Validation of Intraoperative Pull-Up Strength Testing of an Interspinous Fixation Device for Immediate and Long-Term Clinical Stability

A Cadaveric and Prospective Clinical Study

Kingsley R. Chin, MD,†‡§ Mark Jones, MD,‖ Sandra Thompson, MD,¶ Paul Pannozzo, MD,# Soubrata V. Raikar, MD,** Yeshvant A. Navalgund, MD,†† Steven Siwek, MD,‡‡ Sachin Narain, MD,§§ Luis Fandos, MD,‖‖ Rajmani Krishnan, MD,¶¶ Paul Ky, DO,## Glade Roper, MD,*** Tian Xia, DO,††† Erik Spayde, MD,‡‡‡ William M. Costigan, MD,§§§ Vito Lore, PE,‖‖‖ Angel Walker, II, HS,‡ Hope Estevez, HS,*‡ Jason A. Seale, MBBS,*‡ and Chukwunonso C. Ilogu, MD*‡*

Study Design: Prospective, multicenter study on cadaveric models and patients undergoing L4–5 decompression and interspinous fixation device (IFD) placement.

Objective: To validate the intraoperative pull-up strength of the InSpan (InSpan LLC, Burlington, MA) IFD as a standalone device, assessing its immediate and long-term stability.

Summary of Background Data: Interspinous fixation devices (IFDs) are used in spinal stenosis treatment and fusion procedures to distract the disc and foraminal space, providing posterior stabilization. Despite their utility, concerns about spinous process fractures and implant loosening persist.

Methods: A total of 50 cases, including 29 cadavers (group 1) and 21 patients (group 2), underwent L4–5 decompression with InSpan IFD placement. Over 6 months, 21 patients were consecutively enrolled at 3 sites, treated by interventional pain management and spine surgeons, with 100% recruitment. Implant stability was tested intraoperatively using a thumb-index finger pull test, followed by a body lift-off pull-up test, with confirmation through physical and fluoroscopic evaluation. Patients were followed for up to 24 months, and outcome measures such as the Visual Analog Scale (VAS) and Oswestry Disability Index (ODI) scores, implant failure, and revision rates were recorded.

Results: All 29 cadavers in group 1 passed the pull-up tests without implant loosening. In group 2, 95% (20/21) of primary IFD surgeries passed on the first attempt, whereas 1 revision case failed the body lift-up test and required further decompression. Two-year follow-up for 14 patients showed significant improvements in VAS (79.44%) and ODI (68.56%) scores ($P < 0.001$). Radiographic assessments confirmed stable implants with no loosening or fractures. Males had longer surgery times ($P < 0.05$), but outcomes were similar across genders.

Conclusions: The InSpan IFD provides significant immediate and long-term stability. The pull-up test is a reliable method to assess intraoperative fixation, with potential applications in suspected inadequate fixation cases.

Level of Evidence: Level III.

Key Words: spinal stenosis, spinal instability, interspinous process device, interspinous fixation device, inspan, intraoperative manual pullup test.

(*Clin Spine Surg* 2026;00:000–000)

Received for publication October 16, 2024; accepted January 26, 2026.

From the *Less Exposure Surgery Specialists Institute (LESS Institute; LESS Clinic), Fort Lauderdale; †Department of Orthopedics, Herbert Wertheim College of Medicine at Florida International University, Miami; ‡Less Exposure Spine Surgery (LESS) Society 501(c)(3), Fort Lauderdale, FL; §Faculty of Science and Sports, University of Technology, Kingston, Jamaica, West Indies; ‖Pain Medicine of the South, Knoxville, TN; ¶The Pain Center, Boise, ID; #Summa Pain Care, Scottsdale, AZ; **Midwest Anesthesia and Pain Management, Fremont, NE; ††National Spine and Pain Centers, Glen Burnie, MD; ‡‡The Pain Center of Arizona, Phoenix, AZ; §§The Pain Center of Arizona, Gilbert, AZ; ‖‖National Spine and Pain Centers, Bay Shore; ¶¶Island Interventional Pain Management, Commack, NY; ##Advanced Pain Solutions, Fresno; ***VIP Specialists, Visalia, CA; †††Integrated Pain Management, Chicago, IL; ‡‡‡St. Charles Spine Institute, Thousand Oaks; §§§Congress Orthopedic Associates, Pasadena, CA; and ‖‖‖LESSpine, Burlington, MA.

