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Comparison of percutaneous endoscopic lumbar discectomy *vs.* minimally invasive transforaminal lumbar interbody fusion for the treatment of single-segment lumbar disc herniation: a meta-analysis

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Abstract. – OBJECTIVE: Percutaneous endoscopic lumbar discectomy (PELD) and minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF) have been commonly demonstrated as two effective choices for the treatment of lumbar disc herniation (LDH). This meta-analysis aims to compare the effects of PELD and MIS-TLIF for the treatment of single-segment LDH.

MATERIALS AND METHODS: Randomized controlled trials or prospective cohort studies published from the time when databases were built to January 2022 that compared the effects of PELD and MIS-TLIF for single-segment LDH were retrieved from a comprehensive search in six electronic databases (PubMed, Web of Science, Embase databases, Cochrane Library, Google Scholar, and CNKI). All analyses were performed with RevMan 5.4 software.

RESULTS: A total of 9 studies with 1274 patients were included in this meta-analysis. The results showed that the PELD group was associated with lower visual analog scales (VAS) score for back pain at the final follow-up (MD: 1.23; 95% CI: [0.32, 2.14], *p*=0.008), higher Japanese Orthopaedic Association (JOA) score (MD: 2.29; 95% CI: [1.38, 3.19], *p*<0.00001), lower Oswestry Disability Index (ODI) score (MD: -2.46; 95% CI: [-4.50, -0.43], *p*=0.02), shorter operation time at 3 months (MD: -51.77; 95% CI: [-74.63, -28.91], *p*<0.00001) and lesser hospital stay (MD: -5.18; 95% CI: [-6.65, -3.71], *p*<0.00001), and less blood loss (MD: -187.13; 95% CI: [-281.45, -92.81], *p*=0.0001). However, it was associated with a higher rate of recurrent disc herniation (RR: 17.66; 95% CI: [4.25,73.44], *p*<0.0001). There were no significant differences between PELD and MIS-TLIF in VAS leg pain (MD: 0.12; 95% CI: [-0.24, 0.49], *p*=0.51), and complication rate (RR: 0.71; 95% CI: [0.45, 1.12], *p*=0.14).

CONCLUSIONS: The existing evidence showed that PELD had significantly better outcomes than MIS-TLIF in JOA score at six months, operation time, blood loss, and hospital stay as a procedure for LDH, but it had a higher recurrence rate than MIS-TLIF. Meanwhile, we should have a good command of the pros and cons of the two surgical methods to formulate an appropriate surgical plan for the patients.

Key Words:
Lumbar disc herniation, Percutaneous endoscopic lumbar discectomy, Minimally invasive transforaminal lumbar interbody fusion, Surgery, Meta-analysis.

Introduction

Lumbar disc herniation (LDH) is one of the disturbing disorders which presents with the main symptoms of low back pain and sciatica and imposes a heavy economic burden on the people, families, and countries[1]. It is reported that the incidence rate of LDH is as high as 20-35% among people over 50 years old[2]. Although conservative treatment commonly achieves satisfactory clinical and functional outcomes, the surgical treatment seems inevitable if the conservative treatment fails to achieve pain relief[3]. Lumbar discectomy and interbody fusion are the most commonly applied surgical methods for LDH. In contrast, percutaneous endoscopic lumbar discectomy (PELD) and minimally invasive transforaminal lumbar interbody fusion (MIS-TLIF) have been widely demonstrated as two effective choices for the treatment of LDH[4]. PELD was first described by Kambin and Gellman in 1983[5,6]. It has recently gained popularity for its potential advantage in less invasion, fewer postoperative complications, faster rehabilitation, and lower cost[6-9]. Foley et al[10] first introduced MIS-TLIF in 2003, and MIS-

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TLIF has the advantages of lower risk of postoperative radiculitis, reduced retraction of the dural sac, and less iatrogenic soft tissue trauma[11,12]. Despite PELD and MIS-TLIF being demonstrated safe and effective for LDH treatment, it has remained controversial which approach is better for patients with single-segment LDH. Therefore, we sought to conduct a meta-analysis to compare the clinical results of PELD compared with MIS-TLIF for single-segment LDH.

Materials and Methods

This meta-analysis was conducted in line with the AMSTAR (Assessing the methodological quality of systematic reviews) guidelines[13] and PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement[14]. Our meta-analysis was registered on researchregistry.com (Unique Identifying number: reviewregistry1241).

Search Strategy

Randomized controlled trials (RCTs) and prospective cohort studies (PCSs) were acquired by the National Library of Medicine's PubMed database, Web of Science, Embase databases, Cochrane Library, Google Scholar, and CNKI up to January 2022. The search terms "Percutaneous endoscopic lumbar discectomy", "Percutaneous endoscopic lumbar diskectomies", "PELD", "Minimally invasive transforaminal lumbar interbody fusion", "MIS-TLIF", "lumbar disc herniation", "LDH", "lumbar spinal surgery" with the Boolean operators "AND or OR". No language restriction was applied. An attempt to identify other relevant studies not found by the above approaches was made by manually scanning the reference lists of all identified papers. Two investigators independently screened all titles, abstracts, and full-text articles to determine the study's inclusion.

Inclusion and Exclusion Criteria

The inclusion criteria were as followings: (1) Population: All adult patients who were diagnosed with single-segment lumbar disc herniation; (2) Study design: RCTs and PCSs; (3) Interventions: PELD and MIS-TLIF; (4) the study included at least one of the following outcomes: Visual Analog Scale (VAS) score (back pain and leg pain), Japanese Orthopaedic Association (JOA) score, Oswestry Disability Index (ODI) score, complication rate, recurrence rate, operation time, blood loss, and hospital stay. The exclusion criteria were as followings: (1) animal studies; (2) combined with other surgery; (3) disc herniation with disc calcification; (4) instability; (5) have severe abnormal liver and kidney function or respiratory or circulatory diseases; (6) case reports, reviews, comments, letters, and editorials.

