Global Spine Journal
2022, Vol. 12(1) 70–78
© The Author(s) 2020
Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/2192568220946319
journals.sagepub.com/home/gsj

# Local Autograft Versus Iliac Crest Bone Graft PSF-Augmented TLIF in Low-Grade Isthmic and Degenerative Lumbar Spondylolisthesis

**Ali M. Abou-Madawi, MD[1], Sherif H. Ali, MD[1], and Ahmed M. Abdelmonem, MD[1]**

## Abstract

**Study Design:** Prospective randomized controlled cohort study.

**Objective:** To compare the outcome of local autograft versus iliac crest bone graft (ICBG) stand-alone transforaminal lumbar interbody fusion (TLIF) in lumbar spondylolisthesis.

**Methods:** One hundred eight patients with low-grade single-level spondylolisthesis underwent operation with pedicular screw fixation (PSF)-augmented stand-alone TLIF. Patients were randomly divided into groups according to bone graft: group I, autograft group; and group II, ICBG group, with 54 patients each. Fifty-nine patients had isthmic spondylolisthesis and 49 had degenerative spondylolisthesis. Clinical outcome parameters included Visual Analogue Scale (VAS), Oswestry Disability Index (ODI), and patient's satisfaction, while the radiological parameters included fusion rate, slip reduction, segmental angle, and disc height. The mean follow-up period was 38 ± 19 months, with a minimum 24 of months.

**Results:** The preoperative VAS of back pain improved from 8 ± 3.1 to 3.4 ± 2.9 and from 8 ± 3.2 to3.6 ± 2.6 in group I and group II, respectively. The preoperative ODI improved from 41.4 ± 8 to 12.3 ± 7 and from 39 ± 9 to 13 ± 8 in group I and group II, respectively. The fusion rate was 93% in group I and 94.5% in group II. The percentage of slip was reduced from 26.7 ± 7.1% to 16.5 ± 6.1% in group I and from 27.4 ± 8.25 to 15.8 ± 5.2% in group II. Intervertebral disc height increased from 25.27 ± 14.62 to 46.38 ± 15.41 in group I and from 22.29 ± 13.72 to 45.15 ± 16.77 in group II. Segmental angle improved from 10.5 ± 8.1° to 16.7 ± 5.4° in group I and from 11.6 ± 5.3° to 15.9 ± 6.2° in group II. There was no significant difference of the above-mentioned parameters between the 2 groups.

**Conclusion:** Patients with single-level low-grade spondylolisthesis can be effectively treated with PSF-augmented stand-alone TLIF using either local autograft or ICBG with no outcome differences between the 2 groups.

**Keywords**
TLIF, local autograft, iliac crest bone graft, spondylolisthesis, degenerative disc disease, lumbar spine

## Introduction

Low-grade isthmic and degenerative lumbar spondylolisthesis are major low back clinical entities. They affect humans in the most productive age group and hence have a major socioeconomic burden. Conservative therapy plays a major role in the initial management of most patients. A variety of operative techniques have been proposed for the management of this condition including open and minimally invasive procedures.[1-6]

Pedicular screw fixation (PSF) augmented transforaminal lumbar interbody fusion (TLIF) is a standard procedure after failure of conservative therapy. TLIF has been proposed to replace traditional posterior lumbar interbody fusion (PLIF) to address issues of neural retraction, root injury, epidural

[1] Suez Canal University Hospital, Ismailia, Egypt

**Corresponding Author:**
Ali M. Abou-Madawi, Suez Canal University Hospital, Ring Road, Ismailia 41522, Egypt.
Email: aamadawi@gmail.com

Creative Commons Non Commercial No Derivs CC BY-NC-ND: This article is distributed under the terms of the Creative Commons Attribution-Non Commercial-NoDerivs 4.0 License (https://creativecommons.org/licenses/by-nc-nd/4.0/) which permits non-commercial use, reproduction and distribution of the work as published without adaptation or alteration, without further permission provided the original work is attributed as specified on the SAGE and Open Access pages (https://us.sagepub.com/en-us/nam/open-access-at-sage).

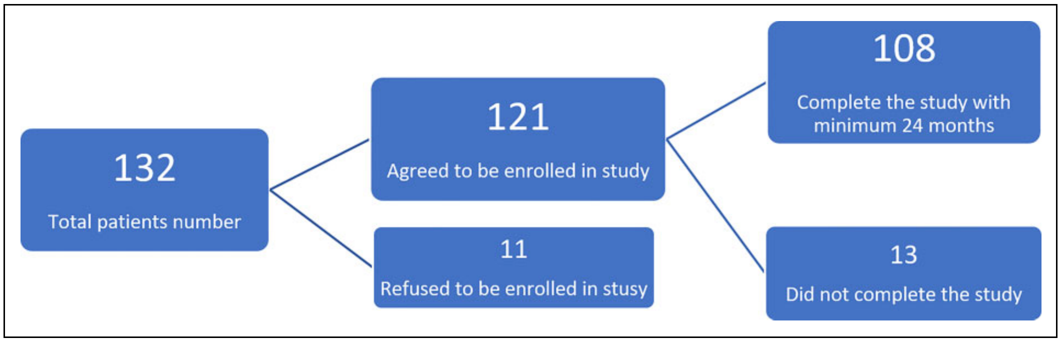


**Figure 1.** An algorism for all patients recruited through the whole study processing.

scaring, and dural injuries.[5,7,8] Introduction of lumbar cages markedly improved both clinical and radiological outcomes of these procedures. To fill fusion cages, either local autograft harvested from resected laminae and facets during decompression, autologous iliac crest bone graft (ICBG), bone bank, or even synthetic bone was used.[9,10] Clinical studies have shown controversy regarding the advantages and disadvantages of each alternative material.[11,12]

Donor site problems were the most negative aspect of autologous ICBG despite its adequate physiological and biomechanical advantages. Synthetic bone eliminates donor graft site morbidity but of less physiological and biomechanical criteria. Homologous bones from bone banks have the same advantages with some immunological reactions and the risk of disease transmission. Local lamina and facet bones harvested in sufficient amount during spinal decompression provide a very good alternative, as donor site morbidity is avoided and the patient does not have to suffer from another wound; meanwhile, they are a natural and physiological source of live osteoblasts and osteocytes. They have the same osteoconductive, osteoinductive, and osteogenic properties of ICBG with variable quantities and qualities.[5,8-10]

The purpose of this study is to compare the clinical and radiological outcomes in patients treated with PSF-augmented stand-alone TLIF using either local autograft or ICBG in 2 similar groups of patients suffering from low-grade lumbar spondylolisthesis.

