Efficacy and safety of unilateral biportal endoscopy vs. percutaneous endoscopic interlaminar approach in lumbar disc herniation: A meta-analysis

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Abstract. Lumbar disc herniation (LDH) is a common cause of lower back and radicular pain. Unilateral biportal endoscopic discectomy (UBE) and percutaneous endoscopic interlaminar discectomy (PEID) are two prevalent minimally invasive techniques, yet their comparative efficacy and safety remain debated. Within the present meta-analysis, the aim was to compare the efficacy and safety of UBE and PEID in treating LDH. A systematic literature search was conducted using Web of Science, PubMed, Embase and the Cochrane Library up to June 10, 2025, to identify comparative studies evaluating UBE and PEID for single-level LDH. Extracted data included operative time, blood loss, fluoroscopy frequency, hospital stay, visual analog scale (VAS) score for back and leg pain, Oswestry Disability Index (ODI), MacNab excellent/good rate and complication rate. Study quality was assessed using the Newcastle-Ottawa Scale. A total of ten studies involving 1,003 patients was included. PEID demonstrated advantages in operative time [mean difference (MD)=7.82 min; P=0.004], blood loss (MD=25.5 ml; P=0.01) and hospital stay (MD=0.56 days; P=0.007). UBE demonstrated ODI improvement at 1 (MD=-0.93; P=0.01) and 6 months (MD=-0.85; P=0.01). No significant differences were observed in VAS scores for back and leg pain, MacNab excellent/good rate, fluoroscopy frequency or complication rates. UBE demonstrated improved postoperative functional recovery, instrument maneuverability and visualization, whereas PEID offered shorter operative time, reduced blood loss and shorter hospital stays. The choice of surgical approach should consider these outcome trade-offs along with patient characteristics and surgeon expertise.

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Abbreviations: UBE, unilateral biportal endoscopic; PEID, percutaneous endoscopic interlaminar discectomy; LDH, lumbar disc herniation; VAS, visual analog scale; ODI, Oswestry Disability Index

Key words: UBE, PEID, interlaminar approach, LDH, meta-analysis

Introduction

Lumbar disc herniation (LDH) is a prevalent spinal disorder and a major cause of global disability, as evidenced by its marked associated healthcare expenditures and economic burden (1). When conservative management proves ineffective, surgical intervention becomes necessary (2,3). The advent of minimally invasive spine surgery (MISS) has notably transformed treatment paradigms, with endoscopic techniques gaining prominence for their ability to minimize tissue trauma and enable precise decompression (4).

Selecting the optimal MISS approach for LDH remains a subject of debate (5). Transforaminal endoscopic lumbar discectomy, pioneered by Kambin and Sampson (6) and based on the anatomical concept of Kambin's triangle, has demonstrated effectiveness but is typically limited at the L5-S1 level due to high iliac crest obstruction and the restricted working corridor within the safe zone (7). Consequently, the interlaminar approach has emerged as a valuable alternative, using the natural anatomical window of the interlaminar space to overcome osseous restrictions. This method provides improved access for central and L5-S1 herniations and has facilitated the development of techniques such as percutaneous endoscopic interlaminar discectomy (PEID) and unilateral biportal endoscopic discectomy (UBE) (8,9).

Although both PEID and UBE employ the interlaminar approach and have yielded favorable outcomes, direct comparative evidence regarding their efficacy and safety profiles

within this shared surgical corridor remains limited (10). Therefore, the present meta-analysis aimed to compare UBE and PEID regarding surgical efficiency, including operative time, intraoperative blood loss, hospital stay length and fluoroscopy frequency, functional outcomes including MacNab excellent/good rate (11), back and leg visual analog scale (VAS) scores (12) and Oswestry Disability Index (ODI) (13), and safety-complication rates. The present study aimed to provide evidence-based guidance for clinical decision-making in selecting the most appropriate surgical technique.

Materials and methods

Search strategy. A comprehensive systematic literature search was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (14). The search encompassed four major electronic databases: PubMed (U.S. National Library of Medicine, https://pubmed.ncbi.nlm.nih.gov/), Web of Science (Clarivate Analytics platform, https://www.webofscience.com/), Embase (Elsevier, https://www.embase.com) and the Cochrane Library (Wiley, https://www.cochranelibrary.com/). The search period spanned from the inception of each database to June 10, 2025. The strategy combined Medical Subject Headings (MeSH) and free-text terms using Boolean operators (AND/OR). For example, the PubMed search syntax was as follows: ('Unilateral Biportal Endoscopy'[MeSH] OR 'Biportal Endoscopic'[tiab] OR UBE[tiab] OR UBED[tiab]) AND ('Percutaneous Endoscopy'[MeSH] OR 'Percutaneous Endoscopic Interlaminar Discectomy'[tiab] OR PEID[tiab] OR PELD[tiab]) AND ('Lumbar Disc Herniation'[MeSH] OR 'Lumbar Intervertebral Disc'[tiab] OR LDH[tiab]). Additionally, the reference lists of relevant reviews were screened to identify potentially eligible studies.

Inclusion and exclusion criteria. Inclusion criteria were as follows: i) Comparative studies of UBE vs. PEID performed exclusively using the interlaminar approach for single-level LDH; ii) retrospective or prospective cohort studies or randomized controlled trials and iii) publications in English. Exclusion criteria were as follows: i) Prior lumbar surgery or multi-level LDH; ii) comorbidity, such as infection, tuberculosis, psychiatric disorders or neoplasms; iii) non-primary literature (reviews, case reports or conference abstracts); iv) studies with inaccessible outcome data and v) procedures not utilizing the interlaminar approach.

Data extraction and quality assessment. Data were extracted by two independent investigators regarding study characteristics (first author, study design, country, sample size, sex, age, BMI and operative levels) and outcome parameters (operative time, blood loss, fluoroscopy frequency, hospital stay duration, VAS for back and leg pain, ODI, modified MacNab criteria with excellent rate and complication rates). Study quality was evaluated using the Newcastle-Ottawa Scale (NOS) (15) with discrepancies resolved through discussion or arbitration by a third author.

Statistical analysis. Meta-analyses were conducted using Review Manager (RevMan; version 5.4; The Cochrane Collaboration). Dichotomous variables (MacNab excellent/good rate and complication rates) were analyzed using odds ratios (ORs) with 95% CIs. Continuous variables (operative time, VAS and ODI) were analyzed using mean difference (MD) or standardized MD (SMD) with 95% CIs. MDs were preferred when outcomes were measured on identical scales across studies, whereas SMDs were applied when outcomes were reported on different scales. $P<0.05$ was considered to indicate a statistically significant difference and heterogeneity was quantified using the I^2 statistic. In accordance with the recommendations of the Cochrane Handbook for Systematic Reviews of Interventions (16), a random-effects model was applied to all meta-analyses to incorporate the expected heterogeneity of intervention effects across studies from different settings. Sensitivity or subgroup analyses were conducted to explore potential sources of heterogeneity sources. Publication bias was assessed using funnel plots and Egger's regression test.

Results

Search results. According to the predefined search strategy, a total of 267 records were retrieved from Embase, the Cochrane Library, PubMed and Web of Science databases. After removing 132 duplicate entries, 135 unique records remained. Following a review of titles and abstracts, 112 records were excluded. The remaining 23 studies underwent full-text evaluation, of which 13 were excluded based on the eligibility criteria. Ultimately, 10 studies were included in the present meta-analysis (Fig. 1) (17-26).

