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Keywords
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ABSTRACT

Purpose: 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).

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 analysed with special consideration on pre- and post-surgical 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.

INTRODUCTION

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

Because of the obliquity of the L5-S1 segment and the sacrum's less cortical bone reserve than other lumbar spine segments, thus when fusions are extended to S1, a strong lever arm forms that transmits the axial weight, torsional, flexion, and extension forces to it. As a result, the cortical purchase of the S1 pedicle screw is lower than other instrumented levels (2–4).

Surgical management is indicated in many cases of advanced lumbosacral degenerative disease, especially when multiple levels are affected. In majority of cases the need for multilevel laminectomies, flavectomies as well as medial facetectomies is needed thus raising the need for achieving fusion of these levels to restore normal lumbar spine alignment as well as preventing 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% and it was the frequently cited reason for reoperation (25%). The first reason might be that the instrumentation at L5-S1 was under more stress as a result of inappropriate bony fusion due to inadequate decortication and bone grafting (8)

S1 screw loosening is still in the dispute. Besides, there is still a lacks of evidence that inserting the iliac screws simply for preventing S1 screw loosening can contribute to a better clinical outcome for patients. On the other hand, iliac screws require extensive subfascial dissection, increasing the rate of complications such as implant prominence deep infection and poor wound-healing. Meanwhile, 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 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 (10,11)

Our study assesses in retrospective manner the effect of sparing vs. including S1 in fusion segment and the effect 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 in our tertiary care center. All the cases with multilevel disco-ligamentous lumbar canal stenosis (LCS) underwent fusion surgery with or without S1 fixation between January 2021 to February 2023 were enrolled in the study. Inclusion criteria included all patients who had posterolateral fusion with posterior transpedicular screw-rod systems and recurrent cases that were managed with re-decompression and fixation. Exclusion criteria included morbid obesity (BMI more than 35), advanced spondylolithesis more than grade III, traumatic fracture spine, pathological fracture due to primary or metastatic tumor, spondylodiscitis, osteoporotic patients, associated congenital anomalies (Fig.1).

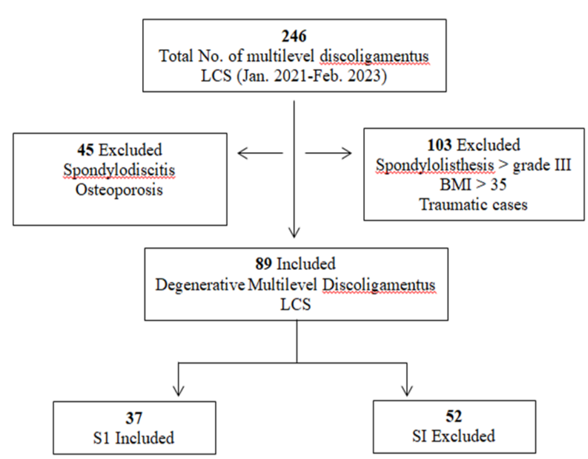

Figure 1. Patients' stratification and selection.

89 patients satisfied the inclusion criteria and enrolled in the study; they were subsequently divided into 2 groups: S1 included (37 patients) vs. S1 sparing fixation (52 patients) were included; their clinical charts, radiological studies, operative notes and follow-up charts results were retrieved and analyzed with special consideration on pre- and post-surgical parameters was done.

Radiological evaluation was obtained in a standing position when there was no neurological deficit. We used Surgimap© to evaluate the different spino-pelvic parameters and relation with sagittal balance parameters. Spinopelvic parameters are geometrical and anatomical measures that evaluate how the spine and pelvis line up. The pelvic incidence was measured by measuring the angle between the line drawn from the center of the femoral heads to the sacral promontory and a line perpendicular to the sacral plate. It is a morphological parameter that does not change with position. The pelvic tilt was measured by measuring the angle between the vertical and the line connecting the midpoint of the sacral plate to the femoral heads' axis. It reflects the position of the pelvis with respect to the femurs and changes with posture. Sacral slope was measured by measuring the angle between the sacral plate and the horizontal plane. It varies with the position of the pelvis and is related to the orientation of the sacrum. Lumbar lordosis is the curvature of the lower spine. It is measured as the angle between the top of the lumbar spine and the bottom. Lumbar lordosis should ideally be proportionate to pelvic incidence for optimal spinal alignment. 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. It assesses the overall balance of the spine in the sagittal plane, and a larger distance indicates a forward shift of the body's center of mass (Fig.2).

