Single oblique cage posterior lumbar interbody fusion with local bone graft as an alternative to double straight-ahead cages posterior lumbar interbody fusion with iliac crest graft

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Background
Posterior lumbar interbody fusion (PLIF) is a fusion technique with reliable and rapid fusion results. The traditional technique describes the use of two cages filled with bone graft and inserted in a straight-ahead direction within the prepared disc space. Bone graft used is usually harvested from the posterior iliac crest. This study evaluates the use of a single cage inserted diagonally through unilateral discectomy and filled with bone fragments obtained from the local decompression procedure.
Patients and methods
Fourteen patients underwent pedicle screw-rod supplemented PLIF and spinal canal decompression for symptomatic spinal canal stenosis, instability, or spondylolisthesis refractive to conservative treatment. PLIF was performed using a single PEEK cage filled with impacted graft from the locally excised bone. The PEEK cage was inserted into the prepared intervertebral disc space in an oblique (diagonal) manner to obtain near-symmetrical end-plate loading across the midline.
Results
The mean follow-up period was 15 months. The mean duration of surgery was 170 and 225 min for single-level and double-level fusions, respectively. The mean volume of blood loss was 850 and 1050 ml for single-level and double-level fusions, respectively. The mean duration for hospital stay was 5 days. Postoperative radiographs showed a mean increase in the disc height by 24.4% and a mean increase in lordosis angle by 4.3°. Pain and functional scores showed marked improvement. The mean Visual Analog Scale decreased from 7.8 to 2.2. The mean Oswestry Disability Index decreased from 82 to 28. The mean Economic Prolo Scale was 3.2 whereas the Functional Prolo Scale was 3.8. Interbody fusion was assessed using lateral radiographs. Loss of demarcation of the bony end-plates with consolidation of graft through the cage was the indication of successful fusion. At final follow-up, 10 patients showed solid fusion, three patients showed delayed fusion, and one patient showed loss of reduction of spondylolisthesis after a traumatic incident and required a revision surgery. Yet, patients with delayed union did show similar improvement to those with early union on the Visual Analog Scale and Oswestry Disability Index.
Conclusion
The use of single unilateral and obliquely inserted PEEK cage is an effective safe procedure for interbody fusion that gives comparable results to the traditional double-cage technique while shortens the operative time, lowers the blood volume loss, and also lowers the cost for implants used without endangering reliability of the technique.

Keywords:
alternative double straight, iliac crest graft, posterior lumbar interbody fusion (PLIF)

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Introduction

Posterior lumbar interbody fusion (PLIF) is one of the most satisfying techniques used to treat patients with degenerative lumbar spine disorders that are refractive to conservative measures. PLIF can help restore and maintain disc height and consequently foraminal height with a resultant indirect decompression of the exiting nerve roots. PLIF also provides immediate stability and allows graft/grafted cage compression within the disc space and thereby promoting fusion. Moreover, according to the cage configuration, it can help restore segmental lumbar lordosis [1–5].

Traditionally, two cages are inserted into the disc space in a posteroanterior direction to gain support for the

end-plates symmetrically on both sides of the midline. This necessitates bilateral wide laminectomy and bilateral partial facetectomy [6,7]. This usually prolongs the operative procedure, increases the blood volume loss and requires the exploration and decompression of a side in the spinal canal that may not be symptomatic and may not be showing any compromise on MRI scans [8].

Most surgeons prefer using either autogenous posterior iliac crest graft as a fusion material. It has the advantage of highest osteogenic power with no risk of infection transmission. Still, the extra time needed for this peocedure and the possibility of donor site morbidity are considered disadvantageous [9–12]. Meanwhile, other surgeons prefer using bone graft substitutes (expanders) mixed with bone marrow aspirate from the iliac crest.

The idea of using local bone fragments from the decompressive procedure was previously addressed by some authors, where some of them were with it whereas the others were against it. The abundance of bone removed during decompression is sometimes tempting to use as a local autograft while sparing some extra time off the operation [9,12].

