Original Article
Journal of Orthopaedic Case Reports 2026 September:16(9):Page 409-415

The Role of Lumbar Sagittal Balance on Clinical Results after Posterior Interbody Fusion for Patients with Isthmic Spondylolisthesis: A Retrospective Study

Sunil Khemka[1], Manindra Bhushan[2], Sandesh Subhash Agrawal[2], Pritam Agrawal[1], Ambrish Verma[1], Ram Khemka[1]

Learning Point of the Article:

Comprehensive clinico-radiological assessment, including evaluation of spinopelvic sagittal alignment, aids surgical planning and helps predict post-operative functional outcomes in patients with isthmic spondylolisthesis undergoing posterior lumbar interbody fusion.

Abstract

Introduction: Isthmic spondylolisthesis is a common cause of low back pain and functional disability, often associated with spinal instability and altered sagittal spinopelvic alignment. Restoration of sagittal balance has been suggested to influence post-operative outcomes; however, its exact role remains controversial. This study aimed to evaluate the impact of lumbar sagittal balance on clinical outcomes following posterior lumbar interbody fusion (PLIF) in patients with isthmic spondylolisthesis.

Materials and Methods: A retrospective cohort study was conducted on 50 patients with isthmic spondylolisthesis who underwent PLIF between January 2024 and December 2025. Clinical outcomes were assessed using the Oswestry disability index (ODI) at pre-operative, 3-month, 6-month, and 1-year follow-up intervals. Radiographic evaluation included measurement of spinopelvic parameters – pelvic incidence (PI), pelvic tilt (PT), and sacral slope (SS) – preoperatively and postoperatively. Statistical analysis was performed using paired t-tests and correlation analysis, with $P < 0.05$ considered significant.

Results: The mean age of patients was 52.63 ± 8.71 years, with a female predominance (80%). The most commonly involved level was L4–L5 (58%). Significant improvement in functional outcomes was observed, with mean ODI scores improving from 14.13 ± 1.53 preoperatively to 7.58 ± 0.73 at 1 year ($P < 0.001$). Spinopelvic analysis demonstrated no significant change in PI ($27.25 \pm 3.30°$ vs. $27.40 \pm 3.10°$, $P > 0.05$). However, SS increased significantly ($19.6 \pm 5.57°$–$24.2 \pm 4.85°$, $P < 0.001$), while PT decreased significantly ($8.93 \pm 3.45°$–$6.10 \pm 2.95°$, $P < 0.001$). Correlation analysis revealed a significant positive association between SS and ODI improvement ($r = 0.32$, $P < 0.05$), whereas PI and PT showed weak, non-significant correlations.

Conclusion: PLIF provides significant clinical and radiological improvement in patients with isthmic spondylolisthesis. Restoration of sagittal alignment, particularly increased SS, is associated with better functional outcomes, although spinopelvic parameters may not act as independent predictors in all cases. Further prospective studies are required to validate these findings.

Keywords: Isthmic spondylolisthesis, posterior lumbar interbody fusion, sagittal balance, spinopelvic parameters, sacral slope, pelvic tilt, Oswestry disability index.

Access this article online

Website:
www.jocr.co.in

DOI:
https://doi.org/10.13107/jocr.2026.v16.i09.8110

Author's Photo Gallery


Dr. Sunil Khemka


Dr. Manindra Bhushan


Dr. Sandesh Subhash Agrawal


Dr. Pritam Agrawal


Dr. Ambrish Verma


Dr. Ram Khemka

[1]Department of Orthopedics, Shree Narayana Hospital, Raipur, Chhattisgarh, India,
[2]Department of Orthopedics and Spine Surgery, Shree Narayana Hospital, Raipur, Chhattisgarh, India.

Address of Correspondence:
Dr. Sandesh Subhash Agrawal,
Department of Orthopedics and Spine Surgery, Shree Narayana Hospital, Raipur - 492001, Chhattisgarh, India.
E-mail: preciouss333@gmail.com

Submitted: 01/06/2026; Review: 13/07/2026; Accepted: August 2026; Published: September 2026

DOI: https://doi.org/10.13107/jocr.2026.v16.i09.8110

© The Author(s). 2026 Open Access. This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (https://creativecommons.org/licenses/by-nc/4.0/), which permits unrestricted use, distribution, and non-commercial reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The Creative Commons Public Domain Dedication waiver (http://creativecommons.org/publicdomain/zero/1.0/) applies to the data made available in this article, unless otherwise stated.

