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REVIEW

Clinical efficacy and safety of unilateral biportal endoscopy for thoracic ossification of ligamentum flavum: A systematic review

Jun Li, PhD[1], Linbo Jiang, MD[2], Ting Zhang, PhD[3]

[1]Department of Orthopaedic, Affiliated Hospital of Southwest Jiaotong University, the Third People's Hospital of Chengdu, Chengdu, China
[2]Department of Radiology, Affiliated Hospital of Southwest Jiaotong University, the Third People's Hospital of Chengdu, Chengdu, China
[3]Department of General Surgery, Center of Obesity and Metabolic Diseases, Affiliated Hospital of Southwest Jiaotong University, the Third People's Hospital of Chengdu, Chengdu, China

ABSTRACT

Objectives: In this systematic review, we discuss the clinical efficacy and complications of unilateral biportal endoscopy (UBE) in the treatment of thoracic ossification of the ligamentum flavum (TOLF), providing surgeons with evidence-based guidance for optimal treatment decisions.

Materials and methods: We systematically searched the PubMed, EMBASE, Cochrane Library, CNKI, Wanfang, and VIP databases up to January 2025. Inclusion criteria encompassed studies reporting UBE outcomes for single/double-segment TOLF. Data on pain (Visual Analog Scale [VAS]), function (Oswestry Disability index [ODI] and Japanese Orthopaedic Association [JOA]), and complications were pooled using random-effects models. Minimal clinically important difference (MCID) was applied as the evaluative benchmark for clinical significance.

Results: Six studies (n=77) were analyzed. Significant improvements were observed in leg pain ($p<0.001$; 95% confidence interval [CI]: –6.63 to –3.57; I^2=88%), back pain ($p<0.0001$; 95% CI: –6.36 to –3.83; I^2=86%), ODI ($p<0.00001$; 95% CI: 31.00 to 53.53; I^2=95%), and JOA scores ($p<0.05$; 95% CI: 2.80 to 3.70; I^2=86%). The overall complication rate was 28% (2/6 reporting zero complications), predominantly mild (headache, hyperalgesia). Severe complications included dural tears (2.6%) and spinal cord injury (2.6%), with heterogeneity attributed to surgical technique evolution.

Conclusion: Preliminary evidence suggests UBE may be a promising minimally invasive approach for TOLF, potentially offering accelerated recovery and reduced perioperative morbidity. However, given the limited sample size and substantial heterogeneity, these findings require validation through large-scale prospective studies.

Keywords: Minimally invasive surgery, spinal stenosis, systematic review, thoracic ossification of ligamentum flavum, unilateral biportal endoscopy.

Ossification of ligamentum flavum (OLF) is a pathological heterotopic ossification process where the fibrous tissue of the ligamentum flavum transforms into bony tissue, with its incidence usually increasing with age. Mechanical stress, genetic susceptibility, metabolism, obesity, and other factors may be associated with OLF. The majority of OLF cases occur in the thoracolumbar, which is associated with the greater mobility of this region and the lack of support from the thoracic cavity.[1] Thoracic OLF (TOLF) is often accompanied by thoracic spinal stenosis and thoracic myelopathy.[2-5] Early clinical symptoms are usually not obvious, while as the condition progresses, it may manifest as unilateral or bilateral lower limb numbness, weakness, intermittent claudication, and dysfunction of bowel and bladder.

Conservative treatment for TOLF is usually ineffective, and early and thorough decompression is the key to treatment, typically requiring prompt

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Correspondence: Ting Zhang, PhD. Department of General Surgery, Center of Obesity and Metabolic Diseases, Affiliated Hospital of Southwest Jiaotong University, the Third People's Hospital of Chengdu, Chengdu, China.

E-mail: zhangting@swjtu.edu.cn

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removal of the ossified ligamentum flavum. However, the treatment of TOLF carries significant risks, such as dural tear, or spinal cord injury.[6] Open posterior thoracic laminectomy with spinal canal decompression remains the standard surgical procedure for treating TOLF. Nevertheless, manipulating the most severely compressed regions of the spinal cord during the procedure still carries inherent risks of iatrogenic spinal cord injury.[7-9] Moreover, the procedure inevitably damages the muscle-ligament complex and the facet joints, which needs instrumentation to maintain the stability of spine.

