

# Transforaminal vs interlaminar full-endoscopic lumbar discectomy at the L4/L5 level: a systematic review and meta-analysis

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## KEY WORDS

endoscopic lumbar discectomy, interlaminar approach, L4/L5 disc herniation, minimally-invasive spine surgery, transforaminal approach

## ABSTRACT

**INTRODUCTION** Full-endoscopic lumbar discectomy (ELD) can be performed using either the transforaminal (TELD) or interlaminar (IELD) approach. Although both techniques are widely used, the optimal approach for the L4/L5 level remains debated. No previous meta-analysis has specifically compared TELD and IELD exclusively for single-level L4/L5 lumbar disc herniation (LDH).

**AIM** We aimed to compare clinical and perioperative outcomes of TELD vs IELD for single-level L4/L5 LDH.

**MATERIALS AND METHODS** A systematic review and meta-analysis were conducted according to the 2020 Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. PubMed, Embase, Scopus, and Web of Science databases were searched through November 2025. Comparative studies reporting outcomes for TELD and IELD specifically at the L4/L5 level were included. Continuous variables were analyzed using mean differences (MDs), whereas risk ratios (RRs) under a random-effects model were used to analyze binary outcomes.

**RESULTS** Three comparative studies including 260 patients undergoing TELD ( $n = 189$ ) and IELD ( $n = 71$ ) met the inclusion criteria. Clinical outcomes were comparable between the techniques. Pooled analysis showed no clinically relevant difference in postoperative Visual Analog Scale leg pain (MD, 0.32; 95% CI, 0–0.63) or Oswestry Disability Index (MD, 1.94; 95% CI, 0.94–2.94). Operative time tended to be shorter with TELD, but the difference was not significant (MD, –12.6 min; 95% CI, –34.6 to 9.4). Length of hospital stay (LOS) was identical between the groups (MD, 0.007 d). Complication (RR, 1.48; 95% CI, 0.23–9.7) and reoperation rates (RR, 0.96; 95% CI, 0.21–4.4) were also similar between the cohorts.

**CONCLUSIONS** TELD and IELD provide equally effective and safe treatment for single-level L4/L5 LDH. Clinical outcomes, LOS, as well as complication and reoperation rates were equivalent. Operative time showed substantial heterogeneity across the studies, precluding a definitive conclusion regarding time efficiency. The choice of approach should be based on patient anatomy, herniation morphology, and surgeon expertise rather than expected differences in technique efficacy.

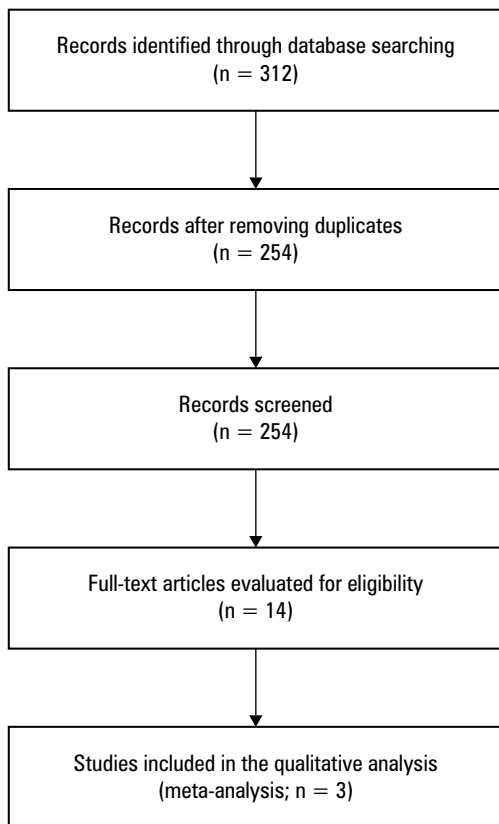
**INTRODUCTION** Lumbar disc herniation (LDH) is a common cause of radiculopathy, with the L4/L5 segment being the most frequently affected due to its unique biomechanical loading and susceptibility to degeneration.<sup>1–3</sup> Full-endoscopic lumbar discectomy (ELD) has become an established minimally-invasive alternative to conventional microdiscectomy, offering reduced tissue trauma, faster recovery, and shorter hospitalization.<sup>4–6</sup> Two endoscopic techniques are most widely used: transforaminal ELD (TELD), performed

through the Kambin triangle, and interlaminar ELD (IELD), which provides dorsal access through the interlaminar window.<sup>7–9</sup>