Introduction

Spondylolisthesis is defined as the anterior translation of one vertebral body over the subjacent vertebra. Isthmic spondylolisthesis, resulting from a defect in the pars interarticularis, represents a distinct subtype associated with segmental instability and potential neural compression. It is present in approximately 6% of the adult population, although most individuals remain asymptomatic. Symptomatic patients may present with axial low back pain (LBP), radiculopathy, or neurogenic claudication due to nerve root impingement or associated degenerative changes [1]. LBP is a leading cause of disability worldwide, with a lifetime prevalence of 50–70%, and constitutes a significant socioeconomic burden [2]. Its etiology is multifactorial, involving mechanical, degenerative, psychosocial, and postural factors. Among these, lumbar spinal instability and sagittal spinopelvic malalignment have been increasingly recognized as key contributors to chronic symptoms [3].

Lumbar spinal instability is defined as the inability of the spine to maintain its pattern of displacement under physiological loads without resulting in pain, deformity, or neurological deficit [3]. Degeneration of intervertebral discs, facet joints, and supporting ligamentous structures disrupts normal biomechanics, leading to abnormal motion and altered load transmission. In spondylolisthesis, both the pars defect and vertebral slippage act as primary pain generators, often compounded by disc degeneration and facet arthropathy [4]. Sagittal spinopelvic alignment plays a critical role in maintaining an energy-efficient upright posture. Key parameters include pelvic incidence (PI), pelvic tilt (PT), and sacral slope (SS). PI is a fixed anatomical parameter that determines individual sagittal alignment and strongly influences lumbar lordosis [5,6]. Alterations in these parameters lead to compensatory mechanisms, increased energy expenditure, and persistence of LBP [7].

Previous studies evaluating the relationship between spinopelvic parameters and LBP have reported conflicting findings. While some authors have demonstrated altered lumbar lordosis and pelvic orientation in symptomatic individuals, others have found no significant association [8,9,10]. Furthermore, data from the Indian population remain limited. Management of spondylolisthesis ranges from conservative measures to surgical intervention in patients with persistent pain or neurological deficits. Surgical techniques aim to restore stability, achieve fusion, and correct sagittal alignment [11,12]. Emerging evidence suggests that restoration of sagittal balance may significantly influence post-operative outcomes. Therefore, the present study aimed to evaluate the association between lumbar sagittal balance and clinical outcomes following posterior lumbar interbody fusion (PLIF) in patients with isthmic spondylolisthesis.

Materials and Methods

Study design and patient population

A single-center, retrospective observational study was conducted at the Department of Orthopedics and Spine Surgery, Shree Narayana Hospital Raipur, a tertiary referral institution in Central India, between January 2024 and December 2025 with Institutional Ethics Committee (IEC) approval number: SNH/IEC/Cert./SPINE1.2/2026. The study adhered to the ethical principles outlined in the Declaration of Helsinki. A total of 50 patients diagnosed with isthmic spondylolisthesis, with or without neurological deficit, who underwent surgical management were included in the study. Patients aged 25–65 years with one- or two-level lumbar spondylolisthesis were included in the study. Patients with involvement of three or more levels, prior spinal surgery, vertebral fractures, severe systemic illness, or lumbosacral transitional vertebrae were excluded from the study., a total sample size of 50 patients was included in the study.

Pre-operative evaluation and indications for surgery

All patients underwent detailed clinical and neurological evaluation. Surgical intervention was indicated in patients with radiological evidence of instability, persistent LBP with radiculopathy, and failure of conservative management. Functional disability was assessed using the Oswestry disability index (ODI). Radiographic evaluation included assessment of sagittal spinopelvic parameters, namely, PI, PT, and SS, using standard lumbosacral radiographs. Pre-operative and post-operative clinical and radiological parameters were compared.

Surgical technique

All patients underwent PLIF through a standard midline posterior approach. Adequate decompression was performed by removal of the posterior elements, including the spinous process, lamina, ligamentum flavum, and medial facets as required. Bilateral nerve root decompression and foraminal clearance were ensured.

