RESEARCH PAPER

Clinical and Radiological Outcomes of Posterior Lumbar Interbody Fusion with Cage and Local Autologous Bone Graft Augmented with Vertebral Bone Marrow Aspirate in Patients with Spondylolisthesis

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Abstract

Background

Lumbar spondylolisthesis is a common cause of chronic low back pain, radicular symptoms, neurogenic claudication, and functional disability. Posterior lumbar interbody fusion (PLIF) provides neural decompression, restoration of disc height, interbody support, and circumferential spinal fusion. This study evaluated the clinical and radiological outcomes of PLIF using an interbody cage with local autologous bone graft augmented with vertebral bone marrow aspirate.

Methodology

A prospective interventional study was conducted from May 2025 to May 2026 at the Department of Orthopaedics, Saveetha Institute of Medical and Sciences, Chennai. Twenty-four patients with symptomatic spondylolisthesis who failed 6 months of conservative treatment underwent PLIF. Clinical outcomes were assessed using Visual Analogue Scale (VAS) and Oswestry Disability Index (ODI). Radiological assessment included disc height, foraminal dimensions, spinopelvic parameters, implant position, and fusion using the Bridwell grading system.

Results

The mean age was 49.6 years. L4–L5 was the most commonly involved level (62.5%). Mean VAS decreased from 7.38 ± 0.82 preoperatively to 2.92 ± 1.08 at 12 months, while mean ODI decreased from 65.70 ± 9.92 to 13.58 ± 5.89 ($p < 0.0001$). Significant improvements were observed in foraminal height, foraminal width, anterior disc height, and posterior disc height. No significant changes were observed in PI, PT, SS, or LL. One patient developed postoperative motor deficit associated with dural tear.

Conclusion

PLIF using an interbody cage, local autologous bone graft, and vertebral bone marrow augmentation provides significant improvement in pain, functional disability, and local radiological parameters in patients with lumbar spondylolisthesis.

Keywords

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INTRODUCTION

Low back pain (LBP) is a common medical problem, with a 50–70% lifetime risk of an individual experiencing low back pain. Spondylolisthesis is one of the common causes of LBP. The term *spondylolisthesis*, which refers to the forward translation or slipping of one vertebral body relative to the vertebra below, is derived from the two Greek words spondylo (vertebra) and olisthesis (to slip or fall).

Spondylolisthesis can result from a defect in the pars interarticularis (isthmic spondylolisthesis) or from degeneration of the posterior facet joints, with or without involvement of the intervertebral disc (degenerative spondylolisthesis). Isthmic spondylolisthesis most commonly occurs at the lumbosacral level (L5–S1), whereas degenerative spondylolisthesis predominantly occurs at the L4–L5 level.[2,3] Isthmic spondylolisthesis is more commonly observed in younger individuals, while

degenerative spondylolisthesis predominantly occurs in adults. Isthmic spondylolisthesis is more common in males, whereas degenerative changes are more frequently observed in females. It is estimated that approximately 7% of individuals younger than 18 years have isthmic spondylolisthesis, while approximately 18% of adults demonstrate isthmic spondylolisthesis on MRI of the lumbar spine.[4]

The symptoms associated with spondylolisthesis may result from chronic muscle spasm, as the body attempts to restrict motion around a painful pseudoarthrosis of the pars interarticularis, tears in the annulus fibrosus of degenerating intervertebral discs, or compression of the nerve roots. Patients may present with low back pain, difficulty in walking, radicular symptoms, and weakness of one or both lower limbs, which may be aggravated by twisting or extension movements of the spine. Extension of the spine can produce sharp, shooting pain radiating into the lower limbs. Consequently, patients may adopt a kyphotic lumbar posture to reduce pressure on the affected nerve roots.[5]

Various non-surgical and surgical treatment modalities have been described for the management of spondylolisthesis. Conservative treatment includes analgesics and non-steroidal anti-inflammatory drugs (NSAIDs) for pain control, epidural steroid injections, and physical measures such as bracing and flexion-based strengthening exercises. Non-operative management should generally be considered as the initial treatment approach in most patients with spondylolisthesis, with or without neurological symptoms.[6] Surgical intervention is indicated in patients with persistent or recurrent back or leg pain, neurogenic claudication, significant reduction in quality of life despite a minimum 3-month trial of conservative treatment, progressive neurological deficit, bladder or bowel dysfunction, and imaging findings that correlate with the clinical presentation.[7]

Symptomatic patients with spondylolisthesis who undergo surgical treatment have been shown to achieve superior clinical and functional outcomes compared with those managed conservatively.