This study addresses a modification in the PLIF technique (using a single cage inserted diagonally) as well as the use of locally obtained bone fragments for fusion rather than iliac crest graft or synthetic bone substitute. The author aimed at evaluation of the advantages and possible drawbacks of using such technique.

Patients and methods

Patient selection

Fourteen patients (nine men, five women) were included in this study. Their mean age was 50.4 years (range: 41–55 years). They had low back pain with/without unilateral radicular lower limb symptoms. The primary intention was to include 20 patients (who underwent the procedure) but six of them did not show up after 4 months of the operation and were thus excluded.

Inclusion criteria

The following were the inclusion criteria:

(1) Patients between 40 and 60 years of age.
(2) Diagnosis of spinal canal stenosis or spondylolisthesis.
(3) Diagnosis of spinal instability proven on dynamic films at one or two spinal levels.
(4) Failed trial of nonsurgical treatment (medications, epidural injection, and physical therapy) for at least 4 months.
(5) Single-level or double-level affection by stenosis, listhesis, or instability.

Exclusion criteria

The following were the exclusion criteria:

(1) Patients with uncontrolled diabetes or advanced medical illnesses.
(2) Female patients suspected of having osteoporosis (DEXA T score<−2.5).
(3) Morbidly obese patients (BMI>35).
(4) Patients not completing at least 10 months of follow-up.
(5) Patients with previous lumbar spine surgery.

Methods

Diagnosis was based on clinical and imaging criteria. Radiographs (static and dynamic views) and MRI (T1 and T2 weighted images) were performed for all patients. This helped determine spinal levels to be targeted and their number. It also ruled out adjacent segment pathology such as occult spondylolysis or instability. Preoperative clinical and functional evaluation of patients was carried out using the Visual Analog Scale (VAS) for each of the back and radicular leg pain as well as the Oswestry Disability Index (ODI).

Bone densitometry (DEXA scan) was performed for the following:

(1) Women with premature menopause (i.e. before 45 years of age).
(2) Women with hysterectomy (as many of them did not know whether oophorectomy was performed or not).
(3) History of prolonged steroid intake or suspected fragility fracture.

Operative technique

The patients were placed on the spinal fixation frame in prone position under general anesthesia with the thighs supported to keep the hips extended (to restore lumbar lordosis) and the knees partially flexed. The posterior midline approach for dissection and spine exposure is performed and then pedicle screws are applied in the target motion segments (one or two segments). Decompressive laminectomy with partial medial facetectomy (and foraminotomy on the symptomatic side) was then performed for the target levels. The author preferred using large Kerrison punches (4 and

5 mm) whenever possible to obtain sizable bone fragments. The dura and nerve root are gently mobilized from any adhesions. The collected bone from decompression is cleaned of any attached soft tissues and is collected in a small bowl with two ampoules of Garamycin added.

A single unilateral rod is applied for distraction and opening of disc spaces (one level at a time). After the symptomatic side is decompressed, and while protecting the dura mater and nerve roots, the disc space is opened, curetted and prepared with preservation of the bony end-plates. A trial sizer is used to check for appropriate cage size. The bone collected from the decompression is used to fill the PEEK cage as well as to fill the anterolateral portion of the disc space on the same side of disc space access. A dissector is used to push the bone fragments to the required position. The dura mater and nerve root are gently retracted. The graft-filled cage is then inserted obliquely into the disc space while keeping its applicator angled 30° to the sagittal plane. The cage applicator is then removed. An image intensifier (lateral view only) is hereby used to confirm proper insertion of the cage. Remaining bone fragments, if any can then be impacted lateral to the inserted cage. The ipsilateral rod is then applied and compression is performed on the cage and graft within the disc space.

