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Short term outcomes of PLIF with cage & bone graft for the management of adult isthmic spondylolisthesis

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Abstract
Background: There are different surgical procedures have been recommended for the treatment of Adult Isthmic Spondylolisthesis, but controversy still exists regarding the optimal surgical technique. In this study, we observed the Clinical, Radiological and Functional outcomes of posterior lumbar interbody fusion (PLIF) with cage & autogenous cancellous bone graft with pedicle screw fixation in the treatment of Adult Isthmic Spondylolisthesis.
Objectives: To evaluate the safety and efficacy of PLIF with cage & bone graft for the treatment of Adult Isthmic Spondylolisthesis
Method and Materials: This Prospective Interventional Study was conducted in the Department of Orthopaedics Surgery, BSMMU & other & private hospitals of Dhaka from March 2022 to May 2023. From this study 13 patients who underwent PLIF with cage & bone graft after meeting inclusion criteria will be included in the study. Assessment will be done preoperatively, immediate postoperatively and after 1 month, 3 months, 6 months and 12 months. Evaluation will be performed by clinical examination and radiology. Functional Outcome will be assessed by Visual Analog Scale (VAS) score and Oswestry Disability Index (ODI), along with overall outcome by Modified Macnab's criteria; and fusion rate by Bridwell criteria.
Results: A total of 13 patients with AIS were included, among whom 8 (61.5%) were female and 5 (38.5%) were male, with a female- male ratio of 1.60:1 The mean age of the study population was 55.46±8.599 years, and the maximum number of patients were between the 60-69 years age group (46.6%). The maximum (61.50%) of patients were housewives, followed by sedentary workers (23.1%) and manual workers (15.4%). According to Meyerding grading, 69.2 percent had grade II, and 30.8 percent had grade III spondylolisthesis in the preoperative x-ray. All found a significant reduction in postoperative radiology. Preoperatively Low back pain and neurogenic claudication were present in all patients. Radiculopathy was found in 12 (92.30%) of the study population; among them, unilateral radiculopathy was present in 5 (42%) and bilateral radiculopathy in 7 (58.0%) patients. Sensory impairment in 12 (92%) cases before operation and motor involvement in 10 (77%) cases, all became intact after the operation. VAS for back pain and leg pain was improved significantly from preoperative 7.23±1.16 and 6.38±2.06 respectively, to postoperatively at final follow-up 0.85±0.80 and 0.77±0.59, respectively. Preoperative ODI was improved significantly from 69.23±7.86 to postoperatively at final follow-up 8.46±2.22. In most of the cases, 8 (61.54%) were fused, and 5 (38.46%) were probably fused after 15 months of operation according to the radiological assessment of fusion according to Hackenberge ctriteria, CT scan was carried out in 5 probably fused cases, where 4 out of 5 (80%) cases were fused, and 1 out of 5 (20%) case was fragmented considering Cristensen assessment scale for CT.
Conclusion: It can be concluded that posterior lumbar interbody fusion (PLIF) by Banana cage with bone graft can be a very good option for the treatment of high-grade lumbar spondylolisthesis at L5-S1 levels.

Keywords: Posterior Lumbar Interbody Fusion (PLIF), Adult Isthmic Spondylolisthesis (AIS), Neurogenic Claudication, Visual Analogue Score (VAS), Oswestry Disability Index (ODI), Hackenberge criteria, Cristensen assessment scale

Introduction
Spondylolisthesis, derived from the Greek words for vertebrae (spondylos) and slippage (listhesis), refers to the forward displacement of one vertebra over another (Lastfogel JF *et al*.,

2010) [11]. The most prevalent subtypes in adults are degenerative and isthmic spondylolisthesis (Butt MF *et al*., 2008) [1]. Both conditions can cause spinal compression and instability, leading to radicular pain and lower back pain (Sivaraman A *et al*., 2015) [14]. Surgical fusion is essential for stabilizing the spine in cases of lumbar spondylolisthesis, effectively alleviating chronic low back pain (Ha KY *et al*., 2008) [6]. Various surgical fusion techniques are available, including anterior interbody fusion, posterior interbody fusion, posterolateral fusion, and repair of the pars interarticularis (Gjessing MH, 1951) [5]. Posterior lumbar interbody fusion (PLIF) can achieve comprehensive spinal stabilization through a single posterior approach by placing pedicle screws and an interbody spacer (Cloward RB, 1952) [3].