Lumbar interbody fusion (LIF) is an established surgical treatment option for symptomatic spondylolisthesis. The procedure involves placement of an implant, such as a structural graft, cage, or spacer, within the intervertebral disc space following discectomy and preparation of the vertebral endplates. There are five major approaches to lumbar interbody fusion: **posterior lumbar interbody fusion (PLIF), anterior lumbar interbody fusion (ALIF), oblique lumbar interbody fusion/anterior-to-psoas (OLIF/ATP), lateral lumbar interbody fusion (LLIF), and transforaminal lumbar interbody fusion (TLIF).**[9]

The initial description of the posterior lumbar interbody fusion (PLIF) technique was provided by Briggs and Milligan in 1944.[10] PLIF uses a posterior surgical approach to achieve interbody fusion of the lumbar vertebrae. It offers several advantages, including restoration of intervertebral disc height, achievement of circumferential or 360° fusion, and direct visualization of the neural elements, thereby facilitating adequate neural decompression.[9] Harms and Rolinger subsequently described the placement of an interbody cage packed with bone graft through the transforaminal approach. Various graft materials have been used to enhance spinal fusion, including synthetic bone grafts such as ceramics, bone morphogenetic proteins (BMPs), autogenous growth factors (AGFs), bone marrow aspirate (BMA), and collagen-based matrices. The iliac crest bone graft (ICBG) has traditionally remained the gold standard as an adjunct to lumbar spinal fusion; however, its use is associated with donor-site morbidity and other complications.[12] Local autograft, similar to ICBG, contains an appropriate combination of osteoconductive scaffold, osteoinductive factors, and osteogenic cells, making it a potentially useful alternative.

In the present study, we hypothesised that the use of interbody cages in PLIF would provide biomechanical advantages, including restoration of disc-space height, improvement of sagittal alignment, and enhanced weight-bearing capacity of the anterior spinal column. Studies have demonstrated that augmentation with bone marrow aspirate (BMA), which possesses osteoinductive and osteogenic properties, may provide additional support for spinal fusion. The vertebral body has been identified as a suitable site for bone marrow aspiration during spinal arthrodesis. Vertebral bone marrow aspirate is associated with lower harvest-site morbidity and may contain a higher proportion of osteogenic mesenchymal cells, which can contribute to successful fusion. However, the procedure requires an appropriate osteoconductive scaffold for effective bone formation. Therefore, it is important to evaluate the clinical and radiological outcomes of posterior lumbar interbody fusion using an interbody cage with bone graft augmented by bone marrow aspirate.

Aim and Objective of this study:

Aim

The aim of the study was to evaluate Clinical and Radiological Outcomes of Posterior Lumbar Interbody Fusion with Cage and Local Autologous Bone Graft Augmented with Vertebral Bone Marrow Aspirate in Patients with Spondylolisthesis".

Objectives

1. To evaluate the efficacy of posterior lumbar interbody fusion in terms of functional and clinical outcomes.
2. To compare the pre-operative and post-operative radiographic spinopelvic

parameters following posterior lumbar interbody fusion.

3. To assess the complications associated with posterior lumbar interbody fusion using an interbody cage and bone graft augmented with bone marrow.

Materials and Methods:

This was a prospective interventional study conducted in the Department of Orthopaedics, Saveetha Institute of Medical and Technical Sciences, Chennai, Tamil Nadu, over a period of one year from May 2025 to May 2026. All patients with spondylolisthesis who underwent posterior lumbar interbody fusion (PLIF) using an interbody cage and bone graft augmented with bone marrow and fulfilled the predefined inclusion and exclusion criteria were included in the study.

