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SYSTEMATIC REVIEW **Open Access**

One-hole split endoscopy versus unilateral biportal endoscopy for lumbar degenerative disease: a systematic review and meta-analysis of clinical outcomes and complications

Chang Deng[1], Xugui Li[1], Congjun Wu[1*], Wei Xie[1] and Ming Chen[1]

Abstract

Background This study aims to systematically review and conduct a meta-analysis to assess the clinical outcomes and complications associated with the one-hole split endoscopy (OSE) and unilateral biportal endoscopy (UBE) in the treatment of lumbar degenerative disease, thereby offering a reference for clinical decision-making.

Methods A comprehensive literature search was conducted utilizing databases such as PubMed, Embase, Web of Science, Cochrane Database, China National Knowledge Network, Wanfang Database, and China Biomedical Literature Database, in conjunction with specific search terms. The retrieved literature was subsequently screened according to stringent inclusion and exclusion criteria. Systematic reviews and meta-analyses were performed using Stata 15.1 software.

Results A total of 513 patients were included across five studies, comprising 246 patients in the OSE group and 267 patients in the UBE group. The findings of this meta-analysis indicated that the incision length in the OSE group was significantly shorter than that in the UBE group (SMD = − 1.92, 95%CI: −3.03 to -0.80, $P = 0.001$). However, no statistically significant differences were observed between the two groups regarding operative duration, intraoperative blood loss, length of hospital stay, Visual Analog Scale (VAS) scores at various postoperative time points, Oswestry Disability Index (ODI) values at various postoperative time points, rates of excellent and good outcomes, sagittal translation (ST), range of motion (ROM), and complication rates.

Conclusions Both OSE and UBE techniques are considered safe and effective for the management of LDD, demonstrating comparable treatment outcomes. However, OSE techniques offer the advantages of smaller surgical incisions and potentially reduced trauma.

Keywords One-hole split endoscopy, Unilateral biportal endoscopy, Lumbar degenerative disease, Meta-analysis

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Introduction

Lumbar degenerative diseases (LDD) represent one of the most common spinal pathologies and are characterized by various conditions resulting from lumbar degeneration, such as lumbar disc herniation, lumbar spinal stenosis, and lumbar spondylolisthesis [1]. The majority of individuals affected by LDD report symptoms that include low back pain, pain in the lower extremities, functional limitations, and paresthesia [2–4]. In recent years, the rapid progression of aging has led to a year-on-year increase in its incidence, significantly impacting the quality of life for middle-aged and elderly individuals [5, 6]. This phenomenon not only presents a substantial threat to human health but also imposes considerable burdens on families and society as a whole. Surgical intervention becomes necessary when patients with LDD experience persistent or exacerbated symptoms despite prolonged conservative treatment [7, 8]. Over the past decade, endoscopic spinal surgery has gained popularity among patients due to its numerous advantages, including reduced blood loss, lower complication rates, expedited postoperative recovery, minimal disruption to bone and soft tissue, and enhanced clinical efficacy [9, 10]. In recent years, unilateral biportal endoscopy (UBE) and one-hole split endoscopy (OSE) have emerged as novel minimally invasive techniques in spinal surgery [11]. The former establishes two distinct channels: a visualization channel dedicated to endoscope placement and a working channel for device manipulation. In contrast, the latter integrates these two channels into a single channel, wherein the device and endoscope are spatially separated within that singular channel [12]. Both surgical techniques have demonstrated favorable outcomes and low complication rates in the treatment of LDD. However, no meta-analysis has been conducted to directly compare these two approaches. The objective of this study is to systematically gather and analyze robust evidence regarding the outcomes associated with each surgical technique, thereby providing pertinent evidence-based insights for the management of LDD.

Materials and methods

Study selection and search strategy

We conducted a systematic review and meta-analysis in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. Since OSE technology was first proposed in 2019, the relevant literature has been limited, and there is a lack of clearly defined subject terms. To enhance the comprehensiveness of our review, we employed the following search terms in the abstract: (((single port endoscope*) OR (one-hole endoscope*)) OR (split endoscope*)) AND (lumbar). The search databases utilized in this study include PubMed, Embase, Web of Science, Cochrane Database, China National Knowledge Network (CNKI), Wanfang Database, and the China Biomedical Literature Database (CBM), encompassing the time frame from January 2019 to November 30, 2024.

Inclusion and exclusion criteria

The criteria for inclusion in our meta-analysis were as follows: (1) Studies considered were published randomized controlled trials (RCTs) as well as retrospective or prospective cohort studies and case-control studies. (2) Each study group was required to include more than 10 patients, with a minimum follow-up duration of one year. (3) The studies needed to compare the efficacy of OSE and UBE in the treatment of LDD. (4) Sufficient data provision was necessary, encompassing surgical data, postoperative clinical or functional outcomes, and information on complications. Studies will be excluded if they fulfill any of the following criteria: (1) Studies that have not undergone peer review or lack pertinent data, including but not limited to case series, technical instructions, meeting reports, and review articles. (2) Publications of duplicate data or those with incomplete statistical data. (3) Research published in languages other than English or Chinese. All titles and abstracts of the reports were meticulously screened, followed by a thorough assessment of the full-text studies for eligibility based on the established inclusion and exclusion criteria. The reports deemed eligible were subjected to a comprehensive review, and relevant data were systematically recorded.

Assessment of literature quality

Two reviewers independently performed the literature screening and quality assessment. High-quality studies were selected based on the results of the quality assessment. Any discrepancies between the two assessors were resolved through discussions with a third adjudicator to achieve consensus. The quality of the included studies was evaluated using the Newcastle-Ottawa Scale (NOS) for observational studies and the Cochrane risk-of-bias (RoB 2) tool for randomized trials.

Data extraction

Data extraction was conducted independently by two researchers, with subsequent summarization and verification performed by a third researcher. The extracted demographic data encompassed the author, year of publication, country, study design, number of patients, age, gender, and follow-up duration. Surgical outcomes were also extracted, including operative duration, intraoperative blood loss, length of hospital stay and incision length. Clinical outcomes were systematically extracted, comprising ST, ROM, rates of excellent and good outcomes, complication rate, VAS scores for low back pain and leg pain at multiple time intervals, and ODI values at multiple time intervals. In instances where data is not accessible from the full text or supplementary materials, it is advisable to reach out to the article's author to request the data. In instances where the author is unavailable for contact, the specialized software (GetData Graph Digitizer 2.2.5 for Windows) is employed to extract the data.

The meta-analysis was conducted utilizing Stata 15.1 software. For continuous variables, the mean difference (MD) and 95% confidence interval (CI) were employed as effect size metrics, whereas for binary variables, the odds ratio (OR) and 95% confidence interval (CI) served as the effect size metrics. Heterogeneity across studies was evaluated utilizing the I^2 statistic and P-values. For datasets exhibiting no significant heterogeneity ($P < 0.05$, $I^2 < 50\%$), fixed effects models were employed. Conversely, in cases of significant heterogeneity, random effects models were applied. The risk of publication bias among studies was assessed using the Egger's test. In instances where significant publication bias was detected, Duval and Tweedie's trim-and-fill method was implemented to correct for publication and small study biases. The leave-one-out sensitivity analysis was performed to ascertain the influence of individual studies. A P-value of 0.05 was considered the threshold for statistical significance.

Results

Literature search results

In this study, a total of 73 articles were initially collected: 11 from PubMed, 22 from Embase, none from Web of Science, 1 from Cochrane Database, 14 from CNKI, 13 from the Wanfang Database, and 12 from CBM. Following the exclusion of duplicate entries, 34 studies remained. Upon reviewing the titles and abstracts, 6 articles were selected for further analysis. Subsequently, a full-text review revealed that the data from 1 article had been repeatedly published. Ultimately, a total of five studies were incorporated into the meta-analysis, comprising two studies conducted in English [13, 14] and three in Chinese [15–17]. Two studies [13, 17] conducted by the same research team were incorporated into the analysis. However, following meticulous examination and verification, the possibility of patient overlap was effectively eliminated. The screening procedure and corresponding outcomes are detailed in the PRISMA flowchart (Fig. 1).