Adult isthmic spondylolisthesis is a common spinal condition characterized by the anterior displacement of one vertebral body relative to the adjacent inferior vertebral body, typically due to a defect in the pars interarticularis (spondylolysis). Spondylolysis affects 4-6% of the population, with a higher prevalence among athletes involved in repetitive hyperextension activities, such as gymnasts, weightlifters, and football linemen. Notably, 82% of cases occur at the L5/S1 level, while 11% occur at L4/5, as these regions experience the greatest forces in the lumbar spine and have a more coronal orientation of the facet joints.

The Wiltse-Newman classification system categorizes spondylolisthesis into six types: Type I (dysplastic), Type II (isthmic), Type III (degenerative), Type IV (traumatic), Type V (pathologic), and Type VI (post-surgical). The isthmic type is further divided into three subcategories: IIA (pars fatigue fracture), IIB (pars elongation from multiple healed stress fractures), and IIC (acute pars fracture) (Lamartina *et al*., 2009) [12].

The Meyerding classification grades spondylolisthesis based on the degree of vertebral slippage measured from standing, neutral lateral radiographs of the lumbar spine. It has five grades: Grade I (0% to 25%), Grade II (25% to 50%), Grade III (50% to 75%), Grade IV (75% to 100%), and Grade V (greater than 100%), with Grade V also referred to as spondyloptosis. The slip percentage is calculated by drawing lines through the posterior walls of the superior and inferior vertebral bodies and measuring the translation of the superior vertebra as a percentage of the distance between the lines. Grades I and II are generally considered low-grade slips, while Grades III, IV, and V are classified as high-grade slips [27].

In terms of pathophysiology, A. Foraminal stenosis in adult isthmic spondylolisthesis at L5/S1 can lead to radicular symptoms due to compression of the exiting L5 nerve root in the L5-S1 foramen, which can occur from hypertrophic fibrous repair tissue, uncinate spur formation on the posterior L5 body, or disc bulging. B. Lateral recess stenosis can arise from facet arthrosis and hypertrophy of the ligamentum flavum. C. Central stenosis is rare since most cases are only Grade I or II.

Diagnosis typically involves lateral radiographs, with flexion and extension views helping to assess instability. MRI can be useful for evaluating central or foraminal stenosis. Initial treatment often consists of non-operative measures such as NSAIDs and physical therapy. Surgical intervention is recommended for patients with progressive pain unresponsive to conservative treatments or for those with worsening neurological deficits (Ortho Bullet).

While many patients with adult isthmic spondylolisthesis remain asymptomatic, those who do experience symptoms typically present with back and leg pain, often relieved by rest. The leg pain may also include numbness or paresthesias, primarily following a dermatomal pattern linked to nerve compression in the lateral recess at the pars defect level. Postural changes associated with this condition can lead to low back pain, tight hamstrings, and postural deformities, with limited lumbar flexion often observed due to paraspinal muscle spasms. Patients may exhibit a classic Phalen-Dickson sign (a knee-flexed, hip-flexed gait). Neurological deficits may vary, potentially including motor weakness or sensory changes depending on the level of nerve compression. Cauda equina syndrome is uncommon, as the canal tends to enlarge when the cephalad vertebra shifts anteriorly, keeping the separated posterior elements in a posterior position (Kasliwal *et al*., 2013) [10].

Indications for surgical intervention in adult isthmic spondylolisthesis include intractable pain, progressive neurological deficits unresponsive to conservative treatment, or significant deformity affecting spinopelvic alignment. Surgeons often face challenges in predicting future anterolisthetic progression, especially since skeletally immature patients are at greater risk of continued slip compared to adults. Various radiographic parameters, such as pelvic incidence, sacral slope, and lumbar lordosis, have been explored for their predictive value regarding slip progression, but none have shown a definitive independent association. Age may be the most reliable indicator for future slip, leading to a higher likelihood of surgical intervention for symptomatic pediatric patients.