Patients aged 20–75 years with a diagnosis of spondylolisthesis with spondylolysis who had failed conservative management for 6 months were included. Patients who were willing to provide informed consent for the surgical procedure and participation in the study were also included. Patients aged less than 20 years or more than 75 years, those with spondyloptosis or stable listhesis, those who had undergone previous spinal surgery, and those with other spinal pathologies were excluded from the study.

A detailed clinical examination was performed for all patients. A step-off between adjacent spinous processes was assessed, and tenderness over the midline and paramedian regions was documented. Neurological examination included assessment of neurological signs, motor and sensory deficits, and contractures of the quadriceps and ischiocrural muscles. Symptoms suggestive of nerve-root compression, including weakness of the foot extensors, were documented. Pain severity and functional disability were assessed using the Visual Analogue Scale (VAS) and Oswestry Disability Index (ODI).

Radiological assessment was performed preoperatively and postoperatively. Relevant radiographic spinopelvic parameters were measured according to the methodology described by Hsieh et al. (2018). Plain radiographs, including anteroposterior, lateral, and flexion-extension views, were obtained to assess spinal alignment, stability, implant position, and fusion. The degree of vertebral slippage was assessed using the Meyerding classification.

Surgery was planned following a minimum 6-month trial of non-operative treatment and was performed under general anaesthesia after administration of appropriate preoperative intravenous antibiotics. Following induction of anaesthesia, the patient was positioned prone on a Rolton Hall frame over a radiolucent operating table, with the hips maintained as close to neutral as possible in an attempt to reduce the listhesis and the knees positioned in flexion to minimise undue stretching of the nerve roots. All pressure points were adequately padded. A longitudinal midline incision was made over the involved lumbar level to expose the posterior spinal elements, including the laminae and facet joints. Wide decompression was performed, including removal of the spinous process, interspinous ligament, hypertrophic ligamentum flavum, and medial portions of the facet joints, as required. Bilateral pedicle screws were inserted under fluoroscopic guidance. Cancellous autologous bone graft obtained from the resected lamina and articular facets was prepared into morselised bone chips.

The intervertebral disc was subsequently removed, and the vertebral endplates were prepared to expose the bleeding subchondral bone and provide an appropriate host bed for interbody fusion. Trial cages were used to determine the appropriate cage size and position. Approximately 8 cc of vertebral body bone marrow aspirate, with approximately 2–3 cc obtained from each instrumented pedicle, was collected. The local bone graft was mixed with the aspirated bone marrow and placed in the anterior portion of the disc space. An appropriately sized interbody cage packed with morselised local bone graft was then inserted into the prepared disc space. After satisfactory restoration of alignment and appropriate cage placement were confirmed, gentle compression was applied across the adjacent pedicle screws to achieve firm contact between the endplates and graft material. The pedicle screw-rod construct was secured to provide immediate postoperative stability and facilitate bony fusion. Haemostasis was achieved, followed by standard layered wound closure.

Postoperatively, patients received routine antibiotics, analgesics, and anti-inflammatory medications according to the institutional protocol. Clinical outcomes were assessed using the Visual Analogue Scale (VAS) and Oswestry Disability Index (ODI) at 3 months and 12 months following surgery. Radiological evaluation was also performed during follow-up to assess spinal alignment, implant position, stability, progression of fusion, and radiolucent lines. Stability and radiolucent lines were assessed using anteroposterior, lateral, and flexion-extension radiographs. Fusion was defined as the presence of bridging bone connecting the adjacent vertebral bodies through or around the interbody implant. The degree of vertebral slippage was assessed using the Meyerding classification, comparing preoperative and postoperative grades.

The Bridwell grading system was used to assess the success of interbody fusion on postoperative plain radiographs. Grade I was defined as fusion with remodelling and the presence of trabeculae. Grade II was defined as an intact graft with incomplete remodelling and no evidence of lucency. Grade III was defined as an intact graft with possible lucency at the cranial or caudal end. Grade IV was defined

as absence of fusion with collapse or resorption of the graft.

