

# Comparative Study of Transpedicular Fixation with and without Interbody Fusion Cage in Management of L4-L5 Lumbar Degenerative Spondylolisthesis

Yasser Bahgat Elsis, Osama Saber Shereef

Neurosurgery Department, Faculty of Medicine, Menoufia University, Menoufia, Egypt

\*Corresponding author: Yasser Bahgat Elsis, Mobile: (+20) 01005866415, Email: Yasser.elsese@med.menoufia.edu.eg

## ABSTRACT

**Background:** Lumbar degenerative spondylolisthesis (LDS) is a clinically symptomatic degenerative slippage of a lumbar vertebra relative to the neighboring vertebra below.

**Objective:** This study aimed to compare clinical and radiological outcomes following management of L4-L5 LDS with and without interbody fusion cage.

**Patients and methods:** This prospective study included 40 patients with degenerative spondylolisthesis who were surgically treated by transpedicular screws with and without interbody fusion cage at the Neurosurgery Department, Faculty of Medicine, Menoufia University over a 3-year period from January 2018 to 21 January 2021. The patients were divided into two equal groups: Group A that involved patients treated by transpedicular screws only, and group B that included patients treated by transpedicular screws and inter body fusion cage.

**Results:** Post-operative follow-up fusion was significantly higher among group B ( $17.01 \pm 0.06$ ) than among group A ( $15.01 \pm 0.06$ ) with a mean difference of 11.75% ( $p < 0.001$ ). On contrast, pseudoarthrosis and slip percentage were significantly increased among group A than among group B with a mean difference of 66.44% and 118%, respectively ( $p < 0.001$ ). VAS (low back pain and leg pain) significantly improved post-treatment compared to pre-treatment among group A ( $p < 0.001$ ) where it was decreased from  $8.01 \pm 0.06$  and  $7.01 \pm 0.06$  to  $1.51 \pm 0.06$  and  $1.61 \pm 0.06$ , with a mean change of  $5.57 \pm 2.31$ , (95% CI, 4.49-6.65); and  $4.64 \pm 1.88$  (95% CI, 3.77-5.52) respectively, ( $p < 0.001$ ). Also, among group B, VAS (low back pain and leg pain) significantly improved post-treatment compared to pre-treatment ( $p < 0.001$ ) where it was decreased from  $7.01 \pm 0.06$  and  $9.01 \pm 0.06$  to  $2.01 \pm 0.06$  and  $2.41 \pm 0.06$  respectively with a mean change of  $4.84 \pm 1.14$  (95% CI, 4.32-5.36), and  $6.21 \pm 1.55$  (95% CI, 5.50-6.91) respectively ( $p < 0.001$ ).

**Conclusion:** Transpedicular fixation by screws with and without interbody fusion produces the same outcomes in terms of postoperative clinical improvement and patient satisfaction.

**Keywords:** Interbody fusion cage, Lumbar degenerative spondylolisthesis, Patient satisfaction, Radiological outcome.

## INTRODUCTION

The clinically symptomatic degenerative slippage of a lumbar vertebra relative to the lower neighboring vertebra is known as lumbar degenerative spondylolisthesis (LDS). Because the neural arch is intact, the drop percentage is often between 30 and 40%, or there will be serious neurologic problems [1].

The condition typically affects 5-7% of the population and is more prevalent in older women with L4-L5 level [2].

To remove a herniated disc or a portion of one that is positioned between two neighboring vertebrae in the lumbar spine, a procedure known as anterior lumbar interbody fusion, or ALIF, is performed on the spine [3]. The formation of a solid arthrodesis over a spinal motion segment is one of the objectives of anterior lumbar inter-body fusion. For the operation, a wide variety of fusion rates have been documented. Patient selection, surgical method, as well as the investigator's concept of fusion, all have a role in the variety of fusion incidence [4,5].

Physically, most LDS patients exhibit minimal or no symptoms that interfere with their regular day-to-day activities. Patients who develop symptoms typically respond appropriately to conservative treatment; but, in resistant circumstances, surgical intervention may be required [6]. Decompression, vertebral reduction, fusion

(posterolateral or interbody), and instrumentation (pedicle screw, rod, plate, interspinous device, etc.) have all been utilized in the operative procedure of LDS, either separately or in combination [7].

The primary finding of spondylolisthesis on a lateral view of forward (or backward) displacement of L4 on L5 or, less frequently, L5 on S1 or L3 on L4 in the presence of an unbroken neural arch is one of the simple radiographic characteristics [8]. Instead of being a straightforward forward (or backward) movement, listhesis is a rotating malformation. Small compensatory curvature in the upper lumbar and lower thoracic spine can also be seen on radiographs [9]. The three main local causes of LDS, all of which are likely to result in the development of degenerative vertebral slippage, are: 1) arthritis of the facet joints with loss of their normal structural support, 2) dysfunction of the ligamentous stabilizing component, most likely brought on by hyperlaxity, and 3) ineffective muscular stabilization [10].