Study characteristics and quality assessment

The characteristics and details of the included studies are delineated in Table 1. These five studies encompassed a cumulative total of 513 patients, with 246 participants in the OSE group and 267 in the UBE group. All studies were retrospective and originated from China. Overall, the quality of the included studies was deemed high according to the NOS. Table 2 provides a summary of the quality assessments based on the NOS for non-randomized studies.

Meta-analysis results

Operative duration

Five studies reported operative durations for the OSE and UBE groups, encompassing a total of 513 patients, with 246 in the OSE group and 267 in the UBE group. The analysis revealed substantial heterogeneity (I^2 = 92.2, $p < 0.001$) and was conducted using a random effects model. The meta-analysis indicated no statistically significant difference in operative time between the OSE and UBE groups (SMD = – 0.21, 95% CI: −0.87 to 0.44, $p = 0.527$; Fig. 2). A subgroup analysis stratified by disease type and case size revealed no sources of heterogeneity. Subsequently, a sensitivity analysis was conducted, demonstrating stability in the results. The potential source of heterogeneity may be attributed to the techniques of different operators.

Intraoperative blood loss

Four articles investigated intraoperative blood loss in the OSE and UBE groups, encompassing a total of 450 patients, with 220 participants in the OSE group and 230 in the UBE group. The analysis demonstrated significant heterogeneity (I^2 = 84.1%, $p < 0.001$), which was addressed using a random effects model. The meta-analysis indicated no statistically significant difference in intraoperative blood loss between the OSE and UBE groups (SMD = – 0.14, 95%CI: −0.63 to 0.34,$p = 0.557$; Fig. 3). A subgroup analysis, stratified by disease type and case size, identified no sources of heterogeneity. A subsequent sensitivity analysis confirmed the stability of the results. The potential source of heterogeneity may be attributed to the techniques of different operators.

Incision length

Five articles examined incision lengths in the OSE and UBE groups, encompassing a total of 513 patients, with 246 in the OSE group and 267 in the UBE group. The analysis revealed significant heterogeneity (I^2 = 96.0%, $p = 0.000$), and consequently, a random effects model was employed for the analysis. The meta-analysis revealed that the incision length in the OSE group was significantly shorter than that in the UBE group, with a statistically significant difference (SMD = – 1.92, 95% CI: −3.03 to -0.80, $P = 0.001$; Fig. 4). Subgroup analyses, stratified by disease type and case size, did not identify any sources of heterogeneity. Subsequent sensitivity analysis confirmed the stability of these findings, suggesting that the observed heterogeneity may be attributable to variations in surgical incision practices among different operators.

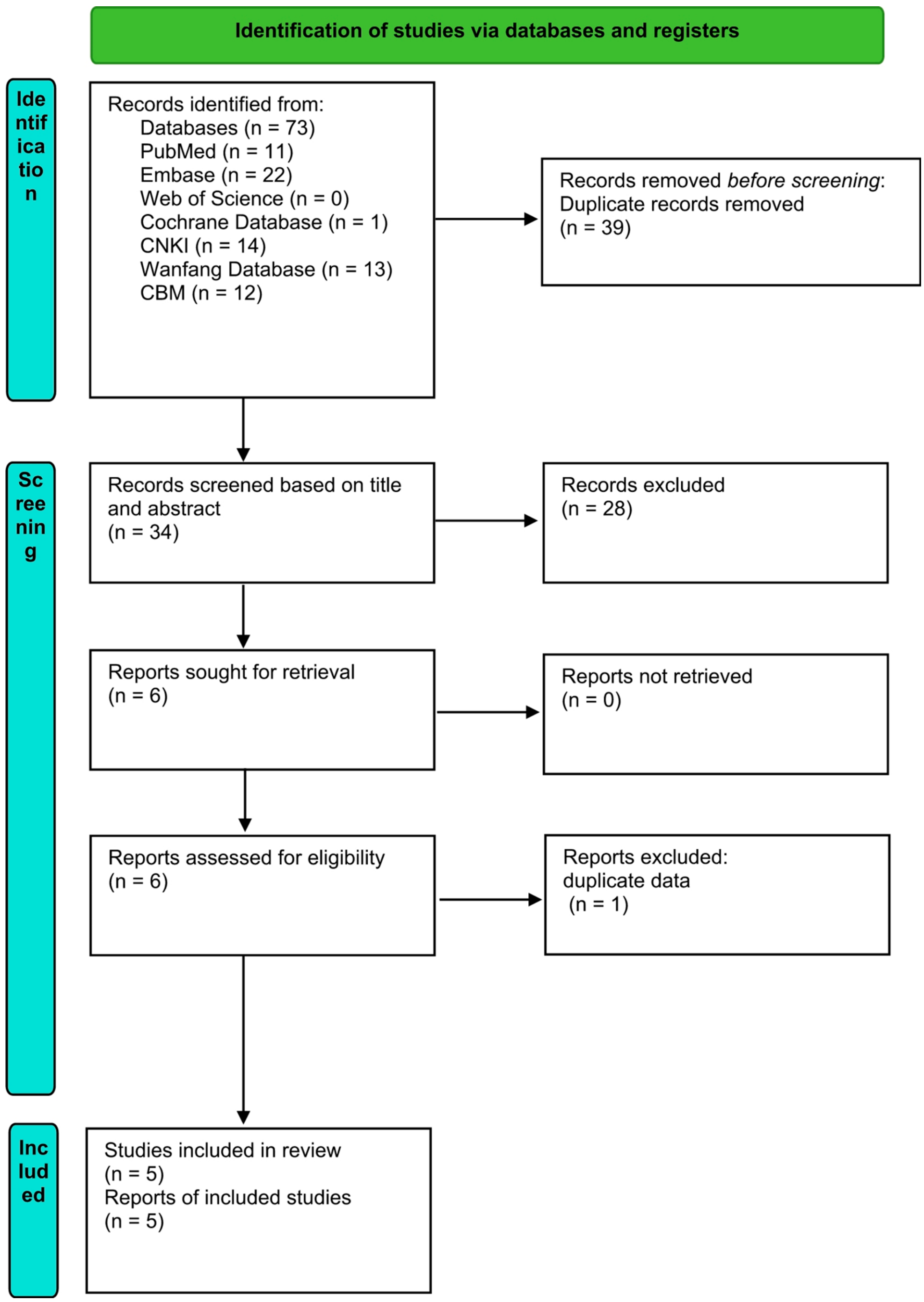

Fig. 1 PRISMA flow chart of literature search

Length of hospital stay

Four articles examined the length of hospital stay among patients in the OSE and UBE groups, encompassing a total of 450 patients, with 220 in the OSE group and 230 in the UBE group. The analysis revealed significant heterogeneity (I^2 = 82.3%, $p = 0.001$), prompting the use of a random effects model for analysis. The meta-analysis results indicated no statistically significant difference in the length of hospital stay between the OSE and UBE groups (SMD = 0.43, 95% CI: −0.03 to 0.89, $P = 0.068$; Fig. 5). Subgroup analyses stratified by disease type and case size did not reveal any sources of heterogeneity. Subsequent sensitivity analysis revealed instability in the results, potentially attributable to various factors. These factors encompass the turnover rate within the visiting department, the timing of suture removal prior to discharge, the post-operative assessment of inflammation indicator levels, and the occurrence of any complications.