The data were analysed using IBM SPSS Statistics for Windows, version 25 (IBM Corp., Armonk, NY, USA) and GraphPad Prism version 8. Continuous variables were expressed as mean ± standard deviation or median with range, as appropriate, along with confidence intervals where applicable. Categorical variables were expressed as frequencies and percentages. The normality of continuous variables was assessed using the D'Agostino–Pearson omnibus normality test. Student's t-test was used for normally distributed continuous variables, while the Mann–Whitney U test was used for non-normally distributed data when comparing two independent groups. One-way ANOVA or the Kruskal–Wallis test was used for comparisons among three or more independent groups, as appropriate. The Wilcoxon signed-rank test was used to compare two related or paired measurements. A p-value <0.05 was considered statistically significant.

RESULTS

Age and sex distribution

There were 24 patients in the study. The mean age of the subjects was 49.6 years and the standard deviation was 6.85. The minimum age of the patient was 37 years and the maximum age was 65 years.

There were 21 females (87.5%) and 3 males (12.5%). The female-to-male sex ratio was 7:1.

Level of disability

Fifteen patients were operated for spondylolisthesis at L4–L5 (62.5%), followed by eight patients at L5–S1 (34%), and only one patient had listhesis at L3–L4.

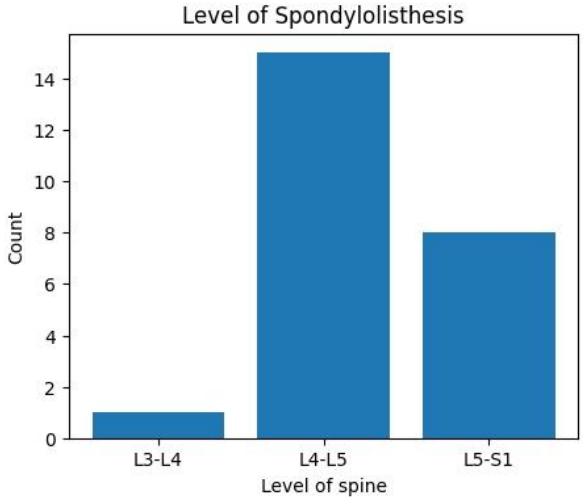


Figure: Level of spondylolisthesis.

Functional Result

Clinical Outcome

Visual Analogue Scale (Average)

The VAS was measured before the surgery and at follow-up periods of 3 months and 12 months.

The mean VAS score decreased from 7.38 (±0.82) before surgery to 4.91 (±1.06) at 3 months and 2.92 (±1.08) at 12 months.

There was a statistically significant improvement in the VAS scale (0–10) at both 3 months and 12 months compared to the preoperative score.

The improvement in VAS score was statistically significant at both follow-up periods, $p < 0.0001$).

Time Period Mean VAS Score

Before Surgery 7.4

At 3 Months 4.9

At 12 Months 2.9

Visual Analogue Score (VAS)

Oswestry Disability Index (ODI)

The ODI was measured preoperatively and postoperatively at 3 months and 12 months follow-up.

The mean ODI score decreased from 65.7 (±9.924) before surgery to 40.17 (±6.58) at 3 months and 13.58 (±5.89) at 12 months.

ODI scores showed a statistically significant improvement between the preoperative assessment and both follow-up periods.

score was significantly different across the different time points during the intervention.

Statistical result: $\chi^2(2) = 47.5$, $p < 0.0001$

Score	Preoperative	At 3 Months	At 12 Months	Preop vs 3 Months	Preop vs 12 Months	3 Months vs 12 Months
VAS Score	7.38 (±0.82)	4.91 (±1.06)	2.92 (±1.08)	P < 0.00 02	P < 0.00 01	P < 0.00 15
ODI Score	65.7 (±9.924)	40.17 (±6.58)	13.58 (±5.89)	P < 0.00 02	P < 0.00 01	P < 0.00 02

ODI Bar Graph

Radiological Outcome

No significant difference was found among preoperative and postoperative values of PI (Pelvic Incidence), PT (Pelvic Tilt), SS (Sacral Slope), and LL (Lumbar Lordosis). However, there was an increase in FH, FW, ADH, and PDH postoperatively.