In recent years, spinal endoscopic techniques have evolved substantially, with growing applications in the management of TOLF. Single-channel endoscopy, despite its minimally invasive nature, is constrained by a narrow operative field, which amplifies risks of dural tears and spinal cord injury. These limitations are exacerbated by the steep learning curve of the technique.[10-12] Microscopic surgery, another minimally invasive option, demonstrates more reliable efficacy for TOLF; however, its adoption in resource-limited settings is impeded by the prohibitive cost of specialized equipment.[13,14] Furthermore, suboptimal visualization under air-mediated operating conditions compromises its practicality, particularly in complex thoracic cases.

Unilateral biportal endoscopy (UBE), a novel minimally invasive spinal technique, has emerged as a promising alternative. Compared to single-channel endoscopy and microscopy, UBE offers distinct advantages, including enhanced maneuverability, a reduced learning curve, and greater accessibility for broader clinical implementation.[15-17] However, its application in TOLF treatment still remains underreported, with insufficient data to conclusively establish its surgical protocols, safety profile, and long-term clinical outcomes. In this systematic review, we, for the first time in the literature, discuss the clinical efficacy and complications of UBE in the treatment of TOLF, providing surgeons with evidence-based guidance for optimal treatment decisions.

MATERIALS AND METHODS

This systematic review was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines.

Search strategy

We performed an extensive literature search in PubMed, EMBASE, Cochrane Library, China National Knowledge Internet (CNKI), Wanfang Data and Chines Science and Technology Periodical Database up to January 24th, 2025. The study is registered at PROSPERO (CRD420250649895). The search strategy was as follows: ((UBE) OR (unilateral biportal endoscopy)) AND ((((ossification of the thoracic ligaments flavum [Title/Abstract]) OR (thoracic ossification of ligamentum flavum [Title/Abstract])) OR (OLF[Title/Abstract])) OR (ossification of ligamentum flavum [Title/Abstract])). Inclusion criteria were as follows: *(i)* patients diagnosed with TOLF, *(ii)* UBE approach for TOLF, *(iii)* the lesion involves one or two segment to reduce heterogeneity in data (e.g., operation time, complications) across literature, and *(iv)* description of outcomes such as operation time, hospital stay, Visual Analog Scale (VAS), Oswestry Disability Index (ODI), Japanese Orthopaedic Association Scores (JOA) and complications. Exclusion criteria were as follows: *(i)* reviews, meta-analysis, animal research, technique report, *(ii)* patients diagnosed with thoracic ossification of posterior longitudinal ligament, *(iii)* inability to obtain the full article or related data, *(iv)* revision surgery and case report, and *(v)* cervical or lumbar spinal stenosis.

Data extraction and quality assessment

Two independent authors screened the articles by reading the titles, abstracts, and full texts according to the inclusion and exclusion criteria. Any disagreements were resolved through discussion. The quality of the included studies (observational studies) was assessed using the Newcastle-Ottawa Scale (NOS), based on study population selection, comparability of parameters, and outcomes evaluation by two independent researchers. Studies with more than seven "stars" were defined as high-quality studies and were included in the analysis.

Statistical analysis

Statistical analysis was performed using the RevMan version 5.4.1 software (R Foundation for Statistical Computing, Vienna, Austria). Quantitative data were expressed in mean difference (MD) and standard devation (SD), while qualitative data were expressed in risk difference (RD) and standard error (SE). Descriptive data were given for operative time and hospital stay. For VAS (back pain), VAS (leg pain), ODI, and JOA scores, we performed meta-analyses using the inverse variance method with a random-effects model to compare preoperative and final follow-up measurements. Minimal clinically important difference (MCID) was

