The Egyptian Journal of Hospital Medicine (October 2025) Vol. 101, Page 5154-5164

Assessment of Spinopelvic Parameters Before and After Posterior Interbody Fusion in Patients with Lumbar Isthmic Spondylolisthesis

Ahmed Hamdy Elshokafy*, Mohammed Amer Ibrahim,
Ebrahim Ahmed Shamhot, Yasser Foaud Elsawaf, Ahmed Samir ElshikhAli
Department of Neurosurgery, Faculty of Medicine, Tanta University, Tanta, Egypt
***Correspondingauthor:** Ahmed Hamdy Elshokafy, **Mobile:** (+20) 01119446634, **E-mail:** ahmed171572_pg@med.tanta.edu.eg

ABSTRACT

Background: Spondylolisthesis is characterized by the anterior displacement of one vertebra relative to the vertebra beneath it in the sagittal plane of the spine. **Objective:** To assess the spinopelvic parameters before and after posterior interbody fusion in patients with lumbar isthmic spondylolisthesis.

Patients and Methods: This observational prospective study included twenty adult patients with isthmic spondylolisthesis subjected to posterior lumbar interbody fusion (PLIF) in Neurosurgery Department, Tanta University Hospitals. Patients were subjected to clinical assessment, radiological investigations and routine laboratory investigations.

Results: Regarding the X-ray evaluation of the spinopelvic parameters, PT was significantly lower postoperatively, and during follow-up after 3 and 6 months and after 1 year, Whereas SS was significantly higher postoperatively, and during follow-up. LL was higher postoperatively, and during follow-up after 3 and 6 months and after 1 year compared to preoperative values.

Conclusions: Posterior interbody fusion with the insertion of a cage and transpedicular screws in patients with lumbar isthmic spondylolisthesis led to significant improvements in spinopelvic alignment, maintenance of spinopelvic parameters, restoration of sagittal balance of the spine, satisfactory fusion rate and clinical outcome, restoration of disc space height, segmental lordosis and reduction of spondylolisthesis.

Keywords: Spondylolisthesis, PLIF, TLIF, Spinopelvic parameters.

INTRODUCTION

Spondylolisthesis refers to the anterior displacement of one vertebra relative to the vertebra beneath it in the sagittal plane of the spine. Spondylolisthesis can have a variety of causes, such as dysplastic, isthmic, degenerative, traumatic, pathologic, and iatrogenic [1].

Previously, there were mechanical complications after adult spinal surgeries like postoperative back pain, proximal and distal junction kyphosis and adjacent segments due to sagittal plane under correction or overcorrection[2].

The PLIF approach has the potential to improve fusion surface area, resolve symptoms, provide complete access for medial canal and lateral recess, restore intervertebral disc height, and keep spinopelvic sagittal balance, alignment, and parameters within acceptable limits [3].

Spinopelvic parameters are measured from whole spine plain X-ray obtained in a relaxed standing position. These parameters are measured by using surgimap software: pelvic incidence (PI), sacral slope (SS), pelvic tilt (PT), lumbar lordosis (LL), thoracic kyphosis (TK), sagittal vertical axis (SVA), global tilt (GT) and slip angle [4].

PI is the morphological parameter that plays a key role in the regulation of positional pelvis as it is unaffected by posture or degenerative changes [5]. PI (morphological) = SS (positional) + PT (positional). So, if the PI is increased, the SS will be increased relatively much more than the PT and it will be the cause of increasing lordosis. High PI correlates with a higher risk of progression of spondylolisthesis. The recommended values for these parameters are: LL= PI ± 9°, PT<20° and SVA <5 cm. Each person has a standard and suitable lordosis value of their own [6].

The Global Alignment and Proportion (GAP) score is a novel pelvic-incidence-based proportionate approach for measuring spinopelvic alignment and sagittal balance. It consists of five basic components: relative pelvic version, relative lumbar lordosis, lordosis distribution index, relative spinopelvic alignment, and age [7].

A straightforward technique for identifying the unstable zone (square) in L5 spondylolisthesis using standing radiographs is demonstrated by **Lamartina *et al.*** [8] which also shows the region of fusion upon reduction. On the X-ray, a square with sides composed of a segment on the horizontal line through S2 may be drawn. The junction of the vertical lines originating from the center of the femoral head and the midway point of the L5 caudal plate defines the boundaries of this segment. When doing L5 reduction, the vertebrae that are part of this square must be united [8].

The aim of this work was to assess the spinopelvic parameters before and after posterior interbody fusion in patients with lumbar isthmic spondylolisthesis.

PATIENTS AND METHODS

This observational prospective study was carried on twenty adult patients with lumbar isthmic spondylolisthesis subjected to PLIF in Neurosurgery

Received: 18/05/2025
Accepted: 20/07/2025

Department, Tanta University Hospitals between April 2024 and April 2025.

Inclusion criteria: Both sexes, all grades according to Meyerding classification and failed conservative treatment after one month.

Exclusion criteria: Surgically unfit patients, with significant cognitive impairment, lumbar infection and significant osteoporosis.

Patients were subjected to clinical assessment including history taking, general, neurological, visceral and vascular examination. Radiological investigations including plain radiographs (anteroposterior (AP), lateral, oblique and dynamic views), Whole spine plain X-ray (AP and lateral views), CT lumbosacral spine, Magnetic resonance imaging (MRI) of the lumbosacral spine, and dual energy X-ray absorptiometry (DEXA) scan. Routine laboratory workup was conducted.

Operative technique:

The patient was put in a prone posture with their legs slightly bent on chest rolls while general anesthesia was administered. Pressure sites were suitably cushioned, and a lateral fluoroscopic image was obtained using the C-arm (Ziehm Vision ®, Germany). A skin incision was created along the midline. The lumbar fascia was separated just lateral to the spinous process. Dissection was then carried out laterally over facets and transverse processes using an electrocautery equipment. Transpedicular screws were placed after detecting pedicle landmarks using a lateral fluoroscopic imaging that revealed the rostrocaudal direction of the pedicle. Decompression includes the removal of spinous processes, as well as laminectomy.

Bilateral facetectomy was performed and the lateral recesses were decompressed. Once an appropriate degree of exposure was achieved, the affected nerve roots were identified. The nerve roots were followed under each pedicle and via their corresponding foramina. If pathologic stenosis was detected, a foraminotomy was performed.