PI, PT, SS and LL Before and After Surgery

Parameter	PI-Preop	PI-Postop	PT-Preop	PT-Postop	SS-Preop	SS-Postop	LL-Preop	LL-Postop
Mean	61.8	61.7	21.2	18.1	41.0	43.7	54.2	53.2
Standard	11.9	10.4	8.83	7.96	9.07	11.0	13.0	15.3

Deviation								
Standard Error of Mean	2.42	2.12	1.80	1.62	1.85	2.25	2.65	3.12

Grade of Listhesis

The mean grade of listhesis decreased postoperatively. A Wilcoxon signed-rank test was used to assess statistical significance.

Preoperative grade:2.25 ± 0.53

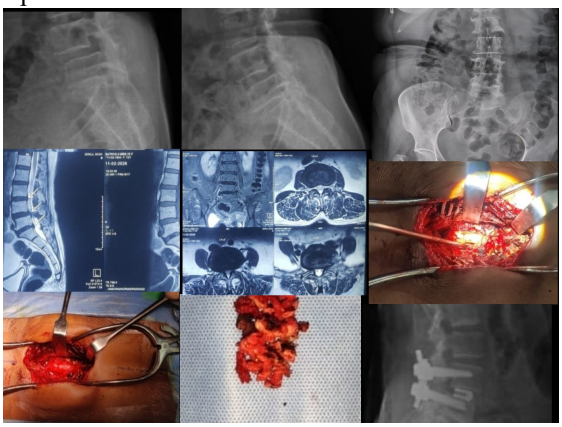
Postoperative grade:1.08 ± 0.28

The improvement in the grade of listhesis was statistically significant ($p < 0.0001$).

Grade (Mean Score)

Time	Mean Grade
Before Surgery	2.3
After Surgery	1.1

Operative Pictures:



The image depicts a case of lumbar spondylolisthesis with associated neural element compression, evaluated with preoperative radiographs and MRI. The preoperative imaging demonstrates vertebral slip with degenerative changes and spinal/foraminal stenotic features. Intraoperative photographs show posterior lumbar decompression with removal of posterior elements and local bone graft harvest. The patient subsequently underwent posterior lumbar interbody fusion (PLIF) with interbody cage and pedicle-screw instrumentation, with augmentation using local autologous bone graft. The postoperative radiograph demonstrates satisfactory placement of the interbody cage and pedicle screw–rod construct with restoration of spinal alignment.

DISCUSSION

Lumbar spondylolisthesis is an important cause of chronic low back pain, radicular symptoms, neurogenic claudication, and functional disability. Posterior lumbar interbody fusion (PLIF) is an established surgical technique that provides interbody support, restoration of disc height, neural decompression, and circumferential fusion through a posterior approach. The technique was pioneered and popularized by Cloward, although an earlier form of posterior interbody grafting had been described by Briggs and Milligan.[1,2] The development of interbody cages and pedicle screw instrumentation has further improved the biomechanical stability and reproducibility of PLIF. The present study included 24 patients with symptomatic lumbar spondylolisthesis who underwent PLIF using an interbody cage and local autologous bone graft augmented with vertebral bone marrow aspirate. The mean age of the patients was 49.6 years, with an age range of 37–65 years. This age distribution is consistent with the adult population commonly affected by symptomatic lumbar spondylolisthesis. Kalichman et al. reported a community-based study of adults demonstrating a substantial prevalence of spondylolysis and spondylolisthesis, supporting the observation that these disorders are frequently encountered in middle-aged and older adults.[3]

In the present study, the most commonly operated level was L4–L5, accounting for 15 patients (62.5%), followed by L5–S1 in 8 patients (34%), while one patient had involvement at L3–L4. The predominance of L4–L5 involvement is consistent with the established distribution of degenerative lumbar spondylolisthesis, which most frequently affects the L4–L5 level.[3]