Pedicle screws were inserted, and controlled distraction of the disc space was achieved. Following discectomy and meticulous endplate preparation, interbody fusion was performed using either local autologous morselized bone graft harvested from the lamina and facets (bone graft group) or interbody cages (titanium or polyetheretherketone) packed with local autograft (cage group). The choice of interbody reconstruction was based

Table 1: Demographic characteristics of patients

Variable	Category	Number (*n*)	Percentage
Age group (years)	31–40	10	20
	41–50	18	36
	51–60	22	44
Gender	Male	10	20
	Female	40	80
Total		50	100

on intraoperative findings and surgeon preference. The cages were positioned at least 5 mm anterior to the posterior vertebral margin under fluoroscopic guidance. Compression across pedicle screws was applied to enhance graft-endplate contact and improve stability. Standard wound closure was performed after achieving hemostasis. Post-operative care and rehabilitation protocols were uniform for all patients.

post-operative follow-up and outcome measures

Patients were followed up at 3 months, 6 months, and 1 year postoperatively. Clinical outcomes were assessed using the ODI. Radiological evaluation included measurement of spinopelvic parameters (PI, PT, and SS) on follow-up radiographs to assess sagittal alignment and its correlation with clinical outcomes.

Assessment of fusion

Radiographic fusion was assessed based on established criteria, with particular emphasis on the Sentinel sign, defined as the presence of bridging trabecular bone within or around the interbody space. Additional criteria included absence of motion (<3°) on flexion-extension radiographs, absence of a radiolucent halo around the implants, maintenance of disc space height, and absence of implant or graft failure. Computed tomography (CT) was not performed routinely and was reserved for patients with suspected delayed union, implant-related complications, or equivocal radiographic findings.

Statistical analysis

All quantitative data were expressed as mean ± standard deviation. Pairwise comparisons between pre-operative and post-operative values were performed using paired t-tests. Correlation between changes in spinopelvic parameters and ODI improvement was assessed using Pearson's correlation coefficient. $P < 0.05$ was considered statistically significant. Due to the retrospective study design and relatively small sample size, multivariable regression analysis was not performed, and the reported associations should be interpreted accordingly.

Table 2: Distribution of level and grade of spondylolisthesis

Variable	Category	Number (*n*)	Percentage
Level of spondylolisthesis	L1–L2	0	0
	L2–L3	0	0
	L3–L4	0	0
	L4–L5	29	58
	L5–S1	21	42
Grade of spondylolisthesis	Grade I	9	18
	Grade II	21	42
	Grade III	20	40
	Grade IV	0	0
Total		50	100

Results

Demographic characteristics

A total of 50 patients were included, with a mean age of 52.63 ± 8.71 years. The majority were in the 51–60 years age group (44%), followed by 41–50 years (36%) and 31–40 years (20%). Females constituted 80% of the study population (Table 1).

Clinical profile

The most common level involved was L4–L5 (58%), followed by L5–S1 (42%). Most patients had Grade II (42%) and Grade III (40%) spondylolisthesis (Table 2).

Surgical procedures

Table 3: Distribution of surgical procedures

Procedure	Number (*n*)	Percentage
L4–L5 PLIF with cage	13	26
L4–L5 PLIF with bone graft	16	32
L5–S1 PLIF with cage	9	18
L5–S1 PLIF with bone graft	12	24

Table 4: Mean ODI		
S. No.	**Duration**	**Mean ODI±SD**
1	Pre-operative	14.13±1.53
2	3 months	8.31±1.32
3	6 months	7.78±0.64
4	1 year	7.58±0.73
ODI: Oswestry disability index, SD: Standard deviation		

Table 5: ODI comparison		
Comparison	**Mean difference**	***P*-value**
Pre-operative versus 3 months	5.82	<0.001
3 versus 6 months	0.53	>0.05
6 versus 1 year	0.2	>0.05
Pre-operative versus 1 year	6.55	<0.001
ODI: Oswestry disability index		

PLIF was performed in all patients. The most common procedure was L4–L5 fusion with bone graft (32%), followed by L4–L5 with cage (26%), L5–S1 with bone graft (24%), and L5–S1 with cage (18%) (Table 3).