Perioperative regimen

(1) Prophylactic intravenous cephalosporins (second/third generation) are given at anesthetic induction, and continued for 4 days, and then a shift to oral route for 4 more days.
(2) Lumbosacral support for 3 months, and then when on duty for 6 months.
(3) Deep vein thrombosis prophylaxis for high-risk patients (two patients with history of deep vein thrombosis): intraoperative elastic stockings to be continued for 3 weeks. Subdose anticoagulant (enoxaparin 20 mg in nonobese patients but 40 mg for obese patients) starting from day 3 for 2 days then full dose for 10 days.

Postoperative radiographic evaluation was done within 48 h after surgery. Recording of cage position and orientation, disc and foraminal height restoration, reduction of listhesis, and restoration of lumbar lordosis was performed. Clinical and functional assessments using the VAD (for back and radicular leg pain) and the ODI were done also within the first 48 h after surgery.

The patients were followed up every 3 weeks for the first 6 weeks, then every 6 weeks for the next 3 months, and then every 6 months thereafter. Follow-up radiographs were performed at 6, 12, and 18 months. The VAS and ODI were performed at 1, 6, and 12 months postoperatively. The Prolo scales were performed at 12 months.

Results

The mean follow-up period was 15 months, with a range of 11–23 months. The mean duration of surgery was 170 min (range: 130–200 min) and 225 min (range: 210–260 min) for single-level and double-level fusions, respectively. The mean volume of blood loss was 850 ml (range: 450–950 ml) and 1050 ml (range: 850–1450 ml) for single- and double-level fusions, respectively. The mean duration for hospital stay was 5 days (range: 4–8 days).

Postoperative radiographs showed a mean increase in the disc space height by 24.4% (range: 21–34%). The mean increase in lordosis angle was 4.3° (range: 0°–5°). These changes were early postoperative changes (at 2–6 weeks), and the author did not measure late changes in disc height or angle of lordosis.

Pain and functional scores measured postoperatively at 1, 6, and 12 months showed marked improvement when compared with the preoperative scores. The mean VAS decreased from 7.8 (preoperative) to 2.2 (12 months). The mean ODI decreased from 82 (preoperative) to 28 (12 months). The mean Economic Prolo Scale was 3.2 whereas the Functional Prolo Scale was 3.8. The Prolo Scale was evaluated only on nine patients (the last nine patients included in the study).

Interbody fusion was assessed using lateral radiographs. Loss of demarcation of the end-plate and bony bridging between the end-plates through the cage was the indication of successful fusion. At 6 month, three (21.4%) patients achieved solid fusion. Those increased to eight (57.1%) patients at 12 months and to 10 (71.4%) patients at 18 months. Still, three (21.4%) patients showed delayed fusion at their final follow-up. Yet, patients with delayed union did show similar improvement to those with complete union using the VAS, ODI, and the Prolo scales.

Discussion

PLIF is a commonly used reliable technique in the treatment of lumbar degenerative spine diseases when conservative treatment fails. It has been proved to show faster and higher rates of spinal fusion as it has a high

biomechanical advantage [10]. It also offers the advantage of indirectly decompressing the exiting nerve roots through the intervertebral foramina by restoration and maintenance of disc space (and consequently foraminal) height without increased stresses on the pedicle screws, the pedicles or their interface (Fig. 1). Thus, it brings relief of low back pain together with referred and radicular leg pain while offloading the instrumentation construct [1,6,7,10,13,14].

Over the years, the success of PLIF has encouraged the modification and invention of new PLIF techniques, instruments, and cage designs regarding design configuration and material of fabrication [10,15,16]. PLIF is traditionally performed through bilateral wide laminectomy, partial facetectomy and implantation of two interbody spacers (cages) filled with impacted bone graft harvested from the posterior iliac crests, and positioned in a posteroanterior straight-ahead direction within the prepared disc space. Some surgeons perform the implantation of a single cage through unilateral laminectomy whereas others perform unilateral laminectomy and implantation of two adjacent cages. All of these techniques (especially the first two) have proved to offer sufficient stability to ensure rapid solid fusion [17–19].