Basic characteristics of included studies. Within the 10 included studies, the following outcomes were reported; i) Operative time (n=10) (17-26); ii) blood loss (n=5) (17-20,22); iii) hospital stay duration (n=5) (17,18,20,21,23); iv) fluoroscopy frequency (n=5) (18,19,23-25) v) back and leg VAS score (n=10) (17-26); vi) MacNab criteria with excellent/good rate (n=7) (17-22,24) and vii) complication rates (n=6) (18-20,23-25). In total, the studies encompassed 1,003 patients (514 male and 489 female). Detailed study characteristics are presented in Tables I and II.

Quality evaluation of the included studies. All 10 included studies were retrospective in design, with no prospective studies identified. Study quality was assessed using the NOS, whereby three studies scored 8 points and seven scored 7 points. All studies met the high-quality threshold (NOS score ≥7; Table III).

Analysis of clinical outcomes

Meta-analysis results of surgical efficiency. A pooled analysis of 10 studies (17-26) comparing operative time demonstrated that PEID required a significantly shorter operative time compared with UBE in the treatment of LDH (MD=7.82; 95% CI: 2.52-13.12; P=0.004; I^2=82%; Fig. 2A). Similarly, analysis of five studies (17-19,22,24) on intraoperative blood loss showed that PEID was associated with a significantly decreased blood loss (MD=25.50; 95% CI: 6.08-44.92; P=0.01; I^2=99%; Fig. 2B), also demonstrated through a random-effects model.

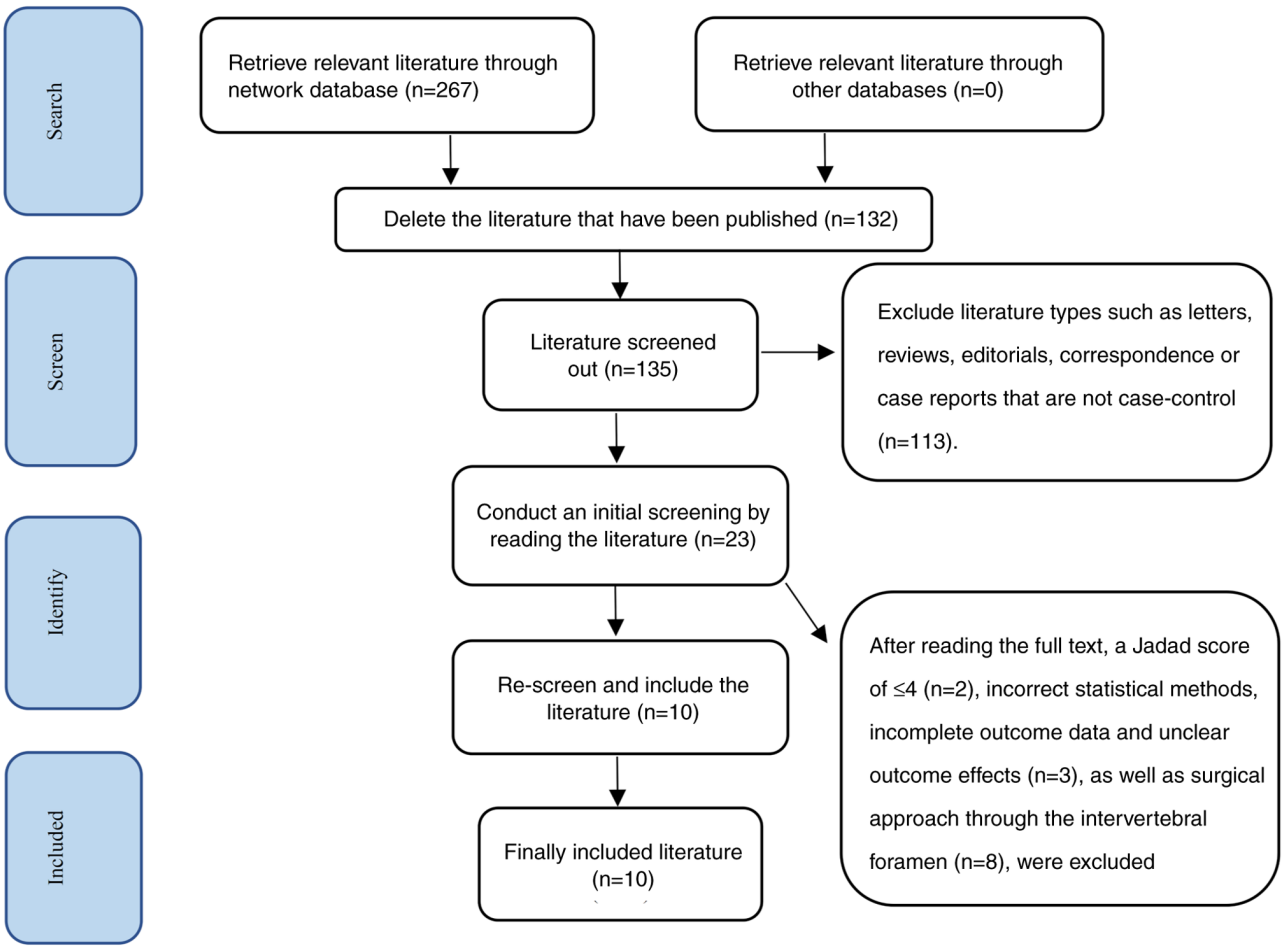

Figure 1. Flowchart of the selection process for the present study.

Furthermore, five studies (18,19,23-25) comparing fluoroscopy frequency revealed no significant difference between PEID and UBE (MD=-0.64; 95% CI: -1.35-0.07; P=0.08; I^2=95%), analyzed using a random-effects model (Fig. 2C).

In the comparison of hospital stay duration of UBE and PEID, five studies (17,18,20,21,23) demonstrated significantly shorter hospitalization with PEID (MD=0.56; 95% CI: 0.06-1.06; P=0.03; I^2=30%; Fig. 2D), analyzed using a random-effects model.

Meta-analysis results of functional outcomes. Back VAS score showed no significant differences between UBE and PEID at preoperative (MD=0.01; 95% CI: -0.13-0.14; P=0.91; I^2=0%) and postoperative day 1 (MD=0.09; 95% CI: -0.10-0.27; P=0.35; I^2=44%) and month 1 (MD=0.05; 95% CI: -0.09-0.19; P=0.49; I^2=0%), 3 (MD=-0.01; 95% CI: -0.13-0.11; P=0.85; I^2=0%) and 6 (MD=-0.06; 95% CI: -0.15-0.04; P=0.24; I^2=0%; Fig. 3), all analysed using a random-effects model.

With regard to leg VAS score, no statistically significant differences were observed between UBE and PEID at preoperative (MD=0.02; 95% CI: -0.11-0.14; P=0.79; I^2=0%] and postoperative day 1 (MD=-0.01; 95% CI: -0.22-0.21; P=0.96; I^2=59%) and month 1 (MD=0.01; 95% CI: -0.14-0.16; P=0.91; I^2=0%), 3 (MD=-0.02; 95% CI: -0.20-0.15; P=0.79; I^2=45%) and 6 (MD=0.00; 95% CI: -0.11-0.12; P=0.96; I^2=0%; Fig. 4), with all analyses performed using a random-effects model.

Preoperative ODI comparisons across nine studies (17-21,23-26) revealed no significant differences (MD=-0.81; 95% CI: -2.20-0.59; P=0.26; I^2=65%). Postoperative ODI analysis results were as follows: Day 1 (17,18,23-25) (MD=-0.42; 95% CI: -1.51-0.66; P=0.45; I^2=42%) and month 1 (17,19,21,23,24) (MD=-0.93; 95% CI: -1.65-0.22; P=0.01; I^2=0%), 3 (17,18,21,23,25,26) (MD=-0.31; 95% CI: -1.24-0.61; P=0.50; I^2=37%) and 6 (18,19,21,23,24,26) (MD=-0.85; 95% CI: -1.52-0.18; P=0.01; I^2=0%; Fig. 5). UBE showed significant superiority at 1 and 6 months (both P≤0.01) but not at preoperative, postoperative day 1 or month 3. All analyses were performed using a random-effects model (Fig. 5).