Post operatively, the patients were routinely followed up immediately and 6-12 months follow-up period to record their functional, and radiological results. Functional outcomes were measured using VAS and mODI (modified Oswestry disability index-Arabic version). Documentation of surgical parameters was also done, 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.

Figure 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)

Surgical Procedure

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

A round-tip probe was used to examine every hole. Under the guidance of C-arm fluoroscopy, transpedicular screws were inserted into these entry points in accordance with pre-operative estimations. Every screw was positioned so that its point reached ahead of two thirds of the length of the vertebral body, rigid rods modeled after the lumbar curve was employed to anchor transpedicular screws. Also there was reduction, facetectomy, osteotomy to achieve the optimal lordotic curve of the lumbar spine in some cases. Microsurgical principles were used in each case in accordance with the pathology. Following the facet and transverse process decortication, autogenous bone grafts were implanted and screws were secured. The patients were ambulated with a lumbar corset reinforced by steel bars on the same day after the surgery.

On the first day after the operation, direct full spine erect radiographs were obtained. In necessary instances, Lumbosacral CT was performed. The patients were advised to place lumbar brace for 3 months.

Data sources

The Patients medical registry between January 2021 to February 2023 was examined and data of interest were extracted. The PACS system (patients' radiological investigations record) was revised for all patients with multilevel disco-ligamentous lumbar canal stenosis that underwent decompression and fixation with or without S1 fixation, recurrent discs who managed with re-decompression and fixation. Full comprehensive review of the sample using (Ibn-sina system for patient medical records) to assess long term post-operative pain and to 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 were a total of 89 cases. The majority of the patients were male (61.8%), while females accounted for 38.2%. The mean age was 41.8 ± 13 (range=19-62) years. The average BMI was 27.3 kg/m2. Various pathologies were observed, with L4-5-S1 stenosis being the most prevalent (49.4%), followed by L5-S1 spondylolisthesis (22.5%). Recurrent cases constituted 29.2% of the cohort. The surgeries performed for all cases were decompression and fixation, with a mean operation time of 120 minutes. Complications were reported in 13.48.1% 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 whole patient's sample was stratified into two groups: S1 transpdicular fixation 41.6% (37 patients) where S1 sparing was in 58.4% (52 patients). There were no significant differences in age and sex between the two groups. However, BMI was significantly higher in the S1 included group (mean of 33.3 kg/m2) compared to the S1 sparing group (mean of 23.1 kg/m2). The mean operation time did not differ significantly between the two groups. Complications were reported in 10.8% of S1 included cases and 18.91% of S1 sparing cases (table 2). Postoperative complications were encountered in 12 cases (13.48%): dural tear in 5 cases, wound dehiscence in 2 cases while CSF leakage in only 1 case, 2 cases with screw neck fracture, only one case of S1 pseudoarthrosis and root injury in only 1 case (table 1).

Recurrent cases were 26 patients; 12 cases with no S1 fixation and 14 with S1 inclusion, patients had significant past surgical history of previous canal decompression. With evidence of clinical as well as radiological recurrence, patient managed operatively according to the patient's complaint as well as evidence of progressive iatrogenic spondylolithesis by dynamic standing flexion and extension X –ray.

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 Female	 34 (65.4%) 18 (34.6%)	 21 (56.8%) 16 (43.2%)	 0.409
BMI (kg/m^2)	23.1 ± 4.92 (0.68)	33.3 ± 4.31 (0.71)	<0.001 *
Pathology L4-5-S1 Stenosis L5-S1 Spondylolithesis L3-4-5-S1 Stenosis L4-5 Spondylolithesis L3-4-5 Stenosis L3-4 Stenosis	 29 (55.8%) 0 (0.0 %) 9 (17.3%) 7 (13.5%) 5 (9.6%) 2 (3.8%)	 15 (40.5%) 20 (54.1%) 0 (0.0%) 0 (0.0%) 1 (2.7%) 1 (2.7%)	<0.001 *
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. (%).
X2: Chi Square, t: Student t test, U: Mann Whitney, P: Comparing Non S1 and SI, *: Significant.