Segmental instability in the sagittal plane and LDS are both caused by disc degeneration. Sports participation and pregnancy are also linked to LDS [11]. 8.7% is the estimated total incidence of lumbar degenerative spondylolisthesis [12]. It affects those older than 50 years old, African and Americans more frequently than Caucasians, and females more

frequently than males. Due to higher ligamentous laxity compared to men, females may be more affected. Additionally, it has been demonstrated that the facet articular cartilage exhibits a high expression estrogen receptor, which may have implications for the emergence of this illness in postmenopausal women [13]. L4-5 is the most frequently impacted level. This could be attributed to the facet joint at this level being less resistant to pressures of forward flexion than the L5-S1 articulation due to its relative horizontal orientation [14]. This study aimed to compare clinical and radiological outcomes following management of L4-L5 lumbar degenerative spondylolisthesis with and without interbody fusion cage.

**PATIENTS AND METHODS**

**Study design and patient enrolment:** A group of 40 patients with L4-L5 degenerative spondylolisthesis who underwent transpedicular screws and interbody fusion cage surgery at the Neurosurgery Department, Faculty of Medicine, Menoufia University over a three-year period from January 2018 to January 2021 were included in a prospective study. All patients were identified using the inclusion and exclusion criteria.

**Inclusion criteria:** Patients with single-level L4-L5 LDS who had neural decompression, posterolateral fusion (PLF), and instrumentation with or without interbody arthrodesis as a primary operation.

**Exclusion criteria:** Spondylolisthesis at different levels, spondylolisthesis at many levels, and

spondylolisthesis of a kind other than degenerative. Prior lumbar spine surgery, and those patients underwent un-instrumented fusion, stand-alone cage, or decompression alone.

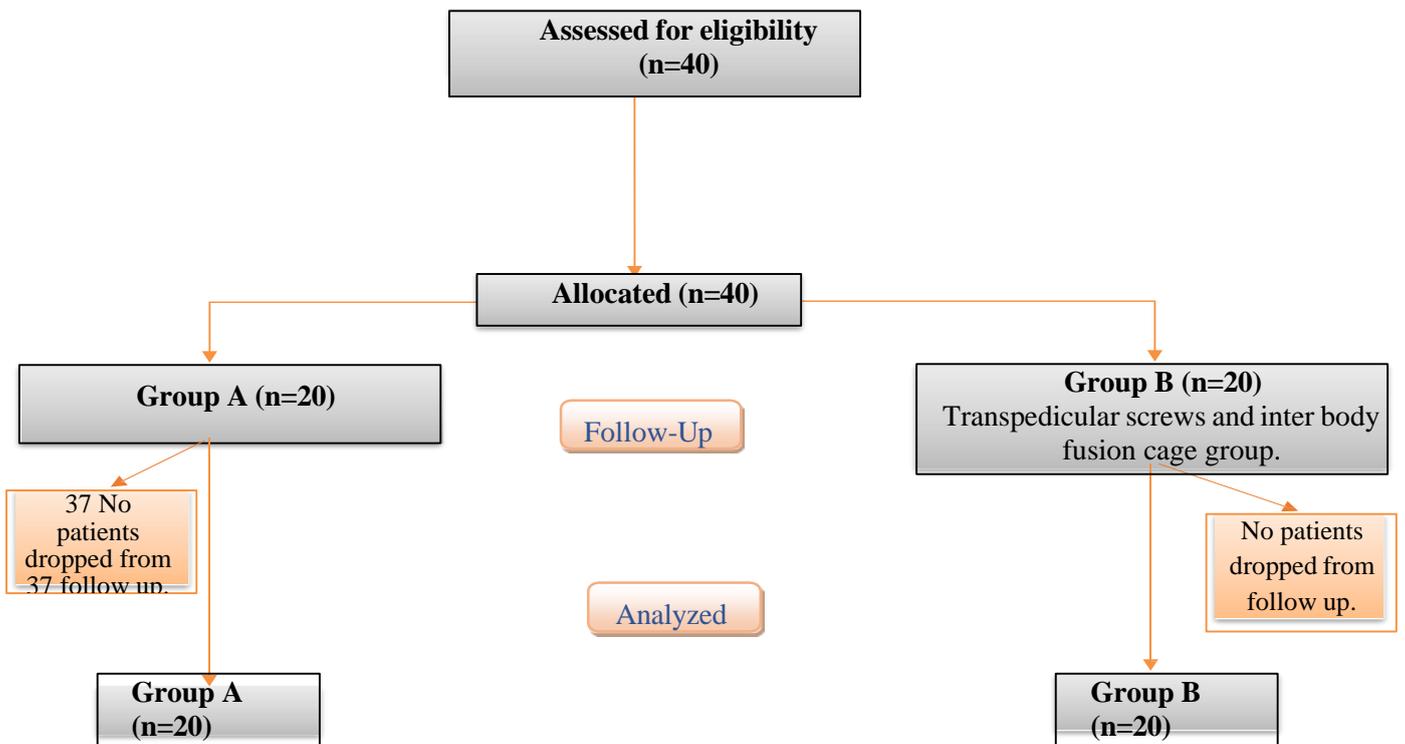
Figure (1) showed a flowchart of the study population. Of the 40 patients with L4–L5 lumbar degenerative spondylolisthesis, 20 patients treated by transpedicular screws only as group A and 20 patients treated by transpedicular screws and inter body fusion cage (Group B).

