A comparative study between Posterior Lumbar Interbody fusion (PLIF) and Intertransverse process fusion in treatment of Lumbar spondylolithesis.

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Abstract

Study Design: A clinical prospective randomized controlled trial involved 75 patients suffering from isthmic and degenerative lumbar spondylolithesis diagnosed at the outpatient clinic of Department of Neurosurgery, Assuit University Hospital, Egypt.

Background: Posterior lumbar interbody fusion (PLIF) and posterolateral fusion (PLF) are widely used methods for treatment of lumbar spondylolithesis. Some studies showed that PLIF results in an improved outcome compared with PLF, while other studies prove the opposite.

Objective: The purpose of this study was to compare the methods of PLIF and PLF in cases of lumbar spondylolisthesis, and to evaluate the clinical efficacy of the procedures.

Methods: 60 patients with lumbar spondylolisthesis were operated between 2017 and 2019. Indications for surgery were low-back pain with or without sciatica and neurogenic claudication that had not improved after at least 6 months of conservative treatment. The study included 38 female and 22 male patients, with mean ages of 49.3±8 years in the PLIF group and 50.43±8 years in the PLF group. These patients were randomly allocated into 2 groups 30 patients each. The 2 groups had similar socioeconomic, age and sex distribution, level of pain, and disability. Inclusion criteria and outcome measurements were identical in both groups. In the PLIF group, Polyetheretherketone (PEEK) cages were used, and autograft material was obtained from laminectomy was used in both groups. A minimum 12 month follow-up was available in all patients. For clinical evaluation, a visual analog scale, and Oswestry Disability Index were used. Improvements in pre- and postoperative spondylolisthesis, segmental angles, occurrence of fusion, and postoperative complications were evaluated radiologically.

Results: The patients were followed up at 3, 6, and 12 months postoperatively. Based on the etiologies, isthmic spondylolisthesis was detected in 25patients and degenerative spondylolithesis was detected in 35 patients. In PLIF patients, Oswestry disability index (ODI) improved from 29.8% to 13.2% and the visual analogue scale (VAS) for back pain from 7.5 to 1.3. The levels of ODI and VAS were similar to that of the PLF group. Fusion ratios were 100% in the PLIF group and 90% in the PLF group. There was no difference in the complication rates for each group.

Conclusions: There is no significant difference in the one year outcome of surgical treatment of adult isthmic and degenerative spondylolisthesis. we advise PLIF when discectomy is needed and PLF when there is no need for discectomy.

Key Words: lumbar spondylolisthesis, isthmic spondylolisthesis, posterolateral fusion, posterior lumbar interbody fusion and intertransverse process fusion.

Introduction:

Spondylolithesis represents about 13% of patients complaining of chronic low back pain.
Spondylolisthesis is graded based upon the degree of slippage of one vertebral body relative to the subsequent adjacent vertebral body.[1] It is classified in to : degenerative, traumatic, dysplastic, isthmic, pathologic.[2]
Symptoms include: Low back pain, claudication pain and Sciatica in the form of intermittent shooting pain from the buttocks to the thigh.
Plain radiography is often the first step in diagnosis of lumbar spondylolithesis.[3] Anteroposterior and lateral dynamic views are used to determine the grade of spondylolithesis. Magnetic Resonance Imaging (MRI) is also required in case of radiculopathy. [4, 5]
Most patients with lumbar spondylolisthesis respond to conservative treatment.[6] The primary indication for surgery is unstable progressive listhesis. Although there are many techniques, ideal method still needs lot of research [7].
Hadra in 1889 was the first man to describe wiring for spondylolisthesis. Later posterolateral fusion in the form of inter transverse process bone graft had shown good results and was widely used because of good results and less complications. Cloward[8] was the first to fuse two adjacent vertebral bodies using bone grafts. Cages were used to fuse two adjacent vertebras by Brantigan. [9]
To date, both PLF and PLIF are widely used fusion techniques.[10, 11] PLIF had been proved to be superior to PLF in certain studies [10-13] whereas certain studies show that PLF is better [11, 14, 15]. The primary aim of our study is to compare both the techniques.