## Patients and Methods

This is a prospective, randomized control cohort study conducted between July 2012 and June 2017. A total of 121 patients were enrolled in this study. Of these, 13 patients were lost a during follow-up period of 38 ± 19 (range, 24-46) months and did not complete the study, while a total of 108 consecutive patients who completed the follow-up period with a minimum of 24 months were included in this study. Apart from these 121 patients, 11 refused to be enrolled in this study and preferred to choose their own procedure (Figure 1). The mean age was 52 ± 18 (range, 34-56) years. Fifty-seven patients were males and 51 were females. All patients were adults and suffered from single-level low-grade (grades I and II according to Meyerding classification) lumbar spondylolisthesis, including 59 patients with isthmic and 49 with degenerative spondylolistheses. All were submitted for adequate conservative therapy for at least 3 months prior to surgery including spinal supports, physical therapy measures, pain killers, and multiple local injections. All have completed a minimum of 2 years of postoperative follow-up. Patients of multilevel spondylolisthesis, high-grade slip, other degenerative spinal disorders, revision surgery, obesity (body mass index [BMI] >30), infections, medical comorbidities that preclude general surgery, and patients with known history of clinical diagnosis of osteoporosis were excluded from this study. Bone health assessment was not performed on all patients to rule out osteoporosis.

Perioperative and follow-up data was recorded by the assistant neurosurgeon team of our hospital who were attendant with consultant surgeons through routinely scheduled outpatient visits. Those assistants (either residents or instructors) were responsible for reporting patients' data in the hospital's medical records. All patients were submitted to full general and neurological assessment before scheduling for surgery. All patients had full-length standing lumbosacral radiographs at a standard constant distance in lateral, anteroposterior, and dynamic views. All images were digitized and imported onto software Surgimap and then were analyzed according to our protocol. All patients were submitted to T2 and T1 sagittal and axial weighted MRI (magnetic resonance imaging) lumbosacral spine. At the time of surgery, all patients suffered from significant low back pain and sciatica with or without neurological deficits. The mean duration of preoperative symptoms was 13 ± 14 (range, 6-32) months. Of the 108 patients, 18 were regular smokers (all smokers were instructed to stop smoking for at least 12 months after fusion surgery), 11 had controlled hypertension, and 14 had controlled diabetes. The patients were evenly distributed between both groups (Table 1).

The level of spondylolisthesis included the following: 6 patients at L3/4; 47 at L4/5; and 55 at L5/S1 vertebra. Seventy patients suffered from grade I spondylolisthesis and 38 from grade II spondylolisthesis. Other details are depicted in Table 1.

All patients were treated with PSF-augmented stand-alone TLIF using either local autograft of spinous process, lamina,

**Table 1.** Summary of Patients' Epidemiological Data (N = 108).

| Parameters | | Group I (N = 54), Local autograft | | Group II (N = 54), Iliac crest bone graft | Total |
|---|---|---|---|---|---|
| Age | All | 47 ± 18 (34-55) | | 49 ± 18 (36-56) | 52 ± 18 (34-56) |
| | Isthmic | | 39 ± 16 (34-50) | | |
| | Degenerative | | 58 ± 15 (38-56) | | |
| Sex | Males | 30 | | 27 | 57 |
| | Females | 24 | | 27 | 51 |
| Slip | Isthmic | 34 | | 25 | 59 |
| | Degenerative | 20 | | 29 | 49 |
| Grade | I | 37 | | 33 | 70 |
| | II | 17 | | 21 | 38 |
| Level | L3/4 | 2 | | 4 | 6 |
| | L4/5 | 14 | | 33 | 47 |
| | L5/L1 | 38 | | 17 | 55 |
| BMI | | 24.9 ± 5.3 | | 23.5 ± 4.5 | 24.6 ± 6.2 |
| Smokers | | 10 | | 8 | 18 |
| Diabetes mellitus | | 5 | | 9 | 14 |
| Hypertension | | 5 | | 6 | 11 |

Abbreviation: BMI, body mass index.

and facet joints bone harvested during decompression (group I, N = 54) or ICBG harvested through the same midline incision (group II, N = 54). Patients' allocation for either group was at random and this was according to the hospital number given to each patient on admission. The pros and cons of each procedure were explained fully to each patient, and patients formally consented to participate in this study. This study was approved by the ethical committee of our institution.

Reported clinical parameters before and after surgery included the following: Visual Analogue Scale (VAS)[13] for low back pain (LBP), Oswestry Disability Index (ODI)[14] for functional outcome, and patients' satisfaction after surgery. Reported radiological parameters before and after surgery included the following: (*a*) Meyerding classification[15] to assess the degree of vertebral slip; the degree of slip was measured relatively to the vertebral end plate of the lower vertebral body and described as percent of slip relative to end plate; (*b*) intervertebral disc space height measurement included the summation of the anterior and posterior disc height divided by sagittal disc diameter; (*c*) Cobb's angle technique[16] to assess the segmental angle where magnification was corrected geometrically; (*d*) the rate of spinal fusion at the last follow-up postoperatively.