Several surgical techniques for managing adult isthmic spondylolisthesis have been described. The most common approaches include: 1) Nerve root decompression with removal of loose lamina and fibrocartilaginous tissue (known as the Gill procedure), 2) *In situ* fusion using autologous iliac crest graft without reduction in patients with preserved sagittal balance, with or without decompression (laminectomy), 3) Posterior instrumented fusion with pedicle screws, potentially involving sacral dome resection for reduction, 4) The Bohlman technique, which involves inserting a transsacral fibular strut graft after decompression and posterior arthrodesis with iliac crest bone, 5) Posterior reduction using interbody cages and pedicle screws, and 6) Posterior trans-discal (PTD) screw fixation, with or without laminectomy, and arthrodesis. The optimal technique for treating adult isthmic spondylolisthesis remains a topic of debate, with decisions influenced by radiological findings, clinical symptoms, and the surgeon's experience and preferences (Joaquim and Patel, 2018) [8].

Surgical fusion for lumbar spondylolisthesis is a critical method for spinal stabilization. Commonly used procedures include anterior lumbar interbody fusion (ALIF), posterolateral fusion (PLF), posterior lumbar interbody fusion (PLIF), and circumferential fusion (Liu *et al*., 2014) [13]. In contrast to staged anterior/posterior fusion methods, two posterior approaches for achieving interbody fusion have emerged: PLIF and transforaminal lumbar interbody fusion (TLIF) (Cole *et al*., 2009) [4]. In recent years, PLIF has gained popularity, and with the addition of instrumentation and posterolateral fusion, fusion rates have been reported as high as 96% to 100%, along with satisfactory clinical outcomes (Yu *et al*., 2008) [15]. Combining PLIF with posterolateral fusion results in a 360° circumferential fusion achieved through a single posterior approach, utilizing pedicle screw fixation to provide anterior support, restore disc height,

lumbar lordosis, and maintain normal spinal biomechanics.

PLIF was first introduced by Briggs and Milligan in 1944, who used bone chips from laminectomy as interbody grafts. Its popularity surged when Cloward utilized iliac crest bone grafts. Initially, PLIF reported fusion rates exceeding 85% but faced complications like arachnoiditis, neural injury, and graft extrusion. The 1990s saw a rise in PLIF use due to the development of interbody implants, which facilitated easier insertion. Synthetic cages and pre-milled allografts have since become integral to PLIF, enhancing stability of the vertebral end plates and maintaining inter-discal height. Recently, threaded fusion cages have been shown to effectively maintain disc height and promote high fusion rates (Hegde *et al*., 2017) [7].

Various types of bone grafts have been utilized for interbody fusion. Autologous iliac bone graft is a viable option due to its excellent biological healing properties, but it can result in significant donor-site morbidity, including local pain, longer surgery duration, blood loss, and infection risks. Local lamina bone and facet joint autografts, obtained during decompression, offer good alternatives without increasing morbidity (Yu *et al*., 2008) [15].

The advantages of the PLIF procedure include effective posterior decompression and the option for segmental fixation, while the TLIF procedure minimizes the risk of dural or nerve injury and spares the contralateral lamina, facet, and pars, thereby increasing the surface area for fusion (Cole *et al*., 2009) [4]. Consequently, this study aims to evaluate the functional outcomes of Posterior Lumbar Interbody Fusion using cages and bone grafts with instrumentation in the treatment of adult isthmic spondylolisthesis.

Methods and Materials

This prospective interventional study was carried out in the Department of Orthopaedic Surgery at BSMMU and various private hospitals in Dhaka from March 2022 to March 2024. A total of 13 patients who underwent posterior lumbar interbody fusion (PLIF) with cage and bone grafts, meeting the inclusion criteria, were included in the study. Assessments were conducted preoperatively, immediately postoperatively, and at 1, 3, 6, and 12 months post-surgery. Evaluation involved clinical examinations and radiological assessments. Functional outcomes were measured using the Visual Analog Scale (VAS) and the Oswestry Disability Index (ODI), with overall outcomes assessed by Modified Macnab's criteria and fusion rates evaluated according to Bridwell criteria.

Surgical Technique

In order to minimize the influence of technical skills of different surgeons, all surgical procedures will be carried out by the same spine surgeon.

