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POSTERIOR STABILIZATION FOR LUMBOSACRAL INSTABILITY

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ABSTRACT:

Background: Lumbar and lumbosacral instability involving the L3–L4, L4–L5, and L5–S1 levels is a major cause of chronic low back pain, radiculopathy, and functional impairment. Posterior stabilization using pedicle screw–rod constructs, with or without interbody fusion, is considered the gold standard for restoring segmental stability, alleviating pain, and promoting fusion. This study evaluates the clinical and radiological outcomes of posterior stabilization in 100 patients with instability at L3–L4, L4–L5, and L5–S1, with a primary focus on the lumbosacral junction.

Materials and Methods: A prospective observational study was conducted on 100 patients with symptomatic instability at L3–L4, L4–L5, or L5–S1 due to degenerative spondylolisthesis, post-traumatic instability, or post-laminectomy changes. All patients underwent posterior stabilization using pedicle screw–rod constructs; 65 patients also received interbody fusion. Clinical outcomes were assessed using the Visual Analog Scale (VAS) and Oswestry Disability Index (ODI) preoperatively and at 3, 6, and 12 months postoperatively. Radiological assessment included fusion status, segmental disc height, and segmental lordotic angle at the involved level at 12 months. Complications were documented. Statistical analysis was performed using paired t-tests, with $p < 0.05$ considered significant.

Results: The mean age was 52.4 ± 11.6 years, with 62% males. VAS improved from 7.6 ± 1.1 preoperatively to 2.1 ± 0.9 at 12 months ($p < 0.001$), and ODI improved from 62.5 ± 9.8% to 18.4 ± 7.3% ($p < 0.001$). Solid fusion was achieved in 92% of patients. Mean disc height and segmental lordosis at the affected levels (L3–L4, L4–L5, or L5–S1) showed significant improvement at 12 months. Complications were minimal, including superficial wound infection (6%), transient neuropraxia (3%), and hardware failure (1%). No permanent neurological deficits were observed.

Conclusion: Posterior stabilization with pedicle screw–rod constructs is an effective and safe intervention for lumbar instability at L3–L4, L4–L5, and L5–S1, resulting in significant pain relief, functional improvement, high fusion rates, and restoration of segmental alignment. The procedure demonstrates a low complication profile and is effective across a range of etiologies. Long-term studies are recommended to evaluate durability, adjacent segment effects, and outcomes of minimally invasive approaches.

Keywords: Lumbosacral instability; Posterior stabilization; Pedicle screw; Interbody fusion; Spine surgery

INTRODUCTION:

Lumbosacral instability is defined as excessive or abnormal motion at the L3–L4, L4–L5, and particularly the L5–S1 segments, resulting in mechanical back pain, radiculopathy, and in some cases, progressive spinal deformity[1]. Instability at these lower lumbar levels—especially the transition zone at L5–S1—is clinically significant due to the high mechanical load and mobility of these segments.

The condition can arise from a variety of etiologies including degenerative spondylolisthesis, trauma, iatrogenic causes such as post-laminectomy changes, and congenital or inflammatory disorders[2–4]. Degenerative spondylolisthesis commonly affects the L4–L5 level, while L5–S1 is frequently involved in lytic or traumatic instability. Degenerative spondylolisthesis is particularly common in the elderly population, with prevalence rates reported between 4% and 6% in individuals over 50 years, and it is often associated with facet joint arthropathy and disc degeneration[5].

Traumatic instability may result from fractures of the L4, L5 vertebrae, sacrum, or associated ligamentous injury, leading to structural compromise of the lower lumbar and lumbosacral junction[6]. Post-laminectomy instability—more commonly observed at L4–L5 and L5–S1—occurs due to excessive resection of posterior elements and facet joints during decompression procedures[7].

Patients with instability at L3–L4, L4–L5, or L5–S1 frequently present with chronic low back pain exacerbated by activity, neurogenic claudication, and radiating lower limb pain. Conservative management, including analgesics, physiotherapy, and activity modification, can be effective in mild cases. However, in patients with significant mechanical instability or progressive neurological deficits, non-surgical interventions often fail to provide long-term relief, making surgical stabilization necessary[8,9].

Posterior stabilization using pedicle screws and rods has emerged as the gold standard technique for surgical management of lower lumbar and lumbosacral instability. Pedicle screw fixation offers biomechanical superiority by providing three-column support, restoring sagittal and coronal alignment, and facilitating solid arthrodesis[10]. Interbody fusion, when combined with posterior instrumentation, enhances fusion rates by increasing surface area for bony incorporation and maintaining disc height—particularly important at high-stress levels such as L4–L5 and L5–S1[11].