Patients were scheduled for outpatient clinic visits on the third and sixth months postoperatively and then every 6 months. Routine clinical assessment included VAS of low back pain and ODI of functional status, and a subjective outcome a 5-point survey of patients' satisfaction was recorded (excellent, good, fair, unchanged, and worse).[17] This was confirmed at the last follow-up where all patients were asked if the operation had helped them and whether they would undergo it again when being in the same situation.

During the clinic visits, a routine radiological assessment was conducted including standing plain X-ray lateral, anteroposterior, and dynamic study to assess the 4 radiological parameters mentioned above. The X-ray criteria of radiographic solid fusion included the presence of bone trabeculae bridging the fusion gap with absence of bony lucency at that gap. Criteria of nonunion include absence of these signs and presence of lucent zone around any of pedicle screws or cage.[18,19] Furthermore, MSCT (multislice computed tomography) scan or MRI was performed during the postoperative follow-up period in cases suffering from significant low back pain or development of new sciatica. Follow-up images were evaluated by a surgeon and a radiologist.

## Statistical Analysis

The SPSS statistical software program (version 25) was utilized for statistical analysis of study data. The outcome descriptive data was given as mean, standard deviation, and range. The analytic data or comparison data used $t$ test. $P$ value $<.5$ was considered to be statistically significant.

## Surgical Procedure

All patients underwent operation in prone position through the standard posterior midline approach. Paraspinal muscles were bilaterally stripped off spinous process, lamina, facets, and transverse processes bilaterally through subperiosteal dissection. Based on anatomical land marks including the transverse process and facet joint, pedicular screws (EgiFix) were inserted under fluoroscopic guidance in the target level. The adjacent rostral facets were preserved, and no posterolateral fusion was conducted.

In group I patients with isthmic-type spondylolisthesis, the whole mobile lamina with both facets was removed as one piece (guillotine laminotomy). In group I patients with degenerative-type spondylolisthesis, a unilateral facetectomy (symptomatic side) and a horseshoe laminotomy were performed for decompression, while the contralateral facet was preserved. In either situation, all collected bones were thoroughly cleaned from soft tissues and cartilages and then cut into small pieces after partially removing their cortical bone. In group II, all local bones were not used and a corticocancellous ICBG was harvested through the same access wound, cleaned off soft tissues, and cut into small pieces.

Target disc space was unilaterally approached from the symptomatic side and prepared by different size bone shavers and curettes to ensure complete disc evacuation and removal of cartilaginous end plates and preserve the integrity of cortical end plates. The target disc was filled with average bone volume 5 to 7 cc of harvested bone graft, and with the aid of cage trial instrument we compressed the bone graft pieces inside the disc leaving room for the prepared bullet PEEK cage. A bullet lumbar PEEK cage (EgiFix) was selected according to the height of the target disc space and filled with harvested and prepared bone graft. Then, a bullet cage was unilaterally inserted as obliquely and as anteriorly as possible in between the inserted bone graft pieces. The corresponding roots were explored for adequacy of decompression. Rods were inserted over screws and relevant nerve roots were explored again to ensure adequate decompression before tightening the screw after screw compression to induce lumbar lordosis.

Meticulous wound hemostasis, wound irrigation with 500 mL normal saline, and insertion of a closed suction drain were performed routinely. Perioperative parenteral cephalosporins and analgesics were introduced to all patients.

## Results

### The Operative Parameters

The mean operative time was 156 ± 27 (range, 135-365) minutes in the whole group, while it was 149 ± 22 in group I and 161 ± 28 in group II. The mean operative blood loss was 377 ± 164 (range, 235-665) mL in the whole group, while it was 355 ± 128 in group I and 385 ± 180 in group II. The mean hospital stay was 1.8 ± 0.9 (1-4) days in the whole group, while it was 1.7 ± 0.7 in group I and 1.9 ± 0.8 in group II. There was no statistically significant difference between these 3 operative parameters in both patient groups ($P > .05$; Table 2).

**Table 2.** Operative Parameters.

| Parameters | Group-I (N = 54), Local autograft | Group-II (N = 54), Iliac crest bone graft | *P* |
|---|---|---|---|
| Operative time (minutes) | 149 ± 22 | 161 ± 28 | NS |
| Blood loss (mL) | 355 ± 128 | 385 ± 180 | NS |
| Hospital stay (days) | 1.7 ± 0.7 | 1.9 ± 0.8 | NS |

### Clinical Outcome Parameters

The preoperative VAS of back pain in group I improved from 8 ± 3.1 to 4.5 ± 2.8 at 3 months, 3.5 ± 2.5 at 6 months, and 3.4 ± 2.9 at the last follow-up, while the preoperative VAS of back pain in group II improved from 8 ± 3.2 to 4.6 ± 2.7 at 3 months, 3.8 ± 3 at 6 months, and 3.6 ± 2.6 at the last follow-up. The preoperative ODI improved in group I from 41.4 ± 8 to 18 ± 8 at 3 months, to 12.6 ± 6 at 6 months, and to 12.3 ± 7 at the last follow-up, whereas the preoperative ODI in group II improved from 39 ± 9 to 17 ± 7 at 3 months, to 13.4 ± 4 at 6 months, and to 13 ± 8 at the last follow-up. The subjective 5-point outcome score showed that 83.3% of patients in group I have excellent or good results, while 87% of patients had excellent or good results in group II. The questionnaire survey showed that surgery helped 44 (81.5%) of the patients in group I and 46 (85.2%) in group II and that 46 (85.2%) of patients reported that they would undergo surgery again in group I and 44 (81.5%) in group II. According to the above clinical parameters and although there was a significant difference ($P < .001$) between preoperative and postoperative values in both patient groups, there was no significant difference between the 2 patient groups ($P > .05$; Table 3).

