعد الجراحة 26,95±10,8 و 19,5±6,37 على التوالى.

كان متوسط قياس المقياس التناظرى البصرى بعد الجراحة مباشرة فى مجموعة عدم تثبيت الفقرة الأولى العجزية قد إنخفض من 7,56±0,87 فى حين كان فى مجموعة تثبيت الفقرة الأولى العجزية 7,59±0,96 وكان متوسط قياس المقياس التناظرى البصرى فى فترة من ٦ الى ١٢ شهرا ما بعد الجراحة فى مجموعة عدم تثبيت الفقرة 4,12±0,97 بينما كانت فى مجموعة تثبيت الفقرة الأولى العجزية 4,95±1,31.

إن تجنيب تثبيت الفقره العجزية الأولى في حالات ضيق القناه العصبية القطنية التى تخضع للتدخل الجراحى لتثبيت الفقرات كان له تأثير ايجابى على دلالات التوازن السهمى للعمود الفقرى والعلاقة بين العمود الفقرى والحوض والتى تشمل القعس القطنى والمنحدر العجزى وإمالة الحوض ومن ثم إنخفض تيبس العضلات والضغط الناتج على المستوى الفقرى المجاور مما أدى الى تحسن مؤشر المقياس التناظرى البصرى ومؤشر إعاقة أوسويسترى المعدل والذى يعكس تحسن الألم والأداء والوظيفى للمرضى فى المتابعة طويلة الأجل.