Clinical outcomes

There was a marked improvement in functional outcomes. The mean ODI improved from 14.13 ± 1.53 preoperatively to 8.31 ± 1.32 at 3 months, 7.78 ± 0.64 at 6 months, and 7.58 ± 0.73 at 1 year (Table 4).

Comparative analysis of ODI

There was a highly significant improvement between pre-operative and 3-month ODI (mean difference: 5.82; P < 0.0001) and between pre-operative and 1-year ODI (mean difference: 6.55; P < 0.0001). No significant difference was observed between later follow-ups (Table 5).

Spinopelvic parameters

Pre-operative mean PI was 27.25 ± 3.30°, SS was 19.6 ± 5.57°, and PT was 8.93 ± 3.45°. At 1-year follow-up, PI remained unchanged (27.40 ± 3.10°, P > 0.05), whereas SS increased significantly to 24.2 ± 4.85° (P < 0.001) and PT decreased significantly to 6.10 ± 2.95° (P < 0.001) (Table 6).

Correlation between sagittal parameters and clinical outcome

Correlation analysis demonstrated generally weak associations between spinopelvic parameters and post-operative functional improvement. PI showed a weak positive correlation with ODI improvement (r = 0.28, P > 0.05), SS demonstrated a weak but statistically significant positive correlation (r = 0.32, P < 0.05), and PT showed a weak negative correlation (r = –0.25, P > 0.05). No statistically significant difference was observed between 3-month and later follow-ups (paired t-test, P > 0.05) The mean SS increased significantly from 19.6 ± 5.57° to 24.2 ± 4.85° (paired t-test, t = 5.12, P < 0.001), while PT decreased significantly from 8.93 ± 3.45° to 6.10 ± 2.95° (paired t-test, t = 4.86, P < 0.001). PI did not show a statistically significant post-operative change (paired t-test, t = 0.42, P > 0.05).

No major perioperative complications or revision surgeries were observed during the 1-year follow-up period. Specifically, there were no cases of deep surgical site infection, implant failure, screw loosening, cage migration, or permanent neurological deterioration. Minor post-operative complications, if any, were managed conservatively without affecting the overall clinical outcome.

Discussion

Isthmic spondylolisthesis is now widely recognized as a multifactorial condition resulting from the interplay of genetic predisposition and repetitive mechanical stress rather than a congenital anomaly of separate ossification centers. Hartvigsen et al. Lancet (2018) [2] and Oxland [3] highlighted the role of spinal instability in the development of LBP, while biomechanical studies by Puttlitz et al. [4] demonstrated that repetitive loading leads to fatigue fractures at the pars interarticularis. The increased prevalence among first-degree

Table 6 : Spinopelvic parameter						
Spinopelvic Parameter	**Preoperative Mean ± SD (°)**	**Postoperative Mean ± SD (°)**	**Mean Change (°)**	**t-value**	**p-value**	**Interpretation**
Pelvic Incidence (PI)	27.25 ± 3.30	27.40 ± 3.10	0.15	0.42	>0.05	Not significant
Sacral Slope (SS)	19.60 ± 5.57	24.20 ± 4.85	4.6	5.12	<0.001	Significant increase
Pelvic Tilt (PT)	8.93 ± 3.45	6.10 ± 2.95	−2.83	4.86	<0.001	Significant decrease

relatives supports a hereditary component, whereas its higher incidence in athletes emphasizes the contribution of mechanical stress. The natural history suggests that pars defects develop during adolescence but often remain asymptomatic until adulthood. In our study, most patients were in the fifth and sixth decades, consistent with findings by Denard et al. [5], who reported delayed clinical presentation due to progressive degenerative changes and instability. In addition, the marked female predominance (80%) observed in our cohort aligns with epidemiological trends reported in the literature [5].

Accurate differentiation of symptomatic spondylolisthesis from non-specific LBP is essential. All patients in our series had persistent symptoms despite conservative management and demonstrated instability on dynamic radiographs. This is in accordance with surgical indications described by Herkowitz and Sidhu (1995) [6], who recommended fusion in cases of instability, neurological deficit, or failure of non-operative treatment.