Patients and methods

Study design: This study is a clinical prospective randomized controlled trial involved 75 patients suffering from isthmic and degenerative lumbar spondylolithesis diagnosed at the outpatient clinic of Department of Neurosurgery, Assuit University Hospital, Egypt. Ten of them were excluded from the study due to presence of other associated systemic diseased such as Rheumatoid Artheritis (2 cases), osteoporosis (5 cases), SLE (2 cases) and tumor of the vertebrae (1 case). Five patients refused to participate in the study.
The patients were collected during the period from September 2017 to September 2018 and randomized in to two groups of 30 patients each, group (A) was treated by posterolateral fusion (PLF), and group (B) was treated by posterior lumbar interbody fusion (PLIF). We followed up the patients for one year post-procedure.
An approval of the study was obtained from Assiut University academic and ethical committee. Every patient signed an informed written consent for acceptance of the operation.

Inclusion criteria: 1) patient with single level isthmic and degenerative lumbar spondylolithesis grade I or II. 2) Age from 18 to 70 years old. 3) Pain that interfered with activities of daily living and not responsive to medical treatment.
Exclusion criteria: Patients with any other spinal pathology. traumatic fracture, infection, osteoporosis and serious systemic disease. 2) Patients with uncontrolled systemic diseases such as SLE, Rheumatoid Artheritis or osteoporosis. 3) Age < 18 or > 70 years.
Preoperative evaluation: All cases underwent thorough history taking, general and neurological examinations.
Investigations: 1- Plain X-ray of lumbar spine (anterior-posterior, lateral) , dynamic views (flexion, extension) to assess the degree of spondylolithesis and presence or absence of fracture pars. 2- Computed tomography (CT) in cases where osteoporosis is suspected. 3- Magnetic resonance imaging of lumbar spine (MRI).
Surgical Techniques:
A posterior decompression, Laminectomy, medial facetectomy, and foraminotomy were performed in all patients. In group (B), a complete facetectomy was performed for PLIF, and 2 cages were routinely used. Pedicle screw instrumentation was used in all patients. In the PLIF group, a Polyetheretherketone (PEEK) cage, lamina obtained during decompression, and spinous process autograft bone material were used. A graft was placed ahead of the cages anteriorly and also in the cage. In the PLF group, inter-transverse process bone fragments (collected from laminectomy) were used.
Routine postoperative evaluation was done clinically by VAS and ODI and radiologically by plan radiographs after surgery and at the follow-up visits (3 months, 6months, 12 months, and every year).
Clinical outcome measures: Oswestry disability index (ODI), visual analogue scale (VAS) and motor deficit recovery. Results for ODI and VAS was measured at 3 months, 6 months, and one year of follow-up for both low back pain and lower limb pain. Preoperative and postoperative values are kept together for comparison purposes.
Radiological outcome measures: A-Lenke classification: It is used for assessment of posterolateral fusion to evaluate the fusion of the posterior elements of the fused segments. Results above the (B) level on the Lenke classification considered fusion. B-The Brantigan-Steffee classification is used to confirm fusion in cases of PLIF.[16] Grades (1, 2, and 3) mean non-union, while Grades (4, 5) mean fusion had successfully occurred.

Results

The age of the patients ranged from 30 to 68 years. The mean age was 50.4 in group A, and 49.3 years in group B, with most common age group between 50-59 years old. The study included 22 male and38 female. That shows female predominance of 63.3 % of the cases. Occupation was described as hard in manual workers and drivers, light in office workers and non-occupied. Associated comorbidities are represented in table (1).

Table (1) Demographic data:

	Group A (PLF) (n=30)		**Group B (PLIF) (n=30)**	
	No.	**%**	**No.**	**%**
Age				
Range	30 – 68		39 – 64	
Mean±SD	50.43±8.94		49.3±7.79	
Sex				
Male	13	43.3	9	30.0
Female	17	56.7	21	70.0
Comorbidities				
Nil	23	76.7	21	70.0
DM	2	6.7	2	6.7
HTN	6	20.0	9	30.0
HCV	1	3.3	0	0.0
Asthmatic	0	0.0	2	6.7
Smoking	6	20	6	20
Occupation				
Hard work	12	40	13	43.3
Light work	5	16.6	7	23.3
Non occupied	13	43.3	10	33.3

Low back pain was the initial presenting complaint in all cases (100 %). Claudication pain was positive in about 21 cases (70%) in group A and 26 cases (86.7%) in group B. Sciatica was positive in about 20 cases(66.7%)in group A and 19 cases (63.3%) in group B. Urinary or stool incontinence was presented in about 36% of all cases. Impotence was presented in about 27% of all male cases. Lower limb weakness was found in 9 cases (30%) in group A, and 6 cases (20%) in group B.