Table 1 Characteristics of included studies

Study	Country design	Surgery procedures	Sample size	Age	Gender (M/F)	BMI	Follow-up duration
Zhang 2023	China	OSE	63	52.1 ± 12.3	42/21	24.7 ± 1.4	3d/3m/18m
	Retrospective	UBE	70	49.1 ± 11.2	42/28	24.9 ± 1.2	
Li 2024	China	OSE	52	61.15 ± 10.14	29/23	24.27 ± 2.73	3d/3m/6m/12m
	Retrospective	UBE	52	60.81 ± 9.81	28/24	24.59 ± 2.93	
Tang 2024	China	OSE	26	47.0 ± 18.9	11/15	24.9 ± 3.06	12 m
	Retrospective	UBE	37	51.3 ± 16.8	25/12	25.0 ± 3.86	
Xue 2024	China	OSE	26	45.23 ± 10.22	/	/	3 m/6m/12m
	Retrospective	UBE	28				
Zhang 2023	China	OSE	79	56.70 ± 11.75	37/42	23.64 ± 1.76	1d/3m/12m
	Retrospective	UBE	80	59.63 ± 7.97	32/48	23.27 ± 1.73	

Table 2 Newcastle-Ottawa scale for assessing the quality of studies in meta-analysis

Study	Selection of the study population	Comparability of groups	Outcome measures	Quality assessment
Zhang 2023	3	1	3	7
Li 2024	3	2	3	8
Tang 2024	3	1	3	7
Xue 2024	3	1	3	7
Zhang 2023	3	2	3	8

VAS scores for low back pain within postoperative three days

Two studies examined VAS scores for low back pain within three days post-surgery in the OSE and UBE groups. The total sample comprised 263 patients, with 131 individuals in the OSE group and 132 in the UBE group. The analysis revealed no heterogeneity in the results (I^2 = 0%, $p = 0.805$), and a fixed-effects model was employed for the analysis. The meta-analysis indicated no significant difference in VAS scores for low back pain within three days post-surgery between the OSE and UBE groups (SMD = -0.04, 95%CI:−0.28 to 0.20, $P = 0.757$; Fig. 6). Sensitivity analysis confirmed the stability of these findings.

VAS scores for leg pain within postoperative 3 days

Two articles examined VAS scores for leg pain within three days post-surgery in the OSE and UBE groups. The study encompassed a total of 263 patients, with 131 individuals in the OSE group and 132 in the UBE group. The analysis, conducted using a fixed effects model, revealed no heterogeneity in the results (I^2 = 0%, $p = 0.580$). The meta-analysis indicated that there was no statistically significant difference in VAS scores for leg pain within three days post-surgery between the OSE and UBE groups (SMD = 0.06, 95%CI: −0.30 to 0.19, $P = 0.655$; Fig. 7). Furthermore, a sensitivity analysis confirmed the robustness of these findings.

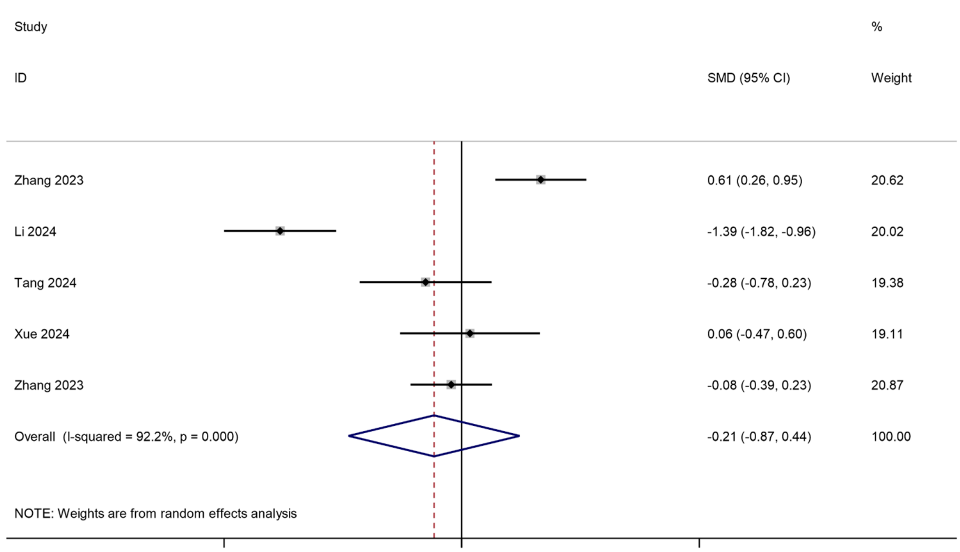

Fig. 2 Forest plot of operative durations

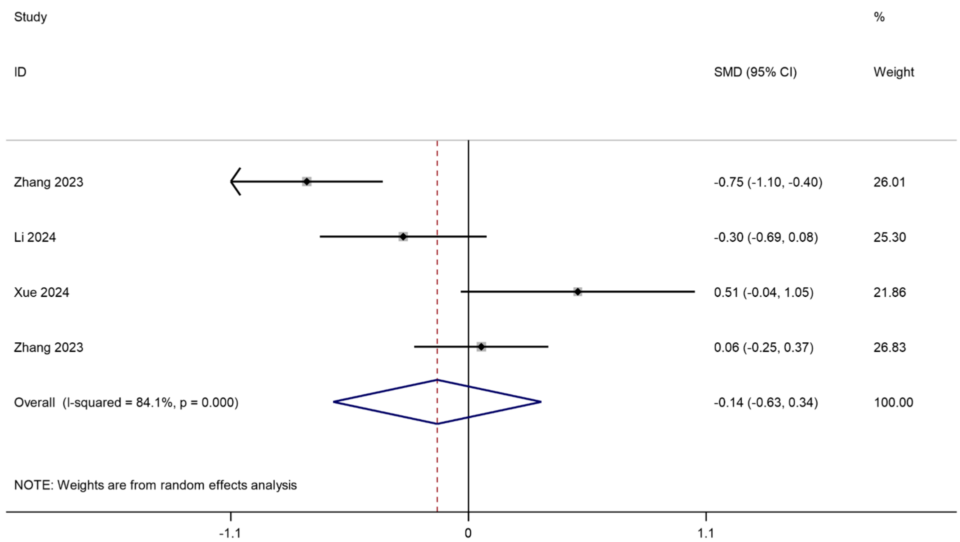

Fig. 3 Forest plot of intraoperative blood loss

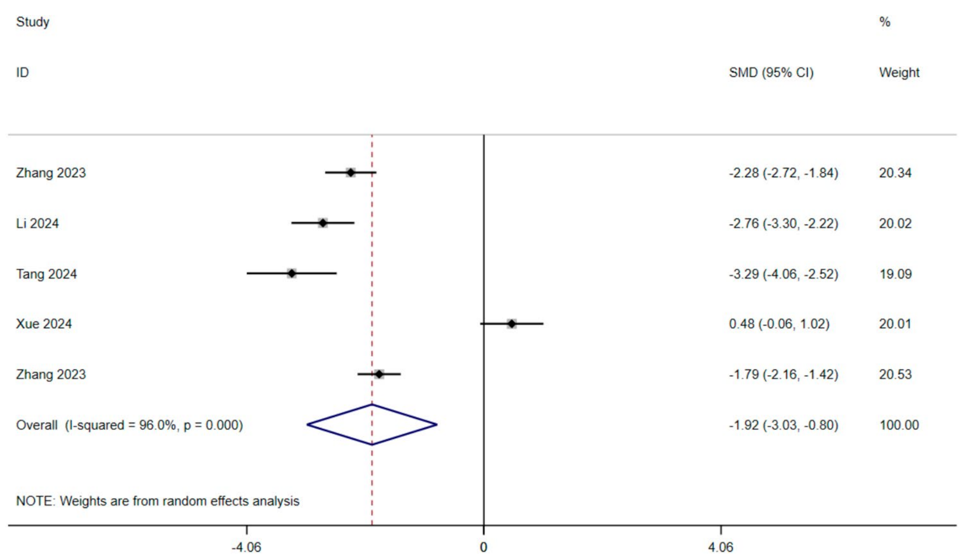

Fig. 4 Forest plot of incision length

VAS scores for low back pain at postoperative 3 months

Three studies examined the VAS scores for low back pain at postoperative 3 months in both the OSE group and the UBE group. An additional study that combined VAS scores for both low back pain and leg pain was excluded from the analysis. The total sample comprised 396 patients, with 194 in the OSE group and 202 in the UBE group. The analysis, conducted using a fixed effects model, revealed no heterogeneity in the results (I^2 = 0%, $p = 0.895$). The meta-analysis indicated no statistically significant difference in VAS scores for low back pain at postoperative 3 months between the OSE and UBE groups (SMD = -0.04, 95%CI: -0.23 to 0.16, $P = 0.722$; Fig. 8). Furthermore, sensitivity analysis confirmed the robustness of these findings.