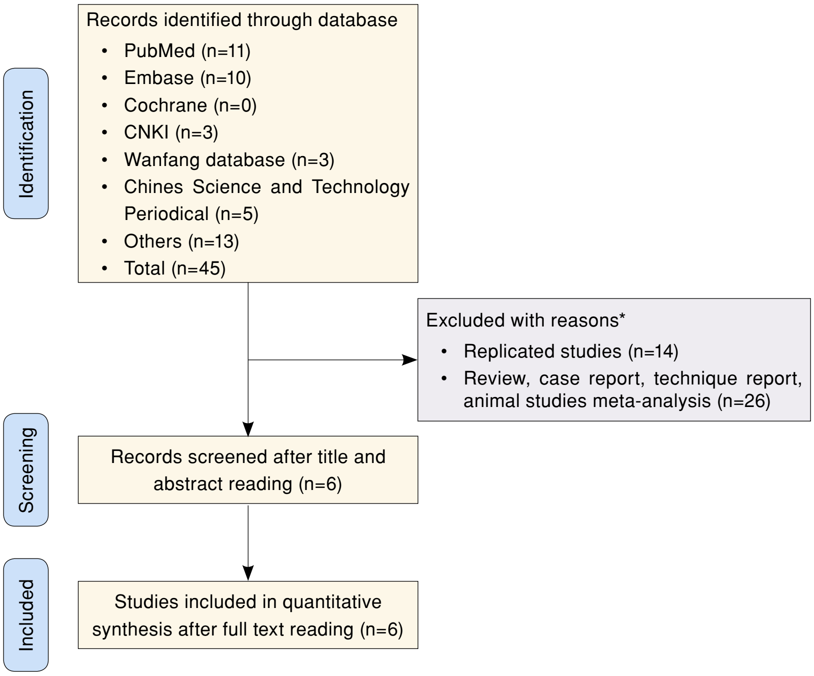

FIGURE 1. Study flowchart.
CNKI: China National Knowledge Internet; * One paper was excluded due to the above both reason.

applied as the evaluative benchmark for clinical significance. Complication rates were synthesized via the generic inverse variance approach. The size of heterogeneity was assessed using the I^2 statistic. I^2<50% indicated no significant heterogeneity among studies, and a fixed-effects model was used for analysis. I^2>50% indicated significant heterogeneity among studies, and a random-effect model was used for analysis. A p value of <0.05 was considered statistically significant with 95% confidence intervals (CIs).

RESULTS

Figure 1 presents the PRISMA-compliant flowchart delineating the systematic literature search and study selection process. Initial database queries identified 45 potentially relevant studies. Following duplicate removal through title screening, 31 unique records underwent abstract evaluation. This preliminary screening yielded 6 articles meeting the predefined inclusion criteria through title/abstract assessment. Subsequent full-text reading identified the six articles meet the inclusion criteria and included in this systematic review. The selected studies, encompassing a pooled cohort of 77 patients undergoing UBE surgery, were systematically evaluated for methodological quality. Table I provides a comprehensive summary of study characteristics and quality assessment

TABLE I
The characteristics of the included studies

	Year	Country	Study type	Sex Male/Female	Sample size	Age (year)	Follow-up (month)	NOS
				n	n	Mean±SD	Mean±SD	
Deng et al.[18]	2022	China	Retrospective	8/6	14	79.4±9.3	15.4±2.8	9
Yang et al.[19]	2023	China	Retrospective	6/5	11	58.2±3.5	17±1.6	8
Zhao et al.[20]	2023	China	Retrospective	8/4	12	54.1±1.7	14.0±1.3	8
Kim et al.[21]	2023	Korea	Prospective	9/7	16	60.4±9.7	17.4±4.4	9
Gatam et al.[22]	2024	Indonesia	Retrospective	9/9	18	56.1±2.3	36.6±4.5	9
Li et al.[23]	2024	China	Retrospective	2/4	6	65±6.4	10.2±2.4	8

SD: Standard deviation; NOS: Newcastle-Ottawa Scale.

TABLE II
The detail of complications of the included studies

Article	Year	Total patients	Complication	Detail of complications	
		n	n		n
Deng et al.[18]	2022	14	5	Hyperalgesia	2
				Neck or headache	2
				Cerebrospinal fluid leakage	1
Yang et al.[19]	2023	11	0	No complication	-
Zhao et al.[20]	2023	12	0	No complication	-
Kim et al.[21]	2023	16	9	Spinal cord injury	2
				Insufficient decompression	1
				Excessive facet decompression	1
				Subdural hematoma	1
				Epidural hematoma	1
				Delayed spinous process fracture	3
Gatam et al.[22]	2024	18	1	NO details on the complication were provided	-
Li et al.[23]	2024	6	1	Dural tear	1

outcomes. Table II presents the raw outcome data from the included studies, including operation time, hospital stay, VAS for back pain, VAS for leg pain, ODI and JOA.