Data Extraction

Two independent observers extracted data from all the included studies and different viewpoints regarding one study were resolved through consensus or consulting by a third author. Each trial was rigorously reviewed for eligibility in this analysis. The following features were collected from each paper. (1) Basic characteristics, including first author name, publication year, study design, gender, age, and surgical level. (2) Primary outcomes are functional outcomes, consisting of VAS score for back and leg. (3) Secondary outcomes, including JOA score, ODI score, complication rate, recurrence rate, operation time, blood loss, and hospital day. Data were extracted from tables.

Quality Assessment

We conducted a quality assessment of each included RCTs based on the Cochrane Handbook for Systematic Reviews[15]. The assessment included seven items: random sequence generation, allocation concealment, blinding of participant and personnel, blinding of outcome assessment, incomplete outcome data, selective reporting, and other biases. Each trial was classified as high risk of bias, low risk of bias, and unclear risk of bias.

We also evaluated the methodological quality of PCSs using the modified Newcastle-Ottawa scale (NOS)[16]. The total scale of this method was 9 points, 3 of selection, comparability, and exposure account for 4, 2, and 3 points, respectively. 5 points or more illustrated a low risk of bias, while 4 or less illustrated a high risk of bias. Any trial was considered high quality if the score was more than 5 points[16].

Statistical Analysis

Two independent investigators used Review Manager (RevMan) 5.4 software (The Cochrane Collaboration, Copenhagen, Denmark) to perform the statistical analysis. For continuous variables, we calculated the mean difference (MD) with 95% confidence interval (CI), such as VAS score for back and leg pain, JOA, ODI, operation

time, blood loss, and hospital stay. For dichotomous variables, we measured risk ratio (RR) with 95% CI, such as complication rate, and recurrence rate. We conducted a heterogeneity test on all included studies and calculated the inconsistency index (I^2) statistics. When I^2>50% or p-value<0.1, significant heterogeneity of studies included was illustrated and a random-effect model was adopted. Otherwise, a fixed-effect model was adopted. Forest plots were constructed. For all these comparisons, p<0.05 was considered statistically significant. When high heterogeneity was identified, we performed a One-way sensitivity analysis by deleting a single study from the overall publications individually to explore each study's effect on the general risk estimates. We also conducted a subgroup analysis based on the type of study to evaluate the sources of high heterogeneity and the effects of these outcomes on the overall estimates.

Results

Study Selection

We initially retrieved 641 relevant publications and excluded 632 studies that did not satisfy the selection criteria. 9 studies (4 RCTs and 5 PCSs) were eventually eligible for the inclusion criteria, and they were included in this meta-analysis[17-25]. Figure 1 illustrates the process and results of the study screening.

Characteristics of Selected Studies

The basic characteristics of all eligible studies were presented in Table I, including first author's name, publication year, study design, gender (male/female), age, surgical level, and operation time. A total of 9 studies (4 RCTs and 5 PCSs) with 1274 patients were included in our meta-analysis. All these studies were published from 2015 to 2020.

Risk of Bias

The Cochrane Handbook for Systematic Review of Interventions was used to assess the risk of bias in RCTs. As shown in Table II, 4 RCTs were considered to have a low risk of bias. Four studies adopted the method of random sequence generation. None of the RCTs found incomplete results data, and selective reports, indicating a low risk of bias.

The quality of 5 PCSs was assessed according to the NOS. The quality assessment results were provided in Table III, and all PCSs scored 6 to 8 points and showed relatively moderate to high quality.

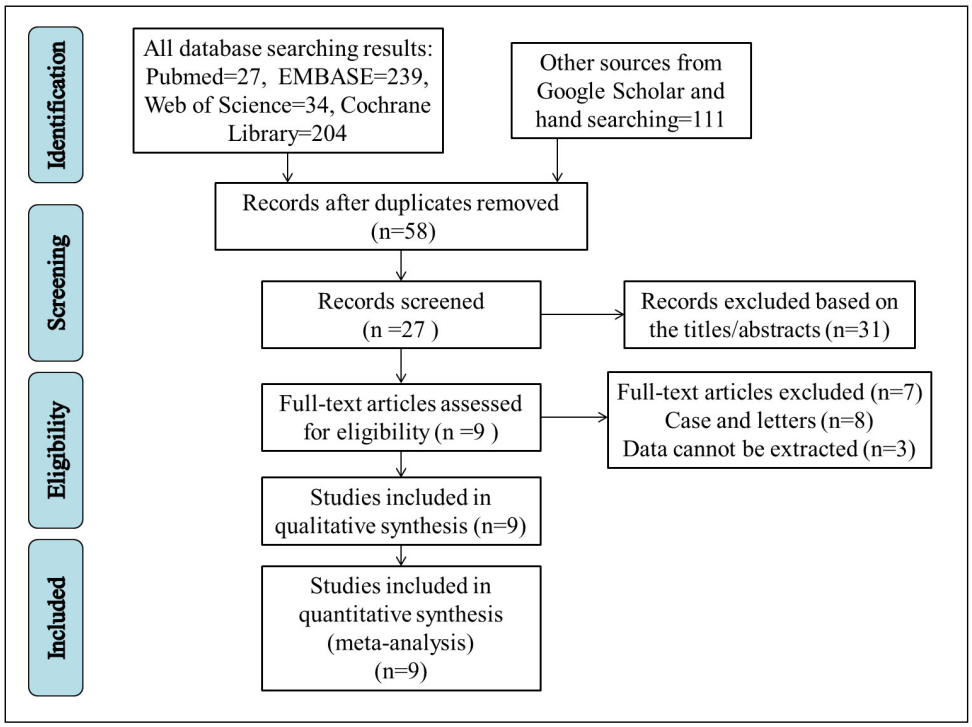

Figure 1. Flow diagram of the study selection process for the meta-analysis.

Table I. Characteristics of all the trials included in the meta-analysis.