**All included patients were subjected to the following:**

Every patient gave a thorough history, including information about their age, sex, past, etc. Motor and sensory tests, reflex affection, and sphincteric affection were all part of the clinical examination and neurological examination. Preoperative evaluation of the patient, including a heart evaluation and full laboratory tests (complete blood picture, liver function test, kidney function test, prothrombin time).

**Pre- and post-operative investigations:**

A neuroradiological evaluation was performed. Anteroposterior, lateral, oblique, and dynamic images were incorporated in the plain X-ray to show the lumbar degenerative spondylolisthesis. CT scan: to define osseous anatomy and determine the extent of middle column deterioration. Magnetic resonance imaging (MRI): to evaluate the soft tissue, bone architecture, and neural components.



**Figure (1):** Flowchart of the studied patients.

**Visual analogue scale (VAS):** A clinical assessment of the degree of pain was conducted using the VAS. Our main criteria for diagnosing pseudoarthrosis included the total absence of a continuous bone bridge, peripheral radiolucency around the screw or cage, more than 10 degrees motion on dynamic images, or screw fracture. Except for individuals who had clinical symptoms, we did not regularly scan patients with computed tomography (CT). Additionally, slip percentages from preoperative and right after surgery radiographs were compared with these radiographs. Under general anesthesia, with preoperative antibiotic prophylaxis, and while lying on a spinal frame with the abdomen free and the spine flexed to open the interlaminar gaps, the surgical procedure was performed. With "0" denoting no pain and "10" denoting the most agonizing pain possible, all patients were asked to rate their discomfort before and after surgery using the visual analogue scale (VAS).

**Sample size estimation:** An idea of studying and comparing the clinical and radiological outcome following management of L4-L5 lumbar degenerative spondylolisthesis with and without interbody fusion cage. Estimation of the total number was about 20 patients treated by transpedicular screws only and 20 patients treated by transpedicular screws and inter body fusion cage. So, it is expected to include about 40 patients in this study.

**Ethical consideration:** After being informed of the trial's benefits and dangers and gaining clearance

from The Local Ethics Committee, patients who opted to participate gave their signed informed consents. The 1964 Declaration of Helsinki and its subsequent amendments or equivalent ethical standards, as well as the ethical standards established by The Institutional and/or National Research Committee, were followed in all processes. Faculty of Medicine's Local Ethics Committee, Menoufia University, approved the study (IRB approval number: 1/2023NEU5).

**Statistical analysis**

SPSS version 21 was used to compile and analyze all the data (SPSS Inc., Chicago, IL). Mean ± standard deviation (SD) were used to present continuous variables, whereas relative frequency distributions and percentages were used to display categorical variables. When comparing continuous variables between the study subjects. Student's t-test and Standard Student t-test were employed. Paired samples were utilized to compare the means of VAS and vertebral body height before and after therapy or the Mann-Whitney (U) test was used to compare quantitative variables with abnormally distributed distributions. While, categorical data were evaluated using the chi-square (X<sup>2</sup>) test. Statistics were considered significant at a P value ≤ 0.05.

**RESULTS**

In our results, there was no significant difference among the studied groups regarding age and sex (p > 0.05) (Table 1).

**Table (1):** Socio-demographic data in the studied groups

	Group A (N=20)		Group B (N=20)		Test of significant	P-value	95% CI		Mean dif.
	N	%	N	%			Lower	Upper	
<b>Age/year</b>					t=	0.586	4.35	12.85	8.60
Mean ±SD	49.55±6.45		46.95±6.82		0.302				
<b>Sex</b>					X <sup>2</sup>				
Male	5	25%	6	30%	0.125	0.723	---	---	---
Female	15	75%	14	70%					

Additionally, mean duration follow-up showed statistically significant increase among group A (19.90 ± 2.27 months) than group B (18.15 ± 1.57), (p=0.007). While incidental durotomy showed statistically significant increase among group B (4.51 ± 0.06) than among group A (2.30 ± 0.06) with mean different 49% (p=0.001) (Table 2).

**Table (2)** Mean duration follow-up and incidental durotomy among the two studied groups.

	Group A (N=20)	Group B (N=20)	U	P- value	95% CI		Mean dif.%
					Lower	Upper	
<b>Mean follow-up (months)</b>			2.83	0.007*	0.50	2.99	9.64%
Mean ±SD	19.90±2.27	18.15±1.57					
<b>Incidental durotomy</b>			10.127	0.001*	-2.24	-2.17	49%
Mean ±SD	2.30±0.06	4.51±0.06					

U (Mann-Whitney test), CI (confidence intervals), \*Significant.