VAS scores for leg pain at postoperative 3 months

Four articles provided data on the VAS scores for leg pain at postoperative 3 months in both the OSE and UBE groups. An additional article that combined VAS scores for back and leg pain was excluded from the analysis. The study encompassed a total of 396 patients, with 194 individuals in the OSE group and 202 in the UBE group. The analysis, conducted using a fixed effects model, revealed no heterogeneity among the results (I^2 = 0%, $p = 0.374$). The meta-analysis indicated no significant difference in VAS scores for leg pain at postoperative 3 months between the OSE and UBE groups (SMD = 0.02, 95%CI: −0.18 to 0.21, $P = 0.879$; Fig. 9). Furthermore, sensitivity analysis confirmed the stability of these results.

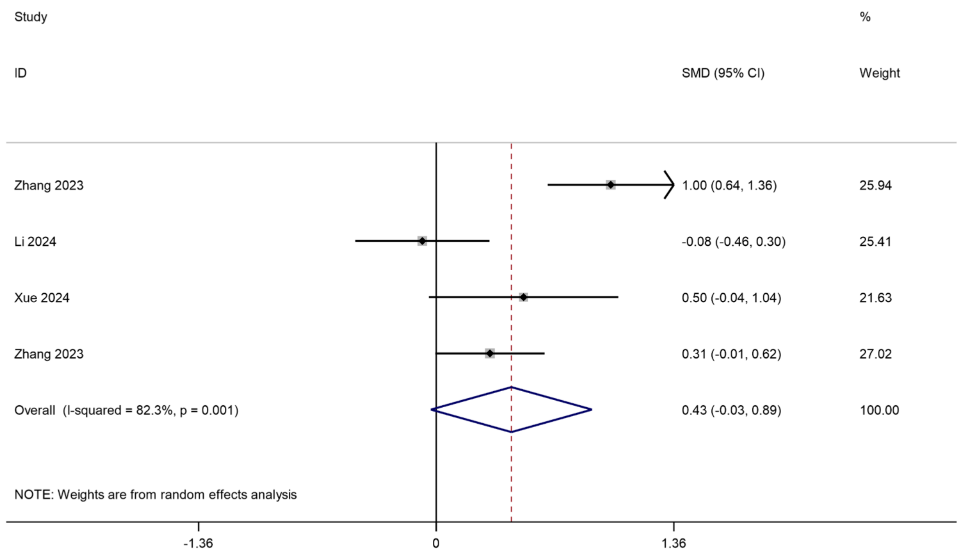

Fig. 5 Forest plot of length of hospital stay

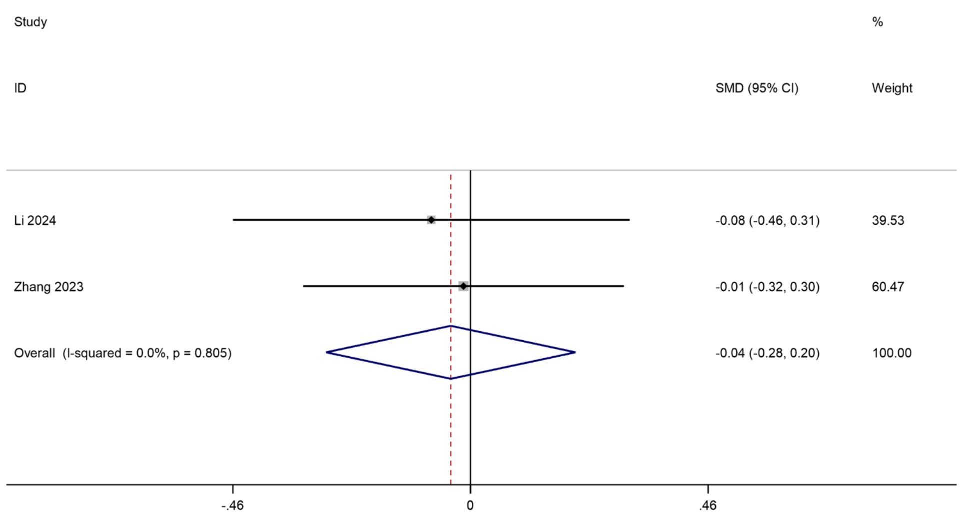

Fig. 6 Forest plot of VAS scores for low back pain within postoperative three days

VAS scores for low back pain at final follow-up

Four articles provided data on the VAS scores for low back pain at the final follow-up for both the OSE group and the UBE group. An additional article that combined VAS scores for both low back pain and leg pain was excluded from our analysis. The study encompassed a total of 459 patients, with 220 in the OSE group and 239 in the UBE group. The analysis revealed no heterogeneity among the results (I^2 = 0%, $p = 0.951$), and a fixed-effects model was employed for the statistical evaluation. The meta-analysis findings indicated that there was no statistically significant difference in the VAS scores for low back pain at the final postoperative follow-up between the OSE and UBE groups (SMD = -0.09, 95%CI: -0.27 to 0.10, $P = 0.525$; Fig. 10). Sensitivity analysis confirmed the stability of these results.

VAS scores for leg pain at final follow-up

Four articles provided data on the VAS scores for leg pain at the final follow-up for both the OSE group and the UBE group. One additional article, which combined VAS scores for both back and leg pain, was excluded from our analysis. The study encompassed a total of 459 patients, with 220 patients in the OSE group and 239 patients in the UBE group. The analysis revealed considerable heterogeneity in the results (I^2 = 72.5%, $p = 0.012$), prompting the use of a random effects model for further examination. The meta-analysis indicated that there was no statistically significant difference in the VAS score for leg pain at the final follow-up between the OSE and UBE groups (SMD = -0.21, 95%CI: -0.57 to 0.15, $P = 0.251$; Fig. 11). Sensitivity analysis confirmed the stability of these results. However, an assessment for publication bias using Egger's test revealed the presence of bias