After that, a discectomy was done. The pedicle screws were attached to a rod, allowing for successive distraction of intervertebral space. To optimize a successful arthrodesis, the disc nucleus and endplates were removed almost completely. Following a thorough interbody discectomy, the cage was packed with removed local bones that had been chopped into small pieces and placed. After placing the cage, the tightening connection between screws and rod was released, and the interspace was compressed. The cage was rechecked for disc space location and tightness. To strengthen the fusion, a posterolateral fusion was inserted.

Follow-up:

All patients were assessed in the outpatient clinic on a regular basis, beginning two weeks following the procedure and continuing for one, three, six, and twelve months. Data collection and result analysis were carried out using the Oswestry Disability Index (ODI), Visual Analog Scale (VAS), Frankel score, and GAP score. In all cases, the ODI was employed to measure impairment prior to and after surgery [9].

VAS was used to compare pain before and after surgery. Frankel score was a classification system used to evaluate the degree of motor and sensory function [10].

Radiological follow up:

All patients were examined using whole spine plain X-ray to assess pedicle screws, cage placement, fusion and spinopelvic parameters and alignment 1, 3, 6 and 12 months after surgery. Fusion was graded according to Bridwell grading system [11]. The GAP score was used to assess the effectiveness of surgical intervention by comparing preoperative and postoperative GAP scores [12].

Ethical approval:

The patients gave their informed written permission. After receiving clearance from Tanta University Hospitals' Faculty of Medicine Ethics Committee, the study was conducted. The study adhered to the Helsinki Declaration throughout its execution.

Statistical analysis

We used SPSS version 28.0 to do the statistical analysis. Data distribution normality was assessed using histograms and the Shapiro-Wilks test. The mean ± SD of quantitative parametric data were displayed. With the same subjects, repeated measures ANOVA tests were employed to examine changes over several time periods or situations **.**Qualitative variables were shown as frequency and percentage (%). It was deemed statistically significant when the two-tailed P value was less than 0.05.

RESULTS

Regarding the clinical presentation, all the studied patients 20 (100%) were presented with low back pain and sciatica. Left-sided sciatica was observed in 50% of cases, followed by bilateral sciatica in 30% and right-sided sciatica in 20%. 2 (10%) patients had motor symptoms (showed bilateral partial foot drop).

The level of slip was mostly at the level of L5-S1 in 14 (70%) patients. The most common grade of slip was grade 1 in 10 (50%) patients. Intraoperative blood loss was the only reported intraoperative complication. It ranged from 150 to 700 ml with a mean of 374.0 ± 170.83 ml (Table 1).

Table (1): Shows demographics, comorbidities, duration of complaint, clinical presentation, grade, level of slip, surgical procedure, operative findings and intraoperative complications of the studied patients

			Total (n= 20)
Demographics	**Age (years)**		39.4± 11.98
	Sex	**Male**	6 (30%)
		Female	14 (70%)
	BMI (Kg/m^2)		29.77± 3.64
Comorbidities	**DM**		2 (10%)
	HTN		4 (20%)
	Cardiac history		5 (25%)
Duration of complaint (months)			7.05± 4.81
Clinical presentation	**Low back pain and sciatica**		20 (100%)
	Motor symptoms (bilateral partial foot drop)		2 (10%)
Grade and level of slip	**Level of slip**	**L4-5**	6 (30%)
		L5-S1	14 (70%)
	Grade of slip	**Grade 1**	10 (50%)
		Grade 2	4 (20%)
		Grade 3	4 (20%)
		Grade 4	2 (10%)
Surgical procedure	**Number of laminectomy levels**	**1 level**	6 (30%)
		2 levels	14 (70%)
	Number of discectomy levels	**1 level**	20 (100%)
		2 levels	0 (0%)
	Number of fixation levels	**1 level**	6 (30%)
		2 levels	14 (70%)
	Involvement of the 1st sacral vertebra		14 (70%)
Operative findings	**Fibrocartilaginous mass**		20 (100%)
	Hypertrophied facets		6 (30%)
	Hypertrophied ligaments		10 (50%)
Intraoperative complications	**Mean blood loss (ml)**		374.0 ± 170.83
	Incidental durotomy		0 (0%)
	Root injury		0 (0%)
	Screws malposition		0 (0%)
	Superior facet violation		0 (0%)

BMI: Body mass index, DM: diabetes mellitus, HTN: hypertension.

Regarding the X-ray evaluation of the spinopelvic parameters, PT was significantly lower postoperatively, and during follow-up after 3 and 6 months and after 1 year. Whereas SS was significantly higher postoperatively and during follow-up. LL was higher postoperatively and during follow-up compared to preoperative values. The other spinopelvic parameters including PI, L4/S1 lordosis, TK and GT were insignificantly different along the follow-up time and compared to preoperative values (Table 2).

Table (2): X-ray evaluation of the spinopelvic parameters of the studied patients

	Preoperative	Postoperative	After 3 months	After 6 months	After 1 year	P value
PT	26.8± 7.56	22± 3.31	22± 3.31	22± 3.31	22± 3.31	**0.002***
	P1	**0.013***	**0.013***	**0.013***	**0.013***	--
	P2		1.00	1.00	1.00	
	P3			1.00	1.00	
	P4				1.00	
SS	35.4± 6.26	39.9± 4.84	39.9± 4.84	39.9± 4.84	39.9± 4.84	**0.021***
	P1	**0.015***	**0.015***	**0.015***	**0.015***	--
	P2		1.00	1.00	1.00	
	P3			1.00	1.00	
	P4				1.00	
PI	61.9± 7.68	61.9± 7.68	61.9± 7.68	61.9± 7.68	61.9± 7.68	1.00
LL	60.2± 11.59	59.3± 6.29	59.3± 6.29	59.3± 6.29	59.3± 6.29	0.994
L4/S1 lordosis	37.9± 14.26	32.5± 4.03	32.5± 4.03	32.5± 4.03	32.5± 4.03	0.078
TK	37.5± 9.12	32.5± 12.72	32.5± 12.72	32.5± 12.72	32.5± 12.7	0.604
GT	22.6± 9.22	17.4± 6.78	17.4± 6.78	17.4± 6.78	17.4± 6.78	0.099

*:Significant, P1: p value compared to preoperative, P2: p value compared to postoperative, P3: p value compared to after 3 months, P4: p value compared to after 6 months. PT: pelvic tilt, SS: sacral slope, PI: Pelvic incidence, LL: lumbar lordosis, TK: thoracic kyphosis; GT: global tilt.