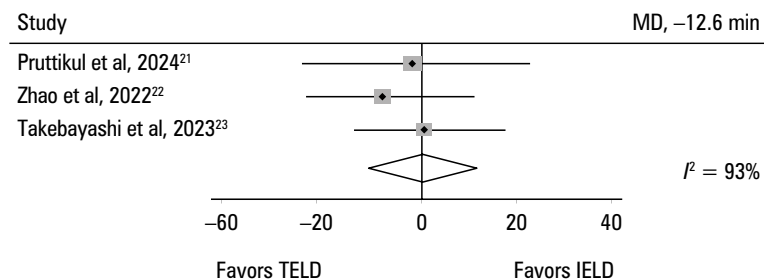
Although both techniques are routinely applied across various lumbar levels, the optimal approach at the L4/L5 segment remains debated. TELD avoids bone resection and may be advantageous for foraminal or extraforaminal herniations, whereas IELD offers more direct canal access, potentially improving management of migrated or central disc fragments.<sup>9–11</sup> Previous

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**FIGURE 1** 2020 Preferred Reporting Items for Systematic reviews and Meta-Analyses flow diagram summarizing the identification, screening, eligibility assessment, and inclusion of the TELD and IELD studies at the L4/L5 level.



Abbreviations: IELD, interlaminar endoscopic lumbar discectomy; TELD, transforaminal endoscopic lumbar discectomy



**FIGURE 2** Forest plot comparing operative time between TELD and IELD at the L4/L5 level. Negative values indicate shorter operative time for TELD.

Abbreviations: MD, mean difference; others, see **FIGURE 1**

comparative studies have reported similar clinical outcomes for TELD and IELD; however, none of the available meta-analyses have evaluated these techniques exclusively at the L4/L5 level.<sup>6,12-17</sup> Level-specific evidence is essential for optimizing approach selection and improving clinical decision-making in minimally-invasive spine surgery.

**AIM** The aim of this study was to perform a systematic review and meta-analysis comparing clinical and perioperative outcomes of TELD vs IELD specifically at the L4/L5 level.

**MATERIALS AND METHODS Study design** This study was conducted as a systematic review and meta-analysis in accordance with the 2020 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.<sup>18</sup> The protocol was prepared a priori. PROSPERO

registration was not performed because the analysis was based exclusively on aggregated published data.

**Search strategy** A comprehensive literature search was performed in PubMed / MEDLINE, Embase, Scopus, and Web of Science databases from inception to November 30, 2025. The search strategy used combinations of the following keywords and MeSH terms: “lumbar disc herniation,” “L4–L5” or “L4/5,” “full-endoscopic” or “endoscopic discectomy,” “transforaminal” or “TELD,” “interlaminar” or “IELD,” and “comparison” or “outcomes.” Reference lists of all eligible studies were screened manually to identify additional publications. No language restrictions were applied during the search process.

