Medical Research
Volume 6, Issue 3, 2024, Page 15-39
https://doi.org/10.6913/mrhk.060303

Medical Research

Clinical Effectiveness and Biochemical Impacts of Minimally Invasive versus Open Transforaminal Lumbar Interbody Fusion: A Meta-Analysis

Jingyu LIU[#1,2], Hongjie ZHENG[#1], Chuncheung CHAN[*1]

*1.The Seventh Affiliated Hospital of Sun Yat-Sen University, ShenZhen ,518000, China. 2.The Fifth Affiliated Hospital of Guangzhou Medical University, GuangZhou,510000, China # should be considered as co-first author * should be considered as correspondence author,chenzhenxiang@sysush.com*

Abstract

Objective: This meta-analysis aimed to compare the clinical effectiveness, safety, and biochemical impacts of two spinal surgery techniques: open transforaminal lumbar interbody fusion (open-TLIF) and minimally invasive TLIF (MIS-TLIF). **Methods:** A comprehensive literature search was conducted through April 2023 across PUBMED, Cochrane Library, SCOPUS, Web of Science, EMBASE, and CNKI, using the terms "transforaminal lumbar interbody fusion" or "TLIF" combined with "minimally invasive" or "open." A total of 44 studies met the inclusion criteria for analysis. **Results:** The meta-analysis found that MIS-TLIF results in higher intraoperative radiological exposure but less blood loss, lower postoperative drainage, shorter hospital stays, and better outcomes on the Visual Analog Scale (VAS) and Oswestry Disability Index (ODI). Biochemically, MIS-TLIF is associated with lower CRP, CK-MM, and CPK levels 24 hours post-operation compared to open TLIF. **Conclusions:** MIS-TLIF demonstrates superior clinical effectiveness, improved safety, and reduced muscle injury compared to open TLIF, making it a better option when minimizing tissue trauma and promoting rapid recovery are priorities.

Keywords Minimally Invasive Surgery (MIS), Transforaminal Lumbar Interbody Fusion (TLIF), Clinical Effectiveness, Biochemical Markers, Postoperative Recovery

To Cite This Article Jingyu LIU,et al. (2024). Clinical Effectiveness and Biochemical Impacts of Minimally Invasive versus Open Transforaminal Lumbar Interbody Fusion: A Meta-Analysis. *Medical Research*, *6*(3), 15-39. https://doi.org/10.6913/mrhk.060303

Medical Research, ISSN 2664-0333 (print), ISSN 2664-0341 (online), DOI 10.6913/mrhk, a bimonthly, founded on 2018, Indexed by CNKI, Google Scholar, AIRITI, Scilit, CrossRef, Elsevier PlumX, etc., published by Creative Publishing Co., Limited. Email: wtocom@gmail.com, https://mrhk.cc, https://cpcl.hk.

1 Background

Lumbar fusion technology is extensively employed in managing lumbar instability and spinal deformities[1]. The primary objective is to restore the height of intervertebral discs and spinal segments, thereby alleviating nerve compression[2]. Since its initial description by Harms and Rolinger in 1982, TLIF has been performed using a single posterolateral approach to achieve circumferential fusion[3]. This technique, executed through a paramedian skin incision, allows transforaminal access with minimal neural retraction. The lateral trajectory offers significant benefits: (1) limited nerve retraction, reducing the risk of iatrogenic injury; (2) utilization of contralateral intact bony structures as additional fusion sites; and (3) potential for bilateral decompression without the morbidity associated with extensive contralateral soft tissue, muscle, and neural manipulation[4, 5].

Despite the widespread adoption of TLIF, its associated challenges, such as muscle atrophy and scar formation due to the anatomical disruption of the paraspinal muscles, have been linked to long-term postoperative pain and disability[6]. These complications, along with prolonged hospital stays and high costs, remain significant drawbacks.