A total of seven studies (17-22,24) comparing MacNab excellent/good rates showed no significant difference between UBE and PEID groups (OR=1.45; 95% CI: 0.78-2.70; P=0.24; I^2=0%; Fig. 6A).

Meta-analysis of safety. A pooled analysis of postoperative complications from six studies (18-20,23-25) showed no significant difference between UBE and PEID (OR=0.64; 95% CI: 0.25-1.64; P=0.36; I^2=52%; Fig. 6B), using a random-effects model.

Publication bias. Publication bias evaluation for the nine primary outcomes including surgical efficiency (operative time, blood loss, hospital stay and fluoroscopy frequency), functional outcomes (MacNab excellent/good rate, back and

Table I. Basic information on included retrospective studies.

First author, year	Country	Group	Sample size (M/F)	Mean age, years	BMI, kg/m^2	Operation level (n)	Mean fluoroscopy frequency, n	(Refs.)
Wang *et al*, 2025	China	UBE	18 (10/8)	40.94±13.73	24.51±3.12	L2-3 (1); L4-5 (12); L5-S1 (11)	NR	(17)
		PEID	21 (14/7)	42.33±11.63	23.14±3.83	L2-3 (0); L4-5 (6); L5-S1 (15)	NR	
Xiao *et al*, 2025	China	UBE	84 (45/39)	53.46±15.60	24.17±2.94	L3-4 (4); L4-5 (52); L5-S1 (28)	4.06±4.63	(18)
		PEID	62 (23/39)	55.61±15.52	23.90±2.61	L3-4 (3); L4-5 (37); L5-S1 (21)	7.72±3.35	
Guo *et al*, 2025	China	UBE	79 (43/36)	47.35±14.07	22.51±2.38	L4-5 (38); L5-S1 (38); other (3)	3.28±1.67	(19)
		PEID	94 (52/42)	44.03±14.19	22.99±2.06	L4-5 (44); L5-S1 (44); other (6)	2.99±1.04	
Yin *et al*, 2025	China	UBE	46 (29/17)	43.85±11.41	24.83±3.92	L5-S1(50)	NR	(20)
		PEID	50 (27/23)	45.64±13.60	24.70±4.24	L5-S1(46)	NR	
Qian *et al*, 2024	China	UBE	15 (8/7)	36.27±11.11	21.93±2.12	L4-5 (4); L5-S1 (11)	NR	(21)
		PEID	26 (18/8)	35.15±9.30	22.38±1.75	L4-5 (12); L5-S1 (14)	NR	
Yang *et al*, 2024	China	UBE	33 (18/15)	43.60±15.80	NR	L4-5 (11); L5-S1 (22)	NR	(22)
		PEID	66 (36/30)	44.70±12.90	NR	L4-5 (22); L5-S1 (44)	NR	
Wei *et al*, 2024	China	UBE	55 (19/36)	56.89±15.01	26.88±4.13	L4-5 (NR); L5-S1 (NR)	3.51±0.63	(23)
		PEID	60 (23/37)	57.19±14.25	27.06±4.93	L4-5 (NR); L5-S1 (NR)	3.28±0.66	
Wu *et al*, 2024	China	UBE	31 (16/15)	58.50±13.20	24.10±3.00	L4-5 (17); L5-S1 (14)	3.40±0.90	(24)
		PEID	65 (29/36)	57.60±16.80	25.00±2.90	L4-5 (35); L5-S1 (30)	4.80±1.00	
Wang *et al*, 2023	China	UBE	51 (22/29)	43.80±14.20	25.40±3.70	L5-S1 (51)	2.50±0.60	(25)
		PEID	55 (28/27)	42.30±3.80	25.80±3.60	L5-S1 (55)	2.40±0.50	
Zuo *et al*, 2022	China	UBE	42 (23/19)	45.57±11.15	NR	L5-S1 (42)	NR	(26)
		PEID	50 (31/19)	46.68±12.09	NR	L5-S1 (50)	NR	

NR, not reported; UBE, unilateral biportal endoscopic; PEID, percutaneous endoscopic interlaminar discectomy; M, male; F, female.

leg VAS and ODI) and safety (complications), was assessed using funnel plots in RevMan 5.4. Visual inspection combined with Egger's test (P>0.05 threshold) confirmed symmetrical funnel plots across all outcomes (Fig. 7), indicating no significant publication bias.

Sensitivity and subgroup analyses. Notable heterogeneity (I^2>50%) was identified for operative time, blood loss and fluoroscopy frequency (Fig. 2). Sensitivity analyses, performed by sequentially excluding each individual study, demonstrated that the overall results and the substantial heterogeneity remained largely unchanged (I^2 consistently >50%) (data not shown). This indicates that the observed heterogeneity is robust and not driven by any single outlier study. Instead, the sources of heterogeneity are likely multifactorial, potentially stemming from variations in surgical techniques, patient selection criteria, case complexity and surgeon experience across the included studies.

Subgroup analysis of complications was performed to delineate the safety profiles of the two techniques beyond the pooled overall rate. While the overall complication rates did not differ significantly between UBE and PEID, the subgroup analysis revealed distinct patterns. Notably, the recurrence subgroup exhibited moderate heterogeneity (I^2=45%), whereas heterogeneity was negligible (I^2=0%) in subgroups for dural tear, nerve root injury and hematoma (Fig. 8).

For the recurrence outcome, subgroup analysis revealed moderate heterogeneity (I^2=45%). To investigate its source, a sensitivity analysis was performed by sequentially excluding each study. The exclusion of Xiao *et al* (18) eliminated the between-study heterogeneity (I^2=0%), identifying it as the primary source of variance. This study (18) reported an exceptionally high recurrence rate in the PEID group (16.13%; 10/62) compared with that in the UBED group (1.19%; 1/84), yielding an extreme effect size (OR, 0.06) that diverged markedly from the other trials (Fig. 8). This disparity was attributed to the technical and anatomical limitations of the interlaminar PEID approach, particularly at the L5-S1 level, such as a high iliac crest or a narrow interlaminar space, which may restrict visual field and lead to incomplete fragment removal. By contrast, the dual-portal design and wider laminar exposure in UBED were described as enabling a broader operative field and more complete decompression.

Table II. Intraoperative data and postoperative recovery indices.