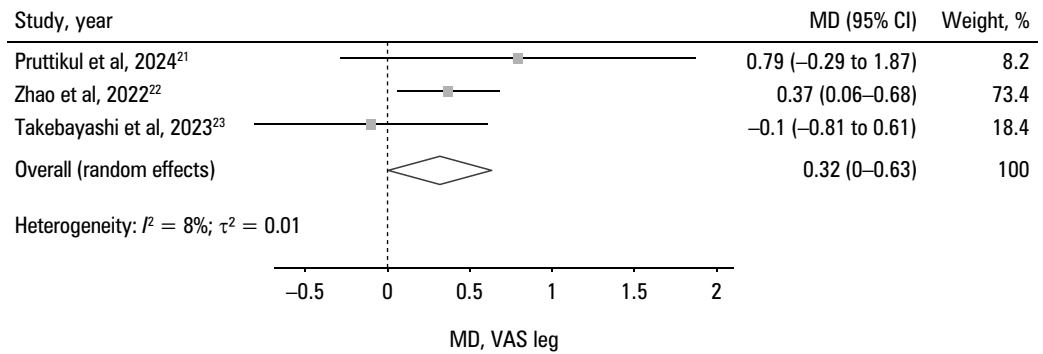
**Eligibility criteria** Eligibility criteria were defined using the Population, Intervention, Comparison, Outcome (PICO) framework. The population consisted of patients undergoing surgery for single-level L4/L5 LDH. The intervention of interest was TELD, whereas IELD served as the comparator. Outcomes included clinical measures, such as Visual Analog Scale (VAS) leg pain, VAS back pain, and the Oswestry Disability Index (ODI), as well as operative time, length of hospital stay (LOS), complications, and reoperation rates. Eligible study designs included randomized controlled trials (RCTs) and comparative cohort studies. Case series, review articles, conference abstracts, analyses combining multiple lumbar levels without extractable L4/L5 data, and studies lacking quantitative outcomes were excluded.

**Study selection** Two reviewers (TS and PK) independently screened all titles and abstracts. Full-text articles were then assessed for eligibility according to predefined criteria. Disagreements were resolved through discussion and consensus. The PRISMA flow diagram summarizing the study selection process is presented in **FIGURE 1**.

**Data extraction** Data were independently extracted by 2 investigators (TS and PK) using a standardized form. Extracted variables included study characteristics (authors, year, country, and study design), sample sizes for TELD and IELD groups, demographic data (age and sex), operative time, postoperative VAS leg pain and ODI scores, LOS, complications, reoperation rates, and duration of follow-up. When data were reported as medians with ranges or interquartile ranges, they were converted to mean (SD) using established statistical methods.

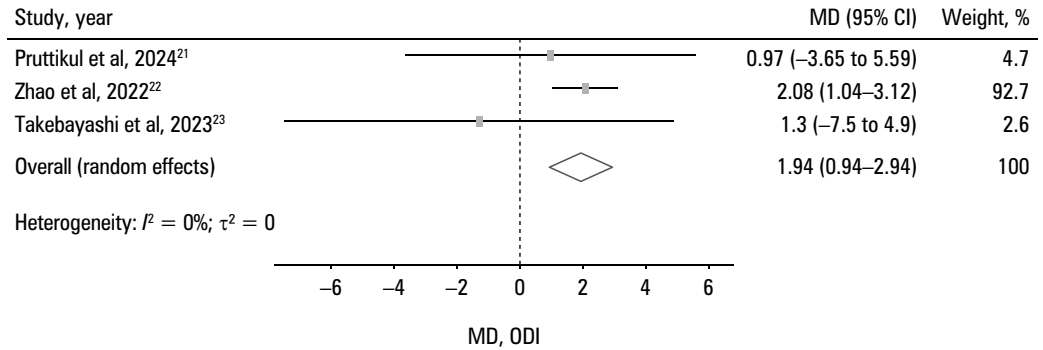
**Risk of bias assessment** The methodological quality of the included RCTs was assessed using the Cochrane Risk of Bias 2.0 tool across 5 domains.<sup>19</sup> Observational studies were evaluated using the Newcastle–Ottawa Scale, with scores of 7 or higher considered indicative of high methodological quality.<sup>20</sup> All assessments were performed

**FIGURE 3** Forest plot comparing postoperative VAS leg pain between TELD and IELD at the L4/L5 level. Positive values indicate higher postoperative VAS scores in TELD.