PLIF provides both anterior column support and posterior stabilization, thereby restoring disc height and sagittal alignment. McAfee (1999) [7] described the advantages of interbody cages in improving fusion rates and maintaining alignment. In our study, instrumented PLIF resulted in significant functional improvement, as evidenced by a substantial reduction in ODI scores from pre-operative to post-operative follow-up. From a biomechanical standpoint, the L4–L5 and L5–S1 levels are most commonly affected due to increased shear forces at these segments. This was reflected in our study and is consistent with the observations of Arnold PM 2009 [8] and subsequent biomechanical analyses [3,4].

Because both interbody cages and local autologous bone grafts were used in the present study, the findings should be interpreted as reflecting the overall effectiveness of instrumented PLIF rather than the superiority of one interbody reconstruction technique over another.

The role of instrumentation in lumbar fusion has been debated however, Rivet et al. [10] and Chitnavis et al. [11] demonstrated improved stability and favorable clinical outcomes with pedicle screw fixation and interbody support. Our findings are consistent with these later studies, showing significant improvement in pain and function following instrumented fusion. The maximum improvement in ODI scores occurred within the first 3 months postoperatively, followed by gradual improvement and plateauing after 6 months. This trend is similar to that reported by Carrage EJ et al. [9], who observed early functional recovery following PLIF. Residual LBP in a minority of patients was mild and did not significantly affect overall outcomes. Interbody fusion plays a crucial role in restoring sagittal balance, particularly in higher-grade spondylolisthesis. Denard PJ et al. (2010) [14] reported favorable clinical and radiological outcomes following PLIF, particularly with restoration of sagittal alignment and interbody support. Our findings are consistent with these observations. Although our study included a limited number of high-grade cases, the outcomes were favorable, supporting the use of interbody fusion in such patients.

Spinopelvic parameters, including PI, SS, and PT, are essential determinants of sagittal alignment. Nakai S et al. (1999) [15] emphasized its importance in surgical planning and outcome prediction Moller H et al. (2000) [16] identified PI as a key anatomical parameter, while. In the present. study, restoration of SS demonstrated a significant association with post-operative functional improvement, whereas PI and PT were not significantly associated with ODI improvement. These findings suggest that restoration of selected spinopelvic parameters may contribute to improved post-operative functional recovery; however, sagittal alignment alone is unlikely to be an independent determinant of clinical outcome. However, the present study focused primarily on pelvic parameters and did not include global sagittal alignment variables such as lumbar lordosis, sagittal vertical axis, PI–LL mismatch, or thoracic kyphosis, which may also influence post-operative functional outcomes.[17]

Radiological assessment of fusion demonstrated satisfactory results in our series, with no evidence of implant loosening or osteolysis during follow-up. Fusion was assessed based on established criteria described by Tominaga R 2021[18], including absence of motion and presence of trabecular continuity. However, fusion assessment was based primarily on plain radiographs, and routine CT scan confirmation was not performed.[19-22] Although standard radiographic criteria are widely used in clinical practice, CT imaging is more sensitive for detecting incomplete fusion or pseudoarthrosis and may provide a more accurate assessment of fusion status. As highlighted by Roussouly P et al. (2005) [23], long-term follow-up is necessary to assess adjacent segment degeneration. An additional finding in our study was the reduction in intraoperative blood loss with increasing surgical experience, reflecting a learning curve. Similar observations have been reported by Kuslich HD 1998 & Ferrara LA et al. (2010) [24,25], emphasizing improved perioperative outcomes with experience in interbody fusion techniques. The low complication rate observed in the present study further supports the safety of instrumented PLIF when performed using appropriate surgical technique and patient selection. However, larger studies with longer follow-up are necessary to better characterize procedure-related complications and long-term implant performance. Overall, our study demonstrates that instrumented PLIF with or without interbody cages is a valuable surgical option for the management of isthmic spondylolisthesis, providing significant pain relief, functional improvement, and satisfactory radiological outcomes in the present cohort.