First author, year	Group	Mean operative time, min	Mean blood loss, ml	Mean hospital stay, days	Back VAS score	Leg VAS score	ODI score	MacNab score excellence rate, %	Complications, n	(Refs.)
Wang *et al*, 2025	UBE	136.44±32.11	18.89±6.54	9.17±2.81	Pre-op; postop day 1; 1 and 3 month postop	Pre-op; postop day 1; 1 and 3 month postop	Pre-op; postop day 1; 1 and 3 month postop	94.44	NR	(17)
	PEID	104.86±35.74	7.14±2.99	6.95±1.69				95.24	NR	
Xiao *et al*, 2025	UBE	66.67±15.83	76.81±26.74	5.39±1.83	Pre-op; 1, 6 and 24 month postop	NR	Pre-op; 1, 6 and 24 month postop	91.70	5	(18)
	PEID	69.11±25.84	69.44±25.74	5.11±3.42		NR		87.10	20	
Guo *et al*, 2025	UBE	116.52±47.20	80.19±22.81	7.34±2.36 (post)	Pre-op; postop day 1; 3 and 6 month postop	Pre-op; postop day 1; 3 and 6 month postop	Pre-op; postop day 1; 3 and 6 month postop	96.20	7	(19)
	PEID	99.96±34.74	20.85±11.06	3.47±1.23 (post)				94.68	8	
Yin *et al*, 2025	UBE	80.98±33.61	394.16±227.96	5.54±1.92	Pre-op; postop day 1; final follow-up	Pre-op; postop day 1; final follow-up	Pre-op; final follow-up	97.80	2	(20)
	PEID	89.42±32.16	273.83±158.53	5.24±1.89				96.00	2	
Qian *et al*, 2024	UBE	133.07±10.46	NR	4.24±1.44	Pre -op; 1, 3 and 6 month postop	Pre -op; 1, 3 and 6 month postop	Pre -op; 1, 3 and 6 month postop	86.70	NR	(21)
	PEID	110.81±11.48	NR	2.73±1.28				92.30	NR	
Yang *et al*, 2024	UBE	100.80±36.10	9.90±3.40	NR	Pre-op; postop	NR	Pre-op; post-op	97.00	NR	(22)
	PEID	86.00±19.40	5.50±2.30	NR		NR		95.50	NR	
Wei *et al*, 2024	UBE	56.74±10.57	NR	7.50±2.12	Pre-op; postop day 1; 1, 3, 6 and 12 month postop	Pre-op; postop day 1; 1, 3, 6 and 12 month postop	Pre-op; postopday 1; 1, 3, 6 and 12 month postop	NR	1	(23)
	PEID	54.34±10.15	NR	7.18±2.30				NR	1	
Wu *et al*, 2024	UBE	77.30±20.40	NR	4.50±2.60 (post)	Pre-op; postop day 1; 1 and 6 month postop; final follow-up	Pre-op; postop day 1; 1 and 6 month postop; final follow-up	Pre-op; postop day 1; 1 and 6 month postop; final follow-up	90.30	1	(24)
	PEID	65.80±15.90	NR	3.10±1.80 (post)				84.60	2	
Wang *et al*, 2023	UBE	83.60±10.80	NR	2.10±0.80 (post)	Pre-op; postop day 1; 3 month postop; final follow-up	Pre-op; postop day 1; 3 month postop; final follow-up	Pre-op; postop day 1; 3-month postop; final follow-up	NR	3	(25)
	PEID	80.20±8.40	NR	2.00±0.80 (post)				NR	2	
Zuo *et al*, 2022	UBE	68.57±10.87	NR	6.88±1.85 (post) 7.36±4.62 (post)	Pre-op; postop day 3; 3, 6 and 12 month postop	Pre-op; postop day 3; 3, 6 and 12 month postop	Pre-op; postop day 3; 3, 6 and 12 month postop	NR	NR	(26)
	PEID	65.6±15.24	NR		NR	NR	NR	NR	NR	

NR, not reported; pre-op, preoperative; postop, postoperative; VAS, visual analog scale; ODI, Oswestry Disability Index.

Table III. Study evaluation using modified Newcastle-Ottawa Scale.

First author, year	Selection	Comparability	Exposure	Total score	(Refs.)
Wang *et al*, 2025	3	2	2	7	(17)
Xiao *et al*, 2025	3	1	3	7	(18)
Guo *et al*, 2025	3	2	2	7	(19)
Yin *et al*, 2025	3	2	3	8	(20)
Qian *et al*, 2024	3	2	2	7	(21)
Yang *et al*, 2024	3	1	3	7	(22)
Wei *et al*, 2024	3	2	2	7	(23)
Wu *et al*, 2024	3	1	3	7	(24)
Wang *et al*, 2023	4	2	2	8	(25)
Zuo *et al*, 2022	4	2	2	8	(26)

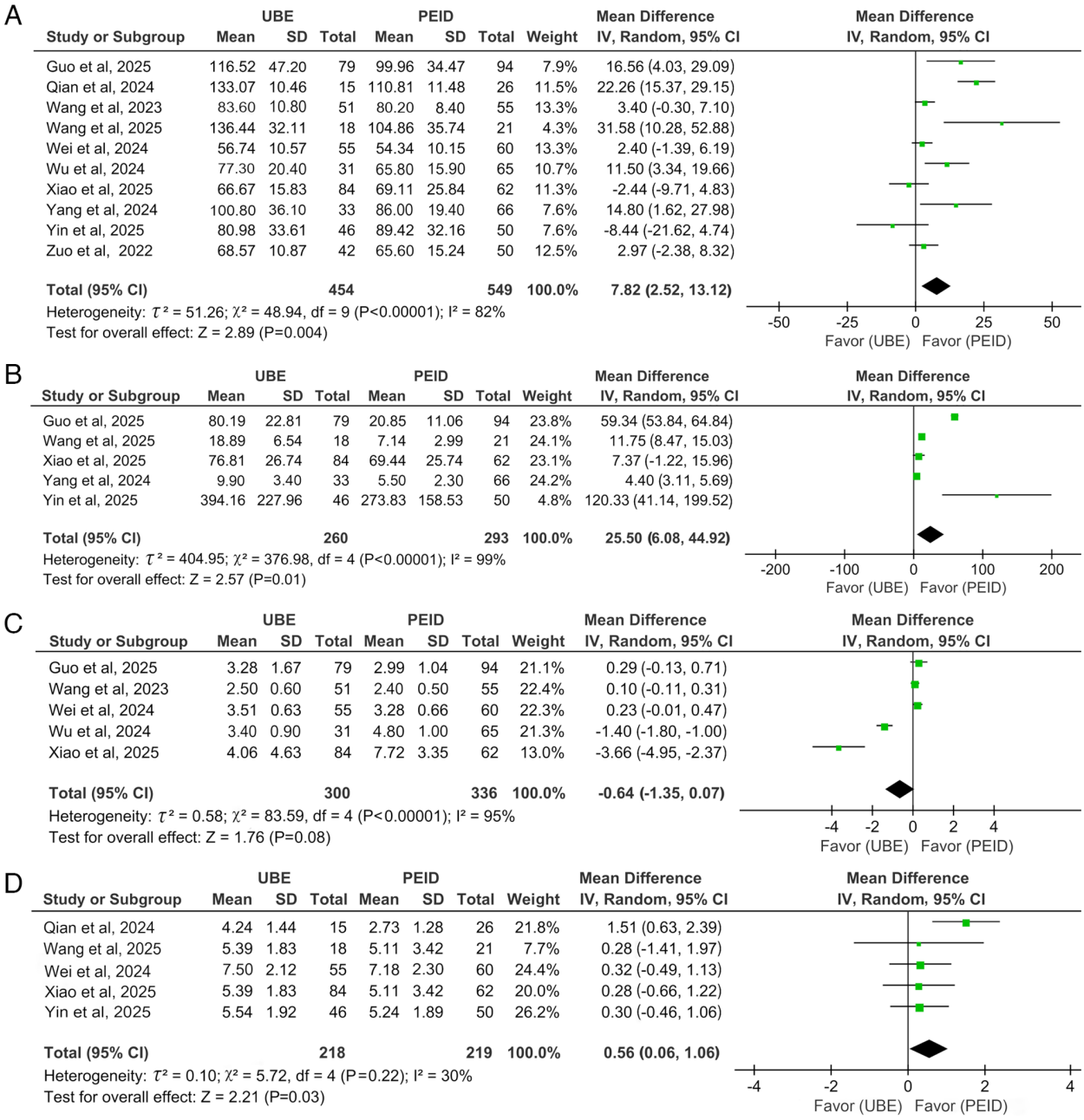

Figure 2. Forest plots comparing surgical efficiency indicators. (A) Operative time, (B) blood loss, (C) fluoroscopy frequency and (D) hospital stay intraoperative parameters. CI, confidence interval; IV, inverse variance; UBE, unilateral biportal endoscopic; PEID, percutaneous endoscopic interlaminar discectomy.