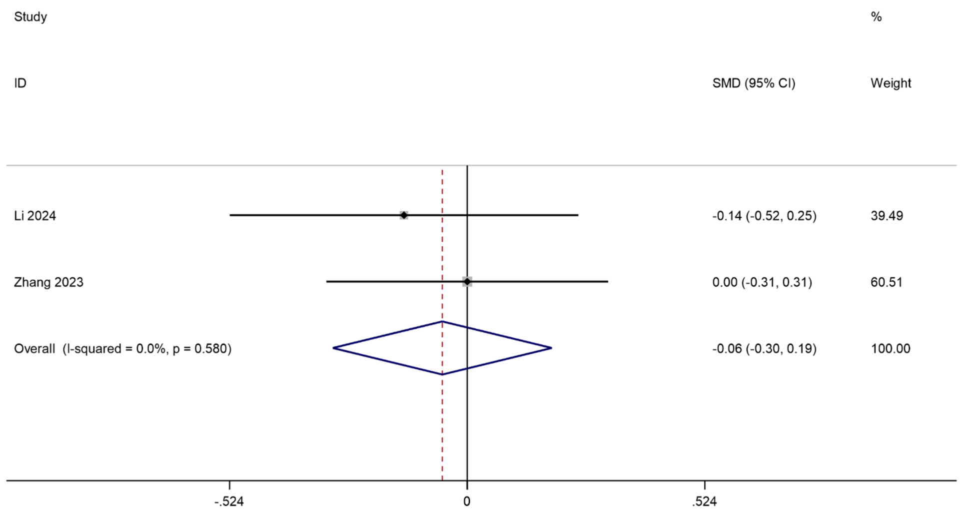

Fig. 7 Forest plot of VAS scores for leg pain within postoperative three days

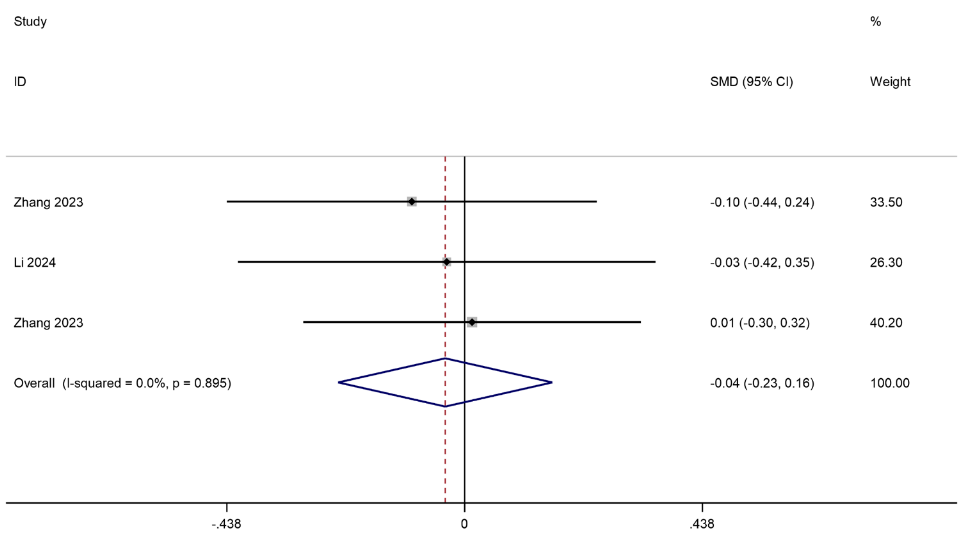

Fig. 8 Forest plot of VAS scores for low back pain at postoperative 3 months

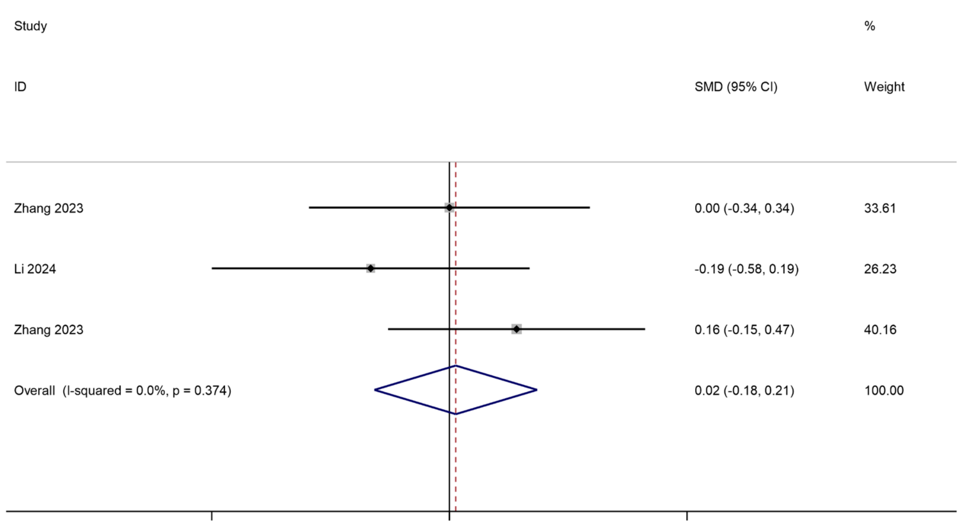

Fig. 9 Forest plot of VAS scores for leg pain at postoperative 3 months

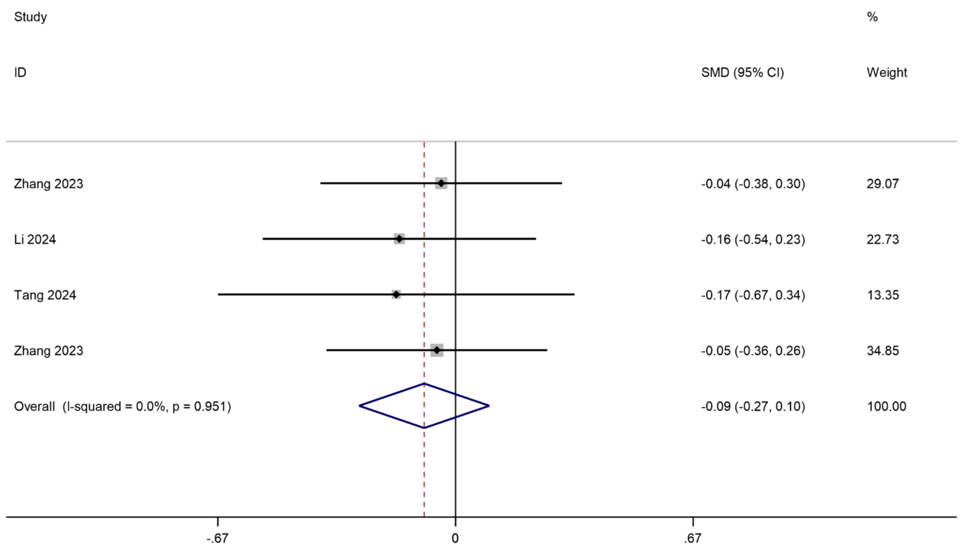

Fig. 10 Forest plot of VAS scores for low back pain at final follow-up

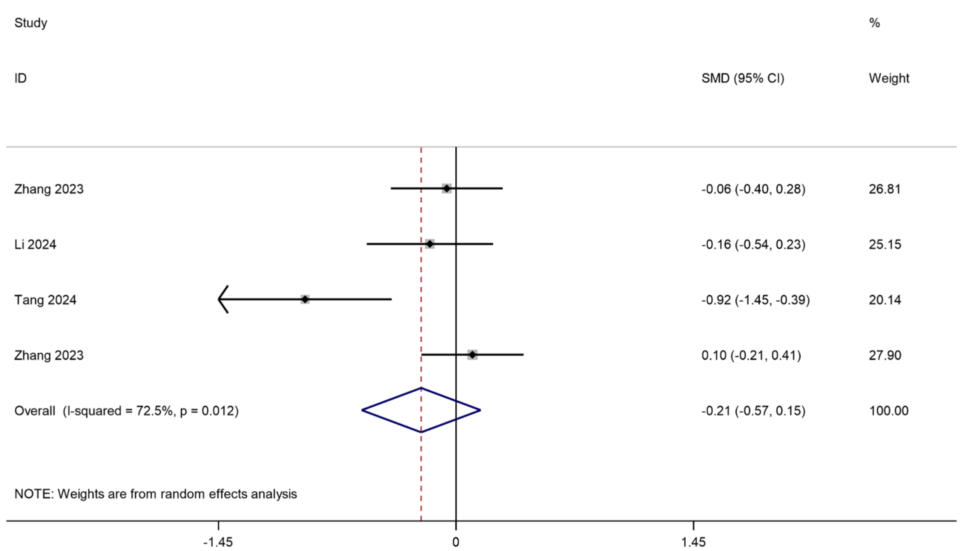

Fig. 11 Forest plot of VAS scores for leg pain at final follow-up

($P = 0.008$). After correcting for publication bias, the VAS score for leg pain at the final follow-up post-surgery was (SMD = -0.34, 95% CI: -0.73 to 0.05, $P = 0.251$).

ODI values at postoperative 3 months

Four articles examined the ODI values at postoperative 3 months in both the OSE and UBE groups. The study encompassed a total of 450 patients, with 220 in the OSE group and 230 in the UBE group. The analysis revealed no heterogeneity in the results (I^2 = 0%, $p = 0.607$), and a fixed-effects model was employed. The meta-analysis indicated no significant difference in ODI values at postoperative 3 months between the OSE and UBE groups (SMD = -0.04, 95%CI: -0.22 to 0.15, $p = 0.700$; Fig. 12). Furthermore, sensitivity analysis confirmed the stability of the results.

ODI values at postoperative 6 months

Two articles reported the ODI values at postoperative 6 months for both the OSE group and the UBE group. The study encompassed a total of 167 patients, with 78 individuals in the OSE group and 89 in the UBE group. The analysis revealed no heterogeneity in the results (I^2 = 0%, $p = 0.438$), and a fixed-effects model was employed for the analysis. The meta-analysis indicated no significant difference in ODI values at postoperative 6 months between the OSE and UBE groups (SMD = 0.05, 95%CI: −0.26 to 0.36, $p = 0.766$; Fig. 13). Sensitivity analysis demonstrated the stability of the results.