Study	Study design	Gender M : F		Age (years)		Level (L3-L4/L4-5/L5-S1)		Operation time (min)	
		PELD	MIS-TLIF	PELD	MIS-TLIF	PELD	MIS-TLIF	PELD	MIS-TLIF
Liu et al 2019[17]	PCS	111/73	108/68	42.2	43.1	0/106/78	0/101/75	NP	NP
Liu et al 2018[18]	PCS	18/24	19/28	46.8	47.4	0/16/26	0/17/30	NP	NP
Liu et al 2016[19]	PCS	110/99	92/100	57.2	55.9	0/127/82	0/101/91	NP	NP
Zhang et al 2015[20]	RCT	18/12	17/13	41.8±12.5	46.3±8.4	3/17/10	1/18/11	72±18.7	137±48.3
Zhao et al 2017[21]	RCT	39/31	38/32	48.4±4.6	48.7±5.1	NP	NP	69.4±11.2	136.8±28.9
Wang et al 2017[22]	RCT	6/9	8/7	53.68±17.1	51.62±10.04	0/11/4	0/13/2	84.8±5.774	155.2±11.71
Mi et al 2018[23]	PCS	26/22	28/20	51.97±8.35	50.02±7.65	9/22/7	10/23/15	78.58±17.65	128.69±23.04
Zhou et al 2020[24]	PCS	16/7	13/10	46.8±5.2	47.4±6.1	0/13/10	0/12/11	NP	NP
Wei et al 2015[25]	RCT	16/10	14/12	40.3±1.8	41.5±2.3	NP	NP	75.4±16.3	124.0±24.5

PELD, percutaneous endoscopic lumbar discectomy; MIS-TLIF, minimally invasive transforaminal lumbar interbody fusion; RCT, randomized controlled trial; PCS, prospective cohort study; M, male; F, female; NP, not provided.

Table II. Quality assessment according to the Cochrane Handbook for Systematic Review of Interventions for randomized controlled trials.

Study	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel	Blinding of outcome assessment (performance bias)	Incomplete outcome data (detection bias)	Selective reporting (reporting bias) (attrition bias)	Other bias
Zhang et al 2015[20]	Low risk	Unclear risk	Unclear risk	Unclear risk	Low risk	Low risk	Low risk
Zhao et al 2017[21]	Low risk	Unclear risk	Unclear risk	Unclear risk	Low risk	Low risk	Unclear risk
Wang et al 2017[22]	Low risk	Unclear risk	Unclear risk	Unclear risk	Low risk	Low risk	Low risk
Wei et al 2015[25]	Low risk	Unclear risk	Unclear risk	Unclear risk	Low risk	Low risk	Unclear risk

Table III. Quality assessment according to the Newcastle-Ottawa Scale for prospective cohort studies.

Study	Selection	Comparability	Exposure	Total Score
Liu et al 2019[17]	3	2	3	8
Liu et al 2018[18]	3	2	3	8
Liu et al 2016[19]	3	2	3	8
Mi et al 2018[23]	2	2	2	6
Zhou et al 2020[24]	2	2	3	7

Outcomes of the Meta-Analysis

VAS scores

Among the 9 studies, 2 presented the results of postoperative back VAS score at 6 months, and 82 patients were included in the analysis: 41 in the PELD group and 41 in the MIS-TLIF group. A random-effects model was adopted because notable heterogeneity was found among the studies (I^2=74%). There was significant difference in postoperative back VAS score at 6 months between groups (MD: -0.65; 95% CI: [-0.92, -0.39], p<0.00001, I^2=74%) (Figure 2A).

Among the 9 studies, 2 presented the results of postoperative back VAS score at 12 months, and 76 patients were included in the analysis: 38 in the PELD group and 38 in the MIS-TLIF group. A random-effects model was adopted because notable heterogeneity was found among the studies (I^2=99%). There was no significant difference in postoperative back VAS score at 12 months between groups (MD: 0.48; 95% CI: [-1.11, 2.08], p=0.55, I^2=99%) (Figure 2B).

Among the 9 studies, 2 presented the results of postoperative leg VAS score at 12 months, and 76 patients were included in the analysis: 38 in the PELD group and 38 in the MIS-TLIF group. A random-effects model was adopted because notable heterogeneity was found among the studies (I^2=73%). There was no significant difference in postoperative leg VAS score at 12 months between groups (MD: -0.21; 95% CI: [-0.68, 0.27], p=0.39, I^2=73%) (Figure 2C).

JOA score

Among the 9 studies, 4 presented the results of postoperative JOA score, and we performed subgroup analyses according to postoperative time points (6 months, 12 months). 2 presented the results of JOA score at 6 months. There was no significant heterogeneity among the studies (I^2=0%). A fixed-effects model was used, and there was a significant difference in JOA score at 6 months in patients who received PELD compared with MIS-TLIF (MD: 3.12; 95% CI: [1.96, 4.29], p<0.00001, I^2=0%). Two studies presented the results of JOA score at 12 months. A random-effects model was adopted because notable heterogeneity was found among the studies (I^2=53%). There was no significant difference in JOA score at 12 months in patients who received PELD compared with MIS-TLIF (MD: 0.77; 95% CI: [-1.04, 2.58], p=0.41, I^2=53%) (Figure 3).