Posterior approach to the lumbosacral spine

After administering general anesthesia with endotracheal intubation, the patient is positioned either prone or in a kneeling position on a padded spinal frame. This allows the abdomen to hang freely, reducing intra-abdominal pressure and minimizing blood loss by collapsing the epidural venous plexus. Following proper aseptic preparation and draping, a posterior midline longitudinal incision is made, centering on the affected level. Dissection is performed along the midline through the skin, subcutaneous tissue, lumbodorsal fascia, and supraspinous ligament, precisely over the tips of the spinous processes. Self-retaining retractors are used to maintain tension on soft tissues during exposure. The paravertebral muscles are stripped subperiosteally from the lateral surface of the spinous processes using the same technique on both sides.

The posterior surface of the laminae and articular facets is exposed through further subperiosteal reflection along the laminae. A subperiosteal dissection is carried out laterally over the lamina one level above and below the affected level. The joint capsule at the affected level is removed bilaterally, while the capsules of the other facets are preserved. The transverse processes and facets are exposed bilaterally, and pedicle screw holes at the affected level are prepared bilaterally, assisted by C-ARM for proper pedicle location and orientation. Each screw hole is checked to ensure there are no cortical breaches. The ligamentum flavum is detached from the caudal and cephalad margins using small angled curets. As the fragment is mobilized, the curet is advanced to the pseudarthrosis site to carefully release the fibrocartilaginous tissue around the affected nerve root. Additional fibrocartilage surrounding the nerve root is removed with a Kerrison rongeur, ensuring that the affected root is visible up to the lateral aspect of the foramen. In some cases, it may be necessary to remove osteophytes from the medial aspect of the facet to decompress the root.

After decompression, pedicle screws are inserted to allow for distraction across the disc space, facilitating disc removal and reduction of the spondylolisthesis. Standard polyaxial screws and rod reduction tools are typically used when the desired translation is less than 1.5 cm; reduction screws with extended threads may be utilized in some cases. A working rod is cut and contoured for placement to provide temporary distraction. This rod is secured to one screw and gradually reduced into the other screw while maintaining distractive force between them. The reduction is performed bilaterally in an alternating fashion, careful not to exert excessive force that could lead to screw pull-out, while monitoring the translation of the affected vertebra under C-ARM.

A wide annulotomy is performed to release the posterior annulus, gently retracting the thecal sac medially. If the nerve position permits, the annulotomy is extended into the foramen. A Kerrison rongeur may be needed to remove the posterior osteophyte extending from the affected vertebra, adequately opening the annulotomy to access the disc space. The cephalad half of the lower facet is also removed to facilitate access. Intervertebral reamers, sizers, and curets are used to prepare the endplates, with C-ARM monitoring to avoid anterior annulus violation and potential vascular injury. Once the endplates are prepared and reduction is deemed satisfactory, the disc space is thoroughly irrigated to clear any residual soft tissue. Morselized local autograft is packed against the anterior annulus, ensuring enough space for the interbody device to be placed no more posteriorly than the anterior 20% of the disc space to achieve lordosis.

The cage is positioned as transversely as possible, and then distraction from the working rods is released. Final rods are placed with mild compression applied to achieve lordosis. A fluted drain is inserted, and the fascia is closed to the remaining spinous processes with interrupted sutures to restore the normal resting length of the muscle. The subcutaneous and subcuticular layers are then closed individually.

Result

The prospective interventional study includes 13 patients who fulfilled the inclusion criteria, were operated by PLIF by Banana cage with bone graft for Adult Isthmic Spondylolisthesis. All patient were followed up at least 15 months postoperatively. All the data was compiled and sorted properly, analyzed statistically and placed in Tables and figures.

Demographic Information

Table 1: Distribution of study population according to age (n=13)

Age (years)	Frequency (n)	Percentage (%)
40-49	2	15.4
50-59	5	38.5
60-69	6	46.6
Total	13	

Mean±SD = 55.46±8.599
Range (Min Max): 41-67
n = number of cases

Out of 13 patients, 2 (15.4%) was 40 to 49 years of age, 5 (38.5%) was 50 t0 59 years of age and 6 (46.6) was 60 to 69 years of age (Table I).

