RESEARCH PAPER

The Impact of Sagittal Balance on Clinical Outcomes after Treatment of Patients with Lytic Spondylolisthesis

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ABSTRACT

Background: Lytic spondylolisthesis can disrupt sagittal and spinopelvic alignment, making restoration and assessment of sagittal balance important for improving postoperative clinical outcomes.

Objective: To assess changes in sagittal balance and pelvic parameters before and after surgical treatment of patients with lytic spondylolisthesis and to evaluate their relationship with clinical outcomes.

Methods: This prospective study included 25 adult patients with symptomatic lytic spondylolisthesis who underwent surgical treatment at Cairo University Hospital between January 2018 and February 2019. Fourteen patients underwent posterolateral fusion (PLF) with posterior instrumentation, six underwent posterior lumbar interbody fusion (PLIF) with posterior instrumentation, and five underwent combined PLF/PLIF with posterior instrumentation. Ethical approval was obtained from the Orthopedic Department Council, Cairo University, and informed consent was obtained from all patients.

Results: Clinical outcomes improved significantly after surgery, with marked reductions in VAS back pain and ODI ($p < 0.001$) and significant changes in some spinopelvic parameters. However, postoperative spinopelvic balance showed no significant correlation with VAS back pain, VAS leg pain, or ODI ($p > 0.05$).

Conclusion: Postoperative improvement was observed in clinical outcomes and spinopelvic parameters, particularly PI and PT. However, VAS back pain showed no significant correlation with the assessed pelvic parameters, while postoperative spinopelvic balance was not significantly associated with VAS back pain, VAS leg pain, or ODI.

Keywords: Lytic spondylolisthesis; Sagittal balance; Spinopelvic parameters; Pelvic incidence; Pelvic tilt; Clinical outcomes; Oswestry Disability Index.

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Conflict of interest: None

INTRODUCTION

Spondylolysis is a defect of the pars interarticularis of the vertebra and is commonly related to repetitive microtrauma. This may initiate a stress reaction that can progress to fracture and subsequent vertebral slippage, resulting in spondylolisthesis. (1)

Patients with lytic spondylolisthesis commonly present with low back pain, which may be aggravated by spinal extension or twisting. Radicular symptoms may also occur when nerve root compression is present. (2)

Spondylolisthesis represents sagittal displacement of one vertebral body relative to another and should be evaluated within the context of global sagittal alignment, as sagittal balance plays an important role in disease progression, surgical planning, and postoperative outcomes. (3)

Spinopelvic alignment is determined by the relationship between spinal and pelvic parameters. Disturbances in these parameters may alter the mechanical balance of the spine and increase the compensatory demands required to maintain an upright posture. (4)

Restoration of optimal sagittal alignment improves spinal biomechanical efficiency, decreases energy expenditure, and may reduce mechanical stress on adjacent spinal segments. Therefore, assessment of sagittal and pelvic parameters is increasingly important when evaluating patients undergoing surgical treatment for lytic spondylolisthesis. (5)

Surgical treatment is considered in symptomatic patients with lytic spondylolisthesis when conservative treatment fails or when significant instability, neurological symptoms, or progressive deformity is present. In such patients, the relationship between postoperative sagittal balance and clinical improvement may be an important determinant of treatment outcome. (6)

The aim of this study was to assess changes in sagittal balance and pelvic parameters before and after surgical treatment of patients with lytic spondylolisthesis and to evaluate their relationship with clinical outcomes.

PATIENTS AND METHODS

This prospective study included 25 adult patients with symptomatic lytic spondylolisthesis who underwent surgical treatment at Cairo University Hospital between January 2018 and February 2019. Fourteen patients underwent posterolateral fusion (PLF) with posterior instrumentation, six underwent posterior lumbar interbody fusion (PLIF) with posterior instrumentation, and five underwent combined PLF/PLIF with posterior instrumentation. Ethical approval was obtained from the Orthopedic Department Council, Cairo University, and informed consent was obtained from all patients.

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Inclusion Criteria

Patients aged 20–60 years with symptomatic lytic spondylolisthesis who failed conservative treatment for at least three months were included.

Exclusion Criteria

Patients younger than 20 or older than 60 years, those with chronic or systemic illnesses rendering them unfit for surgery, patients with failed back syndrome, and patients unwilling to participate were excluded.

Clinical Assessment

All patients underwent preoperative clinical assessment and complete general and local spinal examination. Clinical outcomes were evaluated using the Visual Analogue Scale (VAS) for pain and the Oswestry Disability Index (ODI) for functional disability. VAS and ODI were assessed preoperatively, postoperatively, and during follow-up at 1, 3, 6, and 12 months.

Radiological Assessment

Preoperative radiological evaluation included anteroposterior, lateral, and dynamic flexion-extension radiographs of the lumbosacral spine. The lateral radiograph included the femoral heads to allow accurate assessment of spinopelvic parameters. The degree of spondylolisthesis was classified according to the Meyerding–Newman classification.

The assessed sagittal and spinopelvic parameters included pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), and lumbar lordosis (LL). These parameters were measured preoperatively and compared with postoperative values to assess changes in sagittal balance following surgical treatment.

Postoperative radiographs included anteroposterior and lateral views of the lumbosacral spine. Pelvic incidence, pelvic tilt, and sacral slope were reassessed on lateral radiographs and compared with the corresponding preoperative measurements.