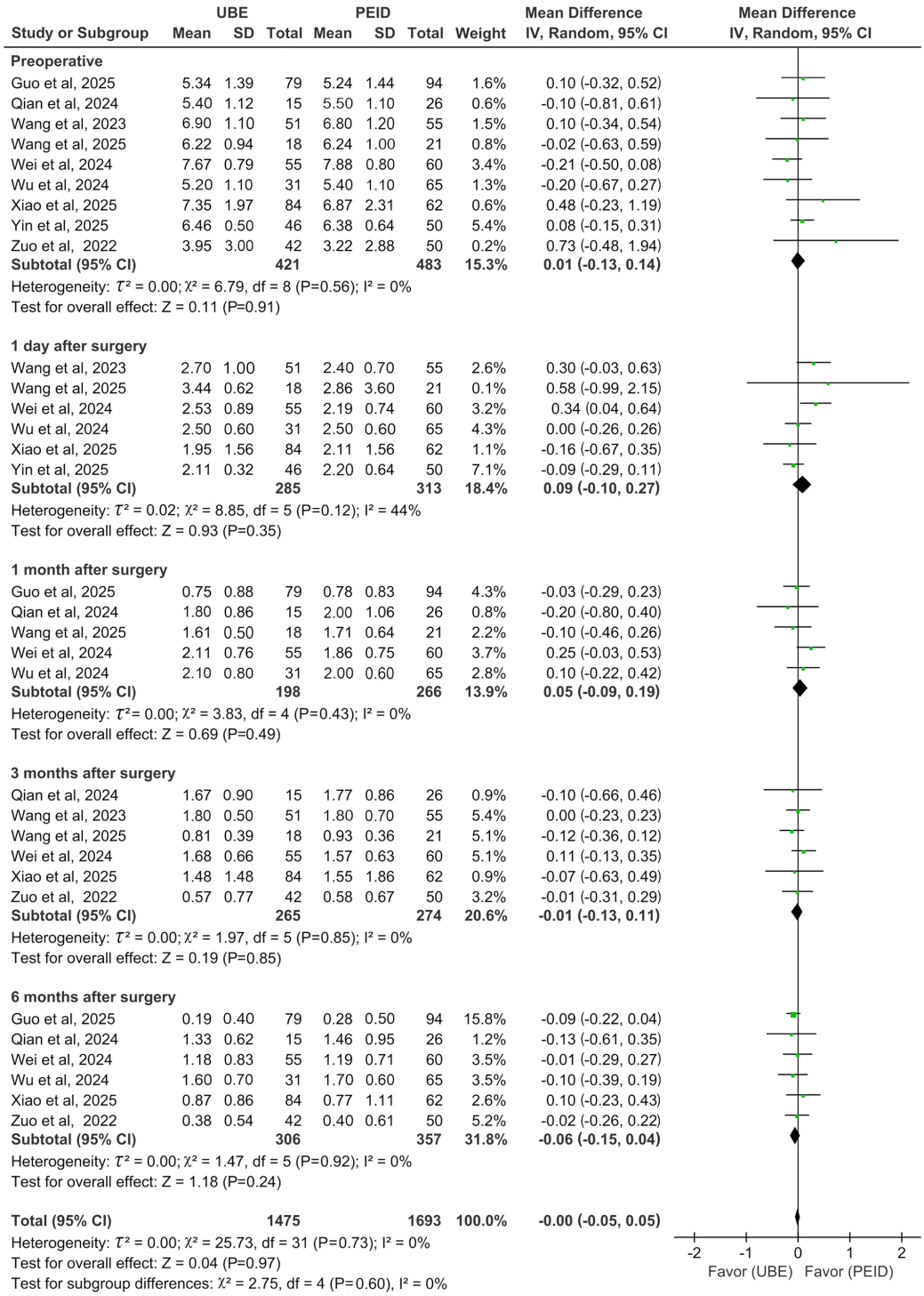

Figure 3. Forest plot comparing back VAS scores between UBE and PEID groups. CI, confidence interval; IV, inverse variance; VAS, visual analog scale; UBE, unilateral biportal endoscopic; PEID, percutaneous endoscopic interlaminar discectomy.

Thus, the sensitivity analysis confirms that the heterogeneity in recurrence rates was largely driven by the distinct findings reported by Xiao *et al* (18).

Discussion

Efficacy and safety of UBE and PEID in the treatment of single-level LDH were compared using the interlaminar approach. By focusing exclusively on this specific surgical corridor, the present study offered a more precise comparison by minimizing confounding variables associated with anatomical variations. The main findings indicate a nuanced balance, whereby EID demonstrated superior surgical efficiency, reflected by shorter operative time, lower intraoperative blood loss and decreased hospital stay durations. Conversely, UBE was associated with improved intermediate-term functional recovery, evidenced by greater ODI improvement at 1 and 6 months postoperatively. No significant differences were found in pain relief (VAS score), MacNab excellent/good rates or overall complication rates.