Spondylolithesis at L4-5 was the most common level (48.3%).Degenerative spondylolithesis was found in 17 cases, while isthmic spondylolithesis in 25 cases. Table (2)

Table (2) level, type and grade of spondylolithesis.

	Group A (PLF) (n=30)		**Group B (PLIF) (n=30)**	
	No.	**%**	**No.**	**%**
Level				
L3-4	4	13.3	7	23.3
L4-5	13	43.3	16	53.3
L5-S1	13	43.3	7	23.3
Type				
Degenerative	17	56.6%	18	60%
Isthmic	13	43.3%	12	40%
Grade				
Grade 1	16	53.8	13	43.3
Grade 2	14	46.2	17	56.6

Outcome analysis:

Surgical outcome: The mean amount of intraoperative blood loss was 176ml in group A, and 217ml in group B. The mean intra operative duration was 208 minutes in group A, and 256 minutes in group B. Intraoperative dural tear occurred in 2 cases (6.7 %). In the two cases the tear was accessible and direct repair with sutures was done. The two cases were in group B. Table (3)

Table (3) operative details.

	Group A (PLF) (n=30)	Group B (PLIF) (n=30)	P. value
Intraoperative (blood loss)			
Range	100 – 200	200 – 250	<0.001**
Mean±SD	176.67±28.57	217.67±23.73	
Intraoperative (Duration)			
Range	130 – 300	160 – 330	<0.001**
Mean±SD	208±25.43	256.6±32.02	
Duration of Hospital stay (days)			
Range	2 – 3	2 – 5	0.253
Mean±SD	2.13±0.35	2.33±0.88	

* Statistically significant difference (p<0.05)**, **** Highly statistically significant difference (p<0.01).

Clinical outcome: In group A, preoperative VAS for back pain and leg pain was 7.3 and 6.6 compared to 1.2 and 1.5 after one year postoperative respectively. In group B, preoperative VAS for back pain and leg pain was 7.5 and 6.9 compared to 1.3 and 1.5 after one year postoperative respectively. Table (4)

Table (4) pre and postoperative VAS.

VAS	Group A (PLF) (n=30) Mean± SD		Group B (PLIF) (n=30) Mean± SD		P. value[1]
	Back pain	Leg pain	Back pain	Leg pain	
Preoperative	7.3±0.79	6.57±1.31	7.47±0.51	6.87±1.5	
Postoperative					
Immediate postoperative	1.43±0.63	1.46±1.58	1.3±1.15	1.75±1.32	0.337
After 3 months	1.1 ±0.3	1.46±1.58	1.43±0.63	1.54±1.21	0.323
After 6 months	1.2±0.4	1.35 ±1.1	1.3±1.13	1.5±1.33	0.209
After 1 year	1.2±0.4	1.5 ±1.66	1.3±1.13	1.53±1.43	0.209
P. value[2]	<0.001**		<0.001**		

P. value[1]: Comparison between Group A and Group B

P. value[2]: Comparison between preoperative and postoperative for each group

* Statistically significant difference (p<0.05)**, **** Highly statistically significant difference (p<0.01).

Preoperative ODI was 29.8% and 30.7% compared to 13.2% and 12.7 after one year postoperatively in both group A and group B respectively. Table (5)

Table (5) pre and postoperative ODI.

ODI	Group A (PLF) (n=30) Mean ±SD	Group B (PLIF) (n=30) Mean ±SD	P. value[1]
Preoperative	29.83%±3.65%	30.73%±3.41%	0.328
Postoperative			
Immediate postoperative	15.53%±3.3%	13.43%±6.36%	0.187
After 3 months	13.4%±3.4%	12.43%±5%	0.166
After 6 months	13.2%±3%	12.23%±5.3%	0.163
After 1 year	13.2%±3%	12.67%±4.2%	0.173
P. value[2]	<0.001**	<0.001**	

P. value[1]: Comparison between Group A and Group B
P. value[2]: Comparison between preoperative and postoperative for each group
* Statistically significant difference (p<0.05), ** Highly statistically significant difference (p<0.01).