Radiological follow-up was performed using AP and lateral radiographs at 1, 3, 6, and 12 months. CT scanning was performed at 6 and 12 months when indicated to assess fusion.

Surgical Treatment

All patients underwent posterior decompression when indicated, posterior instrumentation, and fusion using PLF, PLIF, or combined PLF/PLIF according to the surgical requirements of each case. Restoration and maintenance of lumbar lordosis and spinal alignment were considered during instrumentation and rod contouring.

Follow-up

Clinical follow-up included assessment of low back and leg pain using VAS and functional disability using ODI at 1, 3, 6, and 12 months. Radiological follow-up included AP and lateral radiographs at the same intervals, with CT scanning at 6 and 12 months when indicated.

Statistical Analysis

Data were analyzed using SPSS. Quantitative variables were summarized using mean and standard deviation. Appropriate statistical tests were used to compare preoperative and postoperative measurements. Correlation analysis was performed to evaluate the relationship between spinopelvic sagittal parameters and clinical outcomes.

RESULTS

Table 1: VAS Back pain pre, immediate post-op, 1, 3, 6& 12 months postoperative.

	Mean	SD	Median	Mini	Max	P value
VAS Back (pre)	8.84	0.85	9.00	7.00	10.00	< 0.001
VAS Back (post)	6.76	1.01	7.00	5.00	8.00	
VAS Back (1m)	4.00	0.82	4.00	2.00	5.00	
VAS Back (3m)	2.48	0.92	3.00	1.00	4.00	
VAS Back (6m)	1.76	0.66	2.00	1.00	3.00	
VAS Back (1y)	0.92	0.76	1.00	0.00	2.00	

Statistically P-value <0.001 was significant between results in VAS Back follow-up.

All 25 patients were evaluated postoperatively at 1, 3, 6, and 12 months. Clinical outcomes were assessed using the Oswestry Disability Index (ODI) and the Visual Analogue Scale (VAS) for back and leg pain. VAS back pain showed a significant progressive improvement, decreasing from a preoperative mean of 8.84 ± 0.85 to 6.76 ± 1.01 immediately postoperatively, 4.00 ± 0.82 at 1 month, 2.48 ± 0.92 at 3 months, 1.76 ± 0.66 at 6 months, and 0.92 ± 0.76 at 12 months, with a statistically significant difference over the follow-up period ($p < 0.001$) **(Table 1).**

Table2: ODI follow up pre-op and at 1, 3, 6& 12 months postoperative.

	Mean	SD	Median	Mini	Max	P value
ODI (pre)	69.32	6.91	67.00	60.00	88.00	< 0.001
ODI (1m)	32.16	4.91	32.00	22.00	40.00	
ODI (3m)	23.28	5.62	24.00	13.00	31.00	
ODI (6m)	16.92	4.74	17.00	10.00	27.00	
ODI (1y)	10.76	2.59	11.00	6.00	16.00	

Statistically P-value <0.001 was significant between results in ODI follow-up.

ODI showed a significant progressive improvement, decreasing from a preoperative mean of 69.32 ± 6.91 to 32.16 ± 4.91 at 1 month, 23.28 ± 5.62 at 3 months, 16.92 ± 4.74 at 6 months, and 10.76 ± 2.59 at 12 months postoperatively **(Table 2).**

Table 3: PI, PT, SS, and LL follow-up preoperatively, immediately postoperatively, and at 1 year.

	Mean	Standard Deviation	Median	Minimum	Maximum	P value
PI(pre)	**60.44**	**12.20**	**58.39**	**34.93**	**87.73**	**0.013**
PI(post)	**56.98**	**11.03**	**56.11**	**27.85**	**74.35**	
PI(1y)	**55.07**	**10.27**	**53.66**	**28.28**	**70.46**	
PT(pre)	**36.48**	**17.31**	**37.72**	**-3.52**	**70.03**	**0.002**
PT(post)	**32.86**	**11.32**	**33.41**	**11.96**	**57.38**	
PT(1y)	**29.26**	**10.92**	**28.47**	**12.16**	**53.29**	
SS(pre)	**23.97**	**14.26**	**22.62**	**2.15**	**59.12**	**0.619**
SS(post)	**24.38**	**10.33**	**22.34**	**2.19**	**43.91**	
SS(1y)	**25.77**	**11.21**	**23.81**	**3.00**	**49.44**	
LL (pre)	**50.04**	**16.13**	**48.68**	**11.68**	**93.25**	**0.001**
LL (post)	**49.32**	**14.97**	**49.89**	**26.91**	**81.82**	
LL (1y)	**47.78**	**15.06**	**46.76**	**25.00**	**80.00**	

A P-value < 0.05 was considered statistically significant. Pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), and lumbar lordosis (LL) were measured preoperatively, immediately postoperatively, and at 12 months. The mean PI decreased from 60.44 ± 12.20 preoperatively to 56.98 ± 11.03 immediately postoperatively and 55.07 ± 10.27 at 1 year, while PT decreased from 36.48 ± 17.31 to 32.86 ± 11.32 and 29.26 ± 10.92, respectively. LL changed from 50.04 ± 16.13 preoperatively to 49.32 ± 14.97 immediately postoperatively and 47.78 ± 15.06 at 1 year. Meanwhile, SS increased from 23.97 ± 14.26 preoperatively to 24.38 ± 10.33 immediately postoperatively and 25.77 ± 11.21 at 1 year **(Table 3).**

Table 4: Correlation among VAS Back values and pelvic parameters.