K.R.C. is the cofounder and CEO of Kingsley Investment Company (KIC) Ventures and has ownership shares in the company. W.M.C., E.S., S.N., S.T., P.P., and L.F. have shares in KIC Ventures. InSpan LLC is a portfolio company of KIC Ventures. The remaining authors declare no conflict of interest.

Reprints: Kingsley R. Chin, MD, MBA, Department of Clinical Orthopedics, Herbert Wertheim College of Medicine at Florida International University, 6550 North Federal Highway, Suite #510, Fort Lauderdale, FL 33308 (e-mail: kingsleychin@thelessinstitute.com).

Supplemental Digital Content is available for this article. Direct URL citations are provided in the HTML and PDF versions of this article on the journal's website, www.jspinaldisorders.com.

DOI: 10.1097/BSD.0000000000002052

Spinal stenosis and degenerative lumbar conditions are prevalent issues that often require surgical decompression to alleviate symptoms, restore function, and prevent further deterioration. These conditions can lead to significant pain and disability, affecting the quality of life of the affected individuals. A prospective randomized controlled trial by Herkowitz and Kurz[1] found that adding fusion was more effective than decompression alone in the treatment of degenerative lumbar spondylolisthesis. Posterior spinal instrumentation with pedicle screw constructs is considered the gold standard for stabilizing the spine in the presence of spinal instability.[2]

However, the placement of pedicle screw constructs is technically challenging and is associated with complications, such as nerve injury, screw failure, and prolonged operative time.[3,4] Over time, pedicle screws have been linked to the development of adjacent segment disease (ASD) owing to inherent rigid fixation and increased forces on adjacent segments, requiring further surgery.[5,6]

Over the last 2 decades, interspinous fixation devices (IFDs) have emerged as less invasive alternatives to traditional pedicle screw fixation systems in selected patients. These devices were designed to distract the interspinous space and provide segmental posterior stabilization, thereby reducing the need for more extensive surgical procedures in selected patients. Biomechanical analysis of interspinous devices demonstrated less compensation at adjacent disks and facet joints, with the potential for a lower incidence of ASD compared with rigid fixation.[7] Interest in IFDs has been driven by their potential benefits, including shorter operative times, reduced blood loss, quicker recovery periods, and a lower risk of ASD.[8] Despite these advantages, there are ongoing concerns regarding the long-term durability and effectiveness of IFDs. Potential complications such as spinous process fractures, implant loosening, and failure have been reported, compromising surgical outcomes and necessitating revision surgery. These issues have led to a decline in popularity despite initial positive outcomes.[9]

Reoperation rates for interspinous process (ISP) devices vary significantly across studies, reflecting the differences in device generation and surgical techniques. Pintauro et al[10] compared first-generation ISP devices with next-generation ISP devices, analyzing 37 studies from 2011 to 2016. They reported a mean ISP device failure rate of 13.35%, with next-generation devices showing a lower reoperation rate of 3.7% compared with 11.1% for first-generation devices over a 24-month follow-up period, suggesting improvements in newer device designs. Wang et al[11] reported no major surgery-induced complications, pseudoarthrosis, or hardware failure in a study of 32 patients with rigid ISP SPIRE fixation over a mean follow-up of 5.5 months, highlighting the potential reliability of this ISP.

Unlike earlier nonfixated interspinous devices or alternative asymmetric interspinous fixation devices (IFDs), InSpan is a newer-generation IFD designed to provide fixation through its staggered teeth design that bites into the spinous processes; an anterior curve design that creates an interference fit between the laminae; a central hub that distracts the spinous processes to provide multiple points of contact for load sharing and segmental stabilization; and dual locking set screws that resist separation of the symmetrical plates, as described by Chin et al.[12] This design allows secure fixation and prevents expulsion in all 6 planes of motion, as well as spinous process erosion and fractures. InSpan has been shown to be effective in treating spinal stenosis as a standalone device.[13–15]

A significant gap remains in the literature regarding the long-term reliability and clinical efficacy of newer-generation IFDs in maintaining spinal stability. Addressing this gap is crucial for optimizing surgical outcomes and enhancing patient care.