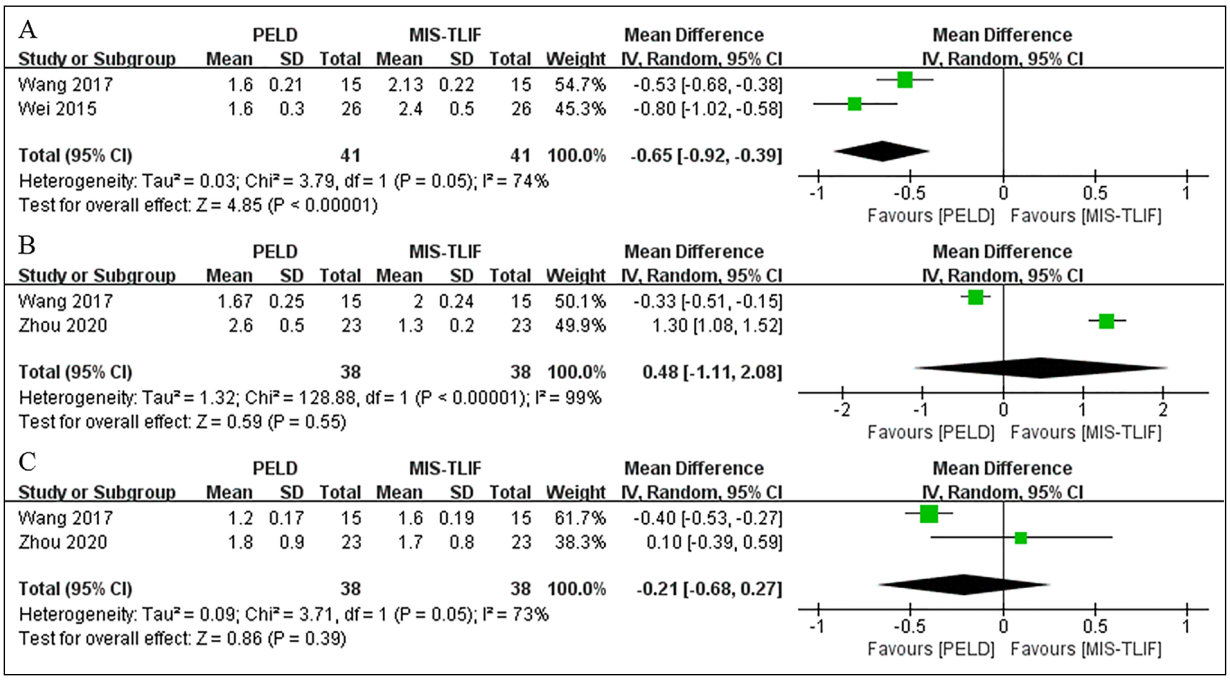

Figure 2. Forest plot for the meta-analysis of postoperative VAS scores. **A**, postoperative back VAS score at 6 months; **B**, postoperative back VAS score at 12 months; **C,** postoperative leg VAS score at 12 months. [95% CI: 95% confidence intervals, df: degrees of freedom, Random: random effects model, Fixed: fixed effects model, IV: inverse variance].

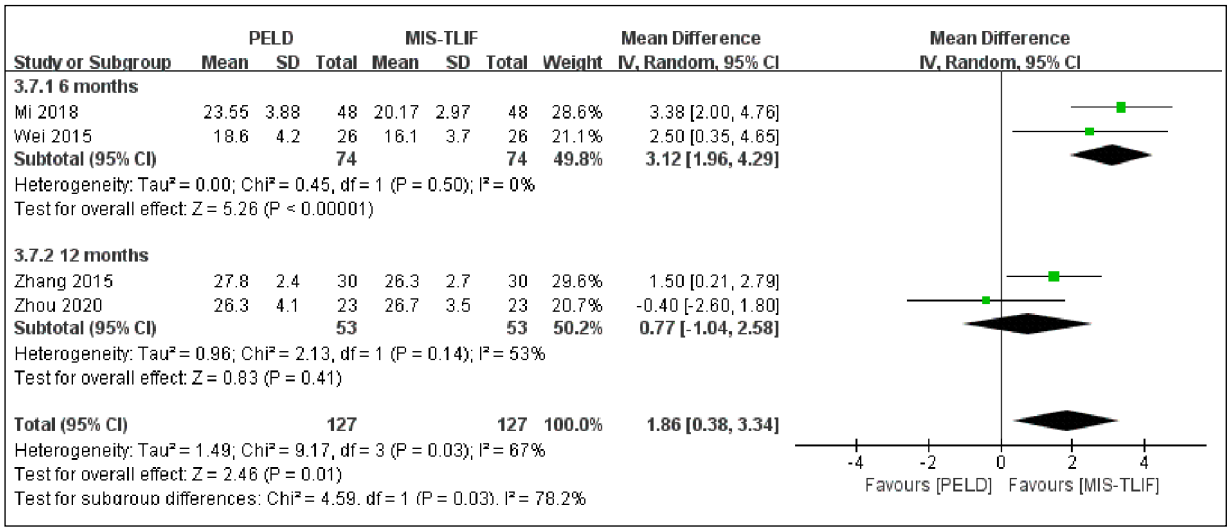

Figure 3. Forest plot for the meta-analysis of JOA score. [95% CI: 95% confidence intervals, df: degrees of freedom, Random: random effects model, Fixed: fixed effects model, IV: inverse variance].

ODI score

Among the 9 studies, 4 presented the results of ODI score, and we performed subgroup analyses according to postoperative time points (6 months, 12 months). Three studies presented the results of ODI score at 6 months. A random-effects model was adopted because notable heterogeneity was found among the studies (I^2=99%). There was no significant difference in ODI score at 6 months between groups (MD: -2.75; 95% CI: [-8.14, 2.64], p=0.32, I^2=99%). Two studies presented the results of ODI score at 12 months. A random-effects model was adopted because notable heterogeneity was found among the studies (I^2=62%). There was no significant difference in ODI score at 12 months between groups (MD: -0.70; 95% CI: [-1.68, 0.29], p=0.16, I^2=62%) (Figure 4).

Complication rate

Among the 9 studies, 7 presented the results of the total complication rate, and 1082 patients were included in the analysis: 551 in the PELD group and 531 in the MIS-TLIF group. There was no significant heterogeneity among the studies (I^2=0%). A fixed-effects model was adopted, and there was