ODI values at final follow-up

Five articles examined the ODI values at the final follow-up after surgery in both the OSE group and the UBE

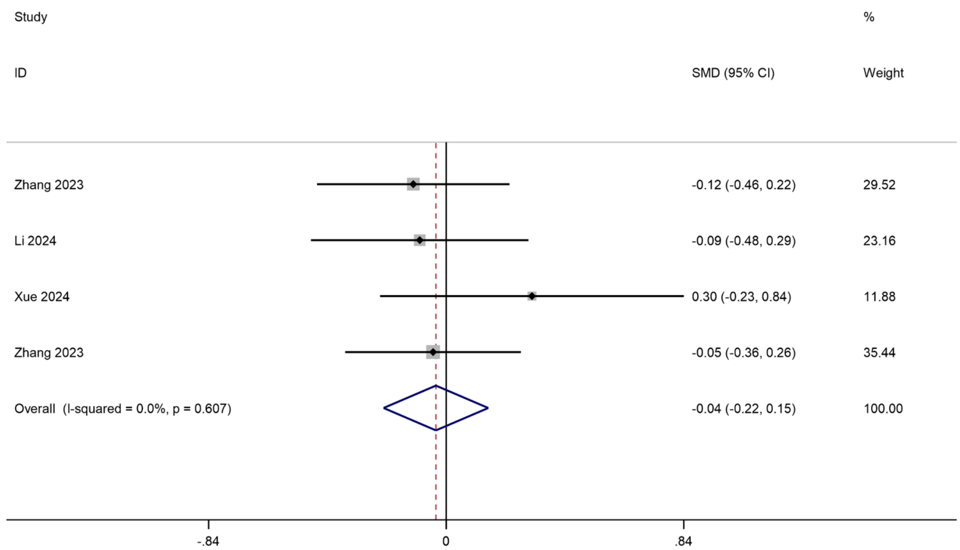

Fig. 12 Forest plot of ODI values at postoperative 3 months

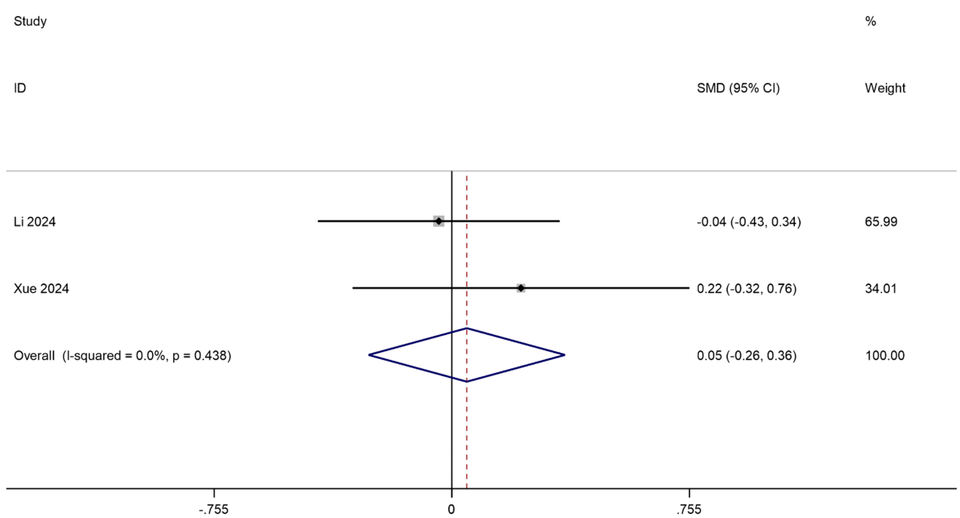

Fig. 13 Forest plot of ODI values at postoperative 6 months

group. The study encompassed a total of 513 patients, with 246 individuals in the OSE group and 267 in the UBE group. The analysis indicated no heterogeneity among the results (I^2 = 0%, $p = 0.600$), and a fixed effects model was employed. The meta-analysis revealed no statistically significant difference in ODI values at the postoperative final follow-up between the OSE and UBE groups (SMD = 0.00, 95%CI: −0.17 to 0.18, $P = 0.978$; Fig. 14). Furthermore, sensitivity analysis confirmed the stability of these findings.

Rates of excellent and good outcomes

Four articles documented the results of the postoperative excellent and good rates, in both the OSE and UBE groups. The studies collectively included a sample size of 450 patients, with 220 patients in the OSE group and 230 in the UBE group. The analysis indicated no heterogeneity among the results (I^2 = 0%, $p = 0.431$), allowing for the application of a fixed-effects model. The meta-analysis revealed no statistically significant difference in the postoperative excellent and good rates between the OSE and UBE groups (SMD = 0.86, 95% CI: 0.45 to 1.65, $P = 0.655$; Fig. 15). Furthermore, sensitivity analysis confirmed the stability of these findings.

Alterations in ST

Three studies investigated alterations in ST within the OSE and UBE groups, encompassing a total of 396 patients, with 194 in the OSE group and 202 in the UBE group. The analysis revealed no heterogeneity among the results (I^2 = 0%, $p = 0.822$), and a fixed-effects model was employed for the analysis. The meta-analysis indicated no statistically significant difference in the changes of ST between the OSE and UBE groups (SMD = 0.04, 95% CI:

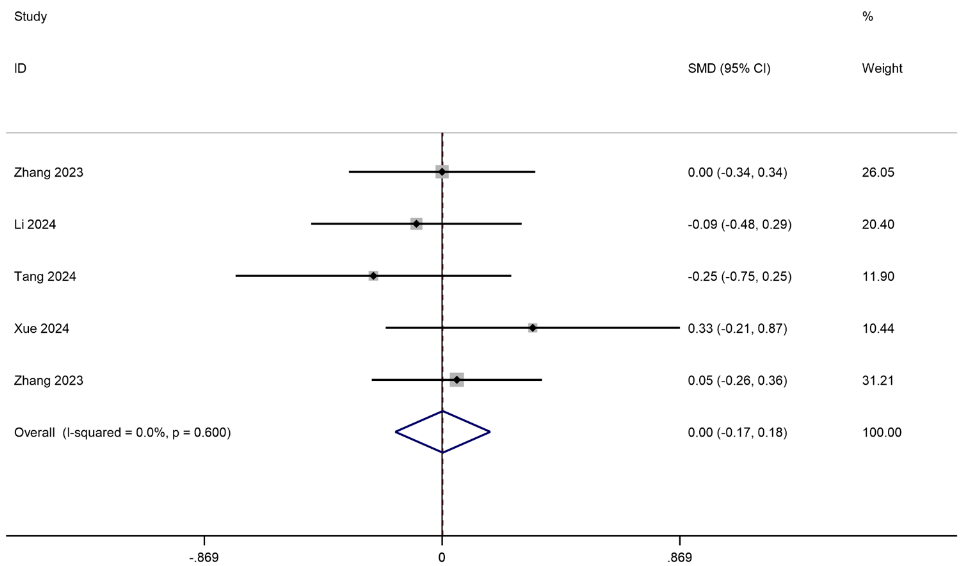

Fig. 14 Forest plot of ODI values at final follow-up

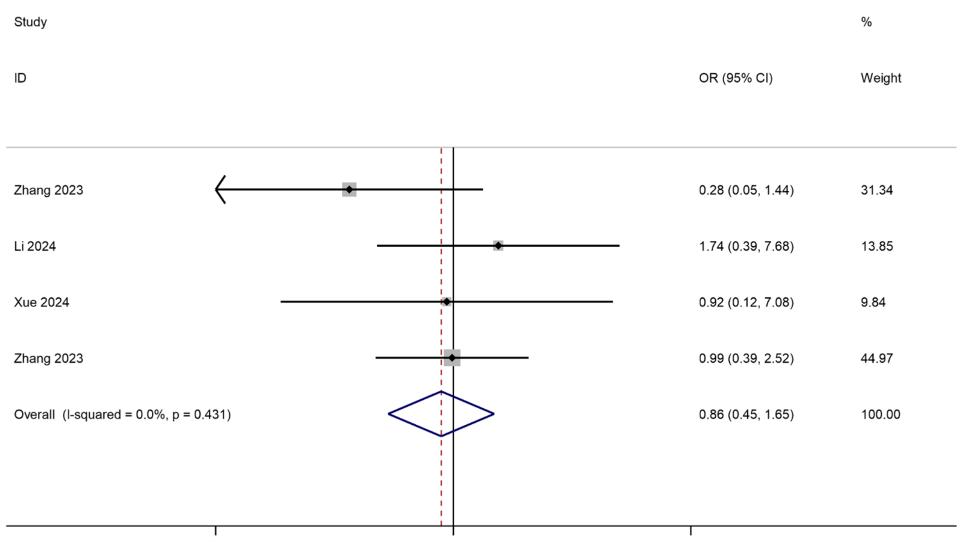

Fig. 15 Forest plot of the postoperative excellent and good rates

-0.24 to 0.15, $P = 0.657$; Fig. 16). Furthermore, sensitivity analysis confirmed the stability of these findings.