Clinical outcomes

The clinical efficacy parameters we evaluated encompassed VAS for leg pain, VAS for back pain, ODI, and JOA. Due to significant heterogeneity (I^2>50%), all parameters were assessed using a random effects model.

VAS for back pain: Three studies with 33 patients described this parameter (Figure 2). The analysis demonstrated significant improvement in back pain VAS scores at final follow-up compared to preoperative assessments (p<0.0001; 95% CI: –6.36 to –3.83; I^2=86%). The magnitude of VAS reduction (Δ=–5.09.) surpassed the MCID threshold of 2.0 points (Figure 2).

VAS for leg pain: Three studies with 41 patients described this parameter (Figure 3). The analysis demonstrated significant improvement in leg pain VAS scores at final follow-up compared to preoperative assessments (p<0.001; 95% CI: –6.63 to –3.57; I^2=88%). The magnitude of VAS reduction (Δ=–4.96) surpassed the MCID threshold of 2.0 points (Figure 3).

Oswestry Disability Index: Two articles with 23 patients documented ODI (Figure 4). The analysis showed significant improvement in ODI at final follow-up compared to preoperative assessments (p<0.00001; 95% CI: 31.00 to 53.53; I^2=95%).

Japanese Orthopaedic Association Scores: As depicted in Figure 5, four studies with 60 patients described this parameter. The analysis demonstrated significant improvement in JOA at final follow-up compared to preoperative assessments (p<0.05; 95% CI: 2.80 to 3.70; I^2=86%).

Complications

As illustrated in Figure 6, a random-effects model was employed to account for substantial

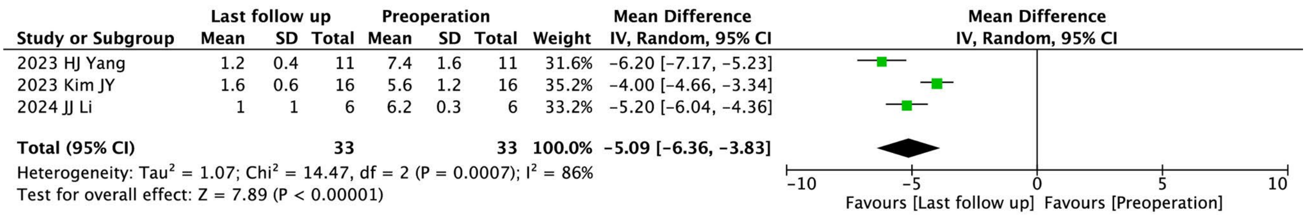

FIGURE 2. Forest plot of VAS for back pain.
SD: Standard deviation; CI: Confidence interval; VAS: Visual Analog Scale.

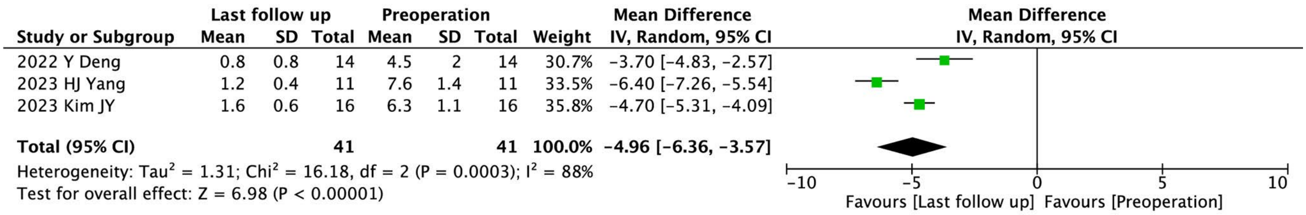

FIGURE 3. Forest plot of VAS for leg pain.
SD: Standard deviation; CI: Confidence interval; VAS: Visual Analog Scale.