In recent years, MIS-TLIF has gained attention due to its smaller incision, reduced tissue damage, and faster recovery[7]. The procedure involves the insertion of a tubular retractor through a small incision, allowing the surgeon to operate without extensive muscle cutting. Damaged discs are removed to relieve pressure on the spinal cord or nerves, followed by the placement of an artificial spacer between vertebrae and stabilization with screws and rods to aid in spinal alignment during healing[8]. While the efficacy and safety of MIS-TLIF are increasingly recognized, its success depends on patient selection, severity of lumbar deformity, and pre-existing conditions such as spinal instability, sagittal imbalance, osteoporosis, and advanced bone loss, which may contraindicate lateral fusion approaches[9]. Furthermore, the learning curve associated with MIS-TLIF can lead to complications such as dural tears, implant misplacement, nerve damage, and incomplete fusion, necessitating enhanced surgical training[10].

Given the inconsistent results from studies comparing the clinical outcomes and fusion rates of these techniques, our meta-analysis seeks to provide cumulative estimates of clinical efficacy and determine which surgical approach offers greater benefits.

2 Methods

2.1 A systematic search of the literature was conducted up to April 2023 across multiple databases

Including PUBMED, the Cochrane Library, SCOPUS, Web of Science, EMBASE, and CNKI. The search employed key terms such as "transforaminal lumbar interbody fusion" or "TLIF" alongside "minimally invasive" or "open". Additionally, reference lists of relevant studies were examined. No language restrictions were applied. This study adheres to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) and AMSTAR (Assessing

the Methodological Quality of Systematic Reviews) guidelines[11].

2.2 Studies were eligible for inclusion if they

(1) utilized a comparative design comparing MIS-TLIF with open TLIF; (2) involved adult patients with degenerative lumbar conditions such as disc herniation, spinal stenosis, or spondylolisthesis; (3) reported on perioperative outcomes such as operative time, blood loss, improvements in pain or disability, or fusion rates; and (4) included a follow-up period of at least six months post-surgery. If multiple studies from the same group met the inclusion criteria, outcomes were compared, and the most comprehensive or recent study was selected.

2.3 Exclusion criteria included literature reviews

Case reports, conference abstracts, editorials, biomechanical studies, animal studies, cadaver studies, and studies where full texts or data could not be retrieved were excluded.

2.4 Data Extraction and Quality Assessment: Data were extracted for each study

Including the first author's name, year of study, study design, patient demographics, and outcomes such as operative duration, blood loss, and hospital stay. The quality of the included studies was assessed by two independent reviewers (CZX and LJY) using the Newcastle-Ottawa Scale[12]. Although high-quality randomized controlled trials were scarce, the included studies (with NOS scores ranging from 5 to 9) are considered to have high methodological quality. However, there were notable limitations that may diminish the overall quality of evidence. These limitations include the small number of studies available for certain subgroup analyses, incomplete clinical outcome data in some studies, and two studies with small sample sizes that potentially increased heterogeneity and bias. Additionally, the restriction to studies published in English may have introduced language bias.

2.5 Statistical Analysis: Data analysis was performed using Review Manager

Clinical outcomes were analyzed as score differences between the 2-year follow-up and pre-surgery values. Mean differences (MD) and 95% confidence intervals (CI) were calculated for continuous variables, and relative risks (RR) for dichotomous variables. Heterogeneity was assessed using the Chi-squared (Cochrane Q) test and the I^2 statistic. A fixed-effects meta-analysis was applied if $p \geq 0.1$ and $I^2 \leq 50\%$; otherwise, a random-effects model was used[13]. Strategies to address heterogeneity were implemented as outlined in the Cochrane Handbook[14]. All tests were two-sided, with statistical significance set at an alpha level of 0.05 unless otherwise specified.