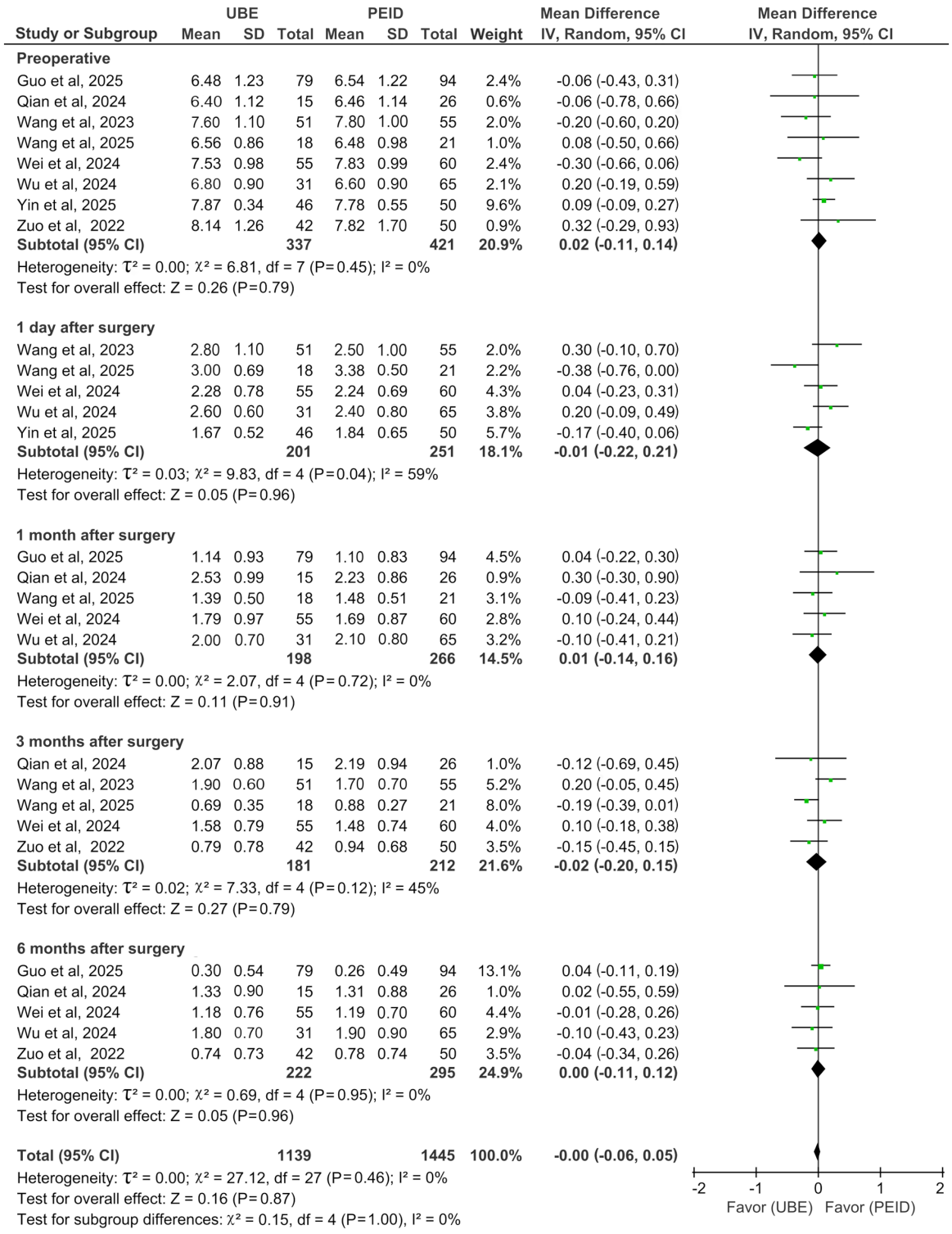

Figure 4. Forest plot comparing leg VAS scores between UBE and PEID groups. CI, confidence interval; IV, inverse variance; VAS, visual analog scale; UBE, unilateral biportal endoscopic; PEID, percutaneous endoscopic interlaminar discectomy.

Observed advantages of PEID in operative time and blood loss align with its minimally invasive, single-portal design, which facilitates direct access and minimizes osseous disruption (27). However, the notable heterogeneity (I^2>80%) in these outcomes warrants cautious interpretation. Sensitivity analyses indicated that the heterogeneity was not random but primarily driven by specific studies (17-26), suggesting both clinical and methodological variability. This variability may be attributable to two primary factors: Case selection bias, as the more versatile UBE technique may be preferentially used for complex cases (such as those involving migrated fragments or spinal stenosis) that inherently require longer operative times and involve more vascularized tissue (28) and variations in surgeon experience and learning curves among the included studies. The technically demanding spatial orientation required for PEID and the steep learning curve associated

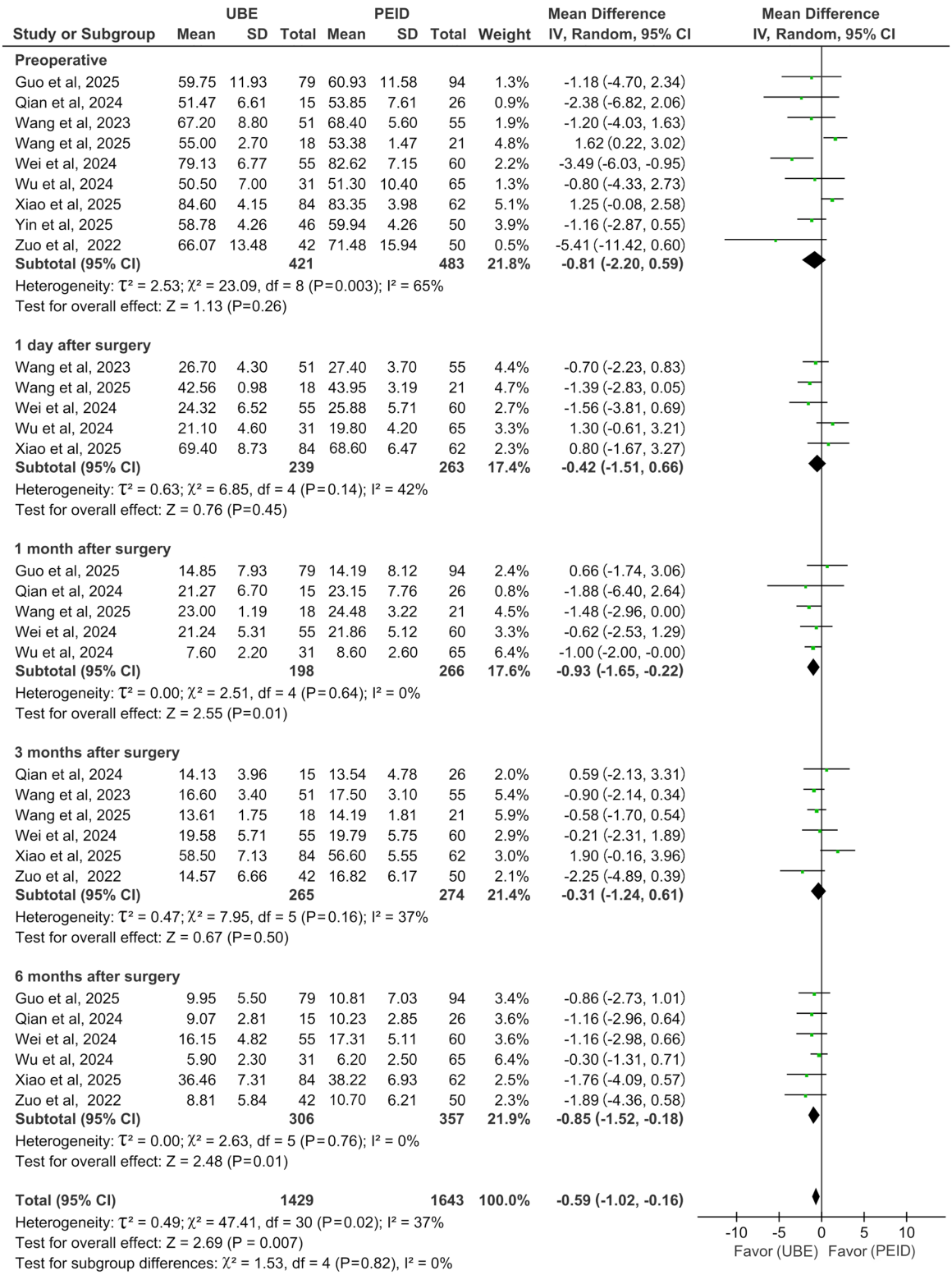

Figure 5. Forest plot comparing ODI scores between UBE and PEID groups. CI, confidence interval; IV, inverse variance; ODI, Oswestry Disability Index; UBE, unilateral biportal endoscopic; PEID, percutaneous endoscopic interlaminar discectomy.

with UBE both affect procedural efficiency (19,29). Therefore, although PEID exhibits higher efficiency in controlled analyses, the notable heterogeneity indicates that real-world outcomes are influenced by patient-specific characteristics and surgeon proficiency. Consequently, the efficiency differences may partially reflect variations in clinical application rather than inherent procedural superiority.

Comparable VAS scores demonstrated that both techniques are highly effective in relieving pain. The key finding, however, is the sustained superiority of UBE in ODI improvement. As the ODI represents a multifactorial index reflecting ability to perform daily activities, this outcome suggests that UBE may promote a more favorable quality of functional recovery. This advantage may be attributed to the biportal configuration of the