Conservative management remains the initial treatment for most patients with low-grade symptomatic spondylolisthesis. Treatment generally includes activity modification, analgesic medication, physiotherapy, and other non-operative measures. Surgical intervention is considered when symptoms persist despite conservative treatment or when there is significant functional limitation, neurological compromise, or progressive neurological deficit. The present study included patients who had persistent symptoms despite an adequate period of conservative management and subsequently underwent surgical stabilization. Evidence from observational studies also suggests that selected patients with symptomatic degenerative spondylolisthesis may achieve better patient-reported outcomes following decompression combined with fusion than with decompression alone.[4]

The principal objective of surgery in symptomatic spondylolisthesis is to achieve adequate neural decompression, restore or maintain spinal stability, provide interbody support, and facilitate solid fusion. In the present study, significant postoperative improvement was observed in both pain and functional disability. The mean VAS score decreased from 7.38 ± 0.82 preoperatively to 4.91 ± 1.06 at 3 months and 2.92 ± 1.08 at 12 months. Similarly, the mean ODI decreased from 65.70 ± 9.92 preoperatively to 40.17 ± 6.58 at 3 months and 13.58 ± 5.89 at 12 months. These improvements were statistically significant, with $p < 0.0001$.

The improvement in VAS and ODI scores observed in this study was clinically meaningful. Ostelo et al. proposed that a change of approximately 10 points in the ODI or a 30% improvement from baseline may represent a clinically important change in patients with low back pain.[5] In the present study, the reduction in VAS and ODI scores exceeded these thresholds, with an approximate 70% reduction in VAS and 79% reduction in ODI at 12 months. The progressive improvement between 3 and 12 months suggests that the benefits of decompression, stabilization, and fusion may continue to develop during the postoperative period.

The improvement in clinical outcomes may be attributed to several components of the surgical procedure. Decompression directly relieves neural compression and may improve radicular pain and neurogenic claudication, while interbody cage placement restores disc-space height and provides anterior column support. Pedicle screw instrumentation provides immediate segmental stability and facilitates maintenance of the corrected alignment. Previous clinical studies of lumbar interbody fusion have similarly demonstrated substantial postoperative improvements in pain and disability scores.[6]

The radiological findings in the present study demonstrated improvement in several local disc-space and foraminal parameters. There was an increase in foraminal height (FH), foraminal width (FW), anterior disc height (ADH), and posterior disc height (PDH) after surgery. Restoration of disc height following interbody fusion can increase foraminal dimensions and may contribute to indirect neural decompression. Similar increases in anterior and posterior disc height and foraminal dimensions have been reported following lumbar interbody fusion.[7]

Kukkar et al. reported significant increases in anterior and posterior disc height following 360° lumbar interbody fusion at L4–L5 and L5–S1, with corresponding improvements in foraminal dimensions.[8] These findings are consistent with the present study, in which improvement in FH, FW, ADH, and PDH was observed after PLIF with cage insertion.

In contrast, there was no statistically significant difference between preoperative and postoperative spinopelvic parameters, including pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), and lumbar lordosis (LL). This finding suggests that, in the predominantly low-grade spondylolisthesis population included in the present study, correction of the local slip and restoration of disc height did not necessarily result in substantial changes in global spinopelvic alignment. Long-term studies of lumbar fusion have emphasized the importance of sagittal alignment and have demonstrated associations between sagittal parameters and patient-reported outcomes.[9],[10] However, the extent to which these parameters change after single-level fusion depends on the severity of deformity, level of fusion, baseline alignment, and surgical technique.

The present findings are also consistent with studies demonstrating that radiographic reduction of the slipped vertebra does not necessarily correlate with clinical improvement. Hagenmaier et al. evaluated patients undergoing instrumented fusion for low-grade spondylolisthesis and found significant improvements in VAS and ODI, but no significant correlation between the extent of slip reduction and improvement in clinical outcome.[11] Similarly, studies of interbody fusion have demonstrated that clinical improvement can occur despite limited correlation between the magnitude of radiological correction and patient-reported outcomes.[7],[11] Therefore, the primary goal of reduction should be restoration of satisfactory alignment and foraminal dimensions without excessive manipulation or neurological risk rather than achieving complete anatomical reduction in every patient.