The mean age of the patients was 55.46±8.599 years, the youngest and the oldest patient was 41 and 67 respectively. Most of the patients are in 50-69 years of age.

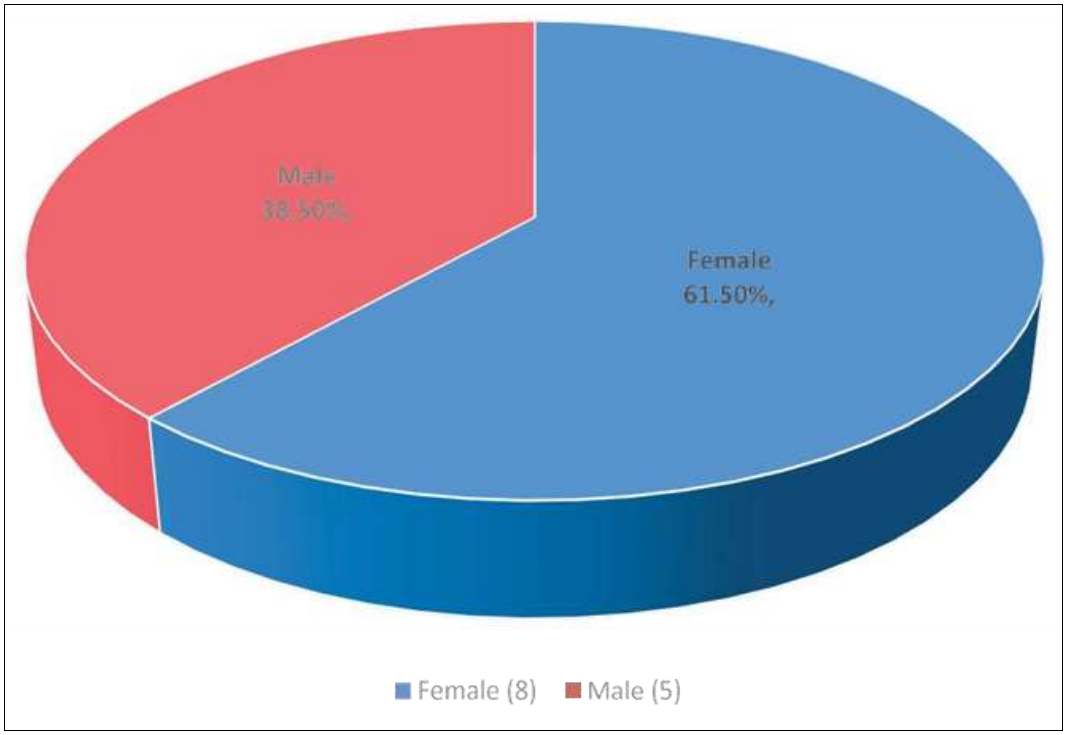

Fig 7: Gender distribution of study population (n=13)

Out of 13 patients, 8 (61.5%) were female and 5 (38.5%) were male. Female was predominant. Male female ratio was 1:1.6

Table 2: Distribution of study population according to occupation (n=13)

Occupation	Frequency (n)	Percentage (%)
Manual worker	2	15.4
Housewife	8	61.5
Sedentary worker	3	23.1
Total	13	100

Most of the patients were housewife (61.5%) followed by Sedentary worker (23.1%) and manual worker (15.4%).
Adult Isthmic spondylolisthesis is common among domestic workers like housewives.

Clinical Information

Table 3: Distribution of study population according to grade of listhesis (n=13) According Meyerding Grade (Canale, ST& Beaty, JH 2012).

Grade of spondylolisthesis	Frequency (n)	Percentage (%)
Grade II	9	69.2
Grade III	4	30.2
Grade IV	0	0

69.2 percent had grade II and 30.2 percent had grade III listhesis. Most of the patients had grade II Lumbar spondylolisthesis.

Table 4: Distribution of study population according to history and physical examination (n=13)

	Frequency (n)	Percentage (%)
Low back pain and Neurogenic claudication	13	100
Radiculopathy		
Unilateral	5	42
Bilateral	7	58

Low back pain and neurogenic claudication present in all patients. Unilateral radiculopathy was found in 5 (42%) and bilateral radiculopathy in 7 (58.0%).
100% patients had Low back pain with neurogenic claudication.