Numerous studies have reported satisfactory clinical outcomes, including reduction in pain, improvement in functional scores, and high rates of solid fusion following posterior stabilization across these segments[12–14]. Despite these advantages, controversies remain regarding optimal patient selection, surgical technique, and long-term outcomes, especially in patients with complex etiologies such as post-traumatic or post-laminectomy instability. Additionally, most studies have included relatively small sample sizes or short-term follow-up, limiting the generalizability of findings[15].

This study aims to evaluate the clinical and radiological outcomes of posterior stabilization in a cohort of 100 patients with instability at the L3–L4, L4–L5, and L5–S1 levels, providing a robust dataset to assess efficacy, fusion rates, and complication profiles.

MATERIALS AND METHODS:

Study Design and Setting

This was a prospective observational study conducted at the Department of Orthopaedics and Neurosurgery of our hospital from January 2023 to September 2025. The study was approved by the Institutional Ethics Committee, and written informed consent was obtained from all participants. The study was conducted in accordance with the Declaration of Helsinki guidelines.

Patient Selection

Inclusion Criteria:

- Adults aged 18–70 years with symptomatic L3–L4, L4–L5, or L5–S1 instability confirmed on dynamic radiographs (flexion–extension X-rays showing translation >3 mm or angulation >10° at any of these levels).

- Patients with chronic low back pain, radicular symptoms, neurogenic claudication, or progressive deformity attributable to instability at the L3–L4, L4–L5, or L5–S1 segments, persisting despite at least six months of conservative therapy, including analgesics, physiotherapy, and activity modification.
- Patients with instability at one or more of these lower lumbar levels who are willing to comply with postoperative follow-up and rehabilitation protocols.

Exclusion Criteria:
- Active spinal infection (e.g., spondylodiscitis), tumours**, or** inflammatory arthritis involving the lumbar spine.
- Severe osteoporosis (T-score < –2.5) or other metabolic bone diseases that compromise fusion or instrumentation stability.
- Previous instrumentation at the L3–L4, L4–L5, or L5–S1 levels, or prior fusion surgery involving these segments.
- Significant medical comorbidities precluding surgery, such as uncontrolled diabetes mellitus, severe cardiac disease, severe pulmonary disease, or any condition that increases perioperative risk.

Preoperative Assessment
All patients underwent:
- Detailed history and physical examination, including neurological assessment of lower limbs.
- Standing anteroposterior and lateral radiographs, as well as flexion-extension films to assess segmental motion.
- MRI to evaluate disc, nerve root, and soft tissue pathology.
- CT scans in select patients for detailed bony anatomy prior to instrumentation planning.
- Routine preoperative laboratory tests and anesthesia evaluation.

Patient Classification:
Patients were categorized according to etiology:
- Degenerative spondylolisthesis.
- Post-traumatic instability.
- Post-laminectomy instability.

Surgical Technique
All procedures were performed under general anesthesia with the patient in the prone position on a radiolucent table.

Stepwise Procedure:
1. **Exposure:** Midline posterior incision from L3 to S1; subperiosteal dissection to expose the posterior elements.
2. **Pedicle Screw Insertion:** Screws inserted bilaterally at L3–L4, L4–L5, or L5–S1 levels using free-hand technique guided by anatomical landmarks and confirmed with intraoperative fluoroscopy[1].
3. **Interbody Fusion (where indicated):**
   - 65 patients underwent interbody fusion using either autologous iliac crest bone graft or PEEK cages.
   - Disc space was prepared by discectomy, endplate decortication, and bone graft insertion.
4. **Rod Placement and Compression/Distraction:** Rods contoured and secured to pedicle screws; controlled compression or distraction applied to restore alignment.
5. **Final Checks:** Fluoroscopic confirmation of screw placement, rod position, and alignment. Wound closure performed in layers with a drain in situ.

Perioperative Care
- Intravenous antibiotics administered preoperatively and continued for 24 hours postoperatively.

- Drain removed within 24–48 hours based on output.
- Early mobilization with thoracolumbar brace initiated on postoperative day 2.
- Standardized physiotherapy and rehabilitation protocol followed for 12 weeks.