This study aimed to evaluate the immediate stability of the InSpan IFD as a standalone treatment using cadaveric and intraoperative manual pull-up testing, and to assess long-term stability through clinical and radiographic follow-up for 2 years. We hypothesized that the InSpan IFD at L4–5 would demonstrate long-term stability, with a low likelihood of implant failure or the need for revision during the follow-up period after pull-up testing, without detectable implant loosening or dislodgement.

MATERIALS AND METHODS

Study Group Selection

Group 1

Twenty-nine cadaver lumbar spines, L1 to the pelvis (15 females and 14 males), were procured from a nontransplant donation company. Inclusion criteria required intact cadavers with lumbar spines from L1 to the pelvis. Cadavers with a history of spine surgery were excluded. Testing was performed in a cadaveric training laboratory by interventional pain management (IPM) physicians and spine surgeons. Cadavers were procured from nontransplant donation companies that, as part of their procurement process, obtained authorization from the individual or their next of kin.

Group 2

Twenty-one patients were consecutively enrolled over a 6-month period across 3 clinical sites by IPM and spine surgeons. All patients meeting the eligibility criteria during this time were invited to participate, resulting in a 100% recruitment rate. Eligible patients were aged 18 years or older, had symptomatic degenerative spinal stenosis and instability at L4–5 for over 4 months, and had failed at least 3 months of conservative management, including physical therapy, nonsteroidal anti-inflammatory drugs (NSAIDs), chiropractic treatment, and epidural steroid injections. Magnetic resonance imaging (MRI) evidence of mild to moderate central and/or foraminal spinal stenosis, disc desiccation, and grade 1 spondylolisthesis was required. Exclusion criteria included acute severe trauma, fractures, malignancy, in-

fection, unstable chronic medical illnesses, prior lumbar fusions, or a body mass index (BMI) >42 kg/m^2. All procedures were performed in an outpatient ambulatory surgery center. The Western Institutional Review Board (IRB) approval was granted through Protocol #20181251.

Surgical Technique

The lumbar decompression and InSpan fixation procedure followed the technique described by Chin et al.[13] Patients were placed in the prone position, and the L4–5 level was confirmed using intraoperative fluoroscopy. A midline incision was made to expose the spinous processes and laminae. For patients, the Wilson frame was adjusted to its natural position before a sizer was used to measure the appropriate implant size. The implant inserters were attached to the selected InSpan device and placed into the interspinous space, between the laminae and against the spinous processes (Fig. 1). The inserters were then compressed together, and the teeth of the implant were buried into the spinous processes. The set screws were locked to ensure stability. Anteroposterior and lateral fluoroscopic images confirmed the position of the implant.

Intraoperative Manual Pull-Up Testing

Thumb and Index Finger Pull-Up Test

The stability of the implanted InSpan IFD was initially verified using the thumb and index fingers to pull up on the implant to visually and physically detect any loosening or movement, representing immediate signs of instability. If there were signs of instability, the implant would have been deemed a failure, and the InSpan IFD would have been removed.

Body Lift-Off Pull-Up Test

The pull-up test was performed on the cadavers and patients. To perform the test, a pull-up force was applied to the InSpan to lift the body off the bed (Video, Supplemental Digital Content 1, http://links.lww.com/CLINSPINE/A441 and Supplemental Digital Content 2, http://links.lww.com/CLINSPINE/A442, which show a pull-up test performed on a cadaver and a patient). If the implant passed the pull-up test, we felt that the implant's fixation was stable (Fig. 2). If the implant failed the pull-up test, it was removed by unlocking the set screws to release the fixation. The implant was then carefully separated from the spinous processes. The implant's locking fixation mechanism was examined to confirm its functionality. The spinous processes were inspected for any visible fractures, track marks created by the implant, or other signs of loosening.