Post-operative clinical Outcome

Table 5: Distribution of study population according to sensory & Motor status preoperatively and at final follow up in 15 months (n=13)

Neurological Status	Preoperative		Post-operative		P-value
Sensory	Number	%	Number	%	
Not involved	1	8	13	100	<0.001
Involved	12	92	0	00	
Motor Not involved	3	23	13	100	<0.004
Involved	10	77	0	00	

McNemar test was done to measure the level of significance.
n=Number of cases
P value <0.05 indicate significant
All improved/regained after surgery.

Sensory involvement in 12 (92%) case before operation and Motor involvement in 10 (77%) case.

Table 5: Distribution of study population according to Knee & Ankle jerk status at preoperative and 15 months after operation.

Reflex Status	Preoperative		Post-operative		P-value
Knee Jerk	**Number**	**%**	**Number**	**%**	
Intact	13	100	13	100	<0.001
Diminished	0	00	0	00	
Ankle Jerk	**Number**	**%**	**Number**	**%**	
Intact	9	69.23	13	100	<0.001
Diminished	4	30.77	0	00	

McNemar test was done to measure the level of significance n=Number of cases
P value<0.05 indicate significant

After operation all 13 (100%) became intact.
Knee jerk was intact in all, ankle jerk was intact in 9 (69.23%) but diminished in 4 (30.77%) case before operation.

Post-operative Radiological Outcome

Table 6: Pre operative and post operative radiological status (X-ray Lumbo Sacral Spine) (n=13) before and 15 months after operation.

Radiological Correction Metrics	Pre-operative (Mean±SD)	Post-operative (Mean±SD)	p-value
Translation Ratio	60.38±11.41	17.30±9.04	<0.001
Slip Angle	-25.54±5.44	-14.31±5.95	<0.001
Disc Height Ratio	2.77±1.09	5.85±1.21	<0.001

Paired t test was done to measure the level of significance. n= Number of cases
P value <0.05 indicate significant & >0.05 indicate non-significant. Data was expressed as mean±SD
All parameter show improvement after PLIF surgery with significant p value.
Translation ratio and slip angle were significantly decreased; and disc height ratio was significantly increased.

Table 7: Mean pre- and post-operative (after 15 months) spinopelvic parameters (n=13)

Radiological Correction Metrics	Pre-operative (Mean±SD)	15 Months After Operation (Mean±SD)	p-value
Pelvic Tilt (%)	26.31±3.52	25.23±3.44	<0.001
Pelvic Index (º)	66.15±8.76	61.23±8.54	<0.001
Lumbar Lordosis (º)	44.08±6.48	36.92±5.26	<0.001

Statistical analysis was done by paired t-test
Data was expressed as mean±SD p value <0.05 indicates significant
n = number of cases

Significant improvement of spinopelvic parameters found after operation.
Test was done between pre operative and 15 months after operation. Pelvic Tilt, Pelvic Index, Lumbar Lordosis were significantly improved.

Radiological assessment of fusion

Table 8: Distribution of study population according to radiological assessment of fusion up to 15 months follow-up (n=13) (According to Hackenberge ctriteria (Hackenberge *et al*. 2005)

X-ray Lumbosacral spine	Frequency (n)	Percentage (%)
Fused	8	61.54
Probably fused	5	38.46
Probably not fused	0	0.00
Pseudo-arthrosis	0	0.00

Most of the cases show good bony fusion after 15 months.

Eight cases (61.54%) were fused and five cases (38.46%) were probably fused after 15 months of operation.

Table 10: Distribution of study population according to post operative CT Fusion. According to Cristensen assessment scale (Faundaez AA *et al*. 2009) n=5.

CT Lumbo-sacral spine	Frequency	Percentage (%)
Fused	4/5	80
Fragmented	1/5	20
Pseudoarthrosis	0	00

Most of the cases were fused by CT scan assessment.

CT scan done in patient those fulfill the X-ray fusion criteria probably fused after 15 months F/U
At CT scan 4 out of 5 (80%) cases fused and 1 out of 5 (20%) case fragmented.