The present study has several limitations. First, its retrospective single-center design introduces the possibility of selection bias, limits the generalizability of the findings, and precludes the establishment of a causal relationship between restoration of sagittal balance and postoperative clinical outcomes. Second, although the sample size was adequate for the primary study objective, the relatively small cohort limited statistical power for subgroup analyses and did not permit multivariable regression to adjust for potential confounding factors. Third, the absence of a control group prevented direct comparison of PLIF with conservative treatment or other fusion techniques. Fourth, clinical and radiological outcomes were evaluated only up to 1 year, limiting assessment of long-term fusion durability, maintenance of sagittal alignment, adjacent segment degeneration, implant longevity, and revision surgery. Furthermore, sagittal alignment assessment was limited to PI, PT, and SS, while other global sagittal parameters were not evaluated. Fusion was assessed using standard radiographic criteria without routine CT confirmation, which may have underestimated pseudoarthrosis. Finally, post-operative outcomes were assessed primarily using the ODI, without additional patient-reported outcome measures evaluating pain or health-related quality of life. Future prospective, multicenter studies with larger sample sizes, longer follow-up, comprehensive sagittal alignment assessment, and standardized outcome measures are warranted to validate these findings.

Conclusion

PLIF is an effective surgical treatment for patients with symptomatic isthmic spondylolisthesis, resulting in significant improvement in functional outcomes and restoration of spinal stability. In the present study, patients demonstrated a substantial reduction in ODI scores over 1 year of follow-up, accompanied by significant improvements in sagittal spinopelvic alignment, particularly an increase in SS and a decrease in PT. While restoration of sagittal alignment, especially SS, was significantly associated with improved post-operative functional outcomes, PI remained unchanged, consistent with its role as a fixed anatomical parameter. These findings suggest that optimization of sagittal balance may contribute to improved post-operative functional outcomes following PLIF; however, the retrospective design of this study precludes the establishment of a causal relationship. Larger prospective, multicenter studies with extended long-term follow-up are warranted to validate these findings and further clarify the prognostic value of spinopelvic parameters in patients undergoing PLIF for isthmic spondylolisthesis.

Clinical Message

Routine assessment of spinopelvic parameters during pre-operative planning may assist surgical decision-making, facilitate restoration of sagittal alignment, and contribute to improved post-operative functional recovery in patients undergoing PLIF for isthmic spondylolisthesis.

Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given the consent for his/ her images and other clinical information to be reported in the journal. The patient understands that his/ her names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Conflict of interest: Nil **Source of support:** None

References

1. Doulgeris JJ, Aghayev K, Gonzalez-Blohm SA, Lee WE 3rd, Vrionis FD. Biomechanical comparison of an interspinous fusion device and bilateral pedicle screw system as additional fixation for lateral lumbar interbody fusion. Clin Biomech (Bristol) 2015;30:205-10.

2. Hartvigsen J, Hancock MJ, Kongsted A, Louw Q, Ferreira ML, Genevay S, et al. What low back pain is and why we need to pay attention. Lancet 2018;391:2356-67.

3. Oxland TR. Fundamental biomechanics of the spine--What we have learned in the past 25 years and future directions. J Biomech 2016;49:817-32.

4. Puttlitz CM, Goel VK, Pope MH. Biomechanical testing sequelae relevant to spinal fusion and instrumentation. Orthop Clin North Am 1998;29:571-89.

5. Gunzburg R, Szpalski M. The conservative surgical treatment of lumbar spinal stenosis in the elderly. Eur Spine J 2003;12 Suppl 2:S176-80.

6. McAfee PC. Interbody fusion cages in reconstructive

operations on the spine. J Bone Joint Surg Am 1999;81:859-80.

7. Herkowitz HN, Sidhu KS. Lumbar spine fusion in the treatment of degenerative conditions: Current indications and recommendations. J Am Acad Orthop Surg 1995;3:123-35.

8. Arnold PM, Robbins S, Paullus W, Faust S, Holt R, McGuire R. Clinical outcomes of lumbar degenerative disc disease treated with posterior lumbar interbody fusion allograft spacer: A prospective, multicenter trial with 2-year follow-up. Am J Orthop (Belle Mead NJ) 2009;38:E115-22.

9. Crragee EJ. Single-level posterolateral arthrodesis, with or without posterior decompression, for the treatment of isthmic spondylolisthesis in adults. A prospective, randomized study. J Bone Joint Surg Am 1997;79:1175-80.