		PI (pre)	PI (post)	PI (1y)	PT (pre)	PT (post)	PT (1y)	SS (pre)	SS (post)	SS (1y)	LL (pre)	LL (post)	LL (1y)
pre VAS Back	**Correlation Coefficient**	**-0.026-**	**0.046**	**0.069**	**-0.020-**	**0.023**	**0.144**	**-0.020-**	**0.108**	**-0.010-**	**-0.278-**	**0.069**	**0.069**
	P value	**0.900**	**0.827**	**0.744**	**0.926**	**0.911**	**0.491**	**0.923**	**0.607**	**0.964**	**0.178**	**0.741**	**0.741**
	N	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**
post VAS Back	**Correlation Coefficient**	**0.074**	**-0.073-**	**-0.080-**	**-0.067-**	**-0.136-**	**-0.050-**	**0.169**	**0.164**	**0.089**	**-0.112-**	**0.155**	**0.155**
	P value	**0.724**	**0.728**	**0.702**	**0.752**	**0.518**	**0.812**	**0.420**	**0.433**	**0.671**	**0.595**	**0.460**	**0.460**
	N	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**
1m VAS Back	**Correlation Coefficient**	**0.073**	**-0.188-**	**-0.200-**	**0.162**	**-0.078-**	**0.017**	**-0.012-**	**-0.115-**	**-0.255-**	**0.048**	**-0.072-**	**-0.072-**
	P value	**0.730**	**0.368**	**0.338**	**0.439**	**0.710**	**0.937**	**0.953**	**0.583**	**0.219**	**0.821**	**0.733**	**0.733**
	N	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**
3m VAS Back	**Correlation Coefficient**	**-0.045-**	**0.095**	**-0.047-**	**-0.031-**	**-0.080-**	**-0.073-**	**0.073**	**0.092**	**0.039**	**0.172**	**0.082**	**0.089**
	P value	**0.831**	**0.653**	**0.822**	**0.884**	**0.703**	**0.730**	**0.727**	**0.660**	**0.855**	**0.412**	**0.697**	**0.671**
	N	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**
6m VAS Back	**Correlation Coefficient**	**0.133**	**-0.025-**	**-0.098-**	**0.132**	**-0.138-**	**-0.066-**	**0.050**	**0.130**	**0.044**	**0.221**	**0.115**	**0.115**
	P value	**0.526**	**0.907**	**0.641**	**0.528**	**0.510**	**0.755**	**0.814**	**0.537**	**0.833**	**0.288**	**0.583**	**0.583**
	N	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**
VAS Back (1y)	**Correlation Coefficient**	**0.100**	**-0.105-**	**-0.142-**	**0.301**	**0.186**	**-0.114-**	**-0.174-**	**-0.228-**	**0.077**	**-0.010-**	**-0.013-**	**-0.013-**
	P value	**0.635**	**0.618**	**0.497**	**0.144**	**0.374**	**0.587**	**0.406**	**0.272**	**0.716**	**0.961**	**0.952**	**0.952**
	N	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**	**25**

Statistically P-value >0.05 was considered insignificant.

No significant correlation was found between VAS back pain and the assessed pelvic parameters **(Table 4).**

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Table 5: Correlation among ODI values and pelvic parameters.

		PI (pre)	PI (post)	PI (1y)	PT (pre)	PT (post)	PT (1y)	SS (pre)	SS (post)	SS (1y)	LL (pre)	LL (post)	LL (1y)
pre ODI	Correlation Coefficient	-0.104-	0.170	-0.060-	-0.406-	-0.031-	-0.124-	0.417	0.144	0.102	-0.126-	0.108	0.113
	P value	0.621	0.418	0.775	0.044	0.882	0.556	0.038	0.493	0.628	0.549	0.606	0.592
	N	25	25	25	25	25	25	25	25	25	25	25	25
1m ODI	Correlation Coefficient	-0.353-	0.027	-0.053-	-0.108-	-0.037-	-0.076-	-0.315-	0.045	0.008	-0.020-	-0.300-	-0.303-
	P value	0.083	0.896	0.800	0.607	0.860	0.719	0.125	0.830	0.971	0.924	0.145	0.141
	N	25	25	25	25	25	25	25	25	25	25	25	25
3m ODI	Correlation Coefficient	-0.355-	-0.182-	-0.322-	-0.149-	-0.045-	0.042	-0.214-	-0.078-	-0.265-	-0.070-	-0.167-	-0.171-
	P value	0.082	0.383	0.116	0.476	0.830	0.842	0.305	0.712	0.200	0.738	0.425	0.415
	N	25	25	25	25	25	25	25	25	25	25	25	25
6m ODI	Correlation Coefficient	-0.266-	-0.190-	-0.312-	-0.142-	-0.156-	0.005	-0.192-	-0.023-	-0.215-	-0.150-	-0.175-	-0.175-
	P value	0.198	0.362	0.129	0.500	0.458	0.981	0.358	0.914	0.302	0.474	0.403	0.403
	N	25	25	25	25	25	25	25	25	25	25	25	25
1y ODI	Correlation Coefficient	-0.478-	-0.275-	-0.335-	-0.199-	-0.100-	-0.082-	-0.271-	-0.224-	-0.249-	0.092	-0.280-	-0.272-
	P value	0.016	0.184	0.101	0.340	0.633	0.697	0.190	0.281	0.230	0.662	0.175	0.188
	N	25	25	25	25	25	25	25	25	25	25	25	25

Statistically P-value >0.05 was considered insignificant.