### Radiological Outcome Parameters

At the last follow-up X-ray images, and according to applied fusion criteria, 93% of patients in group I have solid fusion, while 94.5% have solid fusion in group II, with no significant difference between the 2 groups. The percentage of slip was reduced from 26.7 ± 7.1% to 16.5 ± 6.1% in group I and from 27.4 ± 8.2% to 15.8 ± 5.2% in group II. Intervertebral disc height increased from 25.27 ± 14.62 to 46.38 ± 15.41 in group I and from 22.29 ± 13.72 to 45.15 ± 16.77 in group II. Segmental angle improved from 10.5 ± 8.1° to 16.7 ± 5.4° in group I and from 11.6 ± 5.3° to 15.9 ± 6.2° in group II. According to the above-mentioned 3 radiographic parameters and although there was a significant difference ($P < .001$) between preoperative and last follow-up postoperative values in both patient groups, there was no significant difference between the 2 groups ($P > .05$; Table 4 and Figure 2).

### Morbidity

A total of 8 patients in this study suffered from complications including 4 patients in group I: epidural hematoma (N = 1), wound infection progressed to spondylodiscitis (N = 1), and screw breakage with pseudarthrosis (N = 2); and 4 patients in group II: wound infection (N = 2), contralateral radiculopathy (N = 1), and cage migration with pseudarthrosis (N = 1).

In group I, a patient with postoperative epidural hematoma suffered from progressive sciatica followed by numbness in the saddle area. An urgent MRI was requested 48 hours after surgery and showed an epidural hematoma that was evacuated. Operatively, besides the hematoma, some pieces of swollen Gelfoam were found compressing the cauda equina. Her

**Table 3.** Clinical Outcome Parameters.

| Parameters | | Group I (N = 54), Local autograft | | | | Group II (N = 54), Iliac crest bone graft | | | | P |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Postoperative | | | | Postoperative | | | |
| | | Preoperative | 3 months | 6 months | Last follow-up | Preoperative | 3 months | 6 months | Last follow-up | |
| VAS | | 8 ± 3.1 | 4.5 ± 2.8 | 3.5 ± 2.5 | 3.4 ± 2.9 | 8 ± 3.2 | 4.6 ± 2.7 | 3.8 ± 3 | 3.6 ± 2.6 | NS |
| ODI | | 41.4 ± 8 | 18 ± 8 | 12.6 ± 6 | 12.3 ± 7 | 39 ± 9 | 17 ± 7 | 13.4 ± 4 | 13 ± 8 | NS |
| Subjective score | Excellent/good | | NA | | (45) 83.3% | | NA | | (47) 87% | NS |
| | Fair | | NA | | (7) 13% | | NA | | (5) 9.3% | |
| | Unchanged | | NA | | (2) 3.7% | | NA | | (2) 3.7% | |
| Questionnaire | Operation helped | | NA | | (44) 81.5% | | NA | | (46) 85.2% | NS |
| | Would undergo it again | | NA | | (43) 79.6% | | NA | | (44) 81.5% | NS |

Abbreviations: VAS, Visual Analogue Scale; ODI, Oswestry Disability Index; NS, not significant; NA, not applicable.

**Table 4.** Radiological Outcome Parameters: Preoperative and Last Follow-up Postoperative.

| Parameters | Group I (N = 54), Local autograft | | Group II (N = 54), Iliac crest bone graft | | P |
|---|---|---|---|---|---|
| | Preoperative | Postoperative (last follow-up) | Preoperative | Postoperative (last follow-up) | |
| Intervertebral slip (%) | 26.7 ± 7.1 | 16.5 ± 6.1 | 27.4 ± 8.2 | 15.8 ± 5.2 | NS |
| Intervertebral disc height | 25.27 ± 14.62 | 46.38 ± 15.41 | 22.29 ± 13.72 | 45.15 ± 16.77 | NS |
| Segmental angle (°) | 10.5 ± 8.1 | 16.7 ± 5.4 | 11.6 ± 5.3 | 15.9 ± 6.2 | NS |
| Intervertebral bone fusion (%) | | 93% | | 94.5% | NS |