Clinical Follow-Up

Preoperative and postoperative Visual Analog Scale (VAS) and Oswestry Disability Index (ODI) scores were obtained up to 24 months. Radiographs were assessed postoperatively to evaluate implant stability and detect any complications, failures, or the need for revisions over a 24-month follow-up period. Of the 21 patients initially enrolled, 14 completed the 2-year follow-up. The remaining 7 patients were lost to follow-up due to reasons unrelated to the study, such as relocation or lack of response.

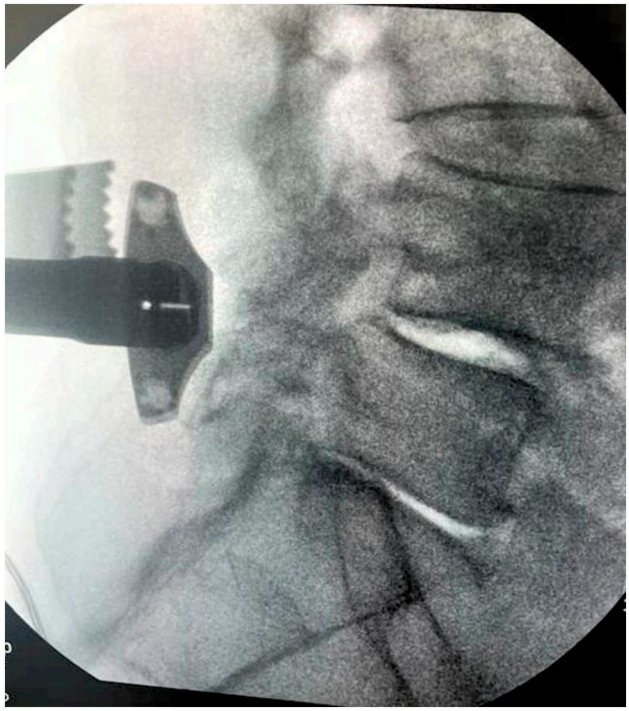

FIGURE 1. Intraoperative lateral fluoroscopy showing InSpan IFD attached to the inserter placed at L4–5. IFD indicates an interspinous fixation device. full color online

RESULTS

Out of the 50 cases across group 1 and group 2, 49/50 (98%) passed the intraoperative pull-up strength test. In group 1, consisting of 29 cadavers (15 females and 14 males) with a mean age of 66.75 years (SD: 10.91). The mean body weight for males was 224.50 lbs. (SD: 83.98) and 114.56 lbs. (SD: 80.78) for females. All cadavers had InSpan IFDs sized between 14 and 16 mm implanted. One hundred percent of the implants in this group successfully passed the intraoperative pull-up tests conducted by spine surgeons and IPM specialists. In addition, all implants were successfully explanted and remained fully functional, with no evidence of fractures or track marks on the spinous processes.

Group 2 included 21 patients from 3 clinical sites with a minimum 6-month follow-up. Of these, 20 were primary IFD surgeries, all of which passed the pull-up strength test. The single case that did not pass was a revision of a failed Vertiflex Superion Interspinous Spacer (Boston Scientific Inc., Marlborough, MA) implanted for over a year. This revision case initially failed the pull-up test but passed after additional decompression. Upon

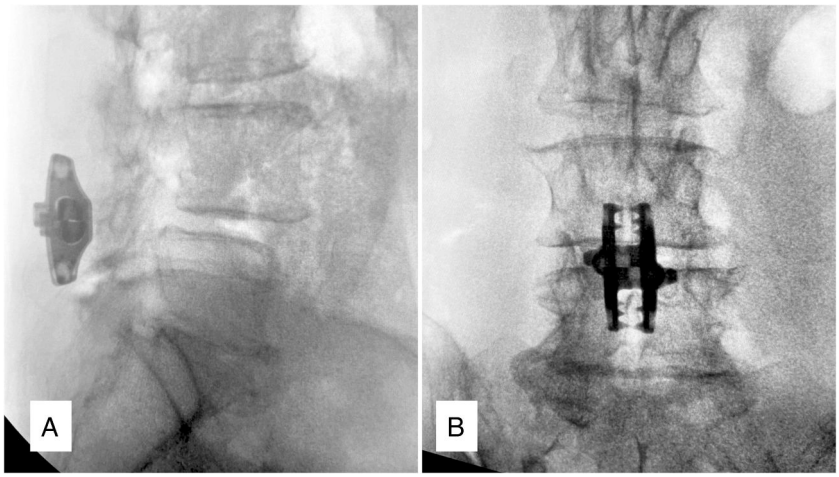

FIGURE 2. Intraoperative fluoroscopy showing anteroposterior (A) and lateral (B) views of the L4–5 InSpan IFD. IFD indicates an interspinous fixation device.