The angle of slip was significantly lower postoperatively, and during follow-up compared to preoperative angle. The GAP score was significantly decreased postoperatively and during follow-up. The ODI scale was significantly decreased postoperatively, and during follow-up. The VAS score was significantly decreased postoperatively, and during follow-up after 3 and 6 months and after 1 year compared to preoperative VAS. The clinical evaluation showed that back pain was significantly improved during follow-up after 3 and 6 months and after 1 year compared to preoperative, while sciatica was significantly improved directly postoperatively and during follow-up after 3 and 6 months and after 1 year compared to preoperative (Table 3).

Table (3): Angle of slip, GAP score, ODI scale and VAS of the studied patients

	Preoperative	Postoperative	After 3 months	After 6 months	After 1 year	P value
Angle of Slip	14.4± 4.62	10± 4.63	10± 4.63	10± 4.63	10± 4.63	**0.009***
	P1	**0.005***	**0.005***	**0.005***	**0.005***	--
	P2		1.00	1.00	1.00	
	P3			1.00	1.00	
	P4				1.00	
GAP score	3.9± 2.27	0.3± 0.92	0.3± 0.92	0.3± 0.92	0.3± 0.92	**<0.001***
	P1	**<0.001***	**<0.001***	<0.001*	**<0.001***	--
	P2		1.00	1.00	1.00	
	P3			1.00	1.00	
	P4				1.00	
ODI scale	63.3± 16.83	44.8± 16.32	32± 13.8	19.2± 10.98	8.6± 4.5	**<0.001***
	P1	**0.001***	**<0.001***	**<0.001***	**<0.001***	--
	P2		**<0.001***	**<0.001***	**0.011***	
	P3			**<0.001***	**0.002***	
	P4				**<0.001***	
VAS score	7.2± 1.2	4.8± 1.11	3.6± 0.82	2.4± 0.82	1.3± 0.8	**<0.001***
	P1	**<0.001***	**<0.001***	**<0.001***	**<0.001***	--
	P2		**<0.001***	**<0.001***	**<0.001***	
	P3			**<0.001***	**<0.001***	
	P4				**<0.001***	

*:Significant as p value <0.05.VAS: visual analogue scale. GAP: global alignment and proportion, ODI: Oswestry disability index.

Regarding the postoperative reduction, the majority of the studied patients 16 (80%) showed complete postoperative reduction. The postoperative back pain improved after 1 month in 16 (80%) patients and improved after 3 months in 4 (20%) patients. The postoperative sciatica had been improved in all the studied patients 20 (100%).

Postoperative motor symptoms were intact in 18 (90%) patients, while 2 (10%) patients showed improved motor symptoms after 1 month. The hospital stay ranged from 2 to 4 days with a mean of 2.8± 0.62 days. Among the studied patients, 2 (10%) patients were discharged to rehabilitation.

None of the studied patients had any postoperative complications (Cage subsidence, cerebrospinal fluid (CSF) leak, wound infection, seroma, paraplegia, bed sores or spondylodiscitis). Based on ODI, the majority of the studied patients 14 (70%) showed excellent outcome. Regarding the radiological fusion rate, 14 (70%) patients had complete fusion (Table 4).

Table (4): Postoperative reduction, evaluation, complications, hospital stay, discharge to rehabilitation, clinical outcome based on ODI, radiological fusion rate of the studied patients

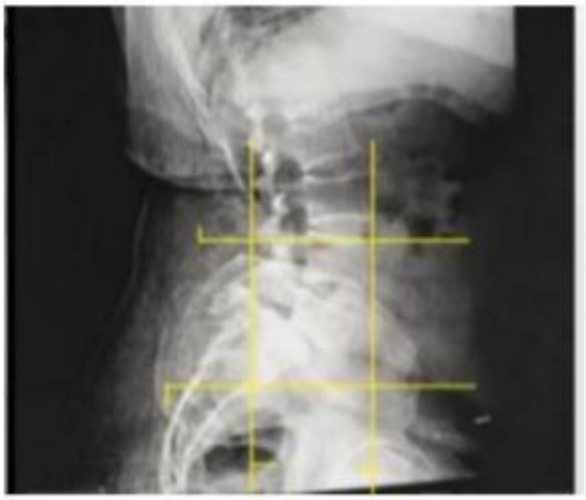
			Total (n= 20)
Postoperative reduction		**Complete**	16 (80%)
		Incomplete	4 (20%)
Postoperative evaluation	**Back pain**	**Improved after 1 month**	16 (80%)
		Improved after 3 months	4 (20%)
	Sciatica	**Improved**	20 (100%)
		Not improved	0 (0%)
	Motor symptoms	**Intact**	18 (90%)
		Improved after 1 month	2 (10%)
Hospital stay (days)			2.8± 0.62
Discharge to rehabilitation			2 (10%)
postoperative complications		**Cage subsidence**	0 (0%)
		CSF leak	0 (0%)
		Wound infection or seroma	0 (0%)
		Paraplegia	0 (0%)
		Bed sores	0 (0%)
		Spondylodiscitis	0 (0%)
Clinical outcome based on ODI		**Excellent**	14 (70%)
		Good	4 (20%)
		Fair	2 (10%)
Radiological fusion rate		**Complete**	14 (70%)
		Incomplete	4 (20%)
		No fusion	2 (10%)

CSF: cerebrospinal fluid. ODI: Oswestry disability index.

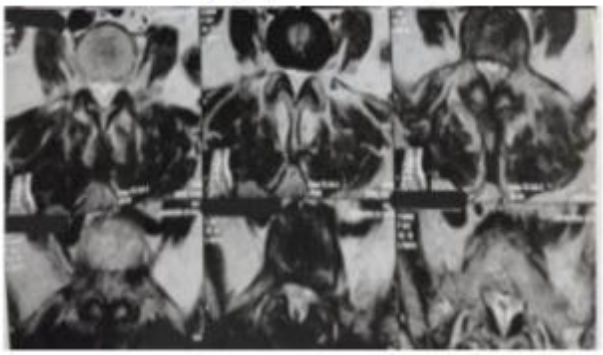
CASE PRESENTATION (Figures 1-5)

A female patient aged 38 years old, hypertensive, no past surgical history, presented with left side sciatica for five months before operation. Patient was intact, GAP score was 4, VAS was 8 and ODI was 70%. Postoperative: Patient was intact with improved radicular pain, GAP score was zero, VAS was 5 and ODI was 50%. After 3 months: Patient was intact, no radicular pain and improved low back pain. The patient returned to her daily activities. GAP score was zero, VAS was 4 and ODI was 42%. After 6 months: Patient was intact, no radicular pain and mild low back pain. GAP score was zero, VAS was 3 and ODI was 20%. After 12 months: Patient was intact, no radicular pain and no low back pain. GAP score was zero, VAS was zero and ODI was 12%.