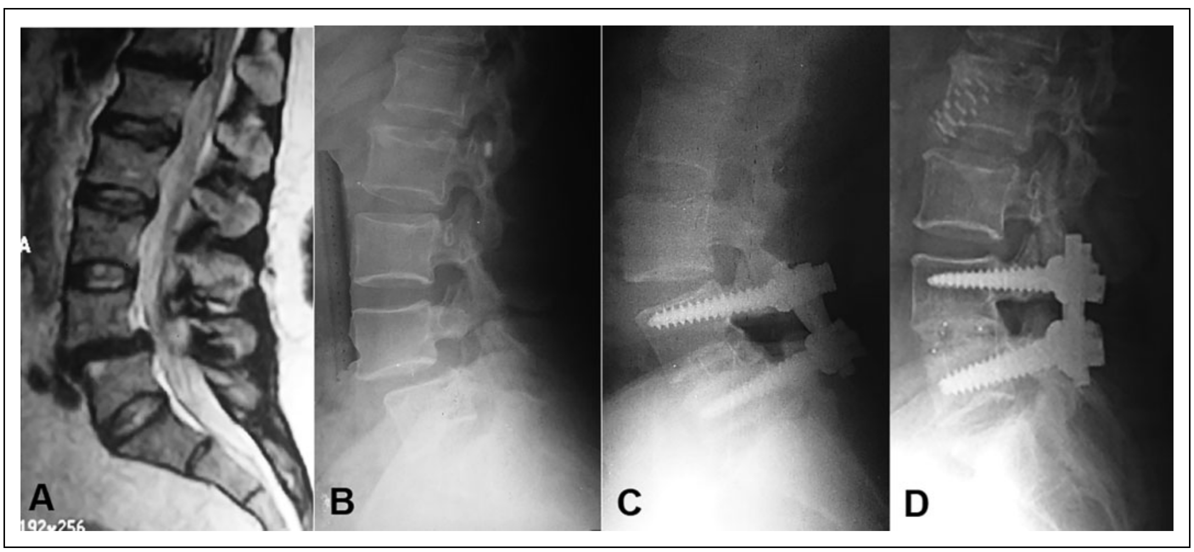


**Figure 2.** Images of L4/5 grade-I isthmic spondylolisthesis: (A) sagittal T2 WI MRI showing L4/5 slip with black pseudo disc bulge, other levels are normal; (B) lateral plain radiograph showing the isthmic defect; (C) lateral radiograph 12 months postoperatively after PSF and TLIF using local bone graft (group I) with sound fusion; (D) lateral plain radiograph 24 months postoperatively with sound fusion and bone remodeling.

symptoms relieved completely after surgery. A diabetic patient suffered from postoperative superficial wound infection and his infection progressed to spondylodiscitis. He was readmitted for surgery where disc curettage and regrafting with ICBG were performed and infection subsided after intravenous antibiotic. His operative wound culture revealed no growth, and his follow-up showed solid bone fusion later on. Two more patients suffered from pseudarthrosis at L5/S1 level with screw breakage in each of them.(Figure 3). Unfortunately, both refused surgery and continued conservative treatment with acceptable LBP VAS.

In group II, 2 patients who suffered from superficial wound infection were treated conservatively and responded well. Another patient had pseudarthrosis with posterior cage

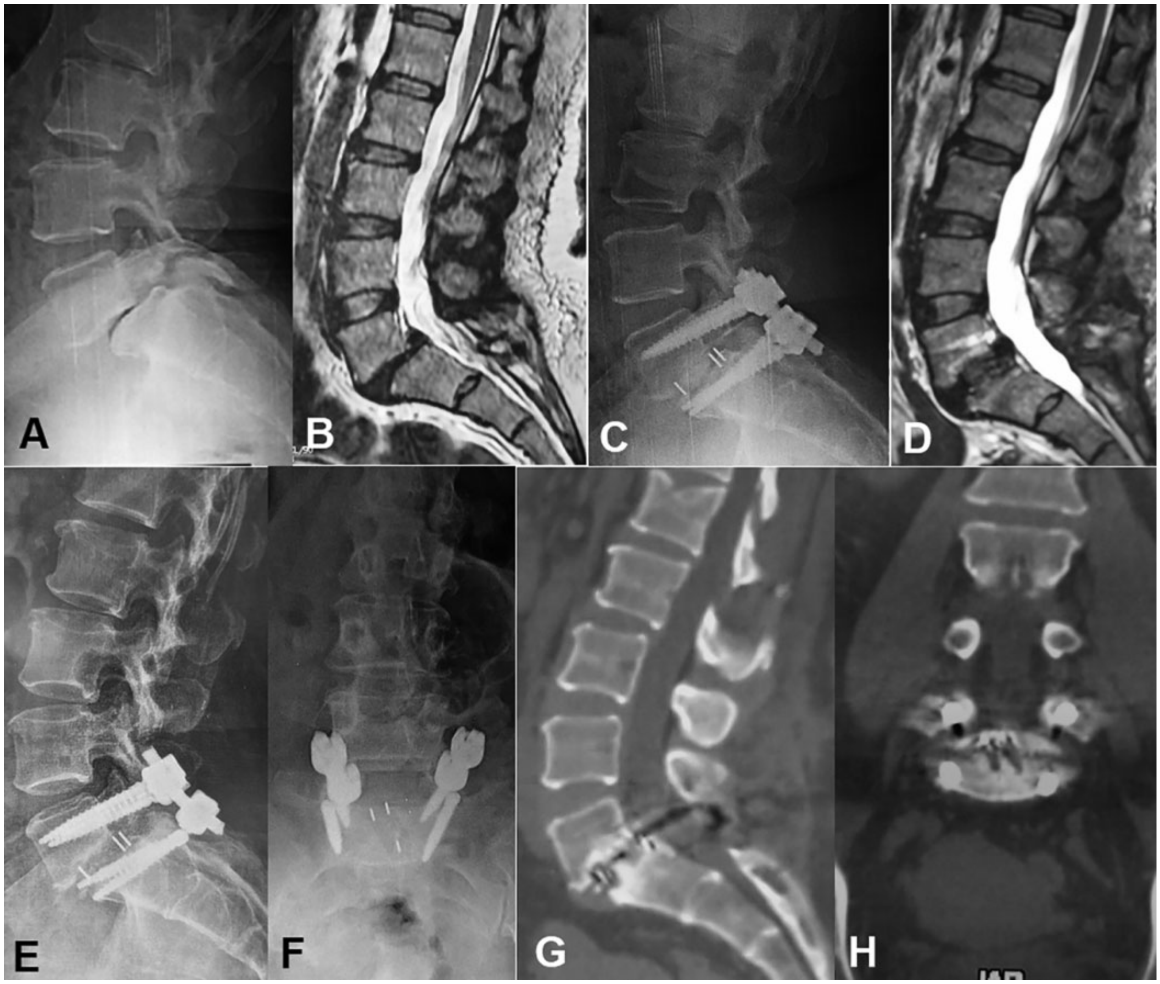


**Figure 3.** Images of L5/S1 grade II isthmic spondylolisthesis: (A) lateral plain radiograph showing isthmic defect and vacuum phenomenon at the markedly narrowed disc space; (B) sagittal T2 WI MRI showing L5/S1 slip with black pseudo disc bulge, other levels are normal; (C) lateral radiograph 6 months postoperatively after PSF and TLIF using local bone graft (group I) with significant slip reduction and no evidence of fusion; (D) sagittal T2 WI MRI slip reduction and marked disc height restoration; (E) lateral and (F) anteroposterior radiograph 12 months postoperatively with both S1 screw break and no evidence of fusion. MSCT scan (G) sagittal reformat and (H) coronal reformat with evident pseudarthrosis.

migration and root compression at L4/L5 level. She was admitted for redo surgery and sound fusion was achieved with resolution of radiculopathy. One patient belonging to group II developed postoperative contralateral radiculopathy due to pushed bone graft pressing on the root that necessitated exploration and decompression.