Correlation analysis between ODI and pelvic parameters showed that preoperative ODI was inversely correlated with preoperative PT and directly correlated with preoperative SS. In addition, ODI at 1 year was inversely correlated with preoperative PI **(Table 5).**

Table 6: Correlation between postoperative spino-pelvic balance and VAS back, VAS leg and ODI.

	Spino-pelvic balance (post)										
	Balanced					Unbalanced					P value
	Mean	SD	Median	Mini	Max	Mean	SD	Median	Mini	Max	
VAS Back (pre)	8.78	0.97	9.00	7.00	10.00	8.88	0.81	9.00	7.00	10.00	0.846
VAS Back (post)	6.89	1.05	7.00	5.00	8.00	6.69	1.01	6.00	5.00	8.00	0.637
VAS Back (1m)	3.89	0.93	4.00	2.00	5.00	4.06	0.77	4.00	3.00	5.00	0.760
VAS Back (3m)	2.89	0.60	3.00	2.00	4.00	2.25	1.00	2.00	1.00	4.00	0.108
VAS Back (6m)	2.00	0.50	2.00	1.00	3.00	1.62	0.72	1.50	1.00	3.00	0.187
VAS Back (1y)	1.11	0.60	1.00	0.00	2.00	0.81	0.83	1.00	0.00	2.00	0.357
VAS Leg (pre)	8.33	0.71	8.00	7.00	9.00	8.06	1.24	8.00	6.00	10.00	0.598
VAS Leg (post)	5.11	1.62	5.00	2.00	7.00	4.50	1.46	5.00	2.00	7.00	0.357
VAS Leg (1m)	3.00	0.87	3.00	2.00	4.00	2.69	0.95	3.00	1.00	4.00	0.522
VAS Leg (3m)	2.00	0.87	2.00	1.00	3.00	1.62	0.96	2.00	0.00	3.00	0.419
VAS Leg (6m)	1.22	0.67	1.00	0.00	2.00	0.94	0.77	1.00	0.00	3.00	0.301
VAS Leg (1y)	0.89	0.78	1.00	0.00	2.00	0.63	0.72	0.50	0.00	2.00	0.452
ODI (pre)	70.78	5.61	69.00	65.00	80.00	68.50	7.59	65.50	60.00	88.00	0.187
ODI (1m)	31.78	4.18	32.00	22.00	36.00	32.38	5.40	33.00	22.00	40.00	0.760
ODI (3m)	23.56	6.00	24.00	13.00	31.00	23.12	5.60	23.00	13.00	31.00	0.760
ODI (6m)	17.56	4.64	17.00	11.00	25.00	16.56	4.91	16.00	10.00	27.00	0.598
ODI (1y)	11.33	2.18	11.00	7.00	15.00	10.44	2.80	10.00	6.00	16.00	0.251

Statistically P-value >0.05 was considered insignificant.

No significant correlation was found between postoperative spinopelvic balance and clinical outcomes, including ODI, VAS back pain, and VAS leg pain **(Table 6).**

Case presentation

Case 1 (no. 8 in sheet):

Female patient, 45 years old, suffered from low back pain radiating to lower limbs of 2 years' duration, preoperative ODI was 68, VAS Back was 9, VAS leg was 7. X-ray showed L5-S1lytic spondylolisthesis grade 1. PLF with posterior instrumentation at L5-S1 by 4 screws and 2 rods was done on 3/7/2018.Operative time was 90 min and blood loss was 200 cc. ODI at 3 months was 23, at 6-month s were 19 and at one year were 10. VAS Back postoperative was 7, at 3 months were 4, at 6 months were 2 and at one year was 1.VAS Leg postoperative was 2, at 3 months was 1, at 6 months was 1 and at one year was 0. Pelvic incidence, pelvic tilt, sacral slope and lumbar lordosis were 68.97, 46.35, 22.62 and 53.16 preoperatively, 59.05, 20.95, 38.1 and 49.89 postoperatively and 57.77, 15.78, 41.99 and 46.76 respectively by the end of the study.

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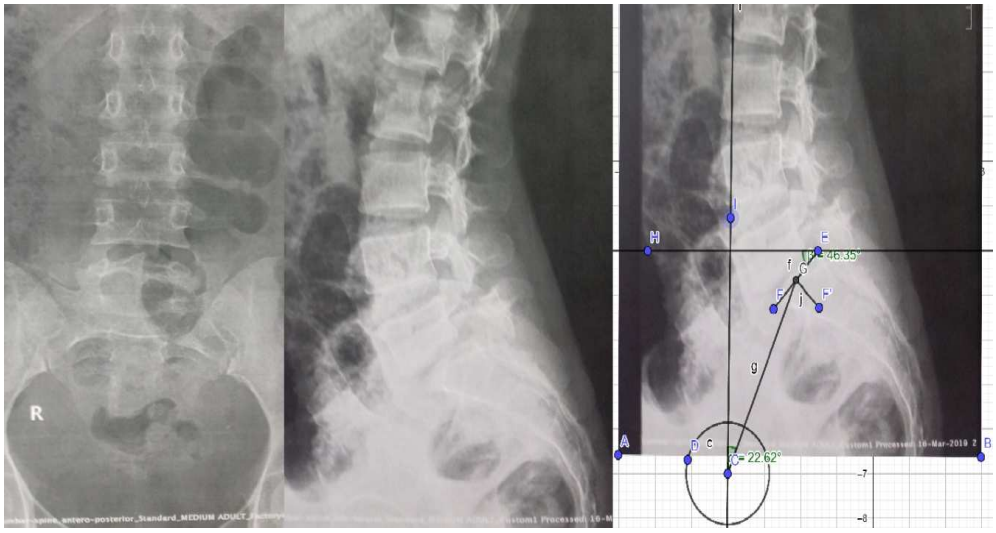


Fig. 1: Preoperative x ray and pelvic parameters of case 1.