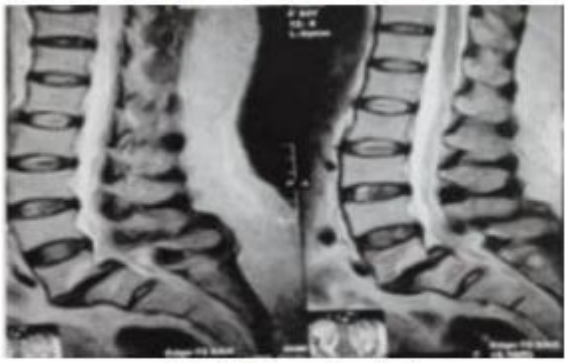
(A) Dynamic x-ray



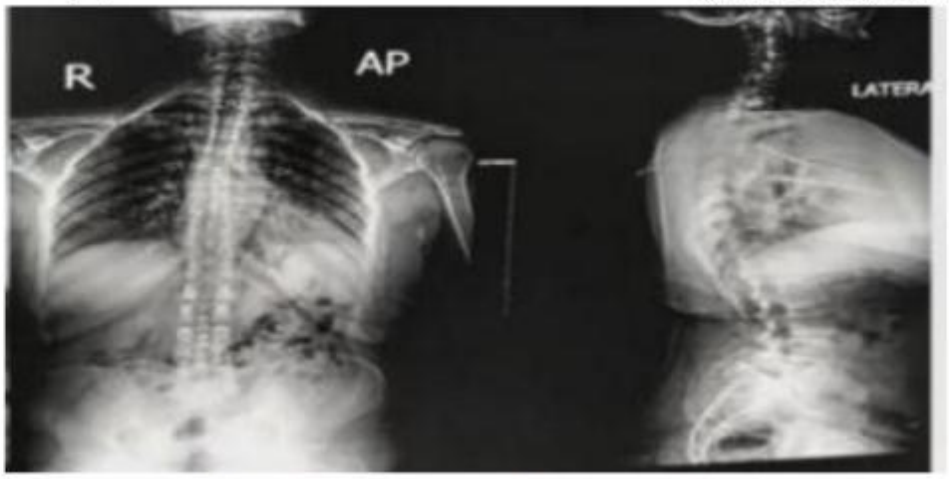
(B) Unstable zone



(C) MRI axial view

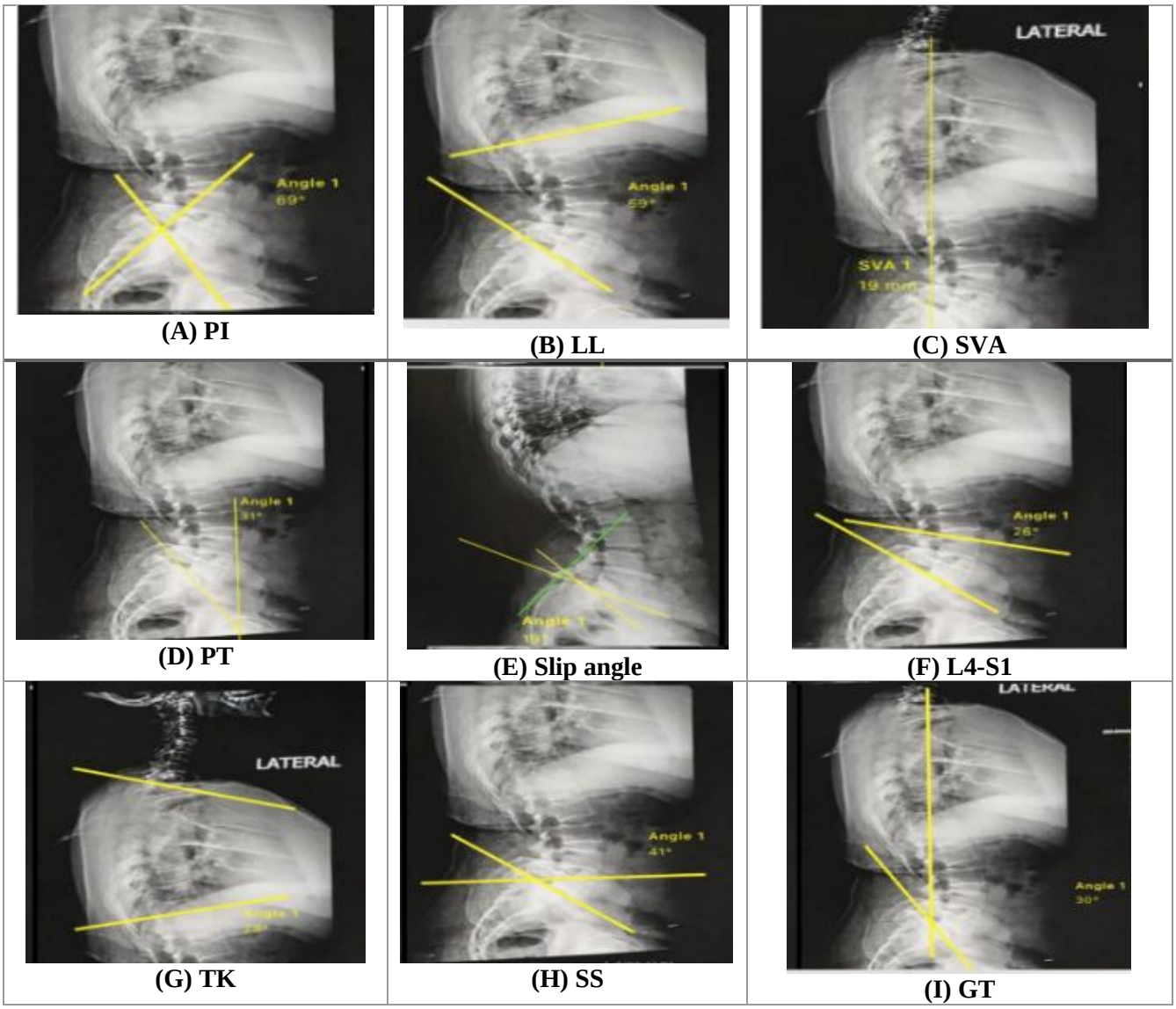


(D) MRI sagittal view



(E) Whole spine x-ray (AP & lateral views)