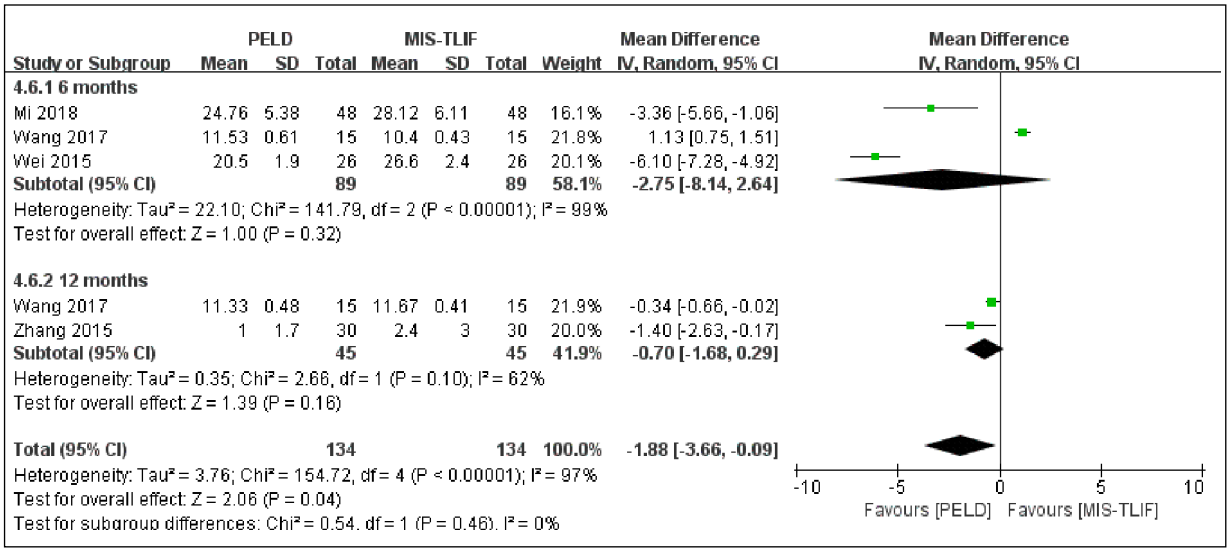

Figure 4. Forest plot for the meta-analysis of ODI score. [95% CI: 95% confidence intervals, df: degrees of freedom, Random: random effects model, Fixed: fixed effects model, IV: inverse variance].

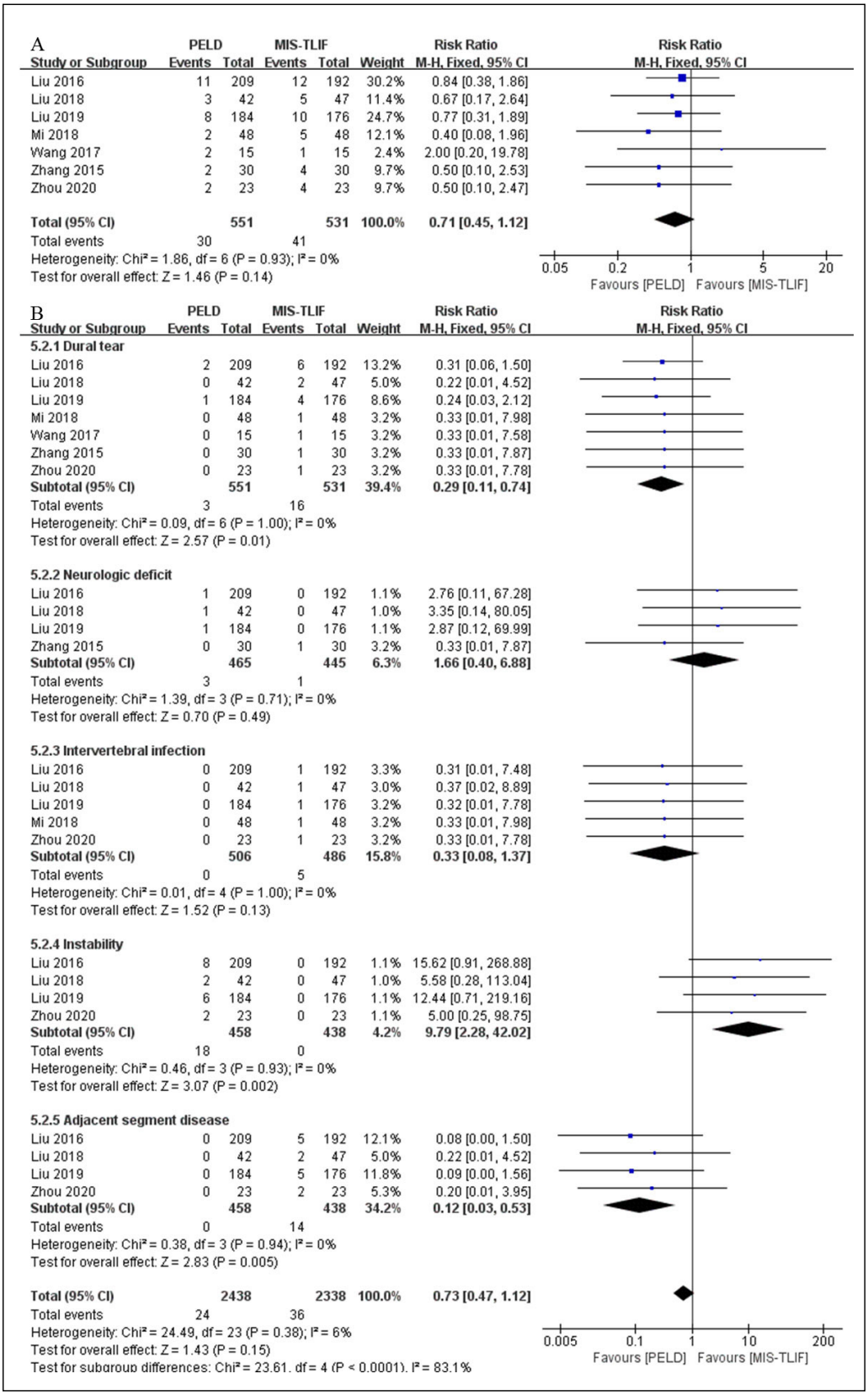

Figure 5. Forest plot for the meta-analysis of complication rate. **A**, Forest plot for the meta-analysis of total complication rate; **B**, Forest plot for the meta-analysis of each complication rate. [95% CI: 95% confidence intervals, df: degrees of freedom, Random: random effects model, Fixed: fixed effects model, IV: inverse variance].