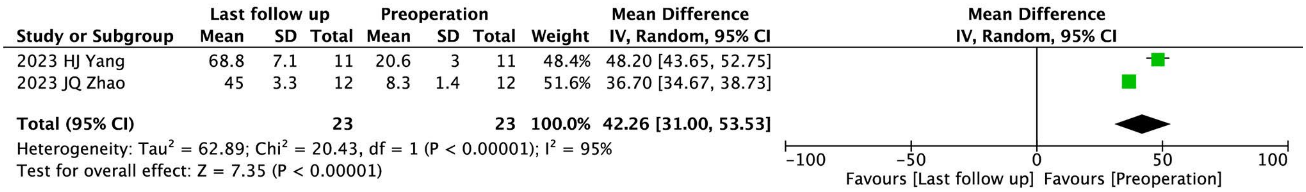

FIGURE 4. Forest plot of ODI.
SD: Standard deviation; CI: Confidence interval; ODI: Oswestry disability index.

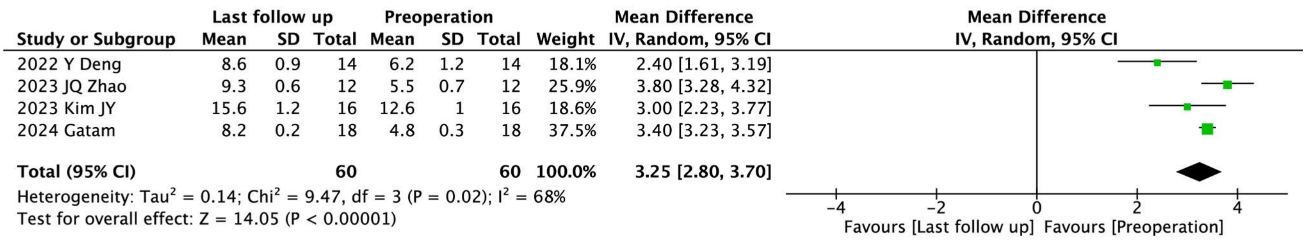

FIGURE 5. Forest plot of JOA.
SD: Standard deviation; CI: Confidence interval; JOA: Japanese Orthopaedic Association.

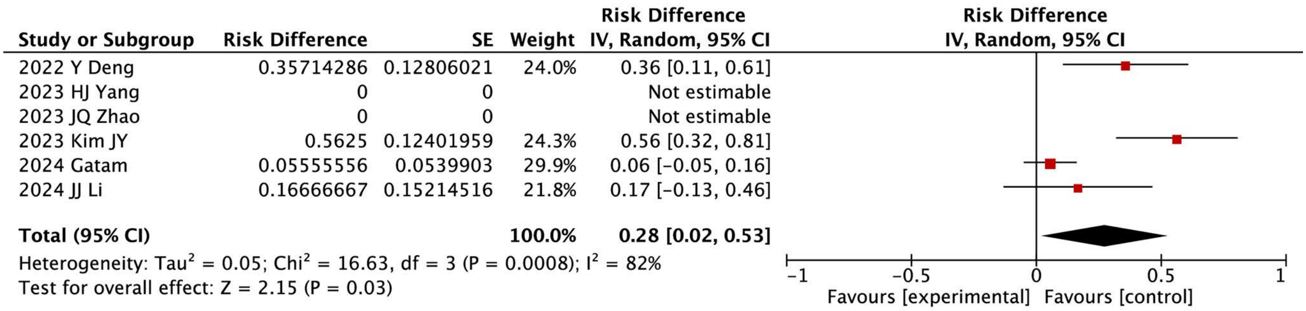

FIGURE 6. Forest plot of complications.
SD: Standard deviation; CI: Confidence interval.

heterogeneity across studies. Pooled analysis revealed an overall complication rate of 28% ($p<0.001<95\%$ CI: 0.02 to 0.53, $I^2=82\%$). The most frequently reported complications included headache and neck pain (n=2, 2.6%), hyperalgesia (n=2, 2.6%), dural tear (n=2, 2.6%), hematoma (n=2, 2.6%), and spinal cord injury (n=2, 2.6%). Surprisingly, an article reported three cases of delayed spinous process fractures, but this complication was not reported in other included literature (Table III).