Assessment of fusion is an important component of postoperative radiological evaluation. In the present study, fusion was evaluated using plain radiographs and the Bridwell grading system. Fogel et al. compared plain radiographs and helical CT with surgical exploration in patients who had undergone PLIF and found that both imaging methods demonstrated useful accuracy for assessing interbody fusion. They also reported that when plain radiographs showed convincing evidence of fusion or pseudarthrosis, CT was unlikely to provide substantial additional information.[12] Thus, serial plain radiographic assessment remains a practical method for postoperative evaluation, although CT may be considered when fusion status remains uncertain.

An important aspect of the present study was the use of vertebral bone marrow aspirate to augment the local autologous bone graft. Vertebral bone marrow provides a readily accessible source of osteoprogenitor cells because the vertebral pedicles are routinely exposed during pedicle screw instrumentation. Hustedt et al. demonstrated that vertebral body bone marrow is a promising source of osteoprogenitor cells and showed that increasing aspiration volume is associated with a reduction in progenitor cell concentration within successive aspirates.[13] This supports the rationale for obtaining marrow aspirate in small aliquots from the vertebral pedicles rather than relying on a large-volume aspiration from a single site.

McLain et al. reported that vertebral body bone marrow aspirates contain concentrations of osteogenic progenitor cells comparable to or greater than those obtained from the iliac crest. The concentration of osteogenic progenitor cells was approximately 71% higher in vertebral aspirates than in paired iliac crest samples in their study.[14] These biological characteristics provide a potential

rationale for the use of vertebral bone marrow aspirate as an adjunct to local autologous bone graft during spinal fusion.

The clinical improvement observed in the present study may therefore reflect the combined effects of neural decompression, restoration of disc height, interbody support, pedicle screw instrumentation, local autologous bone graft, and bone marrow augmentation. However, the present study was not designed to isolate the individual contribution of bone marrow aspirate to clinical or radiological outcomes. Therefore, the improvement observed should not be attributed solely to bone marrow augmentation.

The use of local autologous bone graft obtained from the posterior elements also provides an important advantage by avoiding the additional morbidity associated with iliac crest harvesting. Local bone obtained during decompression can provide an osteoconductive and osteogenic graft source and can be used in combination with an interbody cage. The use of instrumentation together with decompression and fusion has also been associated with improved patient-reported outcomes in selected patients with degenerative spondylolisthesis.[4]

In the present study, one patient (4.16%) developed a postoperative motor deficit associated with a dural tear. Dural injury is a recognized complication of lumbar decompression and fusion surgery, particularly when extensive decompression is required. Large surgical series have reported durotomy rates of approximately 10% in lumbar decompression procedures.[15] The incidence observed in the present study was lower than that reported in these larger series; however, the small sample size limits meaningful comparison.

Overall, the present study demonstrated significant improvement in pain and functional disability following PLIF with cage insertion, local autologous bone graft, and vertebral bone marrow augmentation. The improvement was maintained at 12 months, while several local radiological parameters, including foraminal height, foraminal width, anterior disc height, and posterior disc height, demonstrated postoperative improvement. In contrast, PI, PT, SS, and LL did not show significant postoperative changes. These findings indicate that clinical improvement following PLIF may occur independently of major changes in global spinopelvic parameters and that restoration of local disc and foraminal dimensions may be more directly related to symptomatic improvement in patients with low-grade spondylolisthesis.

Conclusion:

Posterior lumbar interbody fusion with cage and bone graft augmented with bone marrow provides significant improvement in pain, functional disability, and local radiological parameters in patients with lumbar spondylolisthesis. The procedure offers effective neural decompression, spinal stabilization, restoration of disc height, and satisfactory clinical outcomes with acceptable postoperative complications.

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