Comprehensive outcome

Table 11: Pre operative and post operative comparison of clinical outcomes after 15 months (n=13) (According to VAS, ODI & WDI score)

VAS score	Pre operative (Mean±SD)	Post operative (Mean±SD)	p value
Back pain (VAS)	7.23±1.16	0.85±0.80	<0.001
Leg pain (VAS)	6.38±2.06	0.77±0.59	<0.001
WDI	66.92±13.77	17.70±4.38	<0.001
ODI	69.23±7.86	8.46±2.22	<0.001

Wilcoxon Signed Ranks test was done to measure the level of significance. n = Number of cases.
P value <0.05 indicate significant

VAS for back pain, leg pain, WDI and ODI was significantly improved after operation.
Clinical outcomes of pain & disability were significantly decreased after operation.

Table 12: Pre operative and post operative comparison of clinical outcomes (n=13) (According to ODI scoring classification system after 15 months)

ODI grading	Pre operative	Post operative	p value
	n (%)	n (%)	
Minimal	0 (0.0)	13 (100)	< 0.001
Moderate disability	2 (15.38)	0 (0.0)	
Severe disability	1 (7.70)	0 (0.0)	
Crippled	10 (76.92)	0 (0.0)	
Bed bound	0 (0.0)	0 (0.0)	

Wilcoxon Signed Ranks test was done to measure the level of significance. n=Number of cases
P value <0.05 indicate significant

Preoperatively 10 (76.92%) were crippled, 2 (15.38%) were moderate disability 1 (7.70%) were severely disable.
13 (100%) improve postoperatively to minimal disability with a significant P (<0.001)

Complications

Table 13: Distribution of study population according to per and post operative complications (n=13)

Complications	Frequency (n)	Percentage (%)
Per operative		
Dural tear	1	7.70
Root injury	0	0
Post operative		
Wound infection	1	7.70
CSF leak	0	0
Implant loosening	0	0

Minimal complications were observed in PLIF surgery.

One was per operative dural tear and another was post operative wound infection.

Discussion

This study was conducted at Bangabandhu Sheikh Mujib Medical University from March 2022 to May 2023 to evaluate the clinical outcomes, postoperative complications, and fusion status following PLIF surgery for Adult Isthmic spondylolisthesis (AIS). A total of 13 patients with spondylolisthesis underwent PLIF and were followed for 15 months.

The age of participants ranged from 41 to 67 years, with a mean age of 55.46±8.599 years. The youngest patient was 42, and the oldest was 67. These figures align favorably with previous studies; for example, Audat Z *et al*. (2012) reported a mean age of 54±13.6 years, while Kim *et al*. (2007) found an age group of 56.16±12.26 years in patients undergoing PLIF for spondylolisthesis, which is similar to our findings.

In our cohort, 8 patients (61.5%) were female and 5 (38.5%) were male, resulting in a female-to-male ratio of 1.16:1. This female predominance is consistent with previous studies, such as those by Audat Z *et al*. (2012) and Lauber S *et al*. (2006), who also observed more females than males in PLIF groups for spondylolisthesis. Moreau *et al*. (2016) and Kim *et al*. (2007) similarly reported female predominance, aligning with our results. Occupationally, the majority of our patients were housewives (8, 61.5%), followed by sedentary workers (3, 23.1%) and manual laborers (2, 15.4%). This distribution is comparable to a study by Sakib N *et al*. (2013), which reported 65.38% housewives, 15.39% manual workers, and 19.23% sedentary workers.

All patients presented with low back pain and neurogenic claudication (13, 100%). Additionally, 12 patients (92.3%) experienced low back pain with leg pain, with 5 (42%) showing unilateral and 7 (58%) bilateral radiculopathy. Sensory involvement was noted in 12 cases (92%), while 10 cases (77%) had motor involvement preoperatively. Audat *et al*. (2012) reported similar findings, with 27 patients (100%) experiencing back pain with claudication and varying rates of radiculopathy and sensory/motor involvement.