## Discussion

The present cohort study reported on 108 patients with low-grade isthmic or degenerative single-level spondylolisthesis treated with TLIF with minimum 2-year follow-up. It demonstrated significant radiological and clinical improvement in ODI and VAS scores that were comparable to the results published by other authors.[7-10] Several studies have reported various outcome results of different fusion procedures in patients with lumbar spondylolisthesis.[5,9,12] With the same principles, Ito et al[20] showed that the local autograft was as effective as ICBG in PLIF. In our study, we compared the clinical and radiological outcomes after pedicle screw augmented TLIF with the use of either local autograft versus the use of ICBG to fill PEEK lumbar cages. Using these 2 subgroups, our data analysis reported that although there was a significant postoperative improvement of both ODI and VAS in both groups, there was no significant difference between both subgroups ($P > .05$). The goals of surgical management of lumbar spondylolisthesis are as follows: decompression, reduction of slip, and pedicle screw augmented interbody fusion. Different studies have reported that successful fusion of unstable segment reduces mechanical pain from either pars defect or facet arthroplasty, hence contributing to good clinical outcome in patients with spondylolisthesis.[5,7,8] TLIF has the theoretical advantages of anterior column support, large physiological fusion area, restoration of disc height, and restoration of segmental lordosis in comparison to other fusion procedures.[10,21] TLIF has been reported with less incidence of neural retraction, root injury, epidural scaring, and dural injuries.[5,8]

## Clinical Parameters

This study has shown that both ICBG and local autograft have similar clinical outcome parameters including VAS and ODI. Tuchman et al[9] as well as France et al[11] in their systematic reviews reported similar results and added that ICBG was associated with increased risk donor site morbidity. Yang et al[22] in their study reported similar VAS and ODI with TLIF using local autograft and they reported the same efficacy when they used double cages. Von der Hoeh et al[23] showed similar VAS and ODI in their series of TLIF using local autograft mixed with HA versus ICBG.

The subjective 5-point outcome score showed that 83.3% (N = 45) of our patients have excellent or good results in group I and 87% (N = 47) in group II with no significant difference between the 2 groups. Similar outcome was reported by Lauber et al[8] and Lin et al.[24] Similarly, Lian et al[7] in their study reported that 86.7% (N = 39) of their patients had excellent or good outcome and 88.4% (N = 38) had excellent or good outcome with no significant difference between both groups.

The questionnaire survey showed that surgery helped 81.5% (N = 44) of patients in group I and 85.2% (N = 46) in group II and that 85.2% (N = 46) would undergo surgery again in group I and 81.5% (N = 44) in group II. There was no significant difference between the 2 groups. Moreover, similar outcome results were reported by Lian et al.[7] Similarly, Lauber et al[8] in their study reported that 84.2% (N = 15) with degenerative and 85% (N = 16) with nondegenerative spondylolisthesis patients reported that the operation helped them, and 78.9% (N = 15) with degenerative and 80% (N = 16) with nondegenerative spondylolisthesis reported that they would undergo their surgery if they were in the same situation without significant difference between the groups.

## Reduction

Operating upon low-grade spondylolisthesis was associated with partial reduction of slip even if this was not intended. This nonintended partial slip reduction that happened during surgery was due to patients' positioning on table and intervertebral disc manipulations, distraction, and curettage.[8] In our study, the percentage of slip was reduced from 26.7 ± 7.1% preoperative to 16.5 ± 6.1% postoperative in group I and from 27.4 ± 8.2% to 15.8 ± 5.2% in group II, and this has no effect on clinical outcome. Other studies[8,10] reported similar views and results. Lauber et al[8] showed that partial reduction improves the sagittal alignment of the lumbar spine without alteration of segmental lordosis. They showed also a higher degree of reduction in grade 2, yet this did not improve clinical outcome compared with grade 1. Other advocates[25] showed that reduction of slip and restoration of segmental lordosis help in restoring the center of gravity, hence improving the clinical outcome.

## Disc Height

Disc height has been restored and preserved throughout our study. Similar results were reported by Yang et al[22] in their TLIF group, wherein they reported an increased in disc height from 13.3 ± 5.7% to 24.7 ± 4.9%; additionally, Lin et al[24] have reported similar outcomes with improved disc height from 21.9 ± 3.8 mm to 45,4 ± 3.5 mm in PEEK group and from 21.5 ± 4.8 mm to 43.3 ± 3.5 mm in local autograft group. Lee et al[26] in their study have highlighted that systemic diseases such as diabetes mellitus and osteoporosis, which affect bone structures, have significant association with cage subsidence. They highlighted also that excessive disc distraction may affect the incidence of cage subsidence. Restoration of disc height is crucial for restoration of normal height of intervertebral foramen, which is usually concomitant with spondylolisthesis.

## Segmental Angle

Restoration of segmental lumbar lordosis is one of the most important surgical aims in the current era of sagittal balance consideration even during single-level lumbar fusion. Yang et al[22] have reported an increase of segmental lordosis from 11.7 ± 5.7° to 17.5 ± 5.3°. Similar outcome results have been reported by other studies.[24,25] The effect of obtaining adequate segmental lordosis after TLIF has been reported by Kuhta et al.[25] They reported that failure to correct lordosis correlates negatively with favorable clinical outcome.