Spinopelvic parameters

For the S1 sparing group, the mean preoperative PI was 55, while for the S1 included group, it was significantly higher at 62.9 (P<0.001). mean value of preoperative LL in S1 included group was 12.2 while in S1 sparing group was 11.45 with no statistically significant difference between the two groups (p<0.005), as regard preoperative SVA in S1 included group was 7.2 while in S1 sparing group was 7.42, as regard PT in S1 included group was (21+5.12) while in S1 sparing group was (21.4+5.87), SS was (34.1+9.79, 41.9+6.34) S1 included versus S1 sparing 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 (P1<0.001, P2<0.001). LL in S1 included group was 25 while in S1 sparing group was 36 with statistically significant difference between the two groups (P<0.005), as regard SVA was (5.23, 7) in S1 included versus S1 sparing respectively. As regard SS was (21.2+5.24, 26.95+6.14) in S1 included versus S1 sparing respectively. As regard PT was (25.3+6.97, 21.5+10.4) in S1 included versus S1 sparing respectively.

The 6-12 months follow-up PI in S1 included group was (55.4+7.42) while in S1 sparing group was (44+0). As regard LL in S1 included group was 25 while in S1 sparing group was 30 with no statistically significant difference. As regard SVA was (3+.6, 4.52+.7) in S1 included versus S1 sparing respectively. While SS was (21.2+5.24, 26.95+10.8) in S1 included versus S1 sparing respectively. PT was (28.3+6.97, 19.5+ 6.37) in S1 included versus S1 sparing respectively (table 3, fig. 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**		**P3**
	N = 52	**P1**	**N = 37**	**P2**	
PI Preoperative Immediate postop. Follow up	55 ± 0 (0) 48.45 (1.31)	<0.001 *	62.9 ± 6.68 (1.10)	<0.001 *	<0.001* 0.150 <0.001*

	44 ± 0 (0)		50.4 ± 7.42 (1.22) 55.4 ± 7.42 (1.22)		
PT Preoperative Immediate postop. Follow up	21.4 ± 5.87 (0.81) 21.5 ± 10.4 (1.44) 19.5 ± 6.37 (0.88)	<0.001 *	21.0 ± 5.12 (0.84) 25.3 ± 6.97 (1.15) 28.3 ± 6.97 (1.15)	<0.001 *	0.713 0.379 <0.00 1*
SS Preoperative Immediate postop. Follow up	34.1 ± 9.79 (1.36) 26.95 ± 6.14 (0.85) 26.95 ± 10.8 (1.49)	<0.001 *	41.9 ± 6.34 (1.04) 21.2 ± 5.24 (0.86) 21.2 ± 5.24 (0.86)	<0.001 *	0.028 * 0.468 <0.00 1*
LL Preoperative Immediate postop. Follow up	11.45 ± 3.14 (0.76) 36.25 ± 8.15 (1.12) 37.57 ± 7.89 (1.58)	<0.001 *	12.2 ±2.69 (1.24) 25.23 ±1.66 (0.89) 25.69 ±1.84 (1.05)	<0.001 *	0.014 * 0.258 <0.00 1*
SVA Preoperative Immediate postop. Follow up	7.42 ± 2.13 (1.01) 5.23 ± 1.46 (0.69) 4.52 ± 1.0 (0.82)	<0.001 *	7.2 ± 2.0 (1.28) 7 ± 1.39 (1.00) 3 ± 0.6 (0.66)	<0.001 *	0.035 * 0.396 <0.00 1*

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.

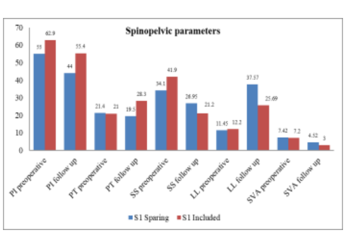

Figure 3. Spinopelvic parameters comparison of preoperative and follow up in both groups of sparing versus S1 included fixation.

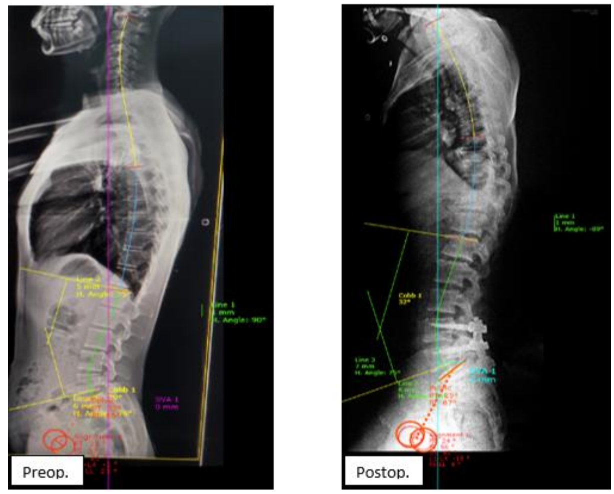

Figure 4. Pre and postoperative radiological evaluation of spinopelvic parameters in S1 included fixation.