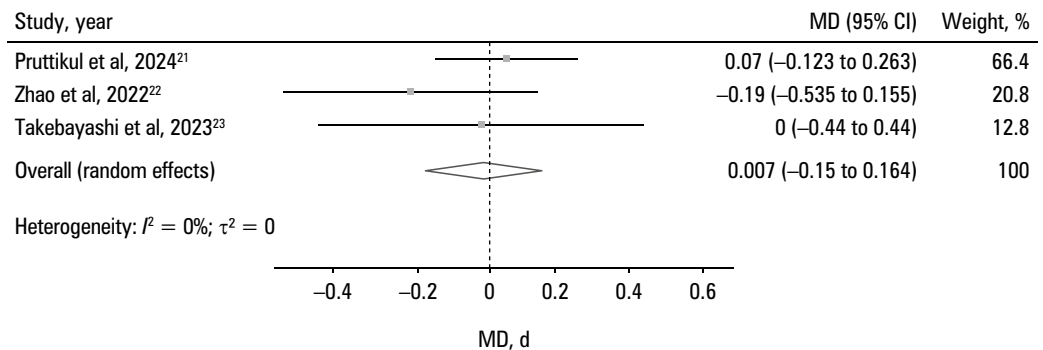
Abbreviations: VAS, Visual Analog Scale; others, see FIGURES 1 and 2

**FIGURE 4** Forest plot comparing postoperative ODI scores between TELD and IELD at the L4/L5 level. Positive values indicate higher postoperative ODI scores in TELD.



Abbreviations: ODI, Oswestry Disability Index; others, see FIGURES 1 and 2

**FIGURE 5** Forest plot comparing postoperative length of hospital stay between TELD and IELD at the L4/L5 level. Positive values indicate longer stay after TELD.



Abbreviations: see FIGURES 1, 2 and 6

independently by 2 reviewers (TS and PK). The results of the risk of bias assessment are presented in TABLE 1.

**Statistical analysis** The meta-analyses were performed using mean differences (MDs) for continuous outcomes and risk ratios (RRs) for binary outcomes. The analyses were conducted using inverse-variance weighting under a random-effects model (DerSimonian–Laird). Statistical heterogeneity was evaluated using the  $I^2$  statistic, with thresholds of 0% to 25% considered low, 25% to 50% moderate, and greater than 50% substantial heterogeneity. The  $\chi^2$  test was also applied, with a significance level of  $P$  below 0.1 indicating heterogeneity. A continuity correction of 0.5 was applied when 0 events were present in 1 or both groups. Forest plots were generated for each outcome. Statistical analyses were performed using Python 3.11 software (Python Software Foundation, Beaverton, Oregon, Inot-ed States). A  $P$  value below 0.05 was considered

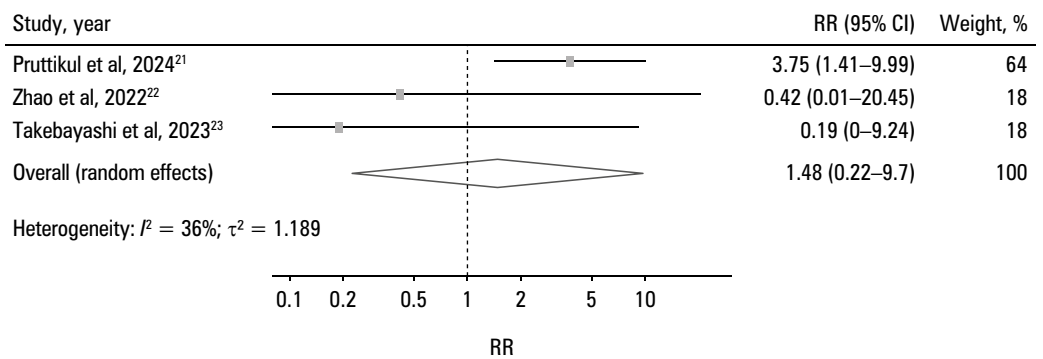
significant. Subgroup and sensitivity analyses were not performed due to the limited number of available studies.

**Ethics** This study is a systematic review and meta-analysis of previously published data and did not involve human participants or identifiable patient information. Therefore, institutional review board approval was not required.

**RESULTS Study selection** The database search identified 312 records, of which 254 remained after removing duplicates. Following title and abstract screening, 14 full-text articles were evaluated for eligibility. Three comparative studies met the inclusion criteria and were subjected to the qualitative and quantitative syntheses. The study selection process is presented in the PRISMA flow diagram (FIGURE 1).