3 Methods

Search Strategy and Inclusion Criteria: A systematic search of the literature was conducted up to April 2023 across multiple databases, including PUBMED, the Cochrane Library, SCOPUS,

Web of Science, EMBASE, and CNKI. The search employed key terms such as "transforaminal lumbar interbody fusion" or "TLIF" alongside "minimally invasive" or "open". Additionally, reference lists of relevant studies were examined. No language restrictions were applied. This study adheres to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) and AMSTAR (Assessing the Methodological Quality of Systematic Reviews) guidelines[11].

Studies were eligible for inclusion if they: (1) utilized a comparative design comparing MIS-TLIF with open TLIF; (2) involved adult patients with degenerative lumbar conditions such as disc herniation, spinal stenosis, or spondylolisthesis; (3) reported on perioperative outcomes such as operative time, blood loss, improvements in pain or disability, or fusion rates; and (4) included a follow-up period of at least six months post-surgery. If multiple studies from the same group met the inclusion criteria, outcomes were compared, and the most comprehensive or recent study was selected.

Exclusion criteria included literature reviews, case reports, conference abstracts, editorials, biomechanical studies, animal studies, cadaver studies, and studies where full texts or data could not be retrieved.

Data Extraction and Quality Assessment: Data were extracted for each study, including the first author's name, year of study, study design, patient demographics, and outcomes such as operative duration, blood loss, and hospital stay. The quality of the included studies was assessed by two independent reviewers (CZX and LJY) using the Newcastle-Ottawa Scale[12]. Although high-quality randomized controlled trials were scarce, the included studies (with NOS scores ranging from 5 to 9) are considered to have high methodological quality. However, there were notable limitations that may diminish the overall quality of evidence. These limitations include the small number of studies available for certain subgroup analyses, incomplete clinical outcome data in some studies, and two studies with small sample sizes that potentially increased heterogeneity and bias. Additionally, the restriction to studies published in English may have introduced language bias.

Statistical Analysis: Data analysis was performed using Review Manager (version 5.3). Clinical outcomes were analyzed as score differences between the 2-year follow-up and pre-surgery values. Mean differences (MD) and 95% confidence intervals (CI) were calculated for continuous variables, and relative risks (RR) for dichotomous variables. Heterogeneity was assessed using the Chi-squared (Cochrane Q) test and the I^2 statistic. A fixed-effects meta-analysis was applied if $p \geq 0.1$ and $I^2 \leq 50\%$; otherwise, a random-effects model was used[13]. Strategies to address heterogeneity were implemented as outlined in the Cochrane Handbook[14]. All tests were two-sided, with statistical significance set at an alpha level of 0.05 unless otherwise specified.

4 Results

4.1 Literature Survey

Our systematic search identified 44 studies, as detailed in Table 1. The initial search strategy yielded 87 records. After screening the titles and abstracts, 64 articles remained. Seventeen studies

were excluded due to duplication, meta-analysis overlaps, technical indications, commentaries, and cadaveric studies. Ultimately, 44 studies met the inclusion criteria after a full-text review (Figure 1).