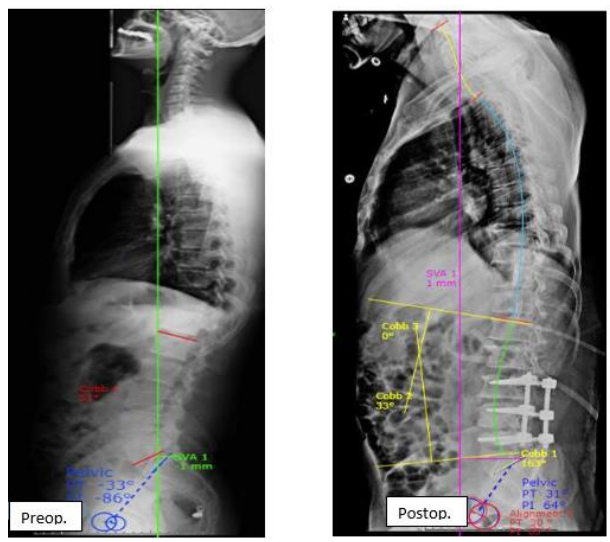

Figure 5. Pre and postoperative radiological evaluation of spinopelvic parameters S1 spared segment. Noted the compensatory tilting of S1 segment led to increased pelvic tilt, lumber lordosis and compensatory balance.

Pain and functional indices

Analysis and comparison of pain indices in both groups in preoperative, immediate postoperative and at follow-up reveal preoperatively, there were significant differences in VAS or ODI between the S1 sparing and S1 included groups (p3=<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 (p1<0.001, p2<0.001). The follow-up VAS scores further decreased to 4.35 for the S1 sparing group and decreased to 5.24 for the S1 included group (p1<0.001, p2<0.001). Comparison between both groups revealed no significant differences regarding immediate postoperative changes (p3=0.339). While SI sparing group showed statistically significant decrease in VAS at follow up when compared to SI included group (p3<0.001).

Regarding ODI, the immediate post-operative mODI scores decreased moderately in SI included group (p2=0.020), and non-significantly in SI sparing group (p1=0.138). Comparison between both groups revealed no significant differences regarding immediate postoperative changes (p3=0.397). While SI sparing group showed better significant improvement in ODI at follow up when compared to SI included group (p3<0.001).

The FABER test (flexion, adduction and external rotation) showed significant differences between the two groups as 11 patients out of 33 had improved in S1 sparing group while there was no improvement in S1 included group (statistically significant p3=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		P3
	N = 52	P1	N = 37	P2	
VAS					
Preoperative	7.56 ± 0.87 (0.12)	<0.001*	7.59 ± 0.96 (0.16)	<0.001*	0.851
Immediate postop.	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 postop.	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 postop.	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.

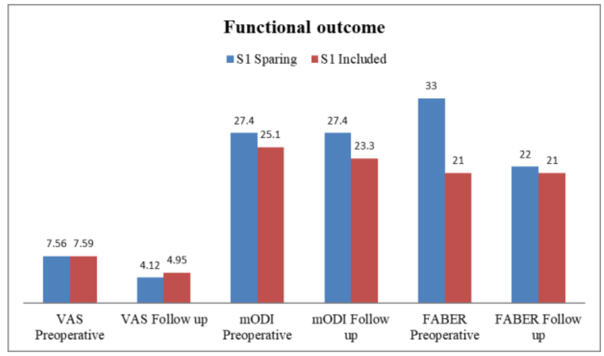

Figure 6. Functional and clinical outcome comparison of preoperative and follow up in both groups of sparing versus S1 included fixation.