Also, there were preoperative VAS low back pain that was statistically significantly high among group A ( $8.01 \pm 0.06$ ) than in group B ( $7.01 \pm 0.06$ ), ( $p < 0.001$ ). However, preoperative VAS leg pain, and final visit VAS (low back pain, leg pain) were statistically significantly high among group B than in group A with a mean difference of 22.19%, 24.87% and 33.19% respectively ( $p < 0.001$ ) (Table 3).

**Table (3):** VAS low back pain and leg pain (pre- and post-treatment) among the studied groups

	Group A (N=20)	Group B (N=20)	U	P-value	95% CI		Mean dif.
					Lower	Upper	
<b>Preoperative VAS low back pain</b> Mean $\pm$ SD	8.01 $\pm$ 0.06	7.01 $\pm$ 0.06	53.45	<0.001*	0.96	1.04	14.26%
<b>Preoperative VAS Leg pain</b> Mean $\pm$ SD	7.01 $\pm$ 0.06	9.01 $\pm$ 0.06	106.9	<0.001*	-2.04	-1.96	22.19%
<b>Final visit VAS low back pain</b> Mean $\pm$ SD	1.51 $\pm$ 0.06	2.01 $\pm$ 0.06	26.72	<0.001*	-0.54	-0.46	24.87%
<b>Final visit VAS Leg pain</b> Mean $\pm$ SD	1.61 $\pm$ 0.06	2.41 $\pm$ 0.06	42.76	<0.001*	-0.84	-0.76	33.19%

Visual Analogue Scale (VAS), U (Mann-Whitney test), CI (confidence intervals), \*Significant  
In our study, post-operative follow-up fusion was statistically significantly high among group B ( $17.01 \pm 0.06$ ) than among group A ( $15.01 \pm 0.06$ ), with a mean difference of 11.75% ( $p < 0.001$ ). On contrast, pseudoarthrosis, and slip percentage were statistically significantly high among group A than among group B with a mean difference of 66.44% and 118% respectively ( $p < 0.001$ ), (Table 4).

**Table (4):** Post-operative follow-up among studied groups

	Group A (N=20)	Group B (N=20)	U	P-value	95% CI		Mean dif.
					Lower	Upper	
<b>Post-operative follow-up fusion</b> Mean $\pm$ SD	15.01 $\pm$ 0.06	17.01 $\pm$ 0.06	106.9	<0.001*	-2.04	-1.96	11.75%
<b>Pseudarthrosis</b> Mean $\pm$ SD	5.01 $\pm$ 0.06	3.01 $\pm$ 0.06	109.54	<0.001*	1.96	2.04	66.44%
<b>Slip percentage</b> Mean $\pm$ SD	5.91 $\pm$ 0.06	2.71 $\pm$ 0.06	171.04	<0.001*	3.16	3.24	118%

According to VAS, low back pain and leg pain were significantly improved post-treatment compared to pre-treatment among group A ( $p < 0.001$ ) where it was decreased from  $8.01 \pm 0.06$  and  $7.01 \pm 0.06$  to  $1.51 \pm 0.06$  and  $1.61 \pm 0.06$  respectively with mean changes of  $5.57 \pm 2.31$ , (95% CI, 4.49-6.65) and  $4.64 \pm 1.88$  (95% CI, 3.77-5.52) respectively ( $p < 0.001$ ) (Table 5).

**Table (5):** Mean changes of VAS post-treatment compared pretreatment among instrumented fusion without a cage group

	Group A (N=20)		Paired t test	P-value	Mean changes $\pm$ SD	95%CI
	Preoperative	Post-operative				
<b>VAS low back pain</b> Mean $\pm$ SD	8.01 $\pm$ 0.06	1.51 $\pm$ 0.06	10.797	<0.001*	5.57 $\pm$ 2.31	4.49-6.65
<b>VAS Leg pain</b> Mean $\pm$ SD	7.01 $\pm$ 0.06	1.61 $\pm$ 0.06	11.075	<0.001*	4.64 $\pm$ 1.88	3.77-5.52

Regarding VAS among group B, low back pain and leg pain were significantly improved post-treatment compared to pre-treatment ( $p < 0.001$ ) where it was decreased from  $7.01 \pm 0.06$  and  $9.01 \pm 0.06$  to  $2.01 \pm 0.06$  and  $2.41 \pm 0.06$  respectively with mean changes of  $4.84 \pm 1.14$  (95% CI, 4.32-5.36) and  $6.21 \pm 1.55$  (95% CI, 5.50-6.91) respectively ( $p < 0.001$ ) (Table 6).