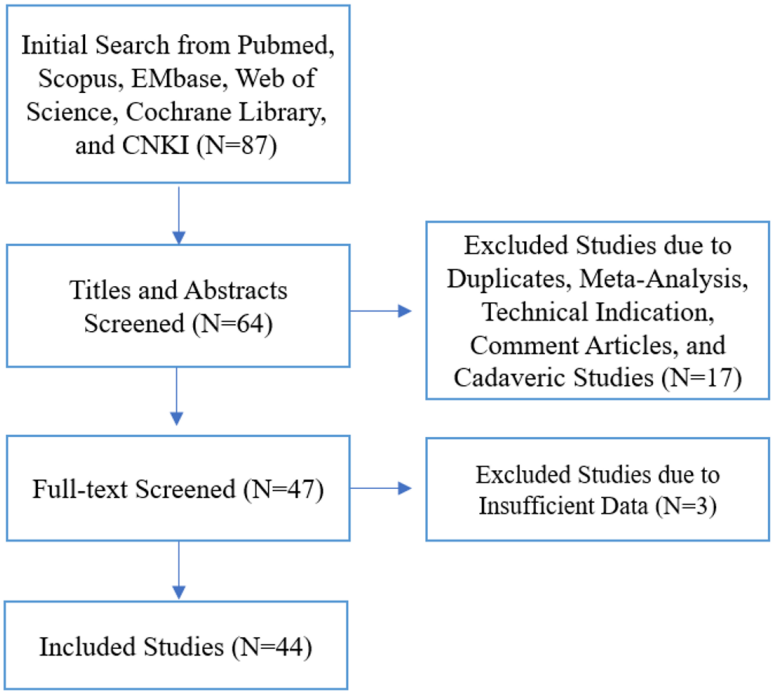

Figure 1: Flowchart

Intraoperative Radiological Exposure: In a meta-analysis of 12 studies involving 1,394 patients, the weighted mean difference (WMD) in intraoperative radiological exposure time favored the open group, with the minimally invasive surgery (MIS) group experiencing an average of 30.97 seconds longer exposure (95% CI: 20.53 to 41.42, P < 0.00001). This result was accompanied by substantial heterogeneity (I^2 = 99%, Figure 2).

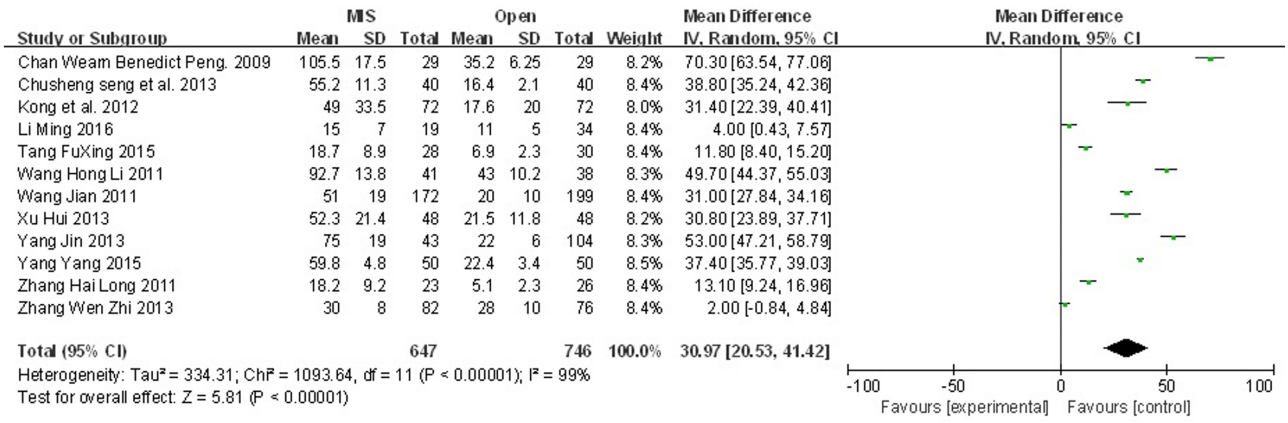

Figure 2: Intraoperative radiological exposure

4.2 Blood Loss

Analysis of 39 studies comprising 3,276 patients revealed significantly greater blood loss in the open group compared to the MIS group, with a WMD of 230.55 ml (95% CI: -273.92 to -187.19, $P < 0.00001$), also demonstrating high heterogeneity ($I^2 = 98\%$, Figure 3).