inspection, scar tissue and bone spurs on the spinous processes were identified, which limited the central hubs of the InSpan plates from fully engaging, preventing the set screws from securely locking the plates together. This was not evident on fluoroscopic views, demonstrating that the pull-up test served as a critical secondary evaluation method. After further decompression, the implant was reinserted, with the central hubs fully engaged, and it subsequently passed the pull-up test.

Two-year follow-up was documented for 14 patients (7 females and 7 males) who had primary IFD surgery, with a mean age of 47.57 years (SD: 10.08) and a mean BMI of 30.62 (SD: 7.42). The average length of surgery (LOS) was 39.64 minutes (SD: 10.82). All patients successfully passed the intraoperative pull-up tests, with no complications or implant failures reported during the 24-month follow-up period. InSpan sizes varied between 12 and 16 mm. Male patients showed an 86.3% improvement in VAS scores (from 9.43 to 1.29) and a 64.8% improvement in ODI scores (from 44.29% to 15.57%). Female patients demonstrated a 70.85% improvement in VAS scores (from 8.57 to 2.50) and a 71.91% improvement in ODI scores (from 49.86% to 14.00%). Overall, patients showed a 79.44% improvement in VAS scores (from 9.00 to 1.85) and a 68.56% improvement in ODI scores (from 47.07% to 14.79%). Radiographic assessments confirmed implant stability with no evidence of loosening or spinous process fractures, and no surgical revisions were necessary.

Statistical Analysis

A paired *t* test was performed to compare preoperative and postoperative VAS scores and revealed a significant reduction, from 9.00 to 1.85, representing a 79.44% improvement ($P < 0.001$). Similarly, there was a significant decrease in ODI scores from 47.07% preoperatively to 14.79% postoperatively, reflecting a 68.56% improvement ($P < 0.001$). Independent *t* tests comparing LOS between male and female patients revealed significantly longer surgeries in males ($P = 0.038$), with a statistical power of 91%, indicating a high likelihood that this result was not due to chance. No significant differences were found in age, BMI, ODI, or VAS scores from presurgery to the 24-month follow-up.

DISCUSSION

Interspinous fixation devices (IFDs) have a long history in the treatment of spinal stenosis and fusion procedures to distract the disc and foraminal space and provide posterior stabilization. However, concerns persist regarding potential complications, such as spinous process fractures and implant loosening, reported with traditional designs, which differ from InSpan's contemporary design with dual locking screws and symmetrical plates. Our study addresses these concerns by evaluating the stability of the InSpan IFD in maintaining secure fixation. Our study was also the first to introduce a validated manual pull-up test as a method to predict the fixation of the InSpan IFD as a standalone device at the L4–5 level, as evidenced by the intraoperative manual pull-up tests performed in both cadaveric and patient groups.

All implants used in primary IFD surgeries remained secure under these tests; however, the 1 implant that failed the body lift-off pull-up test occurred in a revision IFD case of a failed interspinous spacer. In this revision case, there was inadequate decompression of the scar tissue and bone spurs, which likely prevented full compression and locking of the InSpan device. After removing the scar tissue and associated bone spurs, the implant was successfully engaged and subsequently passed the pull-up test. This finding suggests that the body lift-off pull-up test is particularly beneficial in revision cases where previous surgical or pathologic changes might interfere with device fixation.

At the 2-year follow-up, all the implants remained secure, indicating the device's potential to provide ad-

equate long-term fixation. This immediate stability was further supported by the absence of implant failure, loosening, or spinous process fractures observed during the 24-month follow-up period.