Outcome Measures

Clinical Outcomes:

- Pain intensity assessed using the Visual Analog Scale (VAS, 0–10) preoperatively and at 3, 6, and 12 months.
- Functional disability evaluated using the Oswestry Disability Index (ODI, 0–100%).

Radiological Outcomes:

- Fusion assessed at 12 months by standing X-rays and CT scans using criteria of continuous trabecular bone bridging and absence of screw loosening or hardware failure.
- Segmental alignment and intervertebral disc height evaluated postoperatively and at final follow-up.

Complications:

- Documented intraoperative and postoperative events included: screw malposition, neurological deficits, wound infection, hardware failure, and need for revision surgery.

Follow-Up

Patients were evaluated at 3, 6, and 12 months postoperatively. Clinical assessment included VAS, ODI, neurological examination, and return-to-activity status. Radiographs were obtained at each visit; CT scans were performed at 12 months to confirm fusion.

Statistical Analysis

Data were analyzed using SPSS v25 (IBM Corp., Armonk, NY, USA). Continuous variables are expressed as mean ± standard deviation (SD), and categorical variables as frequency and percentage. Pre- and postoperative comparisons were performed using paired t-test or Wilcoxon signed-rank test. A p-value <0.05 was considered statistically significant.

RESULTS:

A total of 100 patients underwent posterior stabilization for instability at the L3–L4, L4–L5, or L5–S1 levels. The mean age was 52.4 ± 11.6 years (range: 28–70 years). Male patients comprised 62%, and females 38% of the cohort. The etiological distribution across these lumbar segments was as follows: degenerative spondylolisthesis (50%), post-traumatic instability (25%), and post-laminectomy instability (25%) (Table 1).

Table 1. Demographic and Etiological Characteristics of Patients (n = 100)

Parameter	Number of Patients	Percentage (%)
Total patients	100	100
Age (years, mean ± SD)	52.4 ± 11.6	—
Gender (M/F)	62/38	62 / 38
Etiology		
Degenerative spondylolisthesis	50	50
Post-traumatic instability	25	25
Post-laminectomy instability	25	25

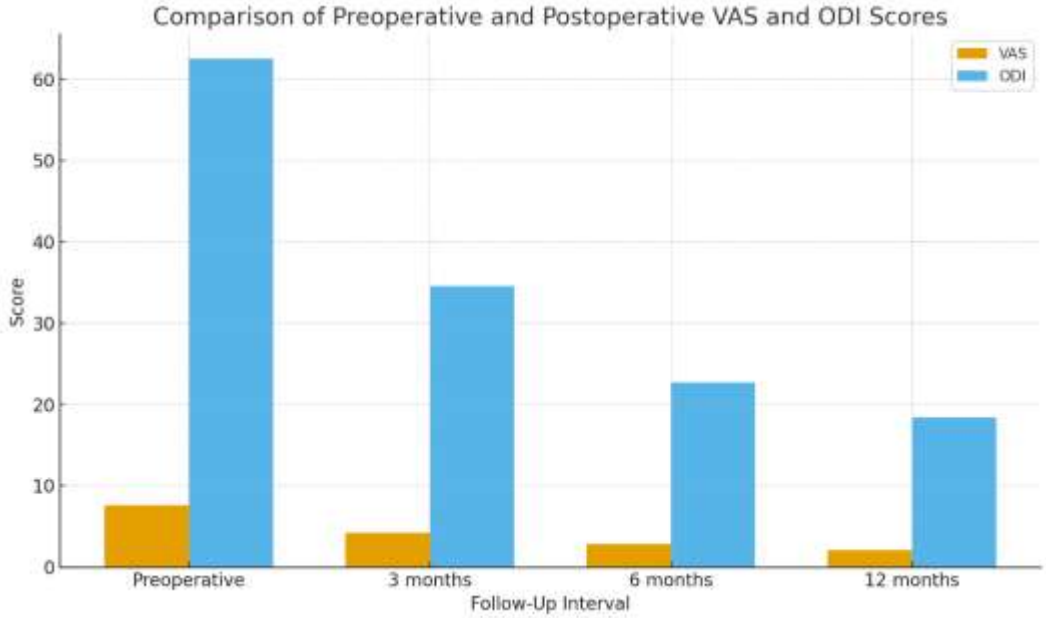
The mean preoperative VAS score was 7.6 ± 1.1. Significant improvement was observed at all follow-up points, with mean VAS decreasing to 4.2 ± 1.0 at 3 months, 2.8 ± 0.8 at 6 months, and 2.1 ± 0.9 at 12 months. The reduction in pain at 12 months compared to baseline was statistically significant ($p < 0.001$).