**Table (6):** Mean changes of VAS post-treatment compared pretreatment among instrumented fusion with cage group

	Group B (N=20)					
	Preoperative	Post-operative	t	P-value	Mean changes ±SD	95%CI
VAS low back pain Mean ±SD	7.01±0.06	2.01±0.06	19.404	<0.001*	4.84±1.14	4.32-5.36
VAS Leg pain Mean ±SD	9.01±0.06	2.41±0.06	18.326	<0.001*	6.21±1.55	5.50-6.91



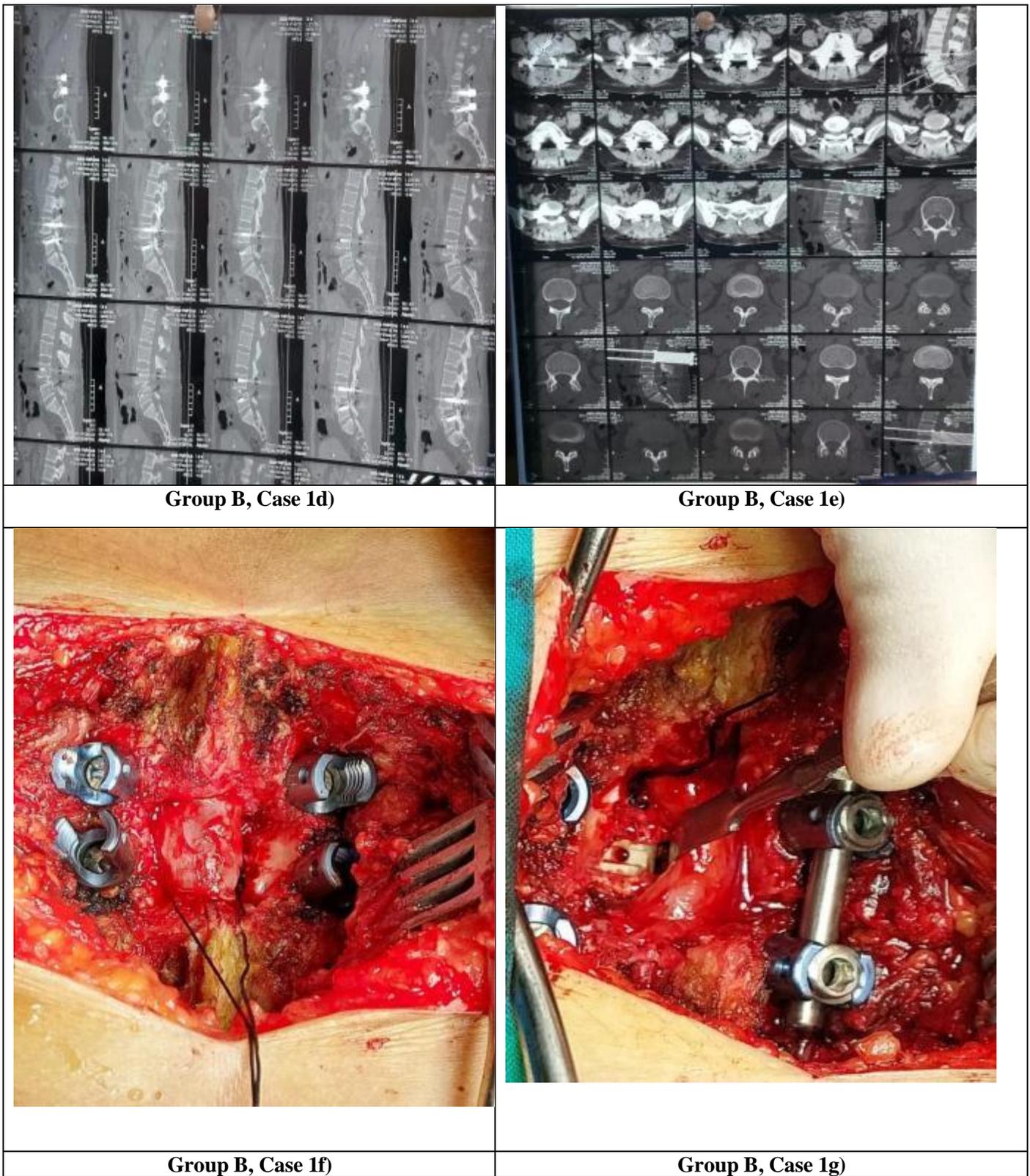
Group B, Case 1a)



Group B, Case 1b)



Group B, Case 1c)



**Figure (1): Case 1 of Fixation with screws and cage, a) preoperative x ray showing l4-5 Spondylolisthesis, b) preoperative MRI showing L4-5 spondylolisthesis, c) postoperative X-ray showing L4-5 fixation with cage fusion, d) postoperative CT showing cage fusion with bone inside, e) postoperative CT axial view of L4-5 screws and cage fusion, g) Intraoperative view showing L4-5 screws, and h) Intraoperative view of L4-5 screws and cage inside.**



**Figure (2): Case 2 of Fixation with screws and cage, a) MRI showing L4-5 spondylolisthesis, b) Plain X-ray showing L4-5 spondylolisthesis, c) postoperative X-ray of L4-5 screws and cage fusion.**



Group A, case 1a)