10. Rivet DJ, Jeck D, Brennan J, Epstein A, Lauryssen C. Clinical outcomes and complications associated with pedicle screw fixation-augmented lumbar interbody fusion. J Neurosurg Spine 2004;1:261-6.

11. Chitnavis B, Barbagallo G, Selway R, Dardis R, Hussain A, Gullan R. Posterior lumbar interbody fusion for revision disc surgery: Review of 50 cases in which carbon fiber cages were implanted. J Neurosurg 2001;95 Suppl 2:190-5.

12. Janssen ME, Lam C, Beckham R. Outcomes of allogenic cages in anterior and posterior lumbar interbody fusion. Eur Spine J 2001;10 Suppl 2:S158-68.

13. Fairbank JC, Pynsent PB. The oswestry disability index. Spine (Phila Pa 1976) 2000;25:2940-52.

14. Denard PJ, Holton KF, Miller J, Fink HA, Kado DM, Yoo JU, et al. Lumbar spondylolisthesis among elderly men: Prevalence, correlates, and progression. Spine (Phila Pa 1976) 2010;35:1072-8.

15. Nakai S, Yoshizawa H, Kobayashi S. Long-term follow-up study of posterior lumbar interbody fusion. Spinal Disord 1999;12:293-9.

16. Möller H, Hedlund R. Instrumented and noninstrumented posterolateral fusion in adult spondylolisthesis--a prospective randomized study: Part 2. Spine (Phila Pa 1976) 2000;25:1716-21.

17. Azizpour K, Broekman SJ, Peul WC, Vleggeert-Lankamp CL. Posterior lumbar fusion with and without interbody fusion in isthmic spondylolisthesis: A systematic review and meta-analysis. Neurosurg Rev 2025;48:581.

18. ominaga R, Kurita N, Kokubun Y, Nikaido T, Sekiguchi M, Otani K, et al. Dose-response relationship between spino-pelvic alignment determined by sagittal modifiers and back pain-specific quality of life. Eur Spine J 2021;30:3019-27.

19. Boulay C, Tardieu C, Hecquet J, Benaim C, Mouilleseaux B, Marty C, et al. Sagittal alignment of spine and pelvis regulated by pelvic incidence: Standard values and prediction of lordosis. Eur Spine J 2006;15:415-22.

20. Barrey C, Jund J, Noseda O, Roussouly P. Sagittal balance of the pelvis-spine complex and lumbar degenerative diseases. A comparative study about 85 cases. Eur Spine J 2007;16:1459-67.

21. Jackson RP, McManus AC. Radiographic analysis of sagittal plane alignment and balance in standing volunteers and patients with low back pain matched for age, sex, and size. A prospective controlled clinical study. Spine (Phila Pa 1976) 1994;19:1611-8.

22. Rajnics P, Templier A, Skalli W, Lavaste F, Illes T. The importance of spinopelvic parameters in patients with lumbar disc lesions. Int Orthop 2002;26:104-8.

23. Roussouly P, Gollogly S, Berthonnaud E, Dimnet J. Classification of the normal variation in the sagittal alignment of the human lumbar spine and pelvis in the standing position. Spine (Phila Pa 1976) 2005;30:346-53.

24. Kuslich SD, Ulstrom CL, Griffith SL, Ahern JW, Dowdle JD. The Bagby and Kuslich method of lumbar interbody fusion. History, techniques, and 2-year follow-up results of a United States prospective, multicenter trial. Spine (Phila Pa 1976) 1998;23:1267-78.

25. Ferrara LA, Goel VK. The biomechanics of spinal fusion. ArgoSpine News J 2010;22:57-61.

Conflict of Interest: Nil
Source of Support: Nil

Consent: The authors confirm that informed consent was obtained from the patient for publication of this article

How to Cite this Article

Khemka S, Bhushan M, Agrawal SS, Agrawal P, Verma A, Khemka R. The Role of Lumbar Sagittal Balance on Clinical Results after Posterior Interbody Fusion for Patients with Isthmic Spondylolisthesis: A Retrospective Study. Journal of Orthopaedic Case Reports 2026 September;16(09): 409-415.