Discussion

Lumbar spinal stenosis is common neurosurgical problem; the overall prevalence of lumbar spinal stenosis 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 on daily basis (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 it to the principles of spinal biomechanics, the lower 3 lumbar vertebrae L4-5-S1 carries the highest proportion of the axial load exerting upon the lumbar spine. It represents the transition zone between the spine and the appendicular skeleton (hips, knee) joints (6)

Furthermore it is common site for degeneration as a response for substantial axial load leading to disc degeneration, facet and ligamentous hypertrophy, resulting in spinal stenosis. Surgically treating cases of advanced lumbar canal stenosis, it 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 (14–16)

S1 segment of the lumbar spine is a greater contribution of the mobility of lower lumbar segment. And a common station for pelvic compensation in response to axial load and degeneration. Leading to specific changes in spinopelvic parameters to regain the sagittal balance reducing the axial skeletal strain. It carries burden of resisting heavy axial load resulting in subsequent degenerative changes and 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 hard question.

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

Sagittal Balance is a dynamic process responsible for balancing spine with aging of the spine 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 the sagittal balance, 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, which guides both diagnosis and therapeutic decision-making. It is important to reinforce that the 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 exerting forces on L5-S1 motion segment in the context of the obliquity of L5-S1 segment, further transmitting axial load to adjacent hip and sacroiliac joints (19)(6)

In our study there was a significant contribution to the functional outcome in cases where S1 segment was spared in fusion this was noticed on post op follow up period in the form of achieving normal range of lumbar lordotic angle (preoperative LL was 11.45o that was corrected to 37.57o postoperative), in relation to the SVA making the principle of cone of economy more prone to be achieved, we can explain by sparing S1 segment in fusion as a principle contribution to lower lumbar spine motion leading to compensatory retroversion of the sacral segment leading to partially balanced spine, thus decreasing the energy expenditure from the upper lumbar, dorsal and cervical segment musculature leading to better tolerance of post-operative period in term of axial muscle pain as well as the resultant hip and knee compensation to achieve balanced spine; these results cope with Shetty AP et al. where there was a significant correlation between maintaining the lumbar lordosis and good functional outcome. Restoration of this lordosis has definite biomechanical advantages and improves the functional outcome of patients (20,21)

In our study immediate post-operative sacral slope was significantly higher in S1 spared group compared to S1 included (21.2+5.24o, 26.95+6.14o) respectively, whereas PT was lower in S1 spared group compared to inclusion group (25.3+6.97o, 21.5+10.4o), thus indicate the freedom of movement of non-fixed S1 segment leading to spinopelvic compensation to achieve the sagittal alignment, these results shows the effect of sacral slope and pelvic tilt on restoring lumbar lordosis and supported by the same results of Liow et al. study in which they assess a 63 patients with degenerative spondylolisthesis and the effect of sacral slope and lumbar lordosis on functional outcomes. The study group found out that increased sacral slope patients in the post-operative period experienced less pain and good functional outcomes (21–23)

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 better outcome. our study showed better immediate and long-term follow up in S1 sparing compared to S1 included group in the form of lower immediate post op VAS scores the mean Immediate post op VAS score in S1 spared group dropped from (7.56 ± 0.87) to (4.52 ± 1.35) ($P<0.001$) compared to S1 included group where per op mean VAS score was (7.59 ± 0.96) and dropped to (5.24 ± 1.31) ($P<0.001$); These results follows the landmark article of 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. The 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 highlighting the value of sparing S1 segment and its effect on better immediate as well as long term follow up achieving better lumbar lordosis was significantly higher in the setting of S1 sparing compared to inclusion which in turn reflect 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 Barrey et al. reflecting 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 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 non- familiar with ODI responses, others had insufficient data record. So, further larger sample size studies should be planned to study the sagittal spinal alignment and its effect on the functional outcomes.

Conclusions

S1 motion segment sparing in the setting of decompression and fusion of lower lumber spine seems to positively impact the post-operative lumber lordships, 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.

Abbreviations

SNF = Screw Neck Fracture
PT = Pelvic Tilt
PI = Pelvic Incidence
SS = Sacral Slope
LL = Lumbar Lordosis
LCS = Lumbar canal stenosis
FH = Femoral head
LL = Lumbar Lordosis
SVA = Sagittal Vertical Axis
PL = Plumb Line
VAS = Visual Analogue Scale
mODI = Modified Oswestry Disability Index.
CT = Computed Tomography
MRI = Magnetic Resonance Imaging
BMI = Body Mass Index
TPA = T1 Pelvic Angle
FABER= Flexion, Adduction and External Rotation

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