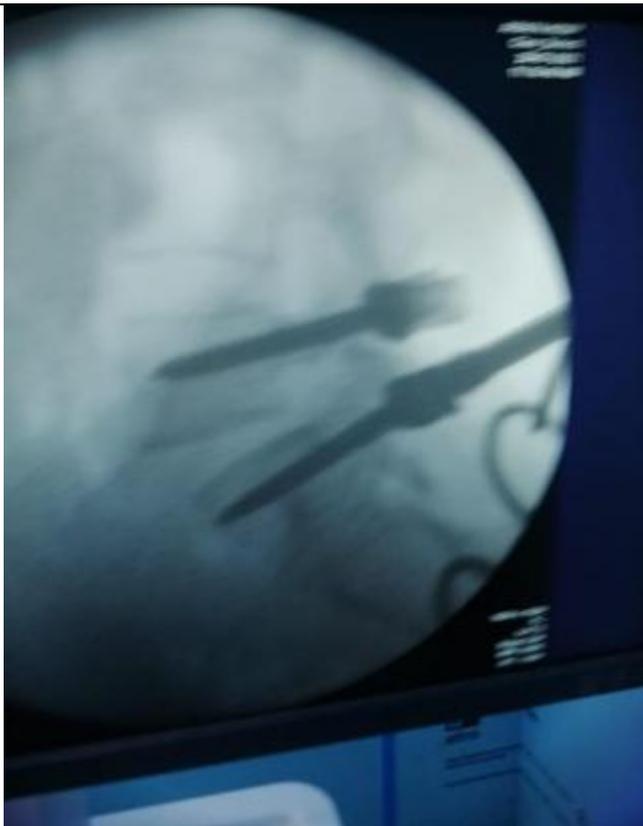


Group A, case 1b)

**Figure (3):** Case 1 of transpedicular screws only, a) Plain X-ray showing L4-5 spondylolisthesis, and b) postoperative X-ray showing L4-5 fixation with screws.



**Group A, case 2a)**



**Group A, case 2b)**



**Group A, case 2c)**

**Figure ( 3): Case 1 of transpedicular screws only, a) Preoperative MRI showing L4-5 spondylolisthesis, b) Intraoperative view of L4-5 screws, and c) Intraoperative A\_P view of L4-5 screws.**

## DISCUSSION

Since 1782, spondylolisthesis, a disorder marked by a visible lumbosacral deformity, slipped vertebrae, fractures, or other deformities of the pars interarticularis, has been recognized as a term used to describe the anterior or posterior displacement of a vertebra or the vertebral column in relation to the vertebrae below. Depending on the race, age, and sex of the population sample, the prevalence of spondylolisthesis in adults is 4-8% [15]. Spondylolisthesis frequently occurs without any symptoms. Although the causes, ages, genders, and pathologies of the many types of spondylolistheses vary, certain clinical symptoms, such as back pain, radicular pain, neuro claudication pain, deformity (such as kyphosis or scoliosis), and gait disturbance, are present in all varieties [16]. It is often possible to treat isthmic spondylolisthesis conservatively. Surgery is necessary in cases where conservative measures have failed. Different combinations of neural decompression, fusion, and internal fixation are used during surgical intervention for spondylolisthesis [17]. So, the aim of this study was to compare clinical and radiological outcomes following management of L4-L5 lumbar degenerative spondylolisthesis with and without interbody fusion cage.

Preoperative VAS low back pain in this study was statistically significantly high in group A ( $8.01 \pm 0.06$ ) compared to group B ( $7.01 \pm 0.06$ ). But group B significantly outperformed group A in terms of preoperative VAS leg pain and final visit VAS, with mean differences of 22.19%, 24.87%, and 33.19%, respectively. This disagree with **Mowafy et al.** [17] who revealed that at the postoperative follow-up, there was no significant difference in the VAS scores between the two groups when comparing the alleviation of leg pain (0.6). Also, **Liu et al.** [18] reported that no discernible difference was discovered in terms of postoperative back and leg VAS scores.

In the current investigation, group B had a considerably greater post-operative follow-up fusion rate ( $17.01 \pm 0.06$ ) than in group A ( $15.01 \pm 0.06$ ), with a mean difference of 11.75%. Pseudoarthrosis and the proportion of slippage, it was statistically significantly high in group A than in group B, with mean differences of 66.44% and 118%, respectively. Although it is theorized that interbody fusion produces a higher rate of bony consolidation than posterolateral arthrodesis due to a larger contact surface and the ability to withstand compression forces, neither this idea is universally accepted nor is it necessarily linked to a better clinical outcome. For example, **Farrokhi et al.** [19] in a randomized prospective trial, PLF and posterior lumbar interbody fusion surgery outcomes were compared in 80 patients of isthmic spondylolisthesis (PLIF). Fusion rate was much higher in the PLIF group, however the PLF group showed a clinically more significant relief in low back pain. The authors argued that a better radiologic union does not necessarily translate into a better clinical outcome when treating spondylolisthesis surgically. Similarly, **Pooswamy et al.** [20] in a

retrospective analysis, 40 patients with low-grade spondylolisthesis who had been monitored for 3 years were compared for surgical results between TLIF and instrumented PLF. Except for more operating time in the TLIF group, they discovered identical clinical and radiologic outcomes in both groups. In another study, **Challier and co-authors** [21] PLF and TLIF were compared for a 2-year follow-up in a monocentric open-label, randomized controlled trial research on 60 patients with one-level LDS.