Figure (1): Preoperative radiological investigations

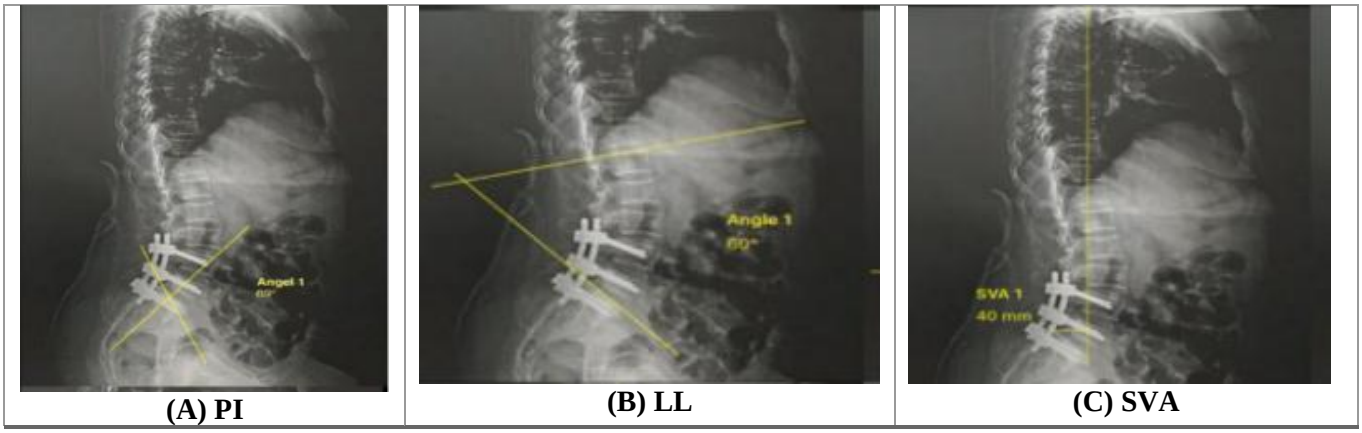


(A) PI (B) LL (C) SVA

(D) PT (E) Slip angle (F) L4-S1

(G) TK (H) SS (I) GT

Figure (2): Preoperative spinopelvic parameters



(A) PI (B) LL (C) SVA

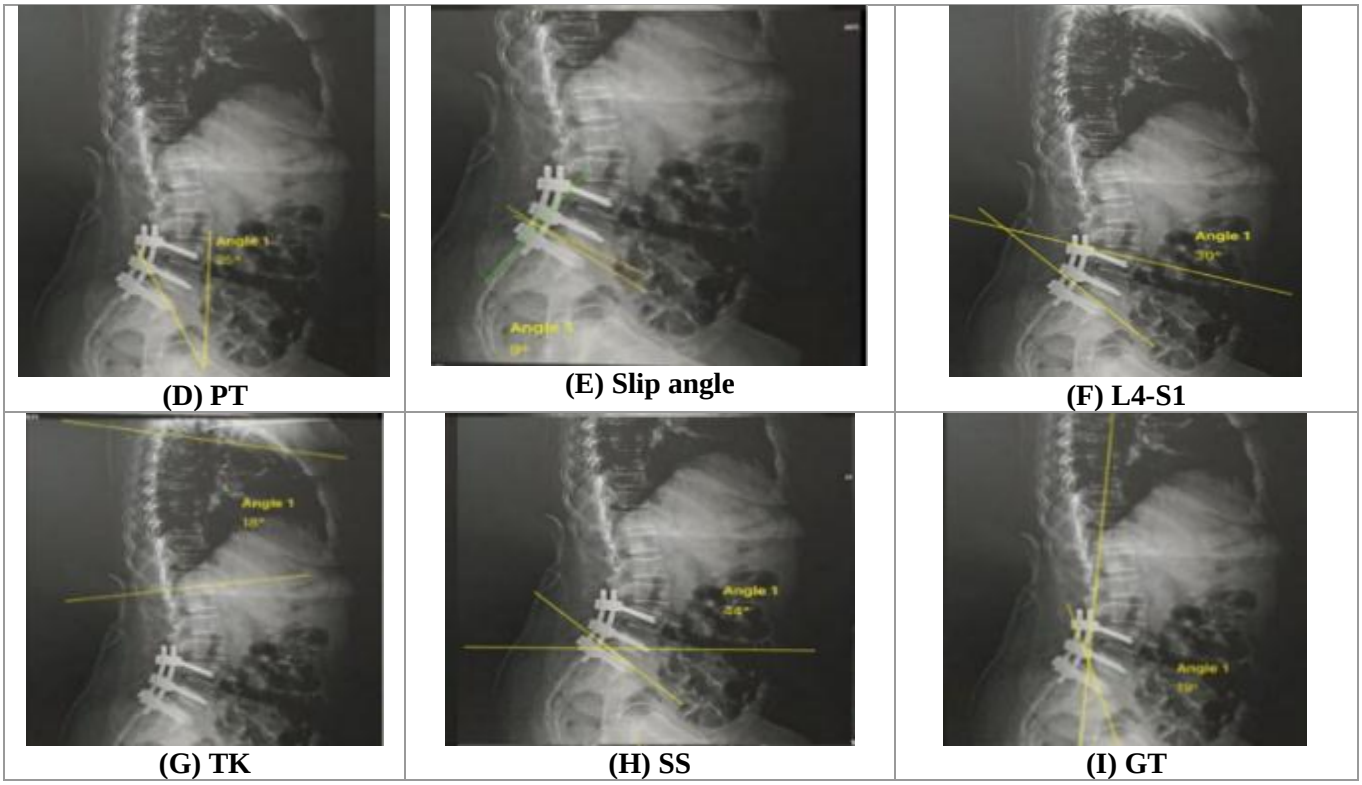


Figure (3): Postoperative spinopelvic parameters (after one month)

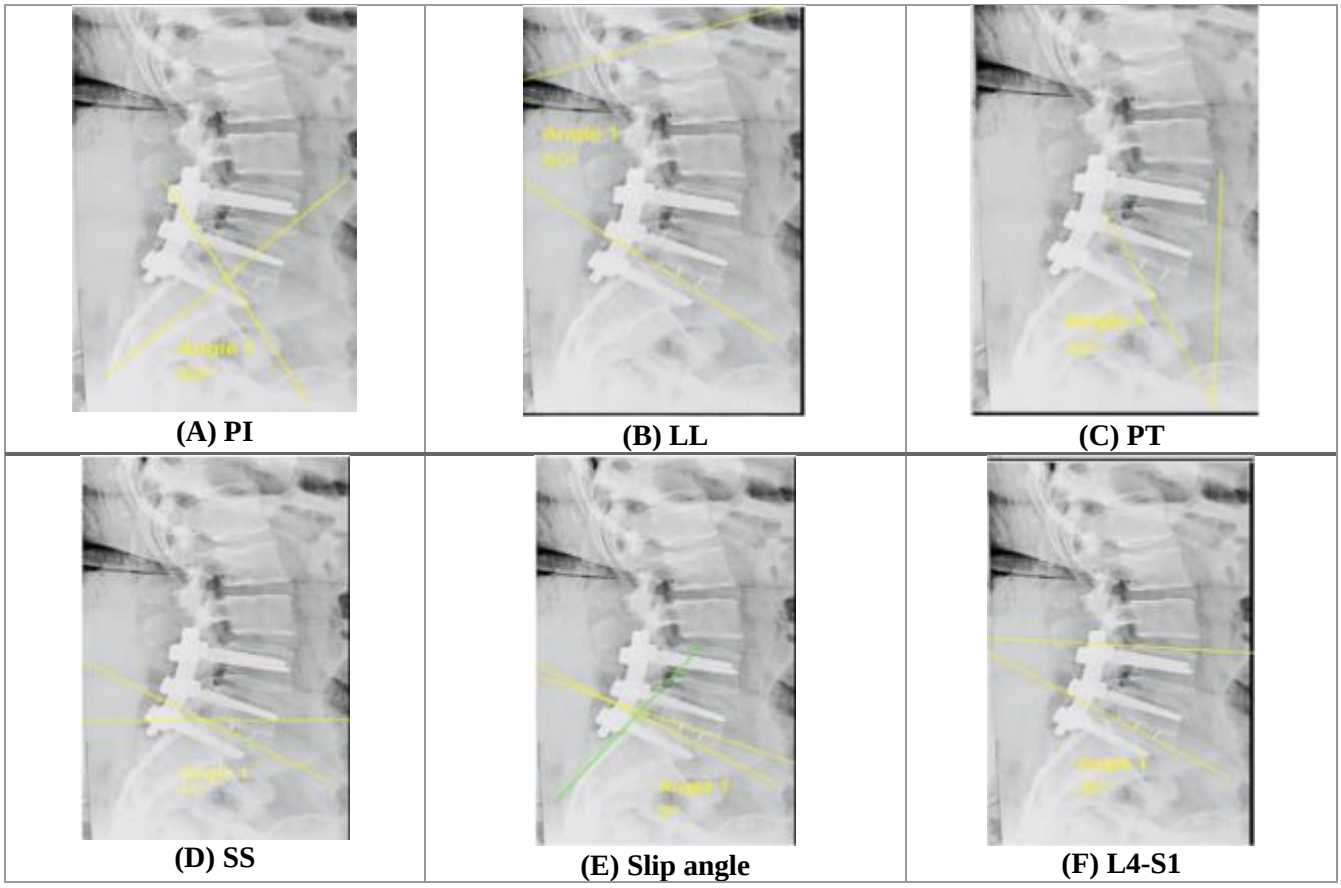


Figure (4): Postoperative spinopelvic parameters (after three months)