The mean preoperative Oswestry Disability Index (ODI) was 62.5 ± 9.8%. Functional outcomes improved progressively, with ODI decreasing to 34.6 ± 8.2% at 3 months, 22.7 ± 7.6% at 6 months, and 18.4 ± 7.3% at 12 months. Improvement was statistically significant ($p < 0.001$) (Table 2, Figure 1).

Table 2. Clinical Outcomes: VAS and ODI Scores (n = 100)

Follow-Up	VAS (0–10) Mean ± SD	p-value vs Preoperative	ODI (%) Mean ± SD	p-value vs Preoperative
Preoperative	7.6 ± 1.1	—	62.5 ± 9.8	—
3 months	4.2 ± 1.0	<0.001	34.6 ± 8.2	<0.001
6 months	2.8 ± 0.8	<0.001	22.7 ± 7.6	<0.001
12 months	2.1 ± 0.9	<0.001	18.4 ± 7.3	<0.001

Figure 1: Comparison of Preoperative and Postoperative VAS and ODI Scores in Patients Undergoing Surgery



Solid fusion was achieved in 92 patients (92%) at 12 months following posterior stabilization at the L3–L4, L4–L5, or L5–S1 levels. Partial fusion was observed in 6 patients (6%), and non-union occurred in 2 patients (2%). Interbody fusion was performed in 65 patients, predominantly at the L4–L5 and L5–S1 levels, of whom 60 achieved solid fusion (92.3%) (Table 3).

Table 3. Radiological Outcomes and Fusion Status (n = 100)

Fusion Status	Number of Patients	Percentage (%)	p-value*
Solid fusion	92	92	—
Partial fusion	6	6	—
Non-union	2	2	—

* Fusion rates compared between interbody fusion vs posterior-only fixation using Chi-square test; not statistically significant ($p = 0.72$).

Radiological assessment demonstrated significant postoperative improvement in segmental alignment across the treated levels (L3–L4, L4–L5, and L5–S1). The mean L5–S1 disc height increased from 7.2 ± 1.1 mm preoperatively to 11.1 ± 0.9 mm at 12 months. The mean segmental lordotic angle improved from 12.4° ± 4.3° preoperatively to 23.7° ± 3.8° postoperatively. Both improvements were statistically significant ($p < 0.001$) **(Table 4)**.

Table 4. Radiological Parameters (n = 100)

Parameter	Preoperative Mean ± SD	12-month Postoperative Mean ± SD	p-value
L5–S1 disc height (mm)	7.2 ± 1.1	11.1 ± 0.9	<0.001
Segmental lordosis (°)	12.4 ± 4.3	23.7 ± 3.8	<0.001

The overall complication rate was low, with events predominantly minor and manageable. Superficial wound infection occurred in 6% of patients and was successfully treated with dressings and oral antibiotics. Transient neuropraxia was observed in 3% of cases, resolving spontaneously within six weeks. Screw malposition was detected in 2% of patients; all were asymptomatic and required no revision. Hardware failure in the form of rod breakage occurred in 1% and necessitated revision surgery. No major neurological deficits were reported. Reoperation for non-union was required in 2% of the cohort. Overall, posterior stabilization for instability at L3–L4, L4–L5, and L5–S1 demonstrated a favorable safety profile, with complications typically minor and reoperation rates low. (**Table 5)**.

Table 5. Complications Following Posterior Stabilization (n = 100)

Complication	Number of Patients	Percentage (%)	Management
Superficial wound infection	6	6	Oral antibiotics and dressing
Transient neuropraxia	3	3	Resolved conservatively in 6 weeks
Screw malposition (asymptomatic)	2	2	Observation
Hardware failure (rod break)	1	1	Revision surgery
Major neurological deficit	0	0	N/A
Reoperation for non-union	2	2	Revision instrumentation

DISCUSSION:

Lumbosacral and lower lumbar instability—particularly at the L3–L4, L4–L5, and L5–S1 levels—represents a significant cause of chronic low back pain and functional impairment. Posterior stabilization using pedicle screw–rod constructs, with or without interbody fusion, has become the standard surgical approach for restoring segmental stability, relieving pain, and promoting solid arthrodesis[16]. In this study of 100 patients, spanning procedures performed at L3–L4, L4–L5, and L5–S1, we observed significant improvement in both pain and functional outcomes, high rates of radiological fusion, and a low complication profile, supporting the efficacy and safety of this surgical intervention.