In our population, all patients had intact knee jerks, while the ankle jerk was intact in 9 (69.23%) and diminished in 4 (30.77%) before surgery. Postoperatively, all 13 (100%) regained intact reflexes. Preoperative reflex involvement was present in 15 cases (28.85%), which showed 100% improvement, as noted by Sakib N *et al*. (2013) in his PLIF study. Among our patients, 69.2% had grade II and 30.8% had grade III spondylolisthesis. Macagno *et al*. (2016) found a similar distribution in their study, with 75% at Meyerding grade III and 25% at grade IV.

Significant improvements were observed in the translation ratio and disc height ratio, which increased from 60.38±11.41 and 2.77±1.09 preoperatively to 17.30±9.04 and 5.85±1.21 postoperatively, respectively. The slip angle changed from 25.54±5.44 to 14.31±5.95. These results align with previous studies, including Kown BK *et al*. (2003) and Lamartina *et al*. (2009) [12], who reported improvements in translation and slip angle.

While we noted a decrease in spinopelvic parameters postoperatively, these remained largely unchanged throughout the follow-up period. Although improved overall sagittal balance is desirable, the radiological parameters of spinopelvic balance did not significantly change, consistent with findings from Lengert *et al*. (2014).

In terms of pain assessment, the mean VAS for back pain decreased from 7.23±1.16 to 0.85±0.80 ($p < 0.001$), while the mean VAS for leg pain reduced from 6.38±2.06 to 0.77±0.59 ($p < 0.001$). The mean ODI dropped from 69.23±7.86 to 8.46±2.22 at the 15-month follow-up. Similar improvements were noted in studies by Sakib *et al*. (2013) and Audat *et al*. (2012).

For disability assessment, the mean WDI score improved from 66.92±13.77 preoperatively to 17.70±4.38 postoperatively, with a significant p-value (< 0.001). Pellisé *et al*. (2005) reported comparable WDI improvements in their study on lumbar fusion.

According to the ODI scoring classification, preoperatively, 10 patients (76.92%) were categorized as crippled, 2 (15.38%) had moderate disability, and 1 (7.70%) was severely disabled. Postoperatively, all 13 patients (100%) improved to minimal disability ($p < 0.001$). This aligns with findings from Audat *et al*. (2012), who noted significant reductions in ODI scores over time.

In terms of fusion rates, 8 patients (61.54%) achieved solid fusion and 5 (38.46%) were considered probably fused after 15 months, based on postoperative radiological assessments using Hackenberg criteria. A CT scan confirmed fusion in 4 out of 5 (80%) of those meeting the X-ray fusion criteria, while 1 case (20%) showed fragmentation according to Christensen assessment. Overall, we found a fusion rate of 92.30% (12 out of 13), which is comparable to rates reported by Mehta *et al*. (2011) and Agazzi *et al*. (1999).

In terms of complications, only two were noted: one (7.7%)

dural tear, which was repaired, and one (7.7%) case of superficial wound infection, treated conservatively. These rates are consistent with Dantas *et al*. (2007), who reported similar infection rates in their study on posterior lumbar sacral interbody fusion.

The overall outcome was assessed using the Modified Macnab criteria, which considers relief of pain, return to employment, physical activity restrictions, and analgesic use. In our series, 11 patients (84.60%) achieved excellent outcomes, 1 (7.70%) had a good outcome, and 1 (7.70%) had a fair outcome. This is comparable to the 85.3% excellent and good results reported by Periasamy *et al*. (2008). Agazzi *et al*. (1999) also reported that 66% of patients were satisfied with their surgical outcomes.

Conclusion

This study may be concluded that decompression, posterior instrumentation and lumbar interbody fusion is an effective procedure for the treatment of AIS spondylolisthesis.

Limitations of the study

There are some limitations in this study

1. Several other confounding variables like obesity, postoperative sexual activity (after 9 months), early weight lifting, general debleating Condition of the patients couldn't be addressed directly.
2. Lack of supervised physiotherapy.
3. Sample size was small due to unavailability of patients in Covid-19 pandemic situation.

Recommendations

1. Similar study should be performed on large number of populations.
2. For study purpose required imaging should be available and cheap.
3. Good post operative physiotherapy needed for more functional outcome.

Conflict of Interest

Not available

Financial Support

Not available

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