## Fusion

Local autograft has been used for fusion in order to avoid donor site morbidities associated with the use of ICBG harvesting. One of the major concerns of ICBG is local pain, which is why there are numerous techniques to reduce pain during graft harvesting. One of these techniques is to harvest the ICBG through the same midline incision used for the primary procedure. Advantages of this include cosmesis, fewer incision, less soft tissue undermining, and less dead space.[11]

TLIF procedure has been reported in many studies[3,22] as a simple, effective, and safe alternative to PLIF with equal or even slightly better outcome. We reported 93% and 94.5% fusion rate in group I and group II, respectively, with no significant difference between both groups. Many studies[9,11,24] have compared local autograft versus ICBG TLIF and reported similar fusion outcome in both groups. Ito et al[20] studied the effect of adding platelet-rich plasma to local autograft in lumbar fusion and reported that it has a positive impact on lumbar fusion. Another study by von der Hoeh et al[23] compared local autograft and hydroxyapatite versus ICBG TLIF and reported 91.7% and 95.3% fusion rates in both groups, respectively, with no significant difference between both groups. We used either local autograft or ICBG to fill the PEEK cage and to be distributed in the disc space around the cage. This was highlighted in a study by Park et al,[27] who reported that the complementary effect of additional bone graft around the cages was not proven; however, it was effective in increasing the fusion area and hence the fusion rate. These data suggest that local autograft was as effective as the standard autologous ICBG as a graft for TLIF. In addition, local autograft was not associated with any of the complications of harvesting autologous ICBG.

In this study, we used plain radiography to assess fusion, while MSCT scan was used in cases of significant back pain or new events. This may be a concern in our study. The literature supports the similarity of the diagnostic capabilities of plain radiography and CT scan in fusion assessment.[28] This may be true in case of sound fusion; however, CT scan proved to be superior in case of pseudarthrosis.[29] Plain radiography is cost-effective, repeatable, and has low radiation hazard. Another concern was that we excluded patients with osteoporotic bone, which is lees biologically active than normal bone. We must highlight that our results of fusion could not be generalized to other osteoporotic patients.

### *Complications*

In this study, we reported 4 revision cases including epidural hematoma, spondylodiscitis, contralateral radicular pain, and pseudarthrosis with cage retropulsion. Lauber et al[8] in their series (N = 39) reported 3 revisions including one case of contralateral radicular pain due to insufficient disc removal. Another case was reported by Hunt et al[30] and 2 more cases by Hu et al[31] and all were related to contralateral asymptomatic foraminal stenosis that was unmasked by increased lordosis by TLIF. Undersizing graft and exaggerated lordosis were associated with contralateral foraminal stenosis and radiculopathy.[30,32] Similar to our study, von der Hoeh et al[23] in their series (N = 50) have reported 3 different cases with epidural hematoma, wound infection, and screw breakage. In this study we did not have any significant donor site morbidity relevant to iliac crest bone graft harvesting. This may be due to the technique of harvesting ICBG through the same surgical access wound. France et al[11] in their review reported that in patients with ICBG harvested through the same incision a higher proportion of patients reported no iliac crest tenderness and that their patients were satisfied with graft procedure and cosmesis.

### *Study Limitations*

One of the important limitations of this study is that we did not evaluate iliac crest tenderness. We excluded patients with BMI >30, so our data may not be generalized to obese patients, and so this work does not indicate whether local bone alone is sufficient in larger people. A sample size of 54 patients of each patient group is another limitation, and we must be cautious with data inference. Further to these points and in such a controversial issue, the sample size and the follow-up period need to be increased in future studies, and a multicenter long-term study is highly recommended.

## Conclusion

Adult patients with single-level low-grade lumbar spondylolisthesis can be effectively treated with PSF-augmented stand-alone TLI Fusing either local autograft or ICBG. In these 2 groups of patients treated with these procedures, there were no significant differences between the 2 groups in terms of operative, clinical, and radiological outcome parameters. More long-term follow-up multicentered studies with large sample size are recommended for the future.

### Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

### Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

### ORCID iD

Ali M. Abou-Madawi, MD https://orcid.org/0000-0003-0581-6458

### References

1. Gala RJ, Bovonratwet P, Webb ML, Varthi AG, Daubs MD, Grauer JN. Different fusion approaches for single-level lumbar spondylolysis have similar perioperative outcomes. *Spine (Phila Pa 1976)*. 2018;43:E111-E117.
2. Mehdian H, Kothari M. PLIF and modified TLIF using the PLIF approach. *Eur Spine J*. 2017;26(suppl 3):420-422.
3. Yan DL, Pei F, Li J, Soo C. Comparative study of PILF and TLIF treatment in adult degenerative spondylolisthesis. *Eur Spine J*. 2008;17:1311-1316.
4. Høy K, Bünger C, Niederman B, et al. Transforaminal lumbar interbody fusion (TLIF) versus posterolateral instrumented fusion (PLF) in degenerative lumbar disorders: a randomized clinical trial with 2-year follow-up. *Eur Spine J*. 2013;22:2022-2029.
5. Wang SJ, Han YC, Liu XM, et al. Fusion techniques for adult isthmic spondylolisthesis: a systematic review. *Arch Orthop Trauma Surg*. 2014;134:777-784.
6. Lu VM, Kerezoudis P, Gilder HE, McCutcheon BA, Phan K, Bydon M. Minimally invasive surgery versus open surgery spinal fusion for spondylolisthesis: a systematic review and meta-analysis. *Spine (Phila Pa 1976)*. 2017;42:E177-E185.
7. Lian XF, Hou TS, Xu JG, et al. Single segment of posterior lumbar interbody fusion for adult isthmic spondylolisthesis: reduction or fusion in situ. *Eur Spine J*. 2014;23:172-179.
8. Lauber S, Schulte TL, Liljenqvist U, Halm H, Hackenberg L. Clinical and radiologic 2-4-year results of transforaminal lumbar interbody fusion in degenerative and isthmic spondylolisthesis grades 1 and 2. *Spine (Phila Pa 1976)*. 2006;31:1693-1698.
9. Tuchman A, Brodke DS, Youssef JA, et al. Iliac crest bone graft versus local autograft or allograft for lumbar spinal fusion: a systematic review. *Global Spine J*. 2016;6(06):592-606.
10. Jacobs WCH, Vreeling A, De Kleuver M. Fusion for low-grade adult isthmic spondylolisthesis: a systematic review of the literature. *Eur Spine J*. 2006;15:391-402.