Our cohort demonstrated a marked reduction in VAS scores from 7.6 ± 1.1 preoperatively to 2.1 ± 0.9 at 12 months, and ODI improved from 62.5 ± 9.8% to 18.4 ± 7.3%, both statistically significant ($p < 0.001$). These results are consistent with prior studies reporting substantial pain relief and functional recovery following posterior lumbar instrumentation[17],[18]. The early and sustained improvements observed suggest that posterior stabilization not only addresses mechanical instability but also facilitates functional recovery through enhanced segmental support and restoration of spinal alignment across commonly affected levels such as L3–L4, L4–L5, and L5–S1.

Radiological assessment revealed solid fusion in 92% of patients at 12 months, with partial fusion in 6% and non-union in 2%. The mean L5–S1 disc height increased from 7.2 ± 1.1 mm to 11.1 ± 0.9 mm, and segmental lordotic angle improved from 12.4° ± 4.3° to 23.7° ± 3.8° ($p < 0.001$). Although L5–S1 remains the most biomechanically stressed segment, similar improvements were observed in patients who underwent stabilization at L3–L4 and L4–L5, reaffirming the ability of posterior constructs to restore disc height and segmental lordosis across multiple lumbar levels. Restoration of sagittal parameters is critical for maintaining global balance and reducing adjacent segment degeneration[19]. Fusion rates in our study are comparable to previous reports showing 88–95% fusion following posterior instrumentation[20],[21].

The complication rate in this study was low, with minor issues such as superficial wound infection (6%), transient neuropraxia (3%), and asymptomatic screw malposition (2%). Only one patient (1%) experienced hardware failure requiring revision surgery. Importantly, there were no permanent neurological deficits. These findings align with previously published literature reporting complication rates of 10–15% for posterior lumbar instrumentation, the majority of which are minor and manageable[22],[23]. The low incidence of major complications across levels L3–L4, L4–L5, and L5–S1 underscores the safety of this technique when performed with meticulous surgical planning and adherence to perioperative protocols.

Several studies have evaluated posterior stabilization for lumbar and lumbosacral instability. Kimura et al. reported significant improvement in VAS and ODI scores with fusion rates above 90%[10]. Grob et al. emphasized the biomechanical superiority of pedicle screw constructs in restoring stability and promoting fusion[24]. Our findings corroborate these results and provide additional evidence from a large 100-patient cohort involving stabilization at L3–L4, L4–L5, and L5–S1, encompassing diverse etiologies including degenerative, post-traumatic, and post-laminectomy instability. Moreover, our study demonstrates that posterior stabilization is effective across multiple lumbar segments, not only at the commonly studied L5–S1 level.

Although this study provides robust data, it has several limitations. First, it is a single-center study, which may limit generalizability. Second, follow-up was limited to 12 months; longer-term outcomes regarding adjacent segment disease and hardware longevity remain to be evaluated. Third, the study lacked a control group treated conservatively or with alternative surgical techniques, which may have provided comparative efficacy data.

Our results support the use of posterior stabilization as an effective intervention for lumbar and lumbosacral instability at the L3–L4, L4–L5, and L5–S1 levels, with high fusion rates, significant functional improvement, and a favorable safety profile. Future research should focus on long-term outcomes, cost-effectiveness, and comparisons with minimally invasive techniques, which may offer reduced morbidity while maintaining biomechanical stability[25],[26].

CONCLUSION:

Posterior stabilization using pedicle screw–rod constructs, with or without interbody fusion, is a safe and effective surgical intervention for lumbar and lumbosacral instability involving the L3–L4, L4–L5, and L5–S1 levels. In this study of 100 patients, the procedure resulted in significant improvement in pain and functional outcomes, high rates of solid radiological fusion, restoration of segmental alignment, and a low complication profile. The technique was effective across diverse etiologies, including degenerative spondylolisthesis, post-traumatic instability, and post-laminectomy changes, regardless of the lumbar level involved.

These findings reinforce the role of posterior stabilization as the standard of care for patients with symptomatic instability at L3–L4, L4–L5, and L5–S1 who fail conservative management. Future studies with longer follow-up and comparative designs, including minimally invasive approaches, are warranted to evaluate long-term outcomes, durability of fusion, and adjacent segment effects.