Preoperative motor deficit was found in 9 cases (30%) and 6 cases (20%) in both group A and group B respectively. Motor power was regained in 100% of cases in group A postoperatively. While in group B one case (3.3%) showed lower limb weakness postoperatively which gradually improved through the follow up period by physiotherapy. There is a highly statistically significant difference (p<0.01) between the preoperative and postoperative VAS, ODI and motor power improvement for each group. But there is no statistically difference between the outcomes of both groups.

Radiolgical outcomes: After one year follow up fusion occurred in 27 cases (90%) in group A and 30 cases (100%) in group B. The three cases in group A where fusion had not been occurred, they are now under follow up as there is no complain. Table (6)

Table (6) Rate of fusion in each group.

Fusion	Group A (PLF) (n=30)		Group B (PLIF) (n=30)		P. value
	No.	%	No.	%	
After 3 months					
Occurred	13	43.3%	15	50%	0.197
Not occurred	17	56.6%	15	50%	
After 6 months					
Occurred	26	86.7	28	93.3	0.389
Not occurred	4	13.3	2	6.7	
After 1 year					
Occurred	27	90.0	30	100.0	0.076
Not occurred	3	10.0	0	0.0	

* Statistically significant difference ($p<0.05$), ****** Highly statistically significant difference ($p<0.01$).

Postoperative complications: Postoperative lower limb pain found in about one case in both group A and B. Postoperative lower limb weakness occurred in only one case (3.3%) in group B.X-rays were done to confirm that pedicle screws and cages are at their places and then they were managed by medical treatment, physiotherapy and showed gradual improvement on follow up.

Discussion

In our study, most patients were between 50 and 59 years (46.7%). Degenerative spondylolithesis was found in 35 cases (58.3%). This may explain that most cases were found in that age group. Female predominated by about 63.3 % of the cases, denoting that the mostly affected were middle aged females. Patients with hard work occupations 43.3% were at a higher risk to develop lumbar spondylolithesis than others.

Low back pain was the predominant complaint, followed by claudication pain then sciatic pain. These results are similar to those reported by AM Musluman et al. In his study, low back pain (94%), leg pain (82%), neurogenic claudication (90%), sensory changes (72%), motor weakness (44%), and incontinence (2%). The distribution of age, sex, severity of pretreatment pain, and disability was similar between the PLIF and PLF groups.[17]

In our study degenerative spondylolithesis was found in more cases than isthmic type. The most affected level was L4-L5 followed by L5-S1 then L3-4. Most cases had grade 1 and grade 2 spondylolithesis. These results are in agreement with those reported by A M Musluman et al. They found that the level of L4-L5 in 27cases (54%), at L5-S1 in 14 cases (28%) and at L3-4 in 9 cases (13%). They concluded that L4-L5 and L5-S1 are the most

common affected levels.[17]Also, Kim et al reported that 50% of the defective levels were L4–5.[18]

In our study, intraoperative duration and blood loss were higher in group B compared to group A. There was a significant statistical difference in the duration and intraoperative bleeding between both groups in addition to more extensive dissection, which make PLIF procedure is more difficult.[19]

Regarding clinical outcomes, PLIF group showed significant relief of low-back pain to greater extent than PLF. The difference between the PLF and PLIF groups at the 3 month follow-up, according to subscales of the ODI, was thought to be due to the earlier maintenance of an adequate sagittal axis and lower loading to the posterior segment of the vertebra with PLIF. There was no significant difference between the two groups in the late postoperative period, but there was a marked difference between preoperative and postoperative values of ODI in each group.

The VAS was better in Group B in the early postoperative period, but there was no significant difference between the groups in the late postoperative period. Motor deficit improved in all cases in each group, except one case that had developed unilateral lower limb weakness postoperatively.

PLIF showed a slight earlier fusion rate than PLF. After one year of follow up fusion had occurred in all patients with PLIF group. However in the PLF group fusion did not occur in 3 patients.