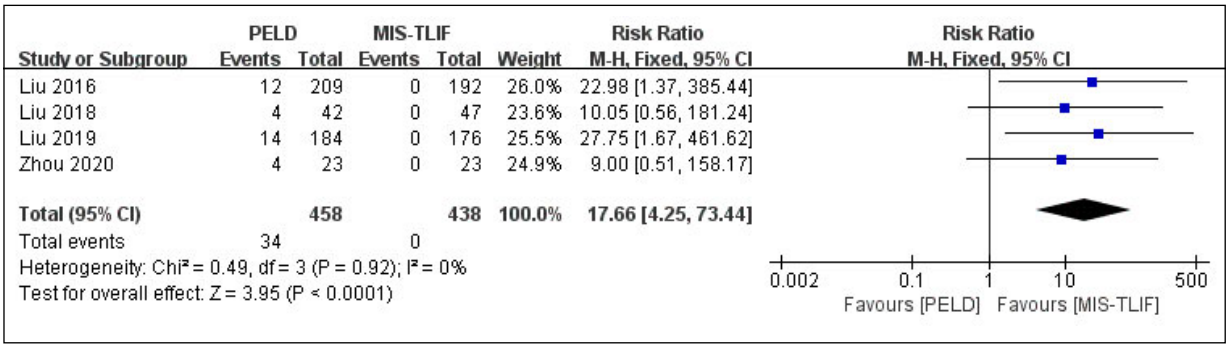

Figure 6. Forest plot for the meta-analysis of recurrence rate. [95% CI: 95% confidence intervals, df: degrees of freedom, Random: random effects model, Fixed: fixed effects model, IV: inverse variance].

a significant reduction in total complication rate in patients who received PELD compared with MIS-TLIF, but there was no significant difference between groups (RR: 0.71; 95% CI: [0.45, 1.12], p=0.14, I^2=0%) (Figure 5A).

Complications include dural tear, neurologic deficit, intervertebral infection, instability, adjacent segment disease (ASD). Subgroup analysis based on the type of complications illustrated that the PELD group was associated with significantly lower incidences of dural tear (RR: 0.29; 95% CI: [0.11, 0.74], p=0.01, I^2=0%), and ASD (RR: 0.12; 95% CI: [0.03, 0.53], p=0.005, I^2=0%), but the incidence of instability was opposite (RR: 9.79; 95% CI: [2.28, 42.02], p=0.002, I^2=0%). And there were no significant differences between PELD and MIS-TLIF in terms of neurologic deficit (RR: 1.66; 95% CI: [0.40, 6.88], p=0.49, I^2=0%), and intervertebral infection (RR: 0.33; 95% CI: [0.08, 1.37], p=0.13, I^2=0%) (Figure 5B).

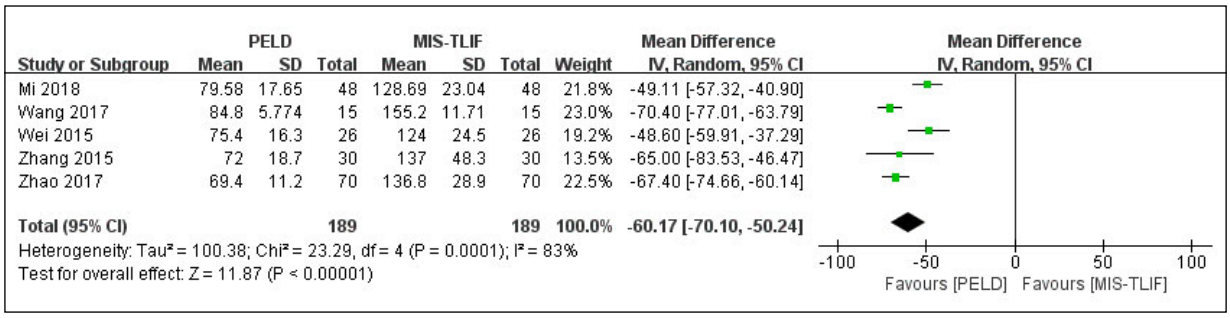

Figure 7. Forest plot for the meta-analysis of operation time. [95% CI: 95% confidence intervals, df: degrees of freedom, Random: random effects model, Fixed: fixed effects model, IV: inverse variance].

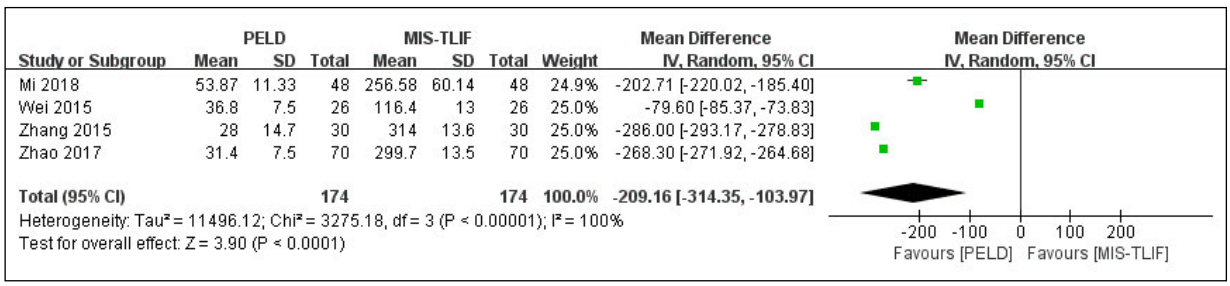

Figure 8. Forest plot for the meta-analysis of blood loss. [95% CI: 95% confidence intervals, df: degrees of freedom, Random: random effects model, Fixed: fixed effects model, IV: inverse variance].

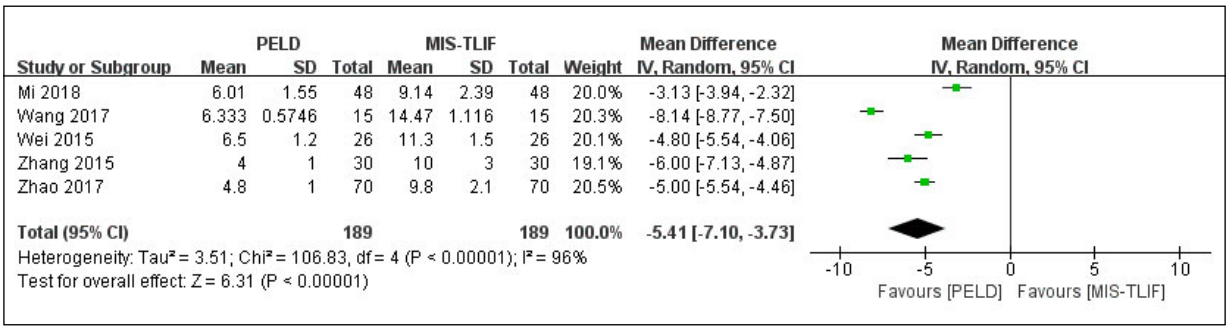

Figure 9. Forest plot for the meta-analysis of hospital stay. [95% CI: 95% confidence intervals, df: degrees of freedom, Random: random effects model, Fixed: fixed effects model, IV: inverse variance].