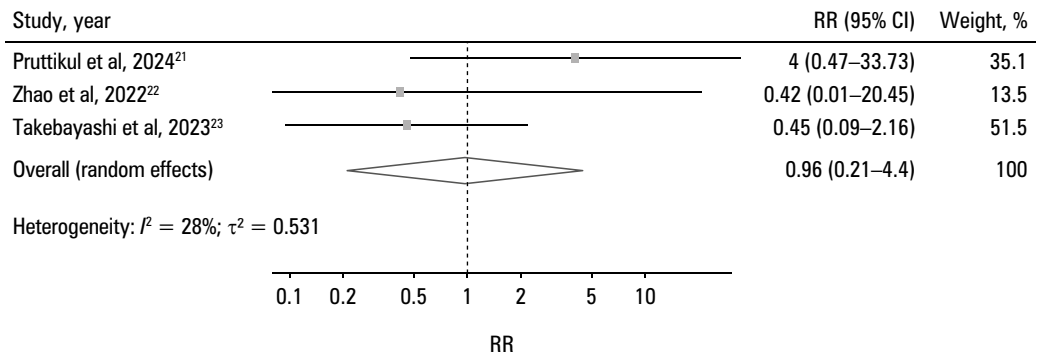
**Characteristics of the included studies** All included studies compared TELD and IELD exclusively

**FIGURE 6** Forest plot comparing perioperative complication rates between TELD and IELD at the L4/L5 level. A continuity correction of 0.5 was applied for 0-event studies.



Abbreviations: RR, risk ratio; others, see FIGURES 1 and 2

**FIGURE 7** Forest plot comparing reoperation rates between TELD and IELD at the L4/L5 level. A continuity correction of 0.5 was applied for 0-event studies.



Abbreviations: see FIGURES 1, 2 and 6

at the L4/L5 level, and together comprised 260 patients, of whom 189 underwent TELD and 71 IELD. One study<sup>21</sup> was an RCT and 2 were retrospective cohort studies.<sup>22,23</sup> Mean (SD) follow-up across the studies was 22.7 (2.3) months, ranging from 20 to 24 months. Study characteristics are presented in TABLE 2.

**Operative time** All studies reported operative time. Two<sup>22,23</sup> demonstrated shorter operative duration with TELD, whereas 1 study<sup>21</sup> favored IELD. In the pooled analysis, the MD was -12.6 minutes, with a 95% CI of -34.6 to 9.4, and substantial heterogeneity ( $I^2 = 93\%$ ). Although operative time tended to be shorter with TELD, the difference did not reach significance (FIGURE 2).

**Postoperative Visual Analog Scale leg pain** All 3 studies reported postoperative VAS leg pain scores. TELD demonstrated slightly higher postoperative VAS values, with a pooled MD of 0.32 points and a 95% CI of 0–0.63. Heterogeneity was low ( $I^2 = 8\%$ ). Although the difference reached marginal significance ( $P = 0.05$ ), it remained far below the minimal clinically important difference, indicating no clinically meaningful difference between the techniques (FIGURE 3).

**Postoperative Oswestry Disability Index** All studies provided postoperative ODI scores. IELD showed marginally lower ODI values, with a pooled MD of 1.94 points and a 95% CI of 0.94–2.94. No heterogeneity was observed ( $I^2 = 0\%$ ). Despite achieving significance ( $P < 0.001$ ), the effect size was well below

the minimal clinically important difference, supporting clinical equivalence (FIGURE 4).

**Hospital stay** LOS was similar across all studies. The pooled MD was 0.007 days, with a 95% CI of -0.15 to 0.16 and no heterogeneity ( $I^2 = 0\%$ ). These results demonstrate identical postoperative LOS of TELD and IELD (FIGURE 5).

**Complications** Perioperative complications were reported in all studies. After applying a continuity correction for 0-event data, the pooled RR was 1.48, with a 95% CI of 0.23–9.7 and moderate heterogeneity ( $I^2 = 36\%$ ). The wide CIs and low event rates indicate no significant or clinically meaningful difference between the procedures (FIGURE 6).

**Reoperations** Reoperation rates were also comparable between the groups. The pooled RR was 0.96, with a 95% CI of 0.21–4.4 and low heterogeneity ( $I^2 = 28\%$ ). A continuity correction was applied due to 0-event studies. No significant difference was observed between TELD and IELD (FIGURE 7).