In comparison with traditional IFDs, the InSpan device demonstrated favorable outcomes in this cohort. The statistically significant improvements in VAS and ODI scores highlight the clinical efficacy of the InSpan device in enhancing patient outcomes following lumbar decompression procedures. The systematic review and critical analysis by Lopez et al[16] revealed that traditional IFDs have limited high-quality evidence supporting their efficacy and safety. The review highlighted that most studies on traditional IFDs were methodologically flawed and biased, with no class I or class II evidence found. Complications like instability at 1-year postoperation were reported without a statistical comparison to other treatment modalities. Our study, conversely, provides a more robust and methodologically sound investigation into the modern InSpan IFD, showcasing its ability to achieve long-term stability and minimize complications, thus addressing the shortcomings identified in previous reviews.

Supporting literature corroborates the clinical strength and positive outcomes associated with the InSpan device. Raikar et al[15] reported excellent results using InSpan for severe low back pain and lumbar radiculopathy, with significant improvements in pain scores over a median follow-up of 19 months. Chin et al[14] demonstrated that the InSpan device provided significant improvements in VAS and ODI scores over a 5-year follow-up for patients with L4–5 degenerative spinal stenosis, with minimal complications and reoperations. In addition, another study by Chin et al[13] comparing InSpan IFD to traditional laminectomies for spinal stenosis at L4–5 and L5–S1 levels showed superior outcomes and lower complication rates with the InSpan device, highlighting its effectiveness as a modern improvement over traditional interspinous fixation devices and laminectomies.

Despite these promising results, our study has limitations. The small sample size (29 cadavers and 21 patients with a 2-year follow-up on 14) necessitates cautious interpretation and highlights the need for additional studies to validate these findings, especially at other lumbar levels such as L5–S1. The loss of 7 patients to follow-up, due to reasons such as relocation or nonresponse, may impact the generalizability of the long-term outcomes. In addition, the study did not assess varying bone qualities, which could impact device stability. Testing was only performed at the L4–5 level, which may not be representative of other lumbar levels. The implants were not subjected to repetitive or angular pull-up testing, and the strength applied during the pull-up test varied according to patient weight. Consequently, the study did not determine the maximum pull-up force the implants could withstand. The only instance of the InSpan IFD failing the body lift-up test occurred during a revision procedure. Further testing in revision cases should be performed to confirm these findings. Given these limitations, independent studies involving larger, more diverse patient populations and assessing multiple spinal levels are essential to validate the reproducibility and broader applicability of these findings.

The findings of this study have significant clinical implications for the treatment of lumbar spinal stenosis and degenerative disc disease. The InSpan IFD, validated through our study, provides a reliable method for achieving immediate and long-term stability, potentially reducing the risk of complications such as spinous process fractures and implant loosening. The quick intraoperative manual pull-up test can serve as a practical tool for surgeons to assess implant fixation during surgery, improving intraoperative decision-making and potentially enhancing patient outcomes. Surgeons should have a high suspicion or low tolerance in cases with excessive scar tissue and bone spurs, such as revision cases, and should perform this test, since, in our experience, it was confirmed on fluoroscopy. Given the favorable results and the support from corroborative literature, the InSpan device may be considered a viable option over traditional IFDs and laminectomies, particularly in cases requiring strong and stable fixation.

Further research is necessary to understand the impact of bone quality on implant success and to refine patient selection criteria. Ensuring the broad applicability and long-term effectiveness of the InSpan device in diverse patient populations will require larger sample sizes and testing at various lumbar levels. This validated manual test could act as a benchmark for modern designs of interspinous fixation devices to overcome the failures in the past.[16]

CONCLUSION

This multicenter study demonstrates the immediate and long-term stability of the InSpan IFD as a standalone treatment. The pull-up test effectively confirmed that the InSpan IFD provides reliable fixation when used independently. In a single revision case, the pull-up test detected incomplete device engagement due to scar tissue and bone spurs, which were successfully addressed with additional surgical intervention. This highlights the test's potential utility in identifying fixation challenges in complex cases. Although not intended as a routine assessment, the pull-up test represents a validated intraoperative method to evaluate the stability of interspinous fixation devices. While the present study focused on the InSpan IFD, the method could be applied to other interspinous fixation devices as part of research into implant stability and design. This may serve as a useful framework for future investigations and design considerations, but further independent studies are necessary before it can be considered a general standard.