Recurrence rate

Among the 9 studies, 4 presented the results of recurrence rate, and 896 patients were included in the analysis: 458 in the PELD group and 438 in the MIS-TLIF group. There was no significant heterogeneity among the studies (I^2=0%). A fixed-effects model was used, and there was a significant difference in recurrence rate in patients who received PELD compared with MIS-TLIF (RR: 17.66; 95% CI: [4.25,73.44], p<0.0001, I^2=0%) (Figure 6).

Operation time

Among the 9 studies, 5 presented the results of the operation time, and 378 patients were included in the analysis: 189 in the PELD group and 189 in the MIS-TLIF group. A random-effects model was applied because notable heterogeneity was found among the studies (I^2=83%). There was significant difference in operation time between groups (MD: -60.17; 95% CI: [-70.10, -50.24], p<0.00001, I^2=83%) (Figure 7).

Blood loss

Among the 9 studies, 4 presented the results of blood loss, and 348 patients were included in the analysis: 174 in the PELD group and 174 in the MIS-TLIF group. A random-effects model was applied because notable heterogeneity was found among the studies (I^2=100%). There was significant difference in blood loss between groups (MD: -209.16; 95% CI: [-314.35, -103.97], p<0.0001, I^2=100%) (Figure 8).

Hospital stay

Among the 9 studies, 5 presented the results of hospital stay, and 378 patients were included in the analysis: 189 in the PELD group and 189 in the

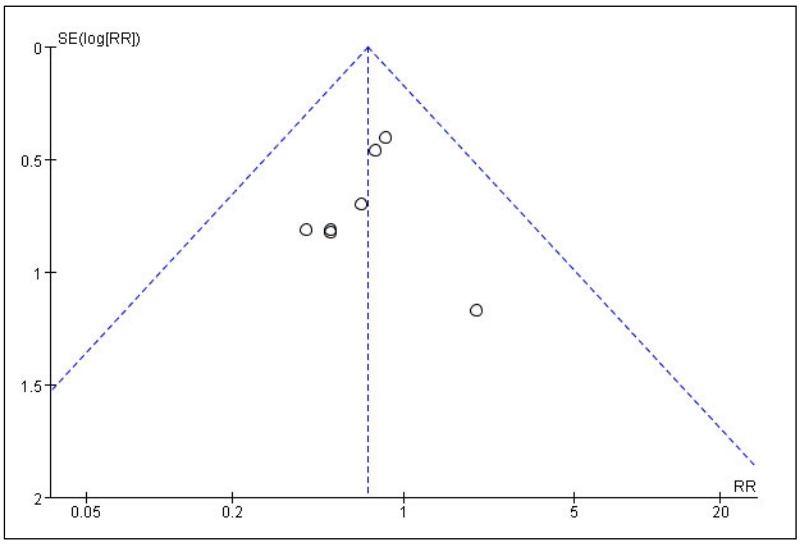

Figure 10. Funnel Plot to evaluate for publication bias regarding total complication rate. [SE(log[RR]), standard error (log[risk ratio])].

MIS-TLIF group. A random-effects model was applied because notable heterogeneity was found among the studies (I^2=96%). There was significant difference in hospital stay between groups (MD: -5.41; 95% CI: [-7.10, -3.73], p<0.00001, I^2=96%) (Figure 9).

Sensitivity Analysis

To further account for high heterogeneity among the results, we performed a sensitivity analysis by removing one study from the overall publications individually to figure out some factors. However, we did not find a change in overall results on any assessed results using this method.

Publication Bias

The funnel plot regarding the total complication rate was presented in Figure 10. The shape of the funnel plot seemed symmetrical on visual inspection, revealing a very low risk of publication bias.

Discussion

Recently, with the development of minimally invasive techniques, PELD and MIS-TLIF have become widely accepted surgical approaches for treating patients with single-segment LDH. Although they can achieve a satisfactory outcome, which surgery has a better clinical effect remains controversial. Some studies have illustrated that both PELD and MIS-TLIF techniques can achieve a satisfactory result, but PELD is significantly better than MIS-TLIF in the short-term treatment effect. At the same time, there is no significant difference in the long-term effect[20,22,24]. However, some studies have demonstrated that PELD is better than MIS-TLIF because of the smaller surgical trauma, less blood loss, and faster recovery[23,25]. Furthermore, the most important advantage of PELD is that local anesthesia can be applied as reported by Choi et al[26], which is beneficial to support the communication between surgeons and patients intraoperatively and avoid nerve roots damage. Compared to MIS-TLIF with general anesthesia, PELD with local anesthesia can accelerate postoperative mobilization[4]. However, PELD also has disadvantages, such as a high recurrence rate, insufficiently removing the disc, and taking a certain time to develop skill proficiency[27-29]. To our knowledge, no meta-analysis has been published comparing PELD and MIS-TLIF in the treatment of single-segment LDH. Therefore, it is important to summarize the related clinical trials to compare these two methods for their clinical effects.

Our meta-analysis included 4 RCTs and 5 PCSs involving 1274 patients with adequate methodological assessment, and we extracted relevant data and pooled the results. The results showed that PELD revealed statistically significantly better outcomes than MIS-TLIF in postoperative back VAS score and JOA score at 6 months, operation time, blood loss, and hospital stay. However, compared with MIS-TLIF, PELD had a higher incidence of recurrent disc herniation. Furthermore, no statistically obvious differences were observed between the two groups in terms of postoperative back/leg VAS score at 12 months and complication rate.