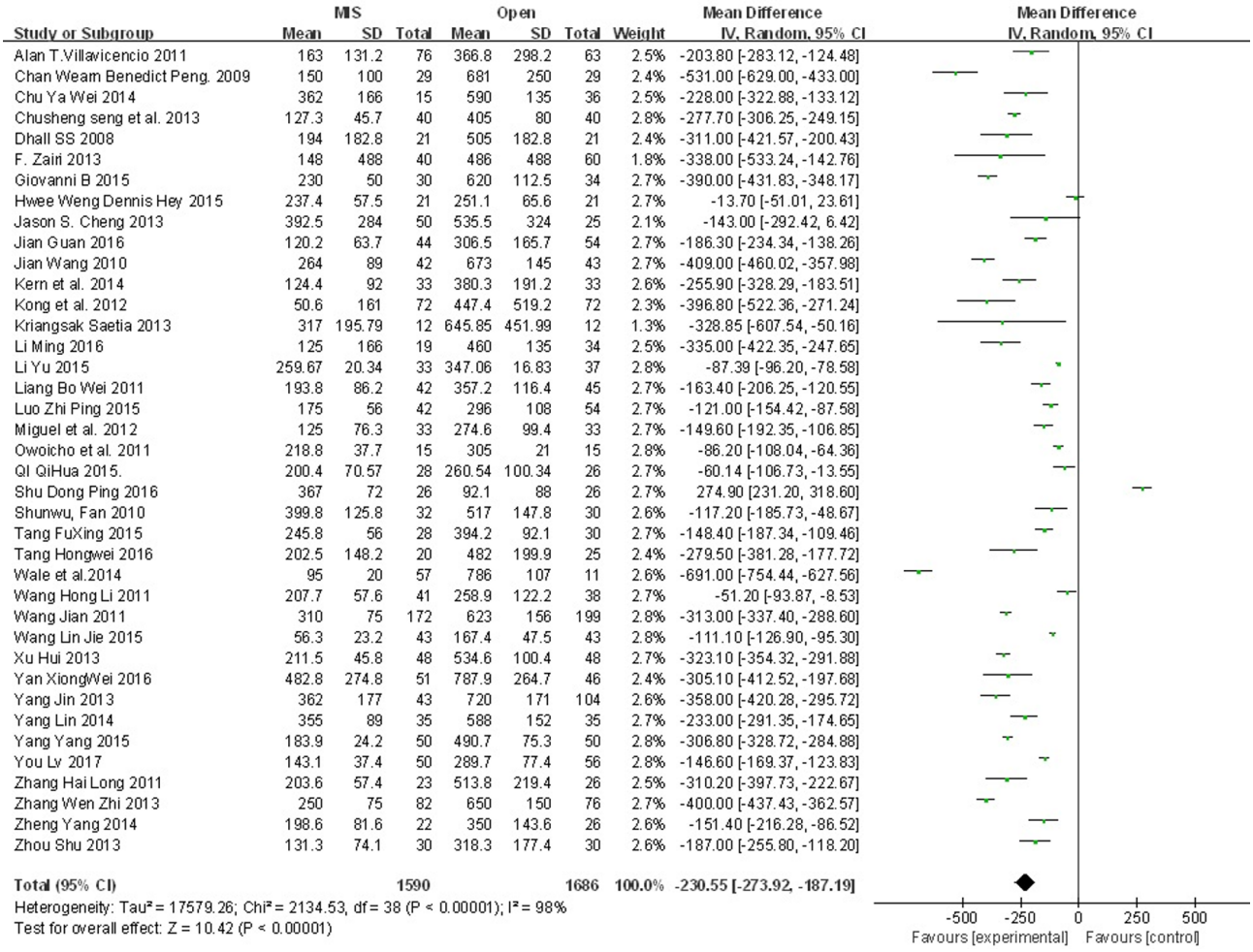

Figure 3: Intraoperative blood loss.

4.3 Postoperative Drainage Volume

Data from 15 studies, including 1,488 patients, indicated that postoperative drainage volume was significantly less in the MIS group by 103.76 ml (95% CI: -125.15 to -82.38, $P < 0.00001$), with notable heterogeneity observed ($I^2 = 94\%$, Figure 4).

4.4 Surgery Time

Despite evidence of substantial heterogeneity, there were