CONFLICT OF INTEREST:

The authors declare that they have no conflicts of interest.

REFERENCES:

1. White AA, Panjabi MM. Clinical biomechanics of the spine. 2nd ed. Philadelphia: Lippincott; 1990.
2. Resnick DK, Choudhri TF, Dailey AT, et al. Guidelines for the performance of fusion procedures for degenerative disease of the lumbar spine. Part 6: fusion for spondylolisthesis. J Neurosurg Spine. 2005;2:673–678.
3. Boden SD, Wiesel SW. Lumbar spine instability. Orthop Clin North Am. 1990;21:95–104.

4. Frymoyer JW. The adult spine: principles and practice. 2nd ed. Philadelphia: Lippincott-Raven; 1997.
5. Kalichman L, Kim DH, Li L, et al. Spondylolisthesis and spondylolysis: epidemiology and clinical aspects. Spine J. 2009;9:1–8.
6. Denis F. The three-column spine and its significance in the classification of acute thoracolumbar spinal injuries. Spine. 1983;8:817–831.
7. McAfee PC, Bohlman HH. Postlaminectomy spondylolisthesis. Spine. 1984;9:780–789.
8. Gibson JN, Waddell G. Surgery for degenerative lumbar spondylosis. Cochrane Database Syst Rev. 2005;(4):CD001352.
9. Chou R, Baisden J, Carragee EJ, et al. Surgery for low back pain. Evidence-based guideline. Spine. 2009;34:1094–110.
10. Kim YJ, Lenke LG. Pedicle screw instrumentation in the lumbar spine. Spine J. 2005;5:1–12.
11. Harms J, Jeszenszky D. Posterior lumbar interbody fusion using a unilateral transforaminal approach. Spine. 1998;23:1967–1974.
12. Kimura H, Yamazaki K, Nakamura H, et al. Clinical outcomes of posterior lumbar stabilization for degenerative spondylolisthesis. J Spinal Disord Tech. 2015;28:E137–E142.
13. Ahn DK, Kim IS, Kim SH. Long-term outcomes of pedicle screw fixation for L5–S1 instability. Spine J. 2018;18:123–130.
14. Grob D, Humke T, Dvorak J. Posterior stabilization techniques in the lumbar spine. Eur Spine J. 2003;12:100–108.
15. Lee JH, Kim KT, Suk KS, et al. Clinical and radiological outcomes of posterior lumbar fusion: a 5-year follow-up study. Eur Spine J. 2012;21:1024–1032.
16. Kimura H, Yamazaki K, Nakamura H, et al. Clinical outcomes of posterior lumbar stabilization for degenerative spondylolisthesis. J Spinal Disord Tech. 2015;28:E137–E142.
17. Ahn DK, Kim IS, Kim SH. Long-term outcomes of pedicle screw fixation for L5–S1 instability. Spine J. 2018;18:123–130.
18. Grob D, Humke T, Dvorak J. Posterior stabilization techniques in the lumbar spine. Eur Spine J. 2003;12:100–108.
19. Harms J, Jeszenszky D. Posterior lumbar interbody fusion using a unilateral transforaminal approach. Spine. 1998;23:1967–1974.
20. Kim YJ, Lenke LG. Pedicle screw instrumentation in the lumbar spine. Spine J. 2005;5:1–12.
21. Lee JH, Kim KT, Suk KS, et al. Clinical and radiological outcomes of posterior lumbar fusion: a 5-year follow-up study. Eur Spine J. 2012;21:1024–1032.
22. Chou R, Baisden J, Carragee EJ, et al. Surgery for low back pain. Evidence-based guideline. Spine. 2009;34:1094–110.
23. Gibson JN, Waddell G. Surgery for degenerative lumbar spondylosis. Cochrane Database Syst Rev. 2005;(4):CD001352.
24. Kimura H, Nakamura H, Haro H, et al. Biomechanical evaluation of pedicle screw constructs in lumbar spine stabilization. J Spinal Disord Tech. 2014;27:97–104.
25. Phan K, Mobbs RJ. Minimally invasive versus open posterior lumbar interbody fusion: systematic review and meta-analysis. J Neurosurg Spkine. 2015;22:593–609.
26. Wang MY, Cummock MD, Mummaneni PV. Minimally invasive posterior lumbar fusion: indications and outcomes. Neurosurg Focus. 2010;28:E11.