Alterations in ROM

Alterations in ROM were examined in three studies focusing on the OSE and UBE groups. The total sample consisted of 396 patients, with 194 in the OSE group and 202 in the UBE group. The analysis revealed no heterogeneity among the results (I^2 = 0%, $p = 0.997$), and a fixed effects model was employed. The meta-analysis indicated no statistically significant difference in the changes of ROM between the OSE and UBE groups (SMD = 0, 95%CI: -0.20 to 0.20, $p = 0.987$; Fig. 17). Sensitivity analysis confirmed the stability of these findings.

Complications

Five articles reported on complication rates within the OSE and UBE groups. The study encompassed a total of 513 patients, with 246 in the OSE group and 267 in the UBE group. The analysis indicated no heterogeneity in the results (I^2 = 0%, $p = 0.824$), and a fixed effects model was employed. The meta-analysis revealed no significant difference in the incidence of complications between the OSE and UBE groups (SMD = 0.60, 95% CI: 0.18 to 1.95, $p = 0.394$; Fig. 18). Sensitivity analysis confirmed the stability of these findings.

Publication bias

The risk of publication bias was evaluated using Egger's test, and the results indicated no publication bias for

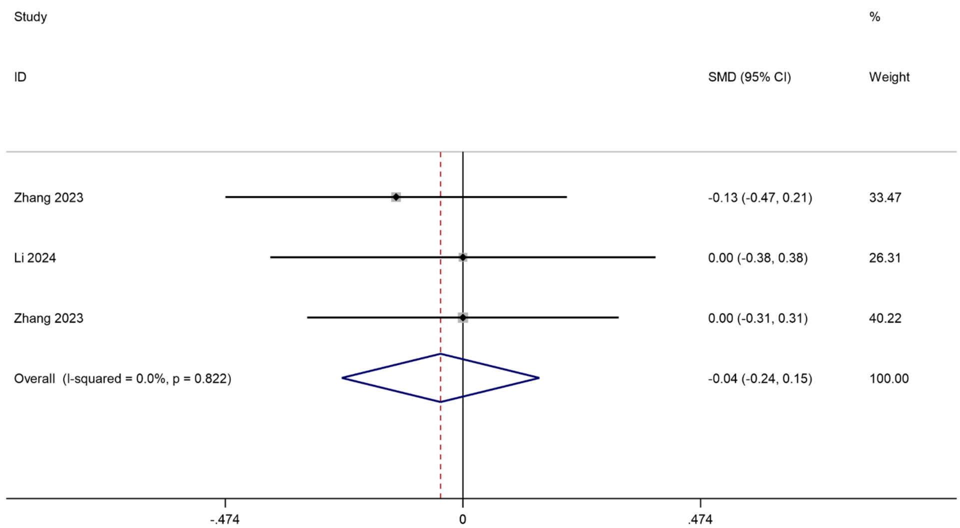

Fig. 16 Forest plot of alterations in ST

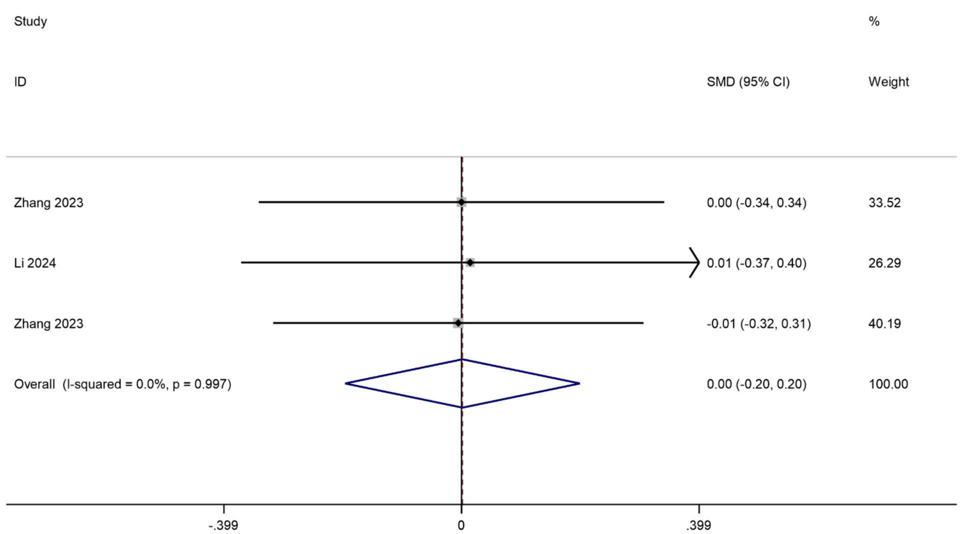

Fig. 17 Forest plot of alterations in ROM

the vast majority of surgical outcome variables. Specifically, the p-values were as follows: operative duration ($p = 0.605$), intraoperative blood loss ($p = 0.612$), incision length ($p = 0.830$), length of hospital stay ($p = 0.968$), VAS scores for low back pain at postoperative 3 months ($p = 0.737$), VAS scores for leg pain at postoperative 3 months ($p = 0.052$), VAS scores for low back pain at final follow-up ($p = 0.202$), ODI values at postoperative 3 months ($p = 0.162$), ODI values at final follow-up ($p = 0.945$), Rates of excellent and good outcomes ($p = 0.907$), Alterations in ST ($p = 0.992$), Alterations in ROM ($p = 0.097$), and complication rate ($p = 0.263$).

Discussion

LDD is prevalent in the field of orthopedics. Conventional open surgical procedures can result in significant damage to the posterior ligament complex, induce steatosis and atrophy of the posterior spinal structures, and lead to prolonged chronic lumbar and back pain as well as muscle weakness in the lumbar region, thereby negatively impacting the patient's quality of life [18–20]. With the ongoing advancement of medical standards and the extensive development of minimally invasive surgical techniques, spinal endoscopic technology has become a conventional approach in the treatment of LDD [21]. Among the emerging minimally invasive spinal surgery methods are the OSE and UBE techniques, both of which have demonstrated promising outcomes in the management of LDD [22]. Nevertheless, a definitive conclusion regarding the superiority or inferiority of these two techniques, as well as a comprehensive safety comparison, remains to be established. To address this uncertainty, we undertook a study involving a meta-analysis of five high-quality studies, encompassing a total of 513 patients. This

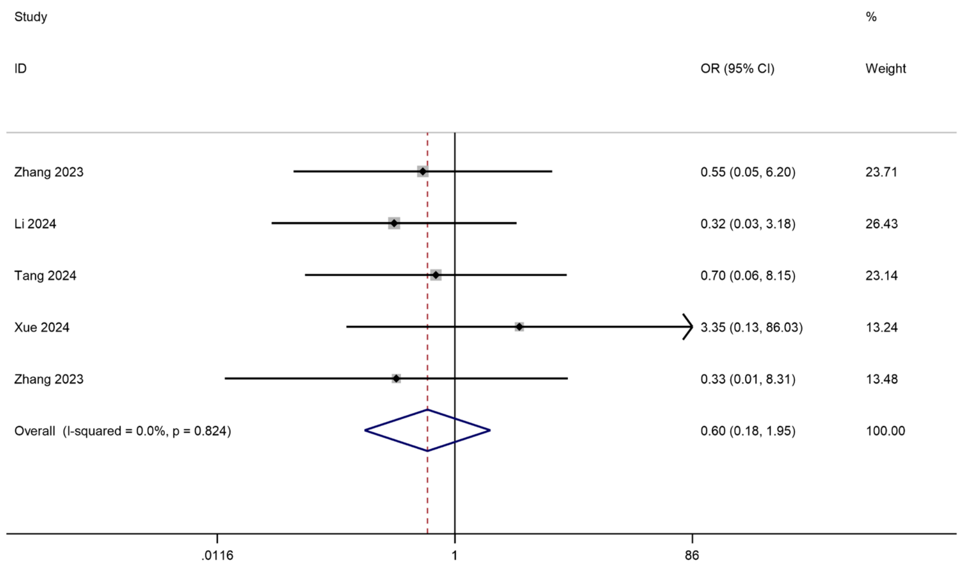

Fig. 18 Forest plot of Complications

analysis focused on perioperative data, clinical outcomes, and associated complications.