Madan and Boeree compared 23 patients treated with PLIF and 21 treated with PLF .Satisfactory clinical outcomes were found at a rate of 69.5% in the PLIF group and 69.5% in the PLF group. In patients with low-grade spondylolisthesis, they obtained better clinical results in the PLF group; however, the quality of fusion and correction was better in the PLIF group. After 2 years of experience with PLF and PLIF, Ekman et al reported that these 2 methods produced similar outcomes in the management of adult isthmic spondylolisthesis (with the exception of higher complication rates when using the PLIF method).[11]

Suk et al. performed decompression, pedicle screw fixation, and fusion in 76 patients with symptomatic spondylolisthesis and a stenotic spinal canal.[20] Of the 40 patients who received PLF, 31 had also been treated with PLIF. In the PLF group, the incidence of nonunion was 7.5%, whereas there was no nonunion in the PLIF group.

In a prospective study, Kim et al could not find any differences among clinical outcomes and fusion ratios after observing PLF, PLIF, and combined PLF/ PLIF groups for 3 years.[15] Despite the similarity between the groups, these investigators still reported better sagittal balance in the PLIF-only group relative to the PLF group.

Crawford et al reproduced the lumbar spondylolisthesis grade I using cadaveric specimens and studied the biomechanics of various hardware combinations.[21] He found that the use of interbody fusion with a cage offers several theoretical advantages: restoration of load-bearing capacity to the ventral spinal column, maintenance of intervertebral disc height,

distraction of intervertebral foramina, immediate stabilization, and higher repeatability of the surgical technique.

We believe that PLIF offers a number of advantages to PLF as the cancellous bone of the vertebral body provides an excellent fusion bed, as opposed to that of transverse process. Interbody fusion allows the disc to be both space evacuated and distracted so distraction allows the neural foramen to be enlarged, eliminating any foraminal stenosis, the incidence of cage subsidence is significantly lowered and the fusion rated increased. This result was consistent with the clinical studies of Brantigan et al. [22]and William et al. [23].

In a recent prospective randomised study on degenerative lumbar disease, Kim et al compared three fusion methods: posterolateral fusion (PLF), posterior lumbar interbody fusion (PLIF), and PLIF combined with PLF (PLF+PLIF), and reported that no significant differences in clinical results and union rates, were found among the three methods.[15]

Dantas et al conducted a study of 60 adult lumbar spondylolisthesis patients and concluded that both surgical procedures were effective. The PLIF with pedicle screws group presented better clinical outcomes. PLF presented more complications when compared with PLIF.[24]

Conclusion

In cases of lumbar spondylolithesis, PLIF offers several theoretical advantages: restoration of load-bearing capacity to the ventral spinal column, maintenance of intervertebral disc height, distraction of intervertebral foramina, immediate stabilization. However it was found that it has minimal advantages in term of clinical outcomes and insignificant better solid fusion than PLF. So from this study we advise PLIF when discectomy is needed and PLF when there is no need for discectomy.