Publication bias and sensitivity analysis

To evaluate publication bias for all the parameters, funnel plots were utilized (Figure 7). The findings indicated that all funnels were relatively symmetrical. Sensitivity analysis was conducted by excluding one study at a time

TABLE III
Outcomes of the included studies

Investigator	Year	Operation time (min)	Hospital stay (Day)	Back pain (VAS)		Leg pain (VAS)		ODI		JOA	
				Pre-op	Last follow-up	Pre-op	Last follow- up	Pre-op	Last follow-up	Pre-op	Last follow-up
	Year	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Deng et al.[18]	2022	66.1±14.4	4.9±1.5	NR	NR	4.5±2	0.8±0.8	NR	NR	6.2±1.2	8.6±0.9
Yang et al.[19]	2023	80±13.75	3.1±0.75	7.4±1.6	1.2±0.4	7.6±1.4	1.2±0.4	68.8±7.1	20.6±3	NR	NR
Zhao et al.[20]	2023	99±11.9	5.6±0.7	NR	NR	NR	NR	45±3.3	8.3±1.4	5.5±0.7	9.3±0.6
Kim et al.[21]	2023	106.6±38	7.1±2.9	5.6±1.2	1.6±0.6	6.3±1.1	1.6±0.6	NR	NR	12.6±1	15.6±1.2
Gatam et al.[22]	2024	62.5±13.7	4.0±1.25	NR	NR	NR	NR	NR	NR	4.8±0.3	8.2±0.2
Li et al.[23]	2024	158.2±43	NR	6.2±0.3	1±1	NR	NR	NR	NR	NR	NR

VAS: Visual Analog Scale; ODI: Oswestry disability index; JOA: Japanese Orthopaedic Association; Pre-op: Pre-operation; SD: Standard deviation; NR: Not reported.

randomly, and the results remained stable after removing any of the included studies.

DISCUSSION

The conventional surgical approach for TOLF involves an open total laminectomy, which removes the posterior spinal canal structures, such as the spinous process, ossified ligamentum flavum, bilateral laminae, and facet joints, to achieve neural decompression.[24,25] While effective in decompression, this approach carries considerable drawbacks: extensive resection of osseoligamentous structures paradoxically increases the risk of iatrogenic destabilization, potentially precipitating postoperative thoracic kyphosis. Furthermore, the open laminectomy is associated with substantial tissue trauma, significant intraoperative blood loss, and frequent reliance on supplemental instrumentation to restore spinal stability. These factors collectively amplify perioperative risks, including spinal cord injury, dural tears, and other procedure-related complications.

In parallel, spinal endoscopic technology has matured considerably, establishing percutaneous endoscopic surgery as a gold standard for lumbar disc herniation and lumbar spinal stenosis.[26-28] However, its application in treating TOLF remains contentious due to anatomical and technical complexities unique to the thoracic region. The thoracic spine presents distinct anatomical constraints, including narrow interlaminar spaces and a highly vulnerable spinal cord with limited tolerance to manipulation. Unlike the lumbar spine, the thoracic region offers minimal capacity for surgical space creation through traction or displacement maneuvers, significantly elevating

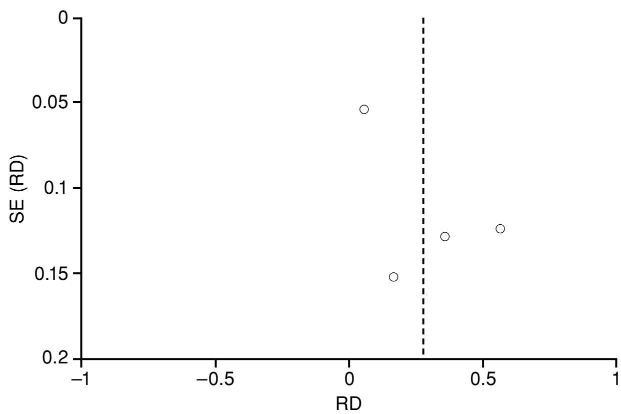

FIGURE 7. Funnel plot of the publication bias of complications.
SE: Standard error; RD: Risk difference.