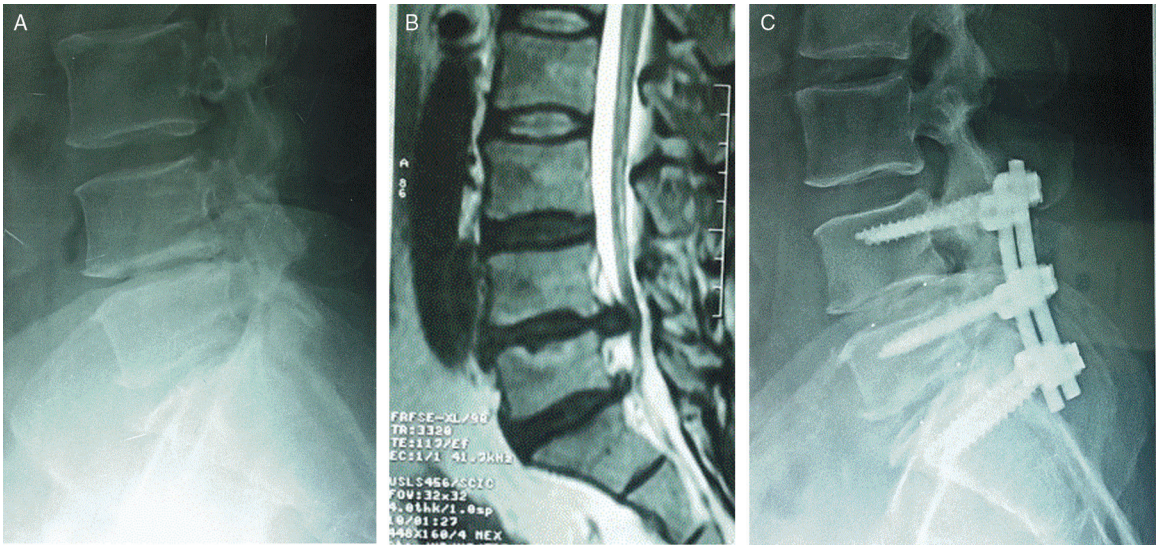
In many patients requiring PLIFs, the radicular symptoms are localized to one side only, and the MRI shows the contra-lateral side foramen, lateral recess to be wide enough, and the nerve root to be uncompromised. This makes the idea of unilateral nerve root decompression and graft-filled cage implantation seem logic. Even in patients with bilateral lower limb radicular symptoms, bilateral canal and foraminal decompression can be performed and still one or two cages can be implanted unilaterally (Fig. 2).

The unilateral implantation of two adjacent cages implies that the first cage is implanted straight-ahead then pushed medially to the midline (or past it), then the second cage is implanted beside it. In addition, manipulation of a cage within the disc space not only needs over-distraction, but can result in neural injury.

Oxland and Lund [20] showed that single-cage PLIF combined with pedicle screws provided high stability in all planes of movement [2]. Zhao *et al.* [15,21] and Seong *et al.* [22] documented that unilaterally implanted single or double-cage PLIFs were easier to perform and of lower risks than bilateral double-cage PLIFs as exploration and retraction of the nerve roots and the dura mater of the asymptomatic side could be avoided. They also added that unilateral PLIF was advantageous in reducing the blood loss, the operative time and the hospital stay [2,15,21]. Zhao *et al.* [15] also documented in a biomechanical study that single cages provided sufficient stability when the posterior structures are stabilized (i.e. with pedicle screw-rod systems).