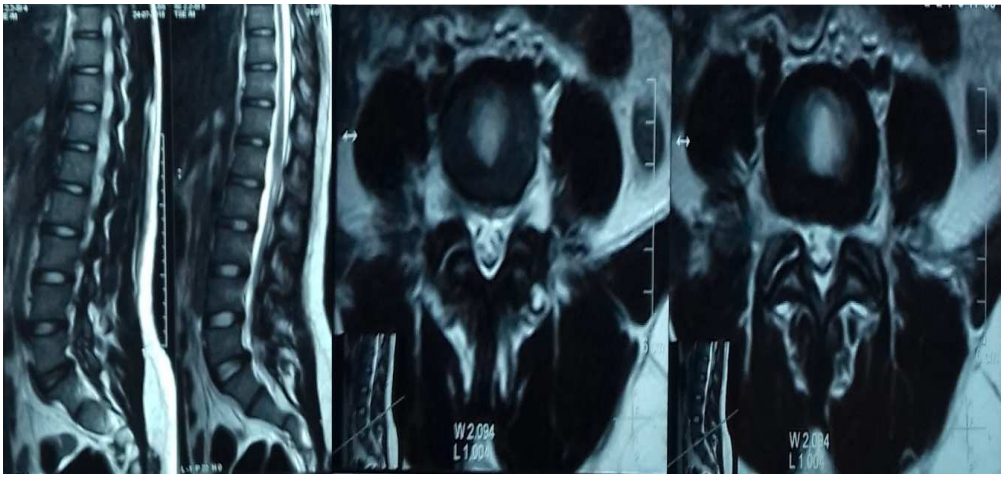


Fig. 2: Preoperative MRI of case 1.

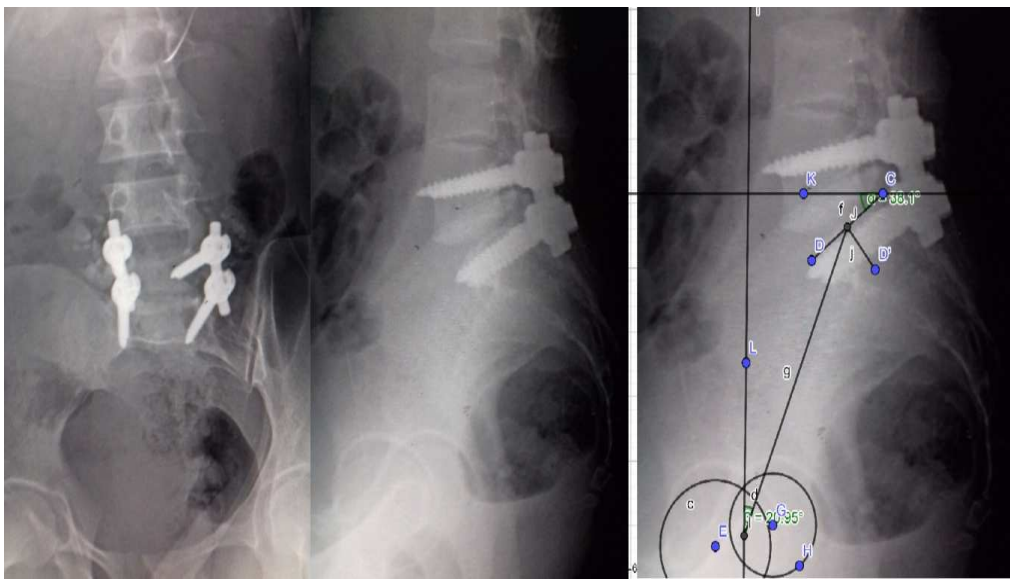


Fig. 3: Postoperative x ray and pelvic parameters of case 1.