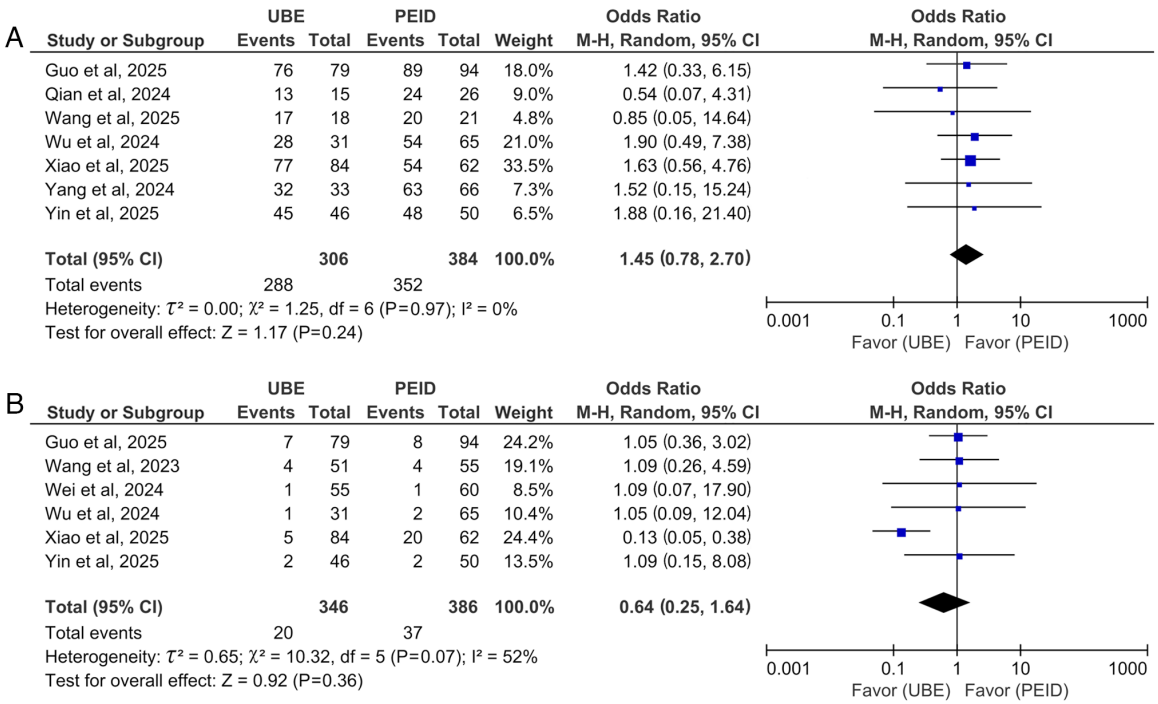

Figure 6. Forest plots comparing MacNab excellent/good and complication rates. (A) MacNab excellent/good and (B) complication rates. CI, confidence interval; M-H, Mantel-Haenszel; UBE, unilateral biportal endoscopic; PEID, percutaneous endoscopic interlaminar discectomy.

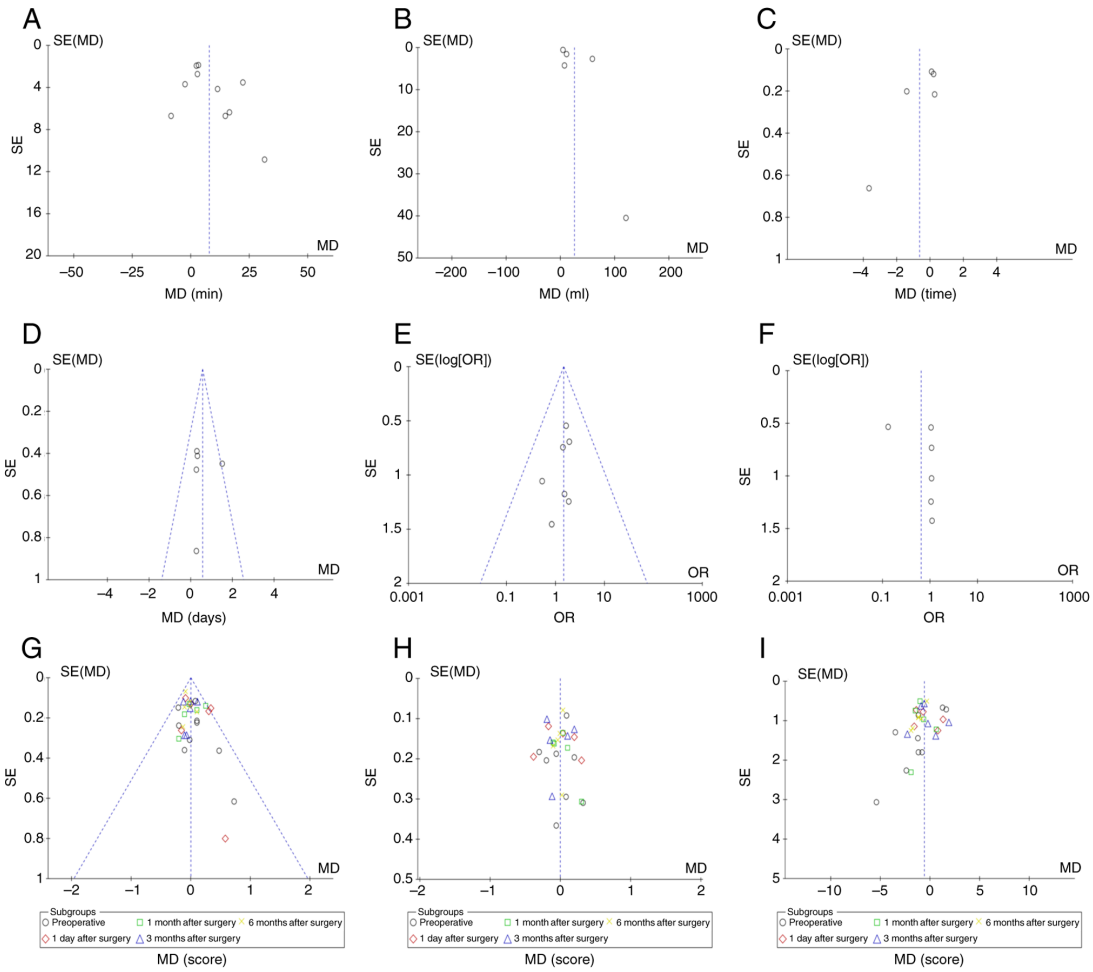

Figure 7. Funnel plots assessing publication bias across (A) operative time, (B) blood loss, (C) fluoroscopy frequency, (D) hospital stay, (E) MacNab excellent/good rate, (F) complications, (G) back VAS score, (H) leg VAS score and (I) ODI score outcomes. SE, standard error; MD, mean difference; OR, odds ratio; VAS, Visual Analog Scale; ODI, Oswestry Disability Index.