Regarding surgical outcomes, this study demonstrated that the OSE group exhibited reduced operating time and intraoperative blood loss, as well as an extended hospital stay, compared to the UBE group. However, these differences were not statistically significant. The pooled analysis of both groups revealed considerable heterogeneity in operating time and intraoperative blood loss, potentially attributable to the techniques of different operators. It is important to note that all surgical methods are subject to a learning curve, and the operating time for clinical procedures tends to stabilize after a sufficient number of cases have been performed [23, 24]. For instance, unilateral biportal endoscopic transforaminal lumbar interbody fusion (ULIF) requires a steep learning curve—with at least 29 cases for master and 41 cases for stable outcomes [25]. In the context of UBE technology, surgeons possessing experience in arthroscopy or demonstrating proficient hand coordination may achieve reduced operating times. However, for OSE technology, surgeons with expertise in percutaneous endoscopic transforaminal discectomy surgery or open lumbar surgery may also experience shorter operating durations. Sensitivity analysis confirmed the robustness of the findings, and Egger's test indicated the absence of significant publication bias. An integrated analysis of the duration of hospital stays across the two groups revealed significant heterogeneity in the outcomes. Subsequent subgroup analyses failed to identify any sources of this heterogeneity. Sensitivity analysis indicated a lack of stability in the results. However, no evident publication bias was detected. This absence of bias may be attributable to various factors, including the turnover rate within the visiting department, the timing of suture removal before discharge, the post-operative assessment of inflammation indicator levels, and the occurrence of any additional complications. An analysis of surgical incision lengths between the two groups indicated that the OSE group exhibited smaller incisions, a finding that can be attributed to the utilization of distinct surgical incision techniques. UBE technology typically involves the creation of two distinct working channels: an observation channel and an operational channel [26]. In contrast, the OSE technique differentiates the working channel from the scope while maintaining a single surgical channel [27]. This approach results in only a skin incision, which is theoretically less traumatic. Sensitivity analysis and the Egger test confirmed the reliability of these findings, indicating no significant publication bias.

This study demonstrated that, regarding clinical outcomes, there was no statistically significant difference between the OSE and UBE groups in terms of the VAS scores for low back and leg pain within postoperative three days, as well as the VAS scores for low back and leg pain at postoperative three months, and the VAS scores for low back pain at the final follow-up. Additionally, no heterogeneity was observed. Sensitivity analysis and the Egger's test confirmed the reliability of the results and indicated an absence of publication bias. Furthermore, there was no statistical significance or heterogeneity in the VAS scores between the two groups at the final follow-up visit. The sensitivity analysis indicated that the results were robust. However, Egger's test revealed the presence of publication bias ($p = 0.008$). The "trim and fill" method imputed 1 study, and the effect size after imputation (SMD = -0.34, 95%CI: -0.73 to 0.05) was similar to the observed effect size (SMD = -0.21, 95%CI: -0.57 to 0.15). This suggests that the findings may be attributable to a limited number of studies included in the analysis. Simultaneously, there was no statistically significant difference observed between the two groups regarding the ODI values at three months and six months postoperatively, as well as at the final postoperative follow-up. Furthermore, there were no statistically significant differences observed in the rates of excellent and good outcomes. And no heterogeneity was detected. Sensitivity analysis and Egger's test confirmed the reliability of these results and indicated an absence of publication bias. These findings suggest that both surgical methods can achieve satisfactory clinical outcomes in the treatment of LDD.

Complications represent a critical consideration for both surgeons and patients [28]. The findings of this study indicated that there was no statistically significant difference in the changes of ST and ROM between the OSE and UBE groups, with no observed heterogeneity. Sensitivity analysis and Egger's test confirmed the reliability of the results and the absence of publication bias. These outcomes suggest that neither surgical method is associated with evident lumbar instability. Subsequent analysis revealed that complications arose in 4 out of 246 patients (1.63%) within the OSE group, compared to 8 out of 267 patients (3.00%) in the UBE group. Despite the absence of a statistically significant difference between the two cohorts, the complication rate observed in the OSE group was notably lower than that in the UBE group. In the OSE group, the prevalent complications included transient hypoaesthesia ($n=1$), dural tear ($n=1$), nerve root injury ($n=1$), and superficial infection ($n=1$). In contrast, the UBE group experienced common complications such as transient hypoaesthesia ($n=1$), dural tear ($n=4$), postoperative epidural hematoma ($n=1$), pseudo-spinal hypertension ($n=1$), and erector spinae muscle hernia ($n=1$).

Research indicates that the manifestation of pain and numbness is attributed to two distinct sensory nerves [29]. Of these, one nerve fiber is comparatively thicker and possesses a myelin sheath, which is associated with the sensation of numbness. In contrast, the other nerve fiber is relatively thinner and lacks a myelin sheath, which is linked to the sensation of pain [30]. Pain is generally perceived as more distressing than numbness and may obscure the presence of numbness prior to surgical intervention. Upon alleviation of surgical pressure, unmyelinated nerve fibers tend to recover rapidly, leading to a swift reduction in pain symptoms. In contrast, myelinated nerve fibers exhibit a slower recovery rate, resulting in the emergence of numbness symptoms [31, 32]. In both groups, there was one instance of transient hypoaesthesia, potentially contributing to its occurrence. Previous studies have identified dural sac tears as the most prevalent complication during endoscopic surgery [33]. Our meta-analysis corroborated these findings, revealing that dural sac tears occurred in both groups, with a significantly higher incidence compared to other complications, aligning with prior research. Furthermore, the UBE group exhibited a greater likelihood of developing dural tears compared to the OSE group, which may be attributable to the surgical characteristics inherent to UBE procedures. It is widely recognized that the ligamentum flavum serves as a protective barrier for the dura mater, with the majority of dural tears occurring during or subsequent to its removal [34]. UBE necessitates the creation of two channels within the surgical site, resulting in a V-shaped blind spot in the visual field during decompression procedures. Concurrently, following the removal of the ligamentum flavum, the delicate dura mater is subjected to hydraulic pressure from both channels. Furthermore, surgeons lacking experience in arthroscopy and demonstrating inadequate manual coordination may be prone to errors during decompression.

Considering the aforementioned factors, the likelihood of dural tears during UBE surgery is increased. Dural tears or elevated water pressure may result in conditions pseudo-spinal hypertension. Additionally, excessive water pressure may obscure bleeding, potentially hindering the prompt achievement of hemostasis and contributing to the formation of postoperative epidural hematoma [35, 36]. The OSE decompression technique is performed under direct endoscopic visualization, offering an enlarged and unobstructed local field of view. In contrast to UBE methods, where the surgical instrument and endoscope are positioned at a "V" angle, this approach aligns them in the same direction, thereby enhancing mutual coordination. Furthermore, the procedure necessitates only a single skin incision, resulting in comparatively lower water pressure, which may contribute to the reduced incidence of complications observed in the OSE group.

Limitations

This study is subject to several limitations. Firstly, the analysis is constrained by the limited number of included studies, all of which are retrospective, potentially introducing a high risk of publication and selection bias. Secondly, variations in the technical proficiency of different surgeons may influence the results. Thirdly, although two studies from the same research team were included, a thorough analysis and verification process was conducted to eliminate the potential risk of patient overlap. Despite these limitations, we contend that this is the first meta-analysis to compare the clinical outcomes and complications of the OSE and UBE techniques, providing valuable reference information for clinical decision-making.

Conclusion

In conclusion, our findings indicate that both OSE and UBE techniques are safe and effective for the treatment of LDD. However, OSE is associated with a shorter incision and potentially reduced trauma compared to UBE. Due to the limited number of studies included in this analysis, further validation through high-quality, multi-center, large-sample prospective randomized controlled trials is necessary.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

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Consent for publication
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