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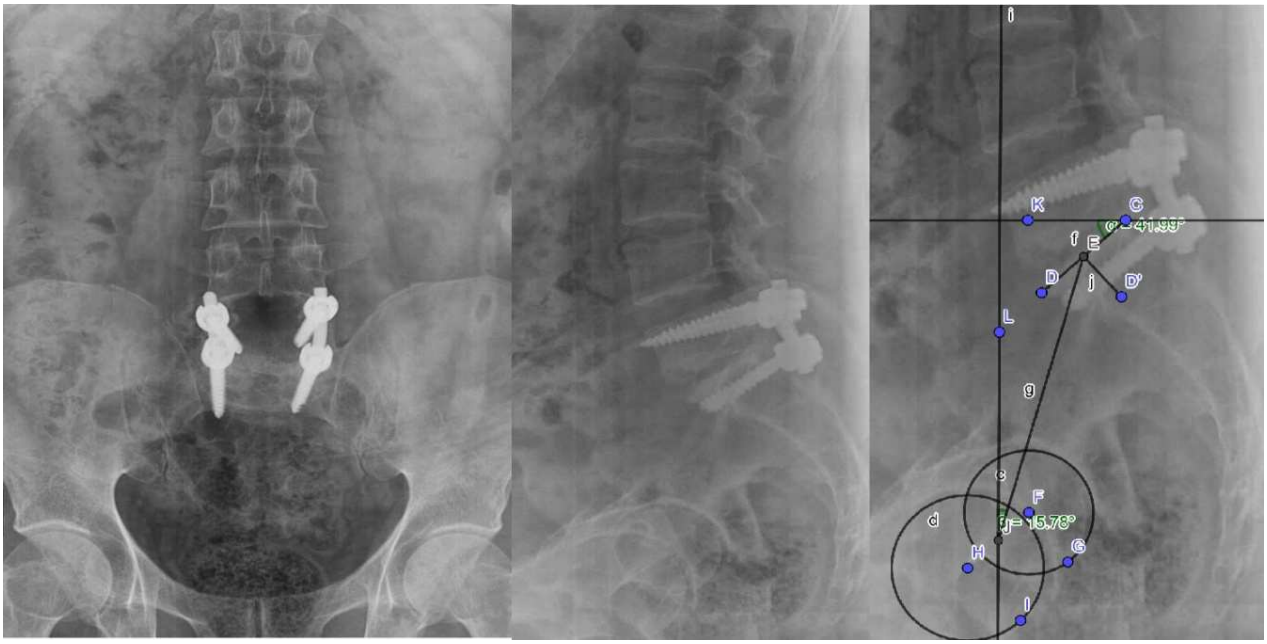


Fig. 4: Postoperative x ray and pelvic parameters of case 1 at 1 year.

Case 2 (no. 25 in sheet):
Female patient, 45 years old, suffered from low back pain of 3 years' duration, radiating to left lower limb, preoperative ODI was 80, VAS Back was 9, VAS leg was 9. X-ray showed L4-5 grade 1 and L5-S1grade 1 lytic spondylolisthesis. MRI revealed disc herniation at of L4-5 and foraminal stenosis at L5-S1. Surgery was done on 2/9/2018 by PLIF at L4-5 and PLF at L5-S1, then posterior instrumentation and fusion by 6 screws, 2 rods. Operative time was 140 min and blood loss was 350 cc. ODI at 3 months was 27, at 6 months were21 and at one year were 11. VAS Back postoperative was 8, at 3 months were 4, at 6 months were 3 and at one year was 1.VAS Leg postoperative was 2, at 3 months was 1, at 6 months was 1 and at one year was 0. Pelvic incidence, pelvic tilt, sacral slope and lumbar lordosis were 55.6, -3.52, 59.12 and 48.68 preoperatively, then 58.68, 14.77, 43.19 and 63.69 postoperatively and 49.3, 13.42, 35.88 and 62.45 respectively by the end of the study.

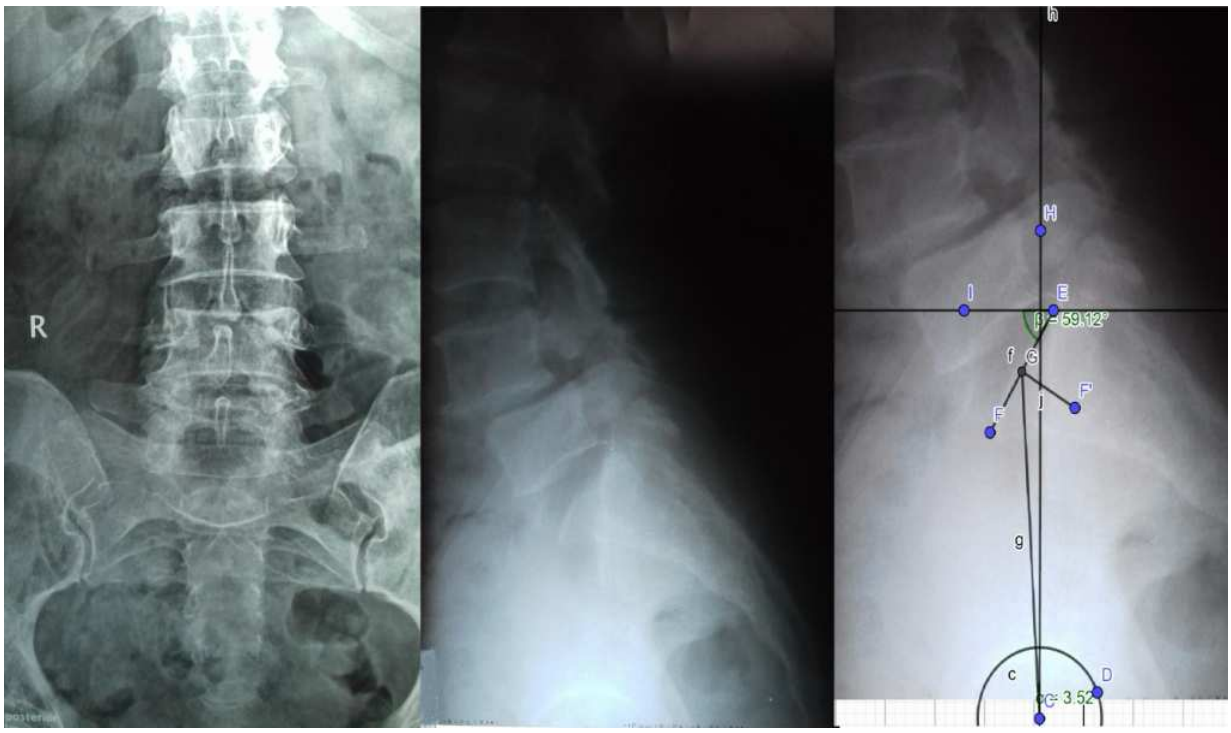


Fig. 5: Preoperative x ray and pelvic parameters of case 2.