**Summary of findings** Across the 3 comparative studies evaluating single-level L4/L5 LDH, clinical outcomes, including VAS and ODI scores, demonstrated equivalence between the transforaminal and interlaminar endoscopic approaches. LOS was identical. Complication and reoperation rates were similar, with no evidence of an increased risk associated with either technique. Operative time showed a trend favoring TELD

**TABLE 1** Risk of bias assessment for the included studies<sup>a</sup>

Randomized controlled trial (Cochrane Risk of Bias 2.0)						
Study, year	Randomization process	Deviations from intended interventions	Missing outcome data	Measurement of the outcome	Selection of the reported result	Overall risk of bias
Pruttikul et al, 2024 <sup>21</sup>	Low	Low	Low	Low	Low	Low
Observational studies (Newcastle–Ottawa Scale)						
Study, year	Study design	Overall methodological quality		Overall risk of bias		
Zhao et al, 2022 <sup>22</sup>	Retrospective cohort	Moderate		Moderate		
Takebayashi et al, 2023 <sup>23</sup>	Retrospective cohort	Moderate		Moderate		

**a** For observational studies, higher methodological quality corresponds to higher NOS scores; NOS  $\geq 7$  was considered high methodological quality. Given the limited number of included studies and the reporting format of the original articles, qualitative NOS-based ratings are presented.

Abbreviations: NOS, Newcastle–Ottawa scale

**TABLE 2** Characteristics of the included studies

Study, year	Country	Study design	Level	TELD, n	IELD, n	Age TELD, y	Age IELD, y	Follow-up, mo
Pruttikul et al, 2024 <sup>21</sup>	Thailand	Randomized controlled trial	L4/L5	30	30	37.7 (8.6)	39.3 (7.9)	24 (0)
Zhao et al, 2022 <sup>22</sup>	China	Retrospective cohort	L4/L5	54	22	47.8 (9.2)	53.3 (10.1)	20.4 (3.1)
Takebayashi et al, 2023 <sup>23</sup>	Japan	Retrospective cohort	L4/L5	105	19	44.8 (13.1)	46.4 (12.6)	24 (0)

Data are presented as mean (SD) unless indicated otherwise.

Abbreviations: see **FIGURE 1**

**TABLE 3** Summary of the pooled outcomes in the meta-analysis<sup>a</sup>

Outcome	TELD vs IELD (MD or RR)	95% CI	<i>P</i> , %	Interpretation
Operative time, min	MD, -12.6	-34.6 to 9.4	93	No difference
Postoperative VAS leg pain score, points	MD, +0.32	0–0.63	8	No clinically meaningful difference
Postoperative ODI score, points	MD, +1.94	0.94–2.94	0	No clinically meaningful difference
Hospital stay, d	MD, +0.007	-0.15 to 0.16	0	No difference
Complications	RR, 1.48	0.23–9.7	36	No difference
Reoperations	RR, 0.96	0.21–4.4	28	No difference

**a** MD represents TELD – IELD. A negative MD favors TELD for continuous outcomes.

Abbreviations: see **FIGURES 1, 2, 3** and **6**

but did not reach significance. Overall, the available evidence supports the clinical equivalence of TELD and IELD at the L4/L5 level. Pooled quantitative outcomes are summarized in **TABLE 3**.

**DISCUSSION** This systematic review and meta-analysis is the first to directly compare TELD and IELD exclusively at the L4/L5 segment, the level most commonly affected by LDH. The findings demonstrate that both approaches provide equivalent outcomes in terms of postoperative pain reduction, functional improvement, LOS, as well as complication and reoperation rates. Although TELD showed a trend toward shorter operative time, this difference was inconsistent across the studies and did not reach significance.