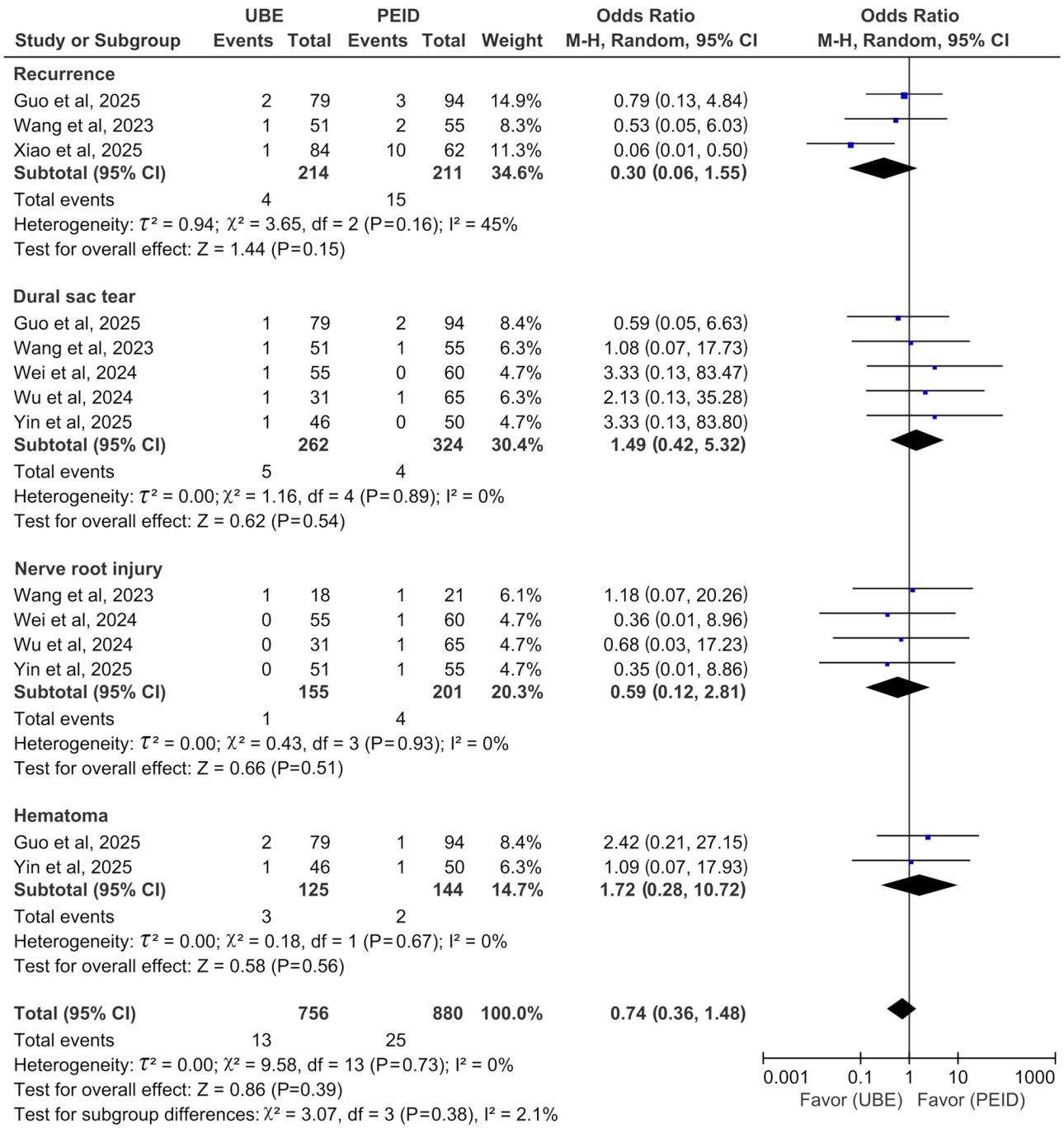

Figure 8. Forest plot stratified by complication type. CI, confidence interval; IV, inverse variance; M-H, Mantel-Haenszel; UBE, unilateral biportal endoscopic; PEID, percutaneous endoscopic interlaminar discectomy.

UBE technique (30). The separation of the endoscope from the surgical instruments provides a panoramic, fluid-maintained visual field. Enhanced visualization, together with the capacity for bimanual instrument triangulation, enables meticulous dissection of herniated fragments and adhesions and facilitates more comprehensive decompression of neural structures, particularly in cases with concomitant pathological changes such as ligamentum flavum hypertrophy or lateral recess stenosis (31). Such complete decompression may contribute to improved medium-term functional restoration. By contrast, the single-channel design of PEID, although minimally invasive, restricts instrument maneuverability and limits the ability to adequately address coexisting pathology, thereby increasing the likelihood of residual compression that may hinder postoperative functional recovery (32,33).

Although the overall complication rates did not differ significantly between UBE and PEID, the specific patterns of complications and recurrence rates varied notably, reflecting their technical characteristics.

The higher recurrence rate associated with PEID in one study may be explained by anatomical and procedural factors (18). At the L5-S1 level, constraints such as a high iliac crest and a narrow interlaminar window may restrict the working angle and motion range of the single portal (34).

These limitations may impede the ability of the surgeon to adequately access and remove migrated or sequestered disc fragments located ventrally to the thecal sac or nerve root, thereby increasing the likelihood of residual fragments and subsequent recurrence (35). By contrast, the configuration and broader operative field of the UBE dual-port mitigate these constraints, enabling more extensive visualization and thorough decompression (36).

Conversely, UBE exhibits a distinct risk profile, primarily involving dural tears and epidural hematoma (37,38). The use of multiple instruments, such as burrs and rongeurs, within a confined space under continuous irrigation heightens the risk of inadvertent dural injury (39,40). Moreover, the greater degree of soft tissue dissection and bone removal creates a larger potential dead space, predisposing patients to postoperative epidural hematoma formation (41,42). By contrast, the primary procedure-specific complications of PEID include iatrogenic nerve root injury and dural tears, typically occurring during working cannula insertion, instrument manipulation or contact within the limited endoscopic field of view (43,44).

Selection between UBE and PEID should be individualized based on a comprehensive evaluation of patient anatomy, pathology and surgeon expertise (22,23). PEID, utilizing a single-portal system, is optimally indicated for contained central or paracentral disc herniations at the L5-S1 level (45). This approach leverages the relatively larger anatomical interlaminar window at this level, facilitating direct access with minimal tissue disruption (46). Consequently, PEID is typically associated with accelerated postoperative recovery, making it a favorable option for patients seeking a rapid return to daily activity (47).

By contrast, UBE, characterized by separate endoscopic and instrumental channels, provides a panoramic field of view and triangulated bimanual maneuverability (48). These technical advantages make it suited for managing complex pathologies, including foraminal or extraforaminal herniation, highly migrated disc fragments and cases complicated by notable central or lateral recess stenosis (49). Furthermore, UBE is advantageous at higher lumbar levels (L1-L4), where the narrower interlaminar space poses a challenge for single-portal techniques (50). From a surgical ergonomics perspective, the operational principles of UBE resemble those of conventional microdiscectomy, which may flatten the learning curve for surgeons transitioning from open procedures to endoscopic spine surgery (30,36).

Within the present meta-analysis, several limitations must be noted. i) All included studies were retrospective cohorts, which inherently carry selection bias. The notable variation in follow-up duration (range, 3-24 months) limited long-term outcome evaluation. Inadequate reporting of disc herniation subtypes (such as protrusion and extrusion) in the primary studies precluded stratified subgroup analyses by pathology severity. The relatively small number of studies/outcome metric (4-10 studies) may have increased methodological heterogeneity. Inclusion of only English language publications introduced potential language bias and omission of parameters such as hidden blood loss may have led to underestimation of total procedural trauma. Consequently, these limitations may restrict the generalizability of the findings to broader clinical settings. Future validation should involve large-scale, multicenter, prospective randomized controlled trials with standardized outcome assessment protocols to demonstrate long-term efficacy and safety.

In conclusion, the present meta-analysis demonstrated that, for the treatment of single-level lumbar disc herniation using the interlaminar approach, PEID is associated with greater surgical efficiency, characterized by shorter operative time, decreased intraoperative blood loss and shorter hospital stay. Conversely, UBE provides improved intermediate-term functional recovery, evidenced by markedly improved ODI scores at 1- and 6-month follow-ups. The notable heterogeneity in efficiency-related outcomes highlights the influence of case selection and surgeon proficiency. Therefore, the choice between techniques should be individualized. PEID is most appropriate for less complex cases in which rapid recovery is a clinical priority, whereas UBE is preferable for complex scenarios requiring extensive decompression. Ultimately, surgical decision-making should be guided by the specific pathological features of the patient, familiarity with the technique and the available institutional resources.

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Availability of data and materials

The data generated in the present study are included in the figures and/or tables of this article.

Authors' contributions

YG and FH conceived and designed the study. FH, JW and SQ performed the literature search, data extraction and meta-analysis. PH and YX conducted the statistical analysis and interpreted the data. PH and YX drafted the manuscript. All authors critically reviewed and revised the manuscript for important intellectual content. All authors have read and approved the final version of the manuscript. YG and FH confirm the authenticity of all the raw data.

Ethics approval and consent to participate

Not applicable.

Patient consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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