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Fig. 6: Preoperative MRI of case 2.

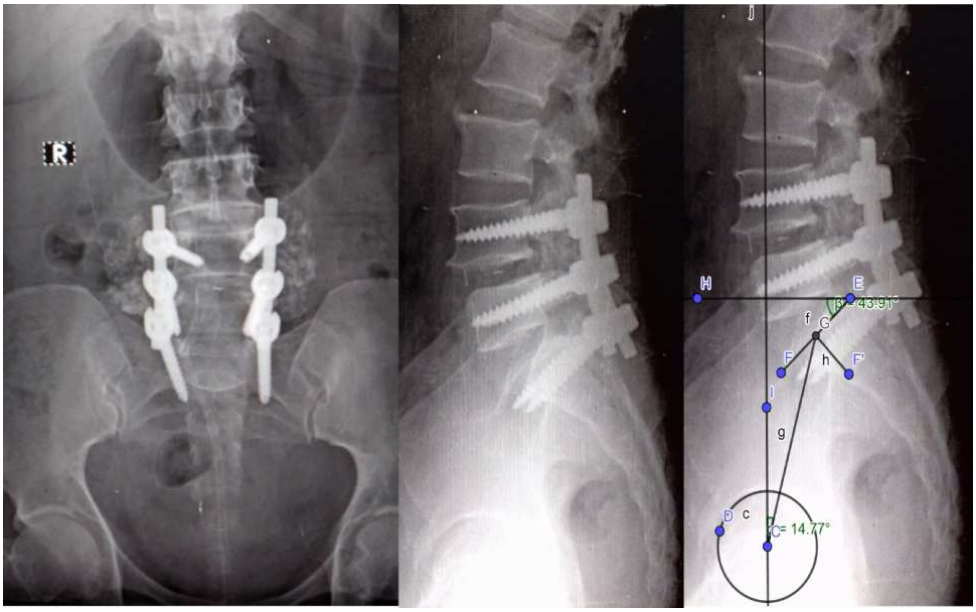


Fig. 7: Postoperative x ray and pelvic parameters of case 2.

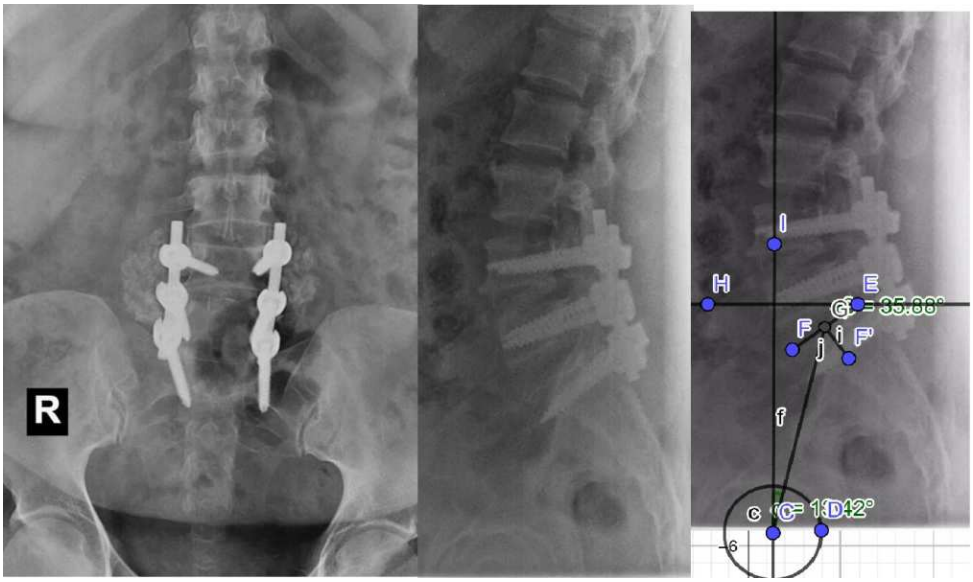


Fig. 8: Postoperative x ray and pelvic parameters of case 2 at 1 year.