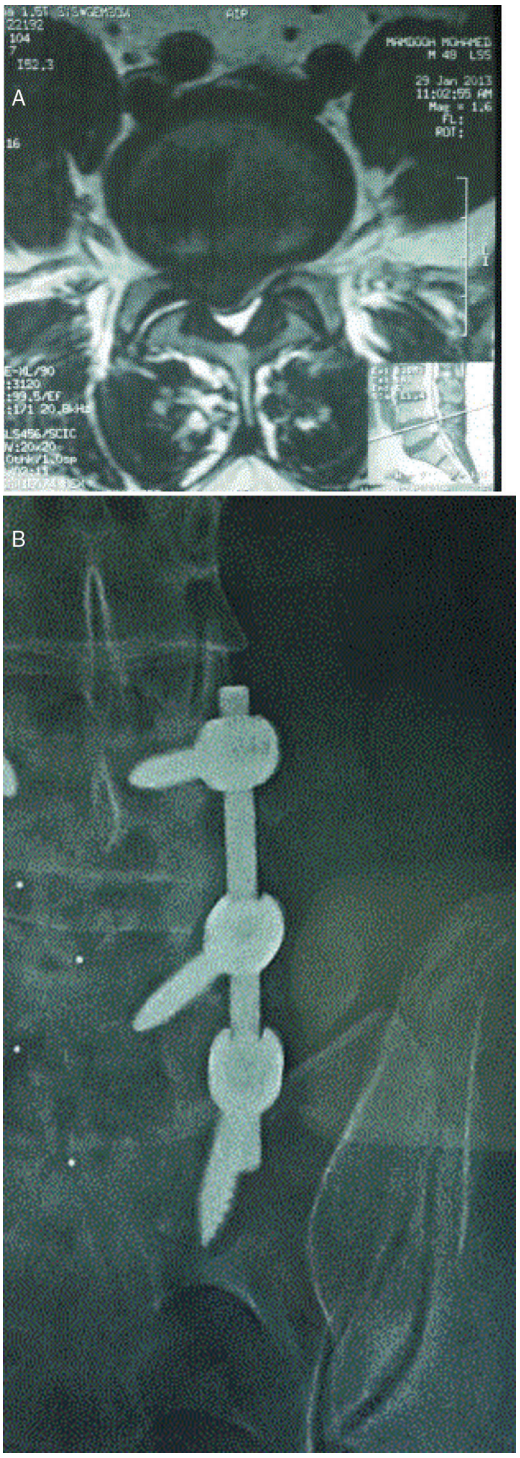
Most of the authors who previously addressed the use of unilateral PLIFs used either single/double titanium cages, or double PEEK cages [19,21,22]. In the current study, the author used a single obliquely inserted PEEK cage

Figure 1



(a) Marked disc space and foraminal narrowing with (b). Central disc prolapsed at two levels (c). Restoration of disc space and foraminal height after single oblique PEEK cage insertion for L4–L5 and L5–S1 levels with partial consolidation at 6 months postoperatively (black arrow).

Figure 2



(a) Although the patient had severe canal narrowing, his complaints were localized to the right lower limb. (b) Two oblique PLIF cages inserted in two adjacent levels through the right side after bilateral laminectomy and partial facetectomy.

together with the use of local bone harvested from canal and foraminal decompression. The progression to solid fusion occurred at an acceptable pace (Figs 1 and 3).

Some authors have even argued about the use of synthetic cages or iliac crest graft for interbody fusion. Raman *et al.* [23] reported no advantage to using an interbody cage to treat single-level degenerative spondylolisthesis compared with interbody fusion without a cage. Kim *et al.* [2] reported that use of a local bone graft impacted into a cage yielded very good outcomes both clinically and radiologically.