References

1. Shamrock AG, Donnally III CJ, Varacallo M. Lumbar spondylolysis and spondylolisthesis. StatPearls [Internet]: StatPearls Publishing; 2019.
2. Tenny S, Gillis CC. Spondylolisthesis. StatPearls [Internet]: StatPearls Publishing; 2019.
3. Tofte JN, CarlLee TL, Holte AJ, Sitton SE, Weinstein SL. Imaging pediatric spondylolysis: a systematic review. Spine. 2017;42(10):777-82.
4. Birch JG, Herring JA, Maravilla KR. Splitting of the intervertebral disc in spondylolisthesis: a magnetic resonance imaging finding in two cases. Journal of pediatric orthopedics. 1986;6(5):609-11.
5. Szypryt E, Twining P, Mulholland R, Worthington B. The prevalence of disc degeneration associated with neural arch defects of the lumbar spine assessed by magnetic resonance imaging. Spine. 1989;14(9):977-81.
6. Haun DW, Kettner NW. Spondylolysis and spondylolisthesis: a narrative review of etiology, diagnosis, and conservative management. Journal of chiropractic medicine. 2005;4(4):206-17.
7. Hadra B. The Classic Wiring of the Vertebrae as a Means of Immobilization in Fracture and Potts' Disease. Clinical Orthopaedics and Related Research®. 1975;112:4-8.
8. Cloward RB. The treatment of ruptured lumbar intervertebral discs by vertebral body fusion: I. Indications, operative technique, after care. Journal of neurosurgery. 1953;10(2):154-68.
9. AID ACFIT. INTERBODY LUMBAR FUSION. TWO-YEAR CLINICAL RESULTS IN THE FIRST 26 PATIENTS. Brantigan JW, Steffee AD. Spine. 1993;18(14):2106-7.
10. Aoki Y, Yamagata M, Ikeda Y, Nakajima F, Ohtori S, Nakagawa K, et al. A prospective randomized controlled study comparing transforaminal lumbar interbody fusion techniques for degenerative spondylolisthesis: unilateral pedicle screw and 1 cage versus bilateral pedicle screws and 2 cages. Journal of Neurosurgery: Spine. 2012;17(2):153-9.
11. Ekman P, Möller H, Tullberg T, Neumann P, Hedlund R. Posterior lumbar interbody fusion versus posterolateral fusion in adult isthmic spondylolisthesis. Spine. 2007;32(20):2178-83.
12. Hai Y, Kopacz K, Lee C, editors. Posterior lumbar interbody fusion with and without pedicle screw fixation: comparison for clinical and radiological results. North American Spine Society; 1997.
13. Fairbank J, Couper J, Davies J, O'brien J. The Oswestry low back pain disability questionnaire. Physiotherapy. 1980;66(8):271-3.
14. Xiuxin H, Yue Z, Cui C, Yajun W. A meta-analysis of circumferential fusion versus instrumented posterolateral fusion in the lumbar spine. Spine. 2009;34(17):E618-E25.
15. Kim K-T, Lee S-H, Lee Y-H, Bae S-C, Suk K-S. Clinical outcomes of 3 fusion methods through the posterior approach in the lumbar spine. Spine. 2006;31(12):1351-7.
16. Brantigan JW, Steffee AD, Geiger JM. A carbon fiber implant to aid interbody lumbar fusion. Mechanical testing. Spine. 1991;16(6 Suppl):S277-82.
17. Müslüman AM, Yılmaz A, Cansever T, Çavuşoğlu H, Çolak İ, Genç HA, et al. Posterior lumbar interbody fusion versus posterolateral fusion with instrumentation in the treatment of low-grade isthmic spondylolisthesis: midterm clinical outcomes. Journal of Neurosurgery: Spine. 2011;14(4):488-96.
18. Kim J-S, Lee K-Y, Lee S-H, Lee H-Y. Which lumbar interbody fusion technique is better in terms of level for the treatment of unstable isthmic spondylolisthesis? Journal of Neurosurgery: Spine. 2010;12(2):171-7.
19. Dai L, Jia L, Yuan W, Ni B, Zhu H. Direct repair of defect in lumbar spondylolysis and mild isthmic spondylolisthesis by bone grafting, with or without facet joint fusion. European Spine Journal. 2001;10(1):78-83.
20. Suk S-I, Lee C-K, Kim W-J, Lee J-H, Cho K-J, Kim H-G. Adding posterior lumbar interbody fusion to pedicle screw fixation and posterolateral fusion after decompression in spondylolytic spondylolisthesis. Spine. 1997;22(2):210-9.

21. Çagli S, Crawford NR, Sonntag VK, Dickman CA. Biomechanics of grade I degenerative lumbar spondylolisthesis. Part 2: treatment with threaded interbody cages/dowels and pedicle screws. Journal of Neurosurgery: Spine. 2001;94(1):51-60.
22. Brantigan JW, Steffee AD, Lewis ML, Quinn LM, Persenaire JM. Lumbar interbody fusion using the Brantigan I/F cage for posterior lumbar interbody fusion and the variable pedicle screw placement system: two-year results from a Food and Drug Administration investigational device exemption clinical trial. Spine. 2000;25(11):1437-46.
23. Klemme LWR, Owens CBD, Dhawan CA, Zeidman MS, Polly Jr DW. Lumbar sagittal contour after posterior interbody fusion: threaded devices alone versus vertical cages plus posterior instrumentation. Spine. 2001;26(5):534-7.
24. Dantas FLR, Prandini MN, Ferreira MA. Comparison between posterior lumbar fusion with pedicle screws and posterior lumbar interbody fusion with pedicle screws in adult spondylolisthesis. Arquivos de neuro-psiquiatria. 2007;65(3B):764-70.