Despite significant intragroup improvement in clinical indicators, there was no difference between groups when compared. Even though the segmental lordosis improvement was equivalent, the fusion rate was greater in the TLIF group. Interbody fusion was not deemed necessary by these authors for the surgical care of these unique individuals. Also, **Müslüman et al.** [22] found that in a retrospective study evaluated clinical and radiologic effectiveness of PLIF and PLF in 50 low-grade spondylolisthesis patients with 3.3-year follow-up. They reported that 88% and 79%, respectively, of the PLIF and PLF patients had satisfactory or excellent clinical results. Without accounting for complication rates, PLIF patients had considerably higher fusion rates and improvements in lumbar lordosis. In adults with low-grade spondylolisthesis, these authors suggested PLIF instead of PLF. In cases of high-grade spondylolisthesis, spondylolisthesis coupled with severe kyphotic or scoliotic deformity, high disc space height, or osteoporosis, interbody fusion may be added to the standard surgical technique for treating lumbar spondylolisthesis [23, 24]. In these situations, the inclusion of an anterior structural support (cage) could be quite beneficial in keeping the decreased vertebra in the optimal position until the bony union takes place. It is preferable to mention the study in support of this claim conducted by **Dehoux et al.** [25] in 2004. 52 patients who had received PLF and PLIF treatment for varying degrees of isthmic spondylolisthesis were the subjects of a prospective study conducted by the authors. While surgical result worsened in patients with high-grade spondylolisthesis who had had PLF treatment, clinical and radiologic outcomes were equivalent in low-grade patients. In patients of high-grade spondylolisthesis requiring slip reduction or having a large disc space height, these authors suggested PLIF.

In the present investigation, patients in the instrumented fusion with and without cage groups experienced a VAS (low back pain and leg pain) post-treatment that was significantly better than pretreatment. Our results are agreeing with the results of **Bisar et al.** [26] who discovered that the preoperative VAS for back pain was  $9.6 \pm 0.9$  and the major postoperative score was  $1.53 \pm 1.126$  as well as the preoperative and postoperative VAS scores for leg pain were  $9.06 \pm 0.7$  and  $2.0 \pm 1.14$  respectively with 87,3% reporting good to great results. Additionally, the study of **Khan et al.** [27] reported that TLIF for DS clinical assessment was based on VAS, with the mean preoperative VAS for

back pain improving to 2 and the mean preoperative VAS for leg pain improving to 1 (0-5). Another study by **Omidi-Kashani et al.** [28] found that, mean VAS (leg or back) improvement was comparable between the two groups, and cage application was unable to demonstrate a greater therapeutic impact. Although the TLIF group had better intervertebral union and loss of reduction, these changes were not statistically significant. Increased patient discontent was linked to loss of decrease, however this trend was insignificant.

## CONCLUSION

Transpedicular fixation with and without interbody fusion produces the same results in terms of postoperative clinical improvement and patient satisfaction.