In the present meta-analysis, we first took the outcome of VAS score (back pain and leg pain), JOA score, and ODI score at 6/12 months for functional assessment. As for postoperative leg VAS score, overall results illustrated no statistical difference between groups, indicating no difference between PELD and MIS-TLIF in alleviating nerve root compression caused by LDH. In addition, there was a significant difference in VAS score for back pain at 6 months; however, there was no significant difference in VAS score for back pain at 12 months. Theoretically, in terms of postoperative back pain, PELD should be superior because it is more likely to retain normal bony structures and minimize injury to nerve roots. Nonetheless, there was no significant difference between the PELD group and the MIS-TLIF group for both back and leg VAS scores over time[30]. Similar results were also observed when assessing for 6 postoperative months JOA score, and there was statistical significance between these two groups. However, there was a high degree of heterogeneity in postoperative back VAS score and ODI score. A sensitivity analysis was performed to assess the robustness of this study. The sensitivity analysis did not find a change in overall results. By comparing the clinical characteristics and demographic data among the included studies, we discovered that different studies had different follow-up times and the sample size was considerably small. Therefore, it is suggested that we should establish a unified follow-up time standard in the design of clinical trials in the future. In addition, larger sample studies with large LDH patients are urgently needed.

Complications included dural tear, neurologic deficit, intervertebral infection, instability, and ad-

jacent segment disease[17-19]. In this study, there was no statistically significant difference in complication rate. However, in the subgroup analysis based on the type of complications (Figure 5B), PELD showed a lower incidence of dural tear and adjacent segment disease than MIS-TLIF, and it showed a higher incidence of instability compared to MIS-TLIF. However, in terms of neurologic deficit and intervertebral infection, there was no significant difference between PELD and MIS-TLIF. Several possible explanations may account for these outcomes. Firstly, due to the development of the advanced camera system, PELD can provide surgeons with high-quality images and clear spinal anatomy; therefore, the rate of dural tear in the PELD group was lower than in the MIS-TLIF group. Secondly, PELD can retain the motor segment, and reduce the incidence of fusion diseases such as adjacent segment disease. MIS-TLIF is a type of interbody fusion surgery that can realize the anterior support of spinal columns and lumbar lordosis and restore the height of the disc on sagittal planes. So, it is more likely to lead to adjacent segment disease. Thirdly, since PELD does not perform pedicle screw fixation and intervertebral fusion, it is not as stable as MIS-TLIF. Furthermore, theoretically, concerning neurologic deficit and intervertebral infection, MIS-TLIF had a higher rate because of implants and limited operative view. By contrast, in our analysis, we came to a different conclusion. We speculated that the learning curves of both PELD and MIS-TLIF are technically deep, even for an experienced surgeon. More time and experience are needed to absorb and master these techniques. Thus, it is reasonable to believe that a firm grasp of spine anatomy, familiarity with the novel instrumentation, and skilled operation are necessary for surgical safety and the prevention of complications. In addition, it is important to realize that not all complications can have a lasting impact on the patients, and most likely do not affect final clinical results.

Furthermore, it is reported that the recurrence rate after PELD is 0-7.4%[31]. In this study, we found that patients who received PELD surgery had a markedly higher rate than those treated with MIS-TLIF surgery, which was in accordance with previous studies[17-19]. Regarding these results, we speculated the main reason was that PELD insufficiently removed the disc due to the limited operative space, causing there were still many nucleus pulposus left, which might lead to herniation again, while MIS-TLIF could completely remove the disc[32]. Moreover, it is important to improve the proficiency of surgical skills. In case the patient is older and meets the indications for MIS-TLIF, MIS-TLIF (a through intervertebral fusion) may be a better choice in terms of recurrence rate.

With regard to operation time, blood loss, and hospital stay, the present study illustrated that patients treated with PELD had 60.17 minutes shorter operation time than those with MIS-TLIF. Compared to MIS-TLIF, PELD causes less injury to soft tissues, thus decreasing blood loss during surgery, and thereby shortening hospital stay and allowing quick postoperative recovery. According to operation time, blood loss, and hospital stay, PELD is more in line with the concept of enhanced recovery after surgery (EARS), which is considered a preferred surgical approach.

Limitations

There are several limitations in our meta-analysis. Firstly, we included only 9 studies with 1274 patients; there was unavoidable heterogeneity and bias when the results were pooled. More high-quality RCTs with larger samples will be urgently needed for stronger evidence to support this recommendation. Second, a surgeon's proficiency makes a significant difference in the results of the trial, and it is strongly believed that the difference in surgeons in each trial would have worked as a bias. In addition, although we used sensitivity and subgroup analysis to assess the derivation of heterogeneity and bias, no useful information was found. Several reasons may account for high heterogeneity and bias, including patient demographic data (age, sex, type of disc herniation, and surgical level) and follow-up time. These factors may have effects on our outcomes. Therefore, considering these potential limitations, caution is recommended when explaining our outcomes and applying them to clinical practice in the field.

Given the overall outcomes of our analysis, we can conclude that PELD and MIS-TLIF have their advantages and disadvantages in the treatment of LHD. For young and middle-aged patients, it should be considered that patients have higher requirements for lumbar spine mobility. PELD guarantees the lumbar mobility of patients. Thus, it is more suitable for young and middle-aged patients. For elderly LHD patients with low requirements for lumbar spine mobility and lower recurrence rates, avoiding secondary surgery is the primary consideration. Hence, MIS-TLIF is supposed to be chosen for elderly patients. However, for patients with cardiopulmonary disease and poor physical function, quick relief of nerve pain and rapid postoperative recovery are the primary factors. There-

fore, it is prone to choose PELD. Taken together, we should have a good command of the pros and cons of the two surgical methods to formulate an appropriate surgical plan for the patients. Meanwhile, we must strictly grasp the indications, so that we can achieve a successful operation.

Conclusions

The current meta-analysis demonstrated that PELD had significantly better outcomes than MIS-TLIF in JOA score at 6 months, operation time, blood loss, and hospital stay as a procedure for LDH, but PELD had a higher recurrence rate than MIS-TLIF. In addition, there was no significant difference in VAS score for back and leg pain at 12 months, JOA score and ODI score at 12 months, and complication rate between the two groups. Considering these findings, more high-quality RCTs with large sample sizes are urgently required for further research.

Conflict of Interests

The authors declare that they have no conflict of interest.

Authors' Contributions

All authors conceived and designed the study. Zhenxin Hu and Jun Han participated in manuscript writing, data collection and data analysis. Yuefeng Sun, and Xiliang Tian critically reviewed and edited the manuscript. All authors read and approved the final manuscript.

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