11. France JC, Schuster JM, Moran K, Dettori JR. Iliac crest bone graft in lumbar fusion: the effectiveness and safety compared with local bone graft, and graft site morbidity comparing a single-incision midline approach with a two-incision traditional approach. *Global Spine J*. 2015;28:195-206.
12. Abou-Madawi A. Pedicle screw augmented posterior interbody versus posterolateral arthrodesis in single-level low-grade isthmic lumbar spondylolisthcsis: radiological and clinical outcome. *Suez Canal Univ Med J*. 2007;10:129-138.
13. Scott J, Huskisson EC. Graphic representation of pain. *Pain*. 1976;2:175-184.
14. Fairbank JCT, Pynsent PB. The Oswestry Disability Index. *Spine (Phila Pa 1976)*. 2000;25:2940-2952.
15. Meyerding HW. Spondylolisthesis. *Surg Gynecol Obs*. 1932;54: 371-377.
16. Cobb JR. Outline for the study of scoliosis. *Instr Course Lect AAOS*. 1948;5:261-275.
17. Greenough CG, Peterson MD, Hadlow S, Fraser RD. Instrumented posterolateral lumbar fusion: results and comparison with anterior interbody fusion. *Spine (Phila Pa 1976)*. 1998;23:479-486.
18. Zhao J, Hou T, Wang X, Ma S. Posterior lumbar interbody fusion using one diagonal fusion cage with transpedicular screw/rod fixation. *Eur Spine J*. 2003;12:173-177.
19. Poussa M, Remes V, Lamberg T, et al. Treatment of severe spondylolisthesis in adolescence with reduction or fusion in situ: long-term clinical, radiologic, and functional outcome. *Spine (Phila Pa 1976)*. 2006;31:583-590.
20. Ito Z, Imagama S, Kanemura T, et al. Bone union rate with autologous iliac bone versus local bone graft in posterior lumbar interbody fusion (PLIF): a multicenter study. *Eur Spine J*. 2013;22: 1158-1163.
21. Høy K, Truong K, Andersen T, Bünger C. Addition of TLIF does not improve outcome over standard posterior instrumented fusion: 5-10 years long-term follow-up: results from a RCT. *Eur Spine J*. 2017;26:658-665.
22. Yang EZ, Xu JG, Liu XK, et al. An RCT study comparing the clinical and radiological outcomes with the use of PLIF or TLIF after instrumented reduction in adult isthmic spondylolisthesis. *Eur Spine J*. 2016;25:1587-1594.
23. von der Hoeh NH, Voelker A, Heyde CE. Results of lumbar spondylodeses using different bone grafting materials after transforaminal lumbar interbody fusion (TLIF). *Eur Spine J*. 2017;26: 2835-2842.
24. Lin B, Yu H, Chen Z, Huang Z, Zhang W. Comparison of the PEEK cage and an autologous cage made from the lumbar spinous process and laminae in posterior lumbar interbody fusion. *BMC Musculoskelet Disord*. 2016;17:374.
25. Kuhta M, Bošnjak K, Vengust R. Failure to maintain segmental lordosis during TLIF for one-level degenerative spondylolisthesis negatively affects clinical outcome 5 years postoperatively: a prospective cohort of 57 patients. *Eur Spine J*. 2019;28:745-750.
26. Lee DY, Jeong ST, Hong CH, Choi YL, Kang BH, Kim DH. Risk factors of cage subsidence after posterior lumbar interbody fusion. *J Korean Soc Spine Surg*. 2016;23:100-107.
27. Park CH, Kim EH, Yun K. Union patterns of local autogenous bone grafts using metal cages, allogenic bone, and local autogenous bone around the cages during posterior lumbar interbody fusion: a retrospective CT analysis. *J Korean Soc Spine Surg*. 2017;24:87-94.
28. Fogel GR, Toohey JS, Neidre A, Brantigan JW. Fusion assessment of posterior lumbar interbody fusion using radiolucent cages: X-ray films and helical computed tomography scans compared with surgical exploration of fusion. *Spine J*. 2008;8: 570-577.
29. Peters MJM, Bastiaenen CHG, Brans BT, Weijers RE, Willems PC. The diagnostic accuracy of imaging modalities to detect pseudarthrosis after spinal fusion—a systematic review and meta-analysis of the literature. *Skeletal Radiol*. 2019;48:1499-1510.
30. Hunt T, Shen FH, Shaffrey CI, Arlet V. Contralateral radiculopathy after transforaminal lumbar interbody fusion. *Eur Spine J*. 2007;16(suppl 3):311-314.
31. Hu HT, Ren L, Sun XZ, Liu FY, Yu JH, Gu ZF. Contralateral radiculopathy after transforaminal lumbar interbody fusion in the treatment of lumbar degenerative diseases: a case series. *Medicine (Baltimore)*. 2018;97:e0469.
32. Janich KW, Kurpad SN. Open transforaminal lumbar fusion: overview and technical consideration. In: Rudrappa S, ed. *Lumbar Interbody Fusion*. 1st ed. Thieme; 2020:23-32.