REFERENCES

1. Herkowitz HN, Kurz LT. Degenerative lumbar spondylolisthesis with spinal stenosis. A prospective study comparing decompression with decompression and intertransverse process arthrodesis. *J Bone Joint Surg Am*. 1991;73:802–808.

2. Zdeblick TA. A prospective, randomized study of lumbar fusion. Preliminary results. *Spine*. 1993;18:983–991.
3. Dickman CA, Fessler RG, MacMillan M, et al. Transpedicular screw-rod fixation of the lumbar spine: operative technique and outcome in 104 cases. *J Neurosurg*. 1992;77:860–870.
4. Wu MH, Dubey NK, Li YY, et al. Comparison of minimally invasive spine surgery using intraoperative computed tomography integrated navigation, fluoroscopy, and conventional open surgery for lumbar spondylolisthesis: a prospective registry-based cohort study. *Spine J*. 2017;17:1082–1090.
5. Etebar S, Cahill DW. Risk factors for adjacent-segment failure following lumbar fixation with rigid instrumentation for degenerative instability. *J Neurosurg*. 1999;90(suppl 2):163–169.
6. Cai P, Xi Z, Deng C, et al. Fixation-induced surgical segment's high stiffness and the damage of posterior structures together trigger a higher risk of adjacent segment disease in patients with lumbar interbody fusion operations. *J Orthop Surg Res*. 2023;18:371.
7. Shen H, Fogel GR, Zhu J, et al. Biomechanical analysis of different lumbar interspinous process devices: a finite element study. *World Neurosurg*. 2019;127:e1112–e1119.
8. Baranidharan G, Bretherton B, Feltbower RG, et al. 24-Month outcomes of indirect decompression using a minimally invasive interspinous fixation device versus standard open direct decompression for lumbar spinal stenosis: a prospective comparison. *J Pain Res*. 2024;17:2079–2097.
9. Gazzeri R, Galarza M, Alfieri A. Controversies about interspinous process devices in the treatment of degenerative lumbar spine diseases: past, present, and future. *Biomed Res Int*. 2014;2014:975052.
10. Pintauro M, Duffy A, Vahedi P, et al. Interspinous implants: are the new implants better than the last generation? A review. *Curr Rev Musculoskelet Med*. 2017;10:189–198.
11. Wang JC, Haid RW Jr, Miller JS, et al. Comparison of CD HORIZON SPIRE spinous process plate stabilization and pedicle screw fixation after anterior lumbar interbody fusion. Invited submission from the Joint Section Meeting On Disorders of the Spine and Peripheral Nerves, March 2005. *J Neurosurg Spine*. 2006; 4:132–136.
12. Chin KR, Lore V, Spayde E, et al. Advancing the design of interspinous fixation devices for improved biomechanical performance: dual vs. single-locking set screw mechanisms and symmetrical vs. asymmetrical plate designs. *J Spine Surg*. 2024;10: 386–394.
13. Chin KR, Seale JA, Spayde E, et al. Prospective 5-year follow-up of L5-S1 versus L4-5 midline decompression and interspinous-interlaminar fixation as a stand-alone treatment for spinal stenosis compared with laminectomies. *J Spine Surg*. 2023;9:398–408.
14. Chin KR, Pencle FJR, Benny A, et al. Greater than 5-year follow-up of outpatient L4-L5 lumbar interspinous fixation for degenerative spinal stenosis using the INSPAN device. *J Spine Surg*. 2020;6:549–554.
15. Raikar SV, Patil AA, Pandey DK, et al. Inter spinal fixation and stabilization device for lumbar radiculopathy and back pain. *Cureus*. 2021;13:e19956.
16. Lopez AJ, Scheer JK, Dahdaleh NS, et al. Lumbar spinous process fixation and fusion: a systematic review and critical analysis of an emerging spinal technology. *Clin Spine Surg*. 2017;30:E1279–E1288.