the risk of neurological injury during endoscopic interventions.[19,21]

The emergence of UBE technology represents a significant advancement in minimally invasive management of TOLF. This innovative approach provides high-definition magnification of surgical anatomy through dual-portal visualization, significantly lowering iatrogenic risks to neural structures.[15] The integrated irrigation system facilitates continuous saline perfusion through the working channel, which serves dual purposes of homeostasis and visual maintenance while optimizing surgical workflow efficiency. Notably, the hydrodynamic environment created by this irrigation system mechanically removes inflammatory cytokines and surgical debris, thereby mitigating postoperative inflammatory responses and secondary stenosis risks. Furthermore, the aqueous medium acts as an effective thermal sink, dissipating energy generated during bone resection procedures to prevent neural thermal injury.

A distinctive technical advantage lies in the capacity of UBE to enable comprehensive bilateral decompression via unilateral approach while preserving over 50% of intact bony structures.[29-31] This preservation principle maintains thoracic spinal bio-mechanical stability, substantially reducing postoperative complications including segmental instability and kyphotic deformity. The minimized tissue trauma contributes to accelerated postoperative recovery. This enhanced recovery profile not only reduces hospitalization duration, but also facilitates faster return to occupational activities, demonstrating significant improvement in quality-of-life metrics.[32] Our systematic review demonstrated that UBE was feasible and effective in treating TLOF, with shorter operation time and hospital stays. Deng et al.[18] compared the clinical efficacy of UBE and open surgery in the treatment of TOLF. The median operation time for UBE was 66.1 min, significantly shorter than the average of 125 min for open surgery. The median hospitalization time for UBE was 4.9 days, significantly shorter than the 15.9 days for open surgery. This is because, under the UBE operating endoscope, which provides an enlarged field of vision, physiological saline irrigation and separation of the dural mater during the operation create operation space without destroying too much bone and muscle. Therefore, it is often not necessary to install instrumentation to maintain spinal stability, resulting in shorter operation time, faster recovery, and shorter hospitalization time. Our systematic review demonstrated satisfactory clinical outcomes with UBE decompression in managing TOLF. Pooled data revealed statistically significant improvements in pain (VAS) and functional metrics (ODI, JOA). Zhao et al.[20] reported comparable efficacy between UBE and open surgery in ODI and JOA improvement at one, six, and 12-month follow-up ($p>0.05$). While Deng et al.[18] identified certain advantages of UBE in VAS for leg pain resolution, demonstrating lower VAS scores and superior JOA scores at post-operation and one-year follow-up ($p<0.01$). Gatam et al.[22] also reported comparable JOA improvements at one month and six months of follow-up, while there were significant differences at 12 months follow-up, suggesting UBE's sustained biological advantage through minimized paraspinal muscle trauma. The observed heterogeneity in outcomes can be attributable to variations in follow-up duration, sample size disparities, differences in the number of affected segments, and variable surgical expertise. The considerable heterogeneity compromises both the generalizability and certainty of the pooled values. The pooled values are applicable only to patients with primary TOLF involving ≤2 vertebral segments. They should not be extrapolated to cases with ossification spanning >2 segments, bridging-type TOLF, or revision surgery. Furthermore, the wide 95% CIs reflect compromised robustness of pooled values due to heterogeneity. Future studies with larger samples and lower heterogeneity are warranted to enhance the conclusiveness of these findings. Based on previous literature and our systematic review, we still believe that UBE surgery is superior to open surgery in terms of clinical efficacy.