Previous meta-analyses evaluating full ELD have generally compared these techniques across

multiple lumbar levels or against microdiscectomy. These analyses consistently reported comparable safety and effectiveness; however, none stratified the outcomes by the spinal level. Because the L4/L5 segment has unique biomechanical properties and is more susceptible to degeneration and instability than other lumbar levels, the present level-specific synthesis provides more clinically relevant evidence than aggregated analyses. Recent technique-oriented reports in endoscopic spine surgery emphasize the importance of individualized approach selection based on anatomy and pathology rather than a universal preference for a single endoscopic corridor, supporting tailored decision-making in minimally-invasive spine surgery.<sup>24,25</sup>

Operative time demonstrated substantial heterogeneity ( $I^2 = 93\%$ ), indicating considerable variability between the studies. This variability likely reflects differences in case selection, surgeon experience, endoscopic equipment, and herniation morphology. TELD may be more efficient in cases of foraminal or paracentral soft-disc herniations due to its extracanal trajectory, whereas IELD may be advantageous when treating migrated or central disc fragments requiring direct canal access.

Importantly, the high degree of heterogeneity precludes any definitive conclusion regarding the time efficiency of either technique, suggesting that operative time is more dependent on anatomical and procedural factors than on the surgical approach itself.

Complication and reoperation rates were comparable between the techniques. Although TELD has been associated with a theoretical risk of

exiting nerve root irritation and IELD with a potential increased risk of dural injury, such complications were infrequent and inconsistently reported across the included studies. The low absolute number of adverse events and wide CIs limit robust statistical comparisons. Nevertheless, the available evidence suggests that both approaches are safe when performed by experienced endoscopic spine surgeons.

While marginal differences were observed for certain outcomes, including postoperative VAS leg pain and ODI scores, these differences remained well below established minimal clinically important difference thresholds.

This finding reinforces the concept of clinical equivalence between TELD and IELD at the L4/L5 level despite isolated significant results.

These findings have important implications for clinical decision-making. Given the comparable mid-term outcomes, the choice between TELD and IELD at the L4/L5 level should be guided primarily by patient-specific anatomy, herniation characteristics, and surgeon expertise rather than expectations of superior clinical effectiveness.<sup>26-31</sup> Both techniques, therefore, represent complementary tools within modern minimally-invasive spine surgery programs, including outpatient and same-day discharge pathways.

This study has several strengths, including its level-specific design, strict inclusion criteria, and standardized quantitative synthesis. However, several limitations must be acknowledged. Only 3 comparative studies met the eligibility criteria, 2 of which were retrospective, introducing a potential risk of selection bias, as surgeons may have preferentially selected the surgical approach based on anatomical considerations or herniation morphology. Additionally, operative time exhibited substantial heterogeneity, and long-term functional outcomes beyond 20–24 months were not consistently reported.

Future prospective, level-specific randomized trials with extended follow-up are required to better define optimal patient selection and further evaluate the long-term comparative effectiveness of transforaminal and interlaminar endoscopic approaches.

**CONCLUSIONS** Both TELD and IELD provide equally effective and safe treatment for single-level L4/L5 LDH. Clinical outcomes, functional improvement, complication and reoperations rates, and LOS were comparable between both techniques.

Although TELD showed a tendency toward shorter operative time, the difference was inconsistent across the studies, demonstrated substantial heterogeneity, and did not allow for a definitive conclusion regarding time efficiency.

The choice between TELD and IELD at the L4/L5 level should therefore be guided primarily by patient anatomy, herniation characteristics, and surgeon expertise rather than expectations of superior clinical outcomes. Further high-quality,

level-specific prospective studies are warranted to refine anatomical selection criteria and optimize surgical decision-making in full-endoscopic lumbar spine surgery.

## ARTICLE INFORMATION

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**CONTRIBUTION STATEMENT** TS conceived the study, analyzed the data, and drafted the manuscript. MG contributed to the study design and critically revised the manuscript. PK participated in the data extraction and literature screening. JK assisted with the data analysis and manuscript preparation. BJ contributed to the methodological supervision and final manuscript revision. All authors read and approved the final version of the manuscript.

**CONFLICT OF INTEREST** None declared.

**AI STATEMENT** Artificial intelligence was not used in the preparation of this manuscript.

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*Videosurgery and Other Minimally Invasive Techniques* is an official journal of the Videosurgery Foundation.

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