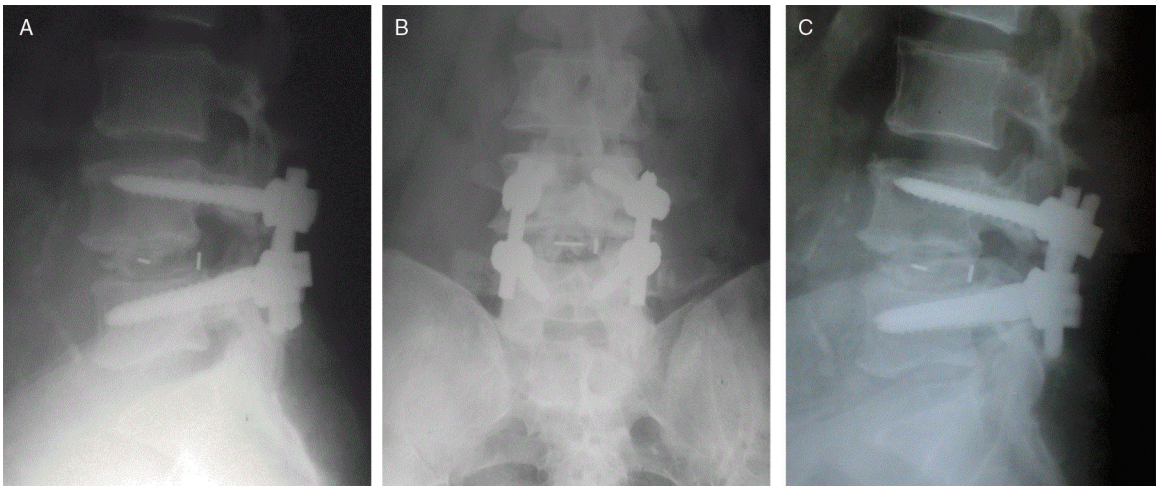
Hu *et al.* [24] reported excellent and good results in 83.4% of patients treated with interbody fusion (PLIF) using the local laminae and spinous process as a 'natural cage' with no interbody cage or iliac crest graft. They documented satisfactory fusion rate and quality together with disc space height restoration and maintenance. They emphasized that the most important part of the PLIF without a cage is to remove all soft tissue on the bone grafts and that when inserting the graft, the smaller portions are introduced into the front of the disc space and the larger grafts, consisting of cortical bone, into the back to restore disc height. They also recommended that, especially in developing countries, using a cage for a PLIF is not the first choice when treating patients with low back pain [24].

The results of the aforementioned authors [23,24] have encouraged the author of the current study to make a compromise, to use one cage instead of two, and to use the locally harvested bone fragment obtained from laminectomy to graft the PEEK cage as well as the disc space. While performing laminectomy, the author preferred to use when possible, a 4- or 5-mm Kerrison punch to obtain relatively larger bone fragments. This would help thorough soft tissue removal and make impaction easier into the cage and the disc space.

The implantation of bone graft followed by a single 'straight-ahead' cage subjects the disc space to possible asymmetrical narrowing after final compression. To avoid this problem while retaining the advantages of unilateral PLIF, there is one of two options: (i) insertion of two adjacent parallel cages, one after the other [22] or (ii) diagonal (oblique) insertion of a single cage [21].

In a comparative biomechanical study on cadaveric models, Wang *et al.* [19] evaluated the difference in stability after the use of two parallel and one oblique metallic cages with or without posterior instrumentation. They found that there were no significant differences in the stability between '2 parallel' and '1 oblique' cages in all loading modes when posterior instrumentation was used. When cages where used without instrumentation, there

Figure 3



(a) Radiographs at 3 months postoperatively with local bone-grafted cage and partial graft consolidation. (b) Oblique position of a single cage. (c) Loss of demarcation of inferior end-plate of L4 with full bony consolidation at 10 months postoperatively.

was 'a much higher degree of left axial rotation in the single oblique cage group in the horizontal plane because the cages where inserted through right facetectomy' [19].

The results of the current study concords with the aforementioned studies regarding the immediate improvement of back and radicular leg pain, the reduced blood loss, operative time, and hospital stay. The lack of spontaneous failures of construct denotes that using an appropriate technique of disc space preparation, local bone graft preparation and a single unilateral and obliquely inserted PEEK cage is biomechanically stable and can yield satisfactory clinical and radiological outcomes.

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Conflicts of interest
There are no conflicts of interest.

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