In the current study, we observed an overall complication rate of 28%, the most common complications is head or neck pain, hyperalgesia, dural tear and spinal cord injury. The pressure of water utilized during UBE surgery can elevate the cerebrospinal fluid pressure, potentially resulting in head and neck pain. Deng et al.[18] reported that effective muscle relaxation and shorter surgical duration could notably reduce the risk of postoperative head and neck pain. Lower limb hyperalgesia represents another prevalent complication of both spinal endoscopic and open surgeries. This could potentially be attributed to intraoperative nerve traction and heat conduction resulting from radiofrequency or drilling abrasion. Dural tear remains a critical intraoperative challenge in TOLF surgery, with our systematic review revealing a 2.6% incidence (2/77 cases) in UBE procedures-markedly lower than the 3.8 to 12.4% range reported for open decompression in contemporary series. Ye et al.,[33] in their meta-analysis, reported that the incidence of dural tear in TOLF treated with endoscopy was 6.2% (20/323). Kumar et al.[34] also reported a 7.4% incidence of dural tear in open surgery and 7.3% in endoscopic surgery in their meta-analysis. The incidence of this complication is closely related to the severity of OLF and whether the dural mater is ossified. Nerve root and spinal cord injuries are most serious complications of TOLF decompression. In traditional open surgery, nerve and spinal cord injuries occur with an incidence rate about 2.25%, which is closely related to the severity of ossification and the surgical experience of the surgeon.[32] Ye et al.[33] reported that the incidence of complications from neuro deficit in TOLF treated with endoscopy was 2.8% (9/323). Lin et al.[32] reported that the incidence of neurological deterioration rate was 2.25% in open surgery and 1.32% in endoscopic surgery. In our study, the overall incidence of spinal cord injury in UBE surgery was 2.6% (2/77), but only Kim et al.[21] reported two cases of spinal cord injury among six articles, and other five articles did not report this complication. The reason why Kim et al.[21] reported an abnormally high incidence of overall complications (9/16, 56.3%) and spinal cord injury (2/16, 12.5%) may be related to the researchers' attempts at two different decompression strategies. They pointed out that in their early attempts, they use the inside out piecemeal removal method have a high incidence of spinal cord injury and are prone to insufficient decompression. However, after gradually transitioning to the outside in *en bloc* method, no spinal cord injury occurred. At the same time, the authors also showed that the surgeon should be more careful doing the upper thoracic decompression due to smaller facet joints, thinner vertebral plates, and smaller spinous processes in the upper thoracic spine, which are prone to excessive decompression leading to delayed spinal process fractures. The pooled value of complication rate in this analysis demonstrates wide confidence intervals and substantial heterogeneity (95% CI: 0.02 to 0.53, I^2=82%), suggesting that UBE for TOLF carries significant technique-dependence and a steep learning curve. While experienced surgeons achieve low complication rates, novice operators or suboptimal case selection may significantly elevate complication risks.

Nonetheless, this study has certain limitations. First, all included studies were retrospective studies in Asian country, which may limit the robustness and reliability of our findings. Second, patients' lesion segments in the included studies are not consistent, including single segment and double segment lesions, which may reduce the representative of the data; Third, the number of literature and patients included in this study was relatively small; Fourth, the occurrence of certain complications in only a single study constitutes a methodological limitation. The UBE technique originated in South Korea and subsequently evolved and spread across various Asian countries. The significant paralysis risk associated with surgery for TOLF has hindered its widespread adoption in other regions. While this limitation may affect the generalizability of our study's conclusions, UBE would gain broader application in more European and American countries in the future. Additionally, our future research will incorporate more international data to validate the findings.

In conclusion, our results suggest that UBE may offer favorable therapeutic outcomes for TOLF, demonstrating improvements in leg pain VAS, back pain VAS, ODI, and JOA scores. Preliminary evidence also indicates potential advantages in reduced operative time and shorter hospitalization. Complication profiles appear usually acceptable, with predominantly minor events. However, given the methodological constraints-particularly limited sample size and substantial heterogeneity-these findings should be interpreted as hypothesis-generating. Definitive conclusions regarding UBE's efficacy and safety profile require validation through prospective, multi-center trials with standardized protocols and adequate statistical power.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Contributed to the conceptualization and design of the study: J.L., T.Z.; Conducted a systematic literature search and data analysis, contributing significantly to the interpretation of the data: J.L., L.J.; Was responsible for drafting the manuscript and performing the statistical review: J.L.; Provided a critical review of the manuscript and took primary responsibility for the final content: T.Z. All authors reviewed and approved the final version of the manuscript.

Conflict of Interest: The authors declared no conflicts of interest with respect to the authorship and/or publication of this article.

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