**Conflict of interest:** None

**Fund:** None.

## REFERENCES

1. **Majid K, Fischgrund J (2008):** Degenerative lumbar spondylolisthesis: trends in management. *JAAOS Journal of the American Academy of Orthopaedic Surgeons*, 16 (4): 208-15.
2. **Jacobsen S, Sonne-Holm S, Rosing H et al. (2007):** Degenerative lumbar spondylolisthesis: an epidemiological perspective: the Copenhagen Osteoarthritis Study. *Spine*, 32 (1): 120-5.
3. **Akter G, MdZ H, Sana D et al. (2017):** Comparison of Simple Lumbar Interbody Fusion with Circumferential Fusion for Treatment of Isthmic Spondylolisthesis. *Orthop Muscular Syst.*, 6 (248): 2161-0533.
4. **Aichmair A, Alimi M, Hughes A et al. (2017):** Single-level lateral lumbar interbody fusion for the treatment of adjacent segment disease: a retrospective two-center study. *Spine*, 42 (9): 515-22.
5. **Burkus J, Foley K, Haid R et al. (2001):** Surgical interbody research group—radiographic assessment of interbody fusion devices: fusion criteria for anterior lumbar interbody surgery. *Neurosurgical Focus*, 10 (4): 1-9.
6. **Weinstein J, Lurie J, Tosteson T et al. (2007):** Surgical versus nonsurgical treatment for lumbar degenerative spondylolisthesis. *New England Journal of Medicine*, 356 (22): 2257-70.
7. **Joaquim A, Milano J, Ghizoni E et al. (2016):** Is there a role for decompression alone for treating symptomatic degenerative lumbar spondylolisthesis: a systematic review. *Clinical Spine Surgery*, 29 (5): 191-202.
8. **Kalichman L, Hunter D (2008):** Diagnosis and conservative management of degenerative lumbar spondylolisthesis. *European Spine Journal*, 17 (3): 327-35.
9. **Wang Y, Kaplar Z, Deng M et al. (2017):** Lumbar degenerative spondylolisthesis epidemiology: a systematic review with a focus on gender-specific and age-specific prevalence. *Journal of Orthopaedic Translation*, 11: 39-52.
10. **DeVine J, Schenk-Kisser J, Skelly A (2012):** Risk factors for degenerative spondylolisthesis: a systematic review. *Evidence-Based Spine-Care Journal*, 3 (02): 25-34.
11. **Toueg C, Mac-Thiong J, Grimard G et al. (2010):** Prevalence of spondylolisthesis in a population of gymnasts. *Stud Health Technol Inform.*, 158: 132-137.
12. **Iguchi T, Wakami T, Kurihara A et al. (2002):** Lumbar multilevel degenerative spondylolisthesis: radiological evaluation and factors related to anterolisthesis and retrolisthesis. *Clinical Spine Surgery*, 15 (2): 93-9.
13. **Wang Y (2017):** Menopause as a potential cause for higher prevalence of low back pain in women than in age-matched men. *Journal of Orthopaedic Translation*, 8: 1-4.
14. **Koyonos L, Rihn J (2014):** Lumbar degenerative spondylolisthesis. In *Spine Surgery Basics*, Pp: 221-227. Springer, Berlin, Heidelberg. [https://link.springer.com/chapter/10.1007/978-3-642-34126-7\\_17](https://link.springer.com/chapter/10.1007/978-3-642-34126-7_17)
15. **Hornung A, Harada G, Siyaji Z et al. (2022):** Clinical Correlations to Specific Phenotypes and Measurements with Classification Systems: Lumbosacral Spine. In *Atlas of Spinal Imaging*, Elsevier. Pp: 225-247. <https://doi.org/10.1016/B978-0-323-76111-6.00013-4>
16. **Santiago F, Ramos-Bossini A, Wang Y et al. (2020):** The role of radiography in the study of spinal disorders. *Quantitative Imaging in Medicine and Surgery*, 10 (12): 2322-55.
17. **Mowafy O, Gameel I, El-Zayat T et al. (2022):** Comparative study between transpedicular screws fixation with and without interbody fusion using cages in lumbar spondylolisthesis. *Al-Azhar International Medical Journal*, 3 (4): 35-39.
18. **Liu X, Qiu G, Weng X et al. (2014):** What is the optimum fusion technique for adult spondylolisthesis PLIF or PLF or PLIF Plus PLF? A meta-analysis from 17 comparative studies. *Spine*, 39 (22): 1887-98.
19. **Farrokhi M, Rahmanian A, Masoudi M (2012):** Posterolateral versus posterior interbody fusion in isthmic spondylolisthesis. *Journal of Neurotrauma*, 29 (8): 1567-73.
20. **Pooswamy S, Muralidharagopalan N, Subbaiah S (2017):** Transforaminal lumbar interbody fusion versus instrumented posterolateral fusion in Grade I/II spondylolisthesis. *Indian Journal of Orthopaedics*, 51 (2): 131-38.
21. **Challier V, Boissiere L, Obeid I et al. (2016):** One-level lumbar degenerative spondylolisthesis and posterior approach: is transforaminal lateral interbody fusion mandatory: a randomized controlled trial with 2-year follow-up. *Spine*, 42 (8): 1. DOI:10.1097/BRS.0000000000001857
22. **Müslüman A, Yılmaz A, Cansever T et al. (2011):** Posterior lumbar interbody fusion versus posterolateral fusion with instrumentation in the treatment of low-grade isthmic spondylolisthesis: midterm clinical outcomes. *Journal of Neurosurgery Spine*, 14 (4): 488-96.
23. **Mobbs R, Phan K, Malham G et al. (2015):** Lumbar interbody fusion: techniques, indications and comparison of interbody fusion options including PLIF, TLIF, MI-TLIF, OLIF/ATP, LLIF and ALIF. *Journal of Spine Surgery*, 1 (1): 2-18.
24. **Takahashi T, Hanakita J, Watanabe M et al. (2014):** Lumbar alignment and clinical outcome after single level asymmetrical transforaminal lumbar interbody fusion for degenerative spondylolisthesis with local coronal imbalance. *Neurologia Medico- Chirurgica*, 54 (9): 691-97.
25. **Dehoux E, Fourati E, Madi K et al. (2004):** Posterolateral versus interbody fusion in isthmic spondylolisthesis: functional results in 52 cases with a minimum follow-up of 6 years. *Acta Orthop Belg.*, 70 (6): 578-82.
26. **Bisar M, Akar A, Albasiony A (2019):** Posterior Lumbar Interbody Fusion in Degenerative Spondylolisthesis. *The Egyptian Journal of Hospital Medicine*, 74 (1): 126-34.
27. **Khan R, Mandice C, Anandan H (2018):** Functional outcome of transforaminal lumbar interbody fusion for lytic and degenerative spondylolisthesis. *International Journal of Orthopaedics*, 4 (3): 165-8.
28. **Omidi-Kashani F, Jalilian R, Golhasani-Keshtan F (2018):** Effect of interbody fusion cage on clinical and radiological outcome of surgery in L4-L5 lumbar degenerative spondylolisthesis. *Journal of Spine Surgery*, 4 (1): 109-114.