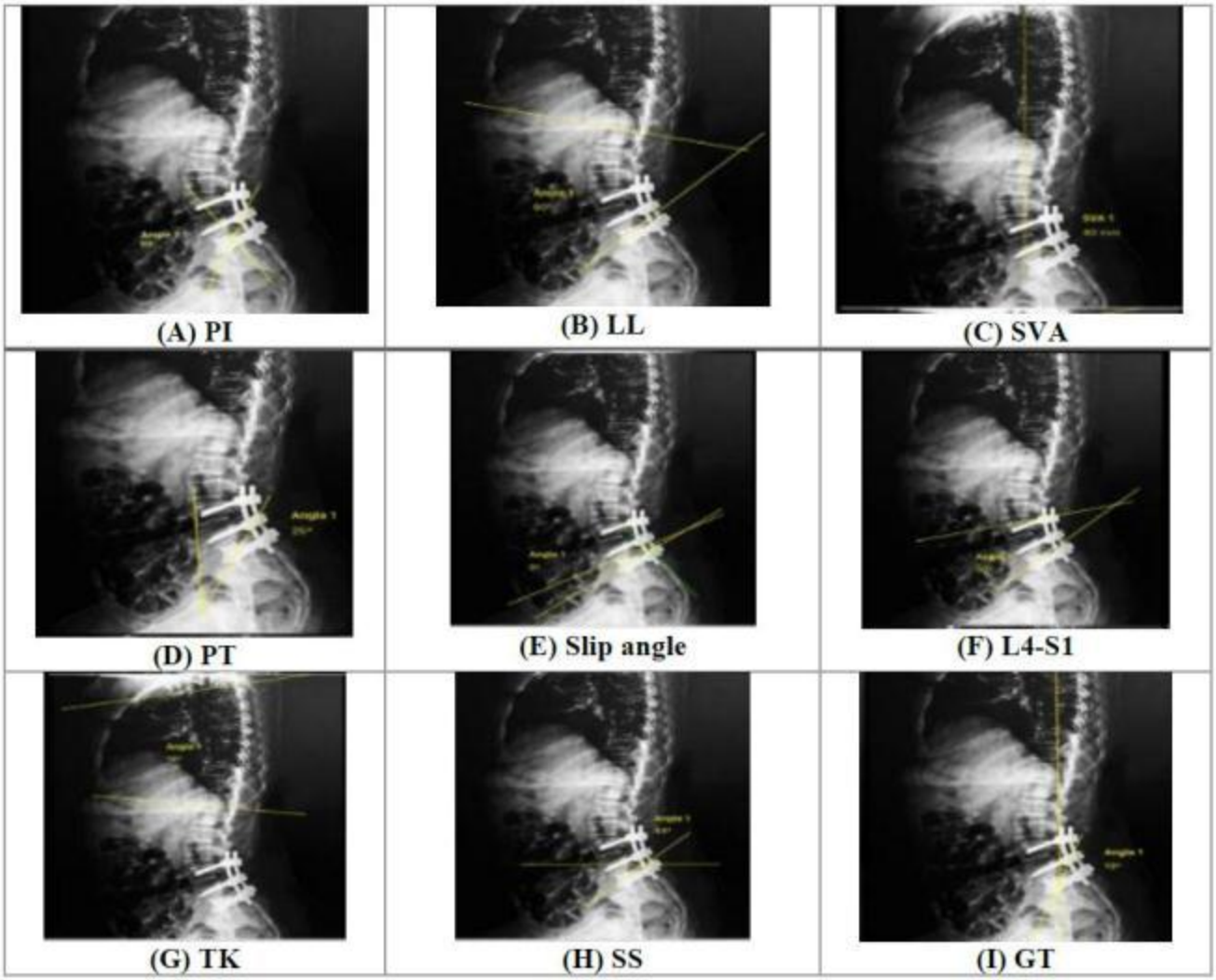


Figure (5): Postoperative spinopelvic parameters (after one year).

DISCUSSION

Isthmic spondylolisthesis is a common spinal condition defined by forward slippage of one vertebra over another, most commonly at the lumbosacral junction, caused by a defect or fracture in the pars interarticularis [13]. Isthmic type is distinct from degenerative or traumatic, as it results primarily from a defect acquired early in life, with progression influenced by biomechanical stress and anatomical predisposition [14].

Regarding the clinical presentation, all the studied patients 20 (100%) were presented with low back pain and sciatica. Left-sided sciatica was observed in 50% of cases, followed by bilateral sciatica in 30% and right-sided sciatica in 20%. 2 (10%) patients had motor symptoms (showed bilateral partial foot drop).

Our findings are in agreement with **Ramadan *et al.*** [15] who showed that low back pain was reported in 100% of patients, making it the most common presenting symptom. Left-sided sciatica was observed in 52% of cases, followed by right-sided sciatica in 32% and bilateral sciatica in 16%. Additionally, neurogenic claudication was present in 32% of patients.

In our study, we found that the mean duration of complaint was 7.05± 4.81 months. The mean hospital stay was 2.8± 0.62 days. Among the studied patients, 2 (10%) patients were discharged to rehabilitation. In contrast, **He *et al.*** [16] determined that the mean hospital stay was 12.4 ± 1.7 days.

In the current study, the level of slip was at the level of L4-5 in 6 (30%) patients and was at the level of L5-S1 in 14 (70%) patients. The grade of slip was grade 1 in 10 (50%) patients, grade 2 in 4 (20%) patients, grade 3 in 4 (20%) patients and was grade 4 in 2 (10%) patients.

Also, our findings are similar to **Marques *et al.*** [17] who demonstrated that the affected spinal levels were predominantly at L4-L5 and L5-S1, each accounting for 44% of cases.

Regarding the postoperative evaluation, the postoperative back pain improved after 1 month in 16 (80%) patients and improved after 3 months in 4 (20%) patients. The postoperative sciatica improved in all the studied patients 20 (100%). Postoperative motor symptoms were intact in 18 (90%) patients, while 2 (10%) patients showed improvement after 1 month.

This came in accordance with **Massel *et al.*** [18] who reported that patients undergoing minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF) experienced substantial improvements in back pain, with the majority of pain reduction occurring within the first six weeks post-surgery.

Regarding the X-ray evaluation of the spinopelvic parameters, PT was significantly lower postoperatively, and during follow-up after 3 and 6 months and after 1 year, Whereas SS was significantly higher postoperatively, and during follow-up. LL was higher postoperatively, and during follow-up compared to preoperative values.

Similarly, our findings agree with **He *et al.*** [16] who determined that there was a significant postoperative decrease in PT postoperatively ($p < 0.001$), indicating an improvement in pelvic alignment following surgery. While in contrast, postoperative measurements showed a statistically significant increase in LL, reaching borderline statistical significance ($p = 0.05$).

In our study, we revealed that the VAS score was significantly decreased postoperatively, and during follow-up after 3, 6 months and after 1 year compared to preoperative VAS ($P<0.05$).

Also, our findings are consistent with **Ibrahim *et al.*** [19] who showed that the VAS score for pain improved significantly, dropping from 5.73 ± 2.38 to 2.39 ± 2.55 ($p < 0.0001$), with a mean pain reduction of 3.33 ± 1.1.

The ODI scale was significantly decreased postoperatively, and during follow-up after 3, 6 months and after 1 year compared to preoperative ODI ($P<0.05$).

Furthermore, **Ibrahim *et al.*** [19] showed that ODI significantly decreased postoperatively ($p < 0.0001$), reflecting a substantial improvement in functional status.

The clinical evaluation showed that back pain was significantly improved during follow-up after 3, 6 months and after 1 year compared to preoperative ($P<0.001$), while sciatica was significantly improved directly postoperatively and during follow-up ($P<0.001$).

Our results are in consistence with **Marques *et al.*** [17] who reported that there was a statistically significant reduction in low back pain over 6 months, indicating a large clinical effect of the intervention on pain reduction.

Regarding the intraoperative complications, the intraoperative blood loss ranged from 150 to 700 ml with a mean of 374.0 ± 170.83 ml. The incidence of incidental durotomy, root injury, screws malposition or superior facet violation were not reported in any of the studied patients.

Our findings are similar to **He *et al.*** [16], who determined that the mean intraoperative blood loss was 358.9 ± 61.5 ml.

None of the studied patients had any postoperative complications (CSF leak, wound infection, seroma, cage subsidence, paraplegia, bed sores or spondylodiscitis). Regarding the radiological fusion rate, 14 (70%) patients had complete fusion, 4 (20%) patients had incomplete fusion, while 2 (10%) patients had no fusion.

Our findings are similar to **He *et al.*** [16], who discovered that the overall fusion rate in the study was 88.8%, demonstrating a high success rate of achieving solid spinal fusion following the surgical intervention.

The present study reported that there was a significant relation between radiological fusion rate and back pain after 3 months, as significantly lower prevalence of back pain was found in patients with complete radiological fusion rate.

Our findings are similar to a research by **Okuda *et al.*** [20] who reported a significant reduction in vertebral slippage, with the average slip decreasing postoperatively. The study found a positive correlation between the degree of slip reduction and improved clinical outcomes, highlighting the benefits of achieving substantial reduction.

LIMITATIONS

The sample size was small, and the follow-up period was only one year. Furthermore, it was carried out at a single center, which may restrict the generalizability of the findings.

CONCLUSIONS

Posterior interbody fusion with the insertion of a cage and transpedicular screws in patients with lumbar isthmic spondylolisthesis led to significant improvements in spinopelvic alignment, reduction of slip angle, restoration of disc space height, segmental lordosis and reduction of spondylolisthesis. It is important in maintenance of spinopelvic parameters, restoration of sagittal balance of the spine, satisfactory fusion rate, and clinical outcomes. The results support the effectiveness and safety of this surgical approach in improving both radiological and functional outcomes in lumbar isthmic spondylolisthesis.

Therefore, the study recommended that early surgical intervention should be considered in patients with higher grades of slip to achieve better reduction and functional outcomes and routine postoperative radiological follow-up is advised to monitor fusion status and detect any complications early.

No funding.

No conflict of interest.

REFERENCES

1. **Amer M, Yousef A (2015):** Transforaminal lumbar interbody fusion for the treatment of spondylolisthesis and degenerative segmental instability; surgical and radiological outcome. Egypt J Neurosurg., 30:213-20.

2. **Stonecipher T, Wright S (1989):** Posterior lumbar interbody fusion with facet-screw fixation. Spine, 14:68-71.
3. **Harms J, Rolinger H (1982):** A one-stager procedure in operative treatment of spondylolistheses: dorsal traction-reposition and anterior fusion (author's transl). Z Orthop Ihre Grenzgeb., 120:43-67.
4. **Vrtovec T, Ibragimov B (2022):** Spinopelvic measurements of sagittal balance with deep learning: systematic review and critical evaluation. Eur Spine J., 31(8): 2031-45.
5. **Gadkari A, Ghodke A, Jha A (2022):** Correlation of pelvic incidence and pelvic parameters in lumbar spondylolisthesis. Surg Neurol Int., 13: 405. doi: 10.25259/SNI_545_2022.
6. **Labelle H, Roussouly P, Chopin D *et al.* (2008):** Spino-pelvic alignment after surgical correction for developmental spondylolisthesis. Eur Spine J., 17:1170–1176.
7. **Yilgor C, Sogunmez N, Boissiere L *et al.* (2017):** Global Alignment and Proportion (GAP) Score: development and validation of a new method of analyzing spinopelvic alignment to predict mechanical complications after adult spinal deformity surgery. J Bone Joint Surg Am., 99(19):1661-1672.
8. **Lamartina C, Cecchinato R, Fekete Z *et al.* (2015):** The unstable zone in severe spondylolisthesis: a radiographic and clinical analysis. Eur Spine J., 24(7):1499-1505.
9. **Brodke D, Goz V, Lawrence B *et al.* (2017):** Oswestry Disability Index: a psychometric analysis with 1,610 patients. Spine J., 17:321-27.
10. **Kirshblum S, Botticello A, Benedetto J *et al.* (2020):** A comparison of diagnostic stability of the ASIA Impairment Scale versus Frankel Classification Systems for traumatic spinal cord injury. Arch Phys Med Rehabil., 101:1556-62.
11. **Soriano Sánchez J, Soriano Solís S, Soto García M *et al.* (2020):** Radiological diagnostic accuracy study comparing Lenke, Bridwell, BSF, and CT-HU fusion grading scales for minimally invasive lumbar interbody fusion spine surgery and its correlation to clinical outcome. Medicine (Baltimore), 99:19-97.
12. **Ali Z, Ahsan Z, Liaqat N *et al.* (2024):** Bridging the gap: evaluation of preoperative patients' education by comparing expectations and real-perioperative surgical experiences: a mixed-methods descriptive cross-sectional study. BMC Health Serv Res., 24:964. doi: 10.1186/s12913-024-11388-z.
13. **Mohile N, Kuczmarski A, Lee D *et al.* (2022):** Spondylolysis and isthmic spondylolisthesis: a guide to diagnosis and management. J Am Board Fam Med., 35:1204-16.
14. **Alomari S, Judy B, Sacino A *et al.* (2022):** Isthmic spondylolisthesis in adults… A review of the current literature. J Clin Neurosci., 101:124-30.
15. **Ramadan A, Abd Elhafez K, Negm M (2018):** Assessment of pelvic parameters before and after postero-lateral interbody fusion surgery in patient with lumbo-sacral instability. Egyptian J of Hospital Med., 71:2365-69.
16. **He S, Zhang Y, Ji W *et al.* (2020):** Analysis of spinopelvic sagittal balance and persistent low back pain (PLBP) for degenerative spondylolisthesis (DS) following posterior lumbar interbody fusion (PLIF). Pain Res Manag., 20:597-1937.
17. **Marques R, Silva A, Nogueira J *et al.* (2023):** Spinopelvic parameters in the clinical and functional outcomes of patients submitted to lumbar interbody fusion surgery – a prospective study. Brazilian Neurosurgy, 42:210-19.
18. **Massel D, Mayo B, Narain A *et al.* (2020):** Improvements in back and leg pain following a minimally invasive transforaminal lumbar interbody fusion. Int J Spine Surg., 14:745-55.
19. **Ibrahim M, Saeed F, El-Morshidy E *et al.* (2025):** Posterolateral fusion versus posterior lumbar interbody fusion for adult low-grade isthmic spondylolisthesis: Analysis of sagittal radiographic parameters - a randomized controlled trial. Global Spine J., 15:1614-24.
20. **Okuda S, Oda T, Yamasaki R *et al.* (2014):** Posterior lumbar interbody fusion with total facetectomy for low-dysplastic isthmic spondylolisthesis: effects of slip reduction on surgical outcomes: clinical article. J Neurosurg Spine, 21:171-78.