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DISCUSSION

Spondylolisthesis is the forward subluxation of one vertebra on another, and its assessment should include not only the degree of vertebral slip but also the associated spinopelvic alignment. **(7)** The Spinal Deformity Study Group introduced a classification system incorporating both slip grade and spinopelvic alignment. **(8)** Sagittal balance is closely related to pelvic morphology and orientation. Pelvic incidence (PI) represents a morphological parameter of the pelvis and is geometrically related to pelvic tilt (PT) and sacral slope (SS). **(9)** Therefore, surgical management of lytic spondylolisthesis aims not only at neural decompression and fusion but also at restoration of appropriate sagittal spinal alignment. **(10)**

In the present study, VAS back pain demonstrated a marked and progressive improvement following surgical treatment, decreasing from 8.84 ± 0.85 preoperatively to 6.76 ± 1.01 immediately postoperatively and reaching 0.92 ± 0.76 at 12 months. This improvement was statistically significant throughout the follow-up period. Similar improvement was reported by **Ahmet Eroğlu et al.**, who observed a reduction in VAS score from 5.98 preoperatively to 2.49 postoperatively. **(11) Gazi Shahinur Akter et al.** also reported substantial reductions in VAS scores following surgical treatment, with final follow-up values of 1.95 ± 0.37 in one group and 2.25 ± 0.41 in the other. **(12)** Likewise, **Francesco Ciro Tamburrelli et al.** reported a reduction in VAS score from 7.1 preoperatively to 2.2 at one year. **(13) Chang-zhi Du et al.** similarly demonstrated improvement in VAS back pain from 6.7 ± 3.7 preoperatively to 3.0 ± 3.2 at the latest follow-up. **(14)** These findings are consistent with the present study and support the effectiveness of surgical treatment in providing sustained relief of back pain in patients with lytic spondylolisthesis.

Functional outcome also improved substantially in the present study. The mean ODI decreased from 69.32 ± 6.91 preoperatively to 32.16 ± 4.91 at one month, 23.28 ± 5.62 at three months, 16.92 ± 4.74 at six months, and 10.76 ± 2.59 at 12 months. This progressive reduction indicates marked improvement in functional disability during follow-up. **Ahmet Eroğlu et al.** similarly reported improvement in ODI from 76.68 preoperatively to 26.65 postoperatively. **(11) Gazi Shahinur Akter et al.** found that ODI decreased from 62.56 ± 8.30 to 17.48 ± 3.90 at final follow-up in one group and from 63.67 ± 8.44 to 19.35 ± 4.04 in the other. **(12) Francesco Ciro Tamburrelli et al.** also demonstrated improvement from a preoperative ODI of 36.8 to 24.1 after one year, while **Chang-zhi Du et al.** reported a decrease from 54.2 ± 22.3 to 30.1 ± 21.4 at final follow-up. **(13,14)** Therefore, the functional improvement observed in the present study is consistent with previously reported clinical outcomes after surgical management of lytic spondylolisthesis.

Regarding radiological outcomes, PI, PT, SS, and lumbar lordosis (LL) were evaluated preoperatively, immediately postoperatively, and at one year. In the present study, PI decreased from 60.44 ± 12.20 preoperatively to 56.98 ± 11.03 immediately postoperatively and 55.07 ± 10.27 at one year. PT decreased from 36.48 ± 17.31 to 32.86 ± 11.32 and 29.26 ± 10.92, respectively, while SS increased from 23.97 ± 14.26 to 24.38 ± 10.33 and 25.77 ± 11.21. LL changed from 50.04 ± 16.13 preoperatively to 49.32 ± 14.97 postoperatively and 47.78 ± 15.06 at one year.

These findings can be compared with those of **Andrzej Maciejczak et al.**, who demonstrated postoperative changes in PT, SS, and LL that varied according to the preoperative spinopelvic balance and slip grade. **(15) Yu Feng et al.** also reported postoperative changes in PT, SS, and LL following PLIF and PLF, with a reduction in PT and an increase in SS after surgery. **(9) Francesco Ciro Tamburrelli et al.** reported an increase in LL from 45.1 to 49.8 and SS from 31.5 to 32.6, together with a reduction in PT from 19.2 to 16.3 following surgery. **(13)** Similarly, **Chang-zhi Du et al.** found a reduction in PT from 30.5 ± 11.6 preoperatively to 19.0 ± 13.5 postoperatively, together with an increase in SS from 32.4 ± 11.4 to 45.3 ± 11.1. **(14)** Collectively, these studies demonstrate that surgical treatment of spondylolisthesis may be associated with postoperative modification of spinopelvic alignment, although the magnitude and direction of these changes vary among different patient populations and surgical techniques.

Our results showed no significant correlation between VAS back pain and PI, PT, SS, or LL at the evaluated time points. This suggests that improvement in back pain was not directly related to changes in a single spinopelvic parameter and may reflect the combined effects of decompression, stabilization, fusion, and correction of the underlying pathology.

Our results showed that preoperative ODI was inversely correlated with PT and directly correlated with SS, while ODI at one year was inversely correlated with preoperative PI. However, most other correlations between ODI and spinopelvic parameters were not significant, indicating that only some pelvic characteristics were associated with functional disability.

Our results showed no significant differences between balanced and unbalanced postoperative spinopelvic alignment regarding VAS back pain, VAS leg pain, or ODI during follow-up. Thus, although clinical outcomes improved after surgery, postoperative spinopelvic balance alone did not appear to determine the degree of clinical improvement.

CONCLUSION

In conclusion, postoperative improvement was observed in clinical outcomes and spinopelvic parameters, particularly PI and PT. However, VAS back pain showed no significant correlation with the assessed pelvic parameters, while postoperative spinopelvic balance was not significantly associated with VAS back pain, VAS leg pain, or ODI.

RECOMMENDATIONS

Further prospective randomized studies with larger samples and longer follow-up are recommended. Sagittal balance correction should be considered in symptomatic patients. Since PT and SS may be affected by patient posture, a standardized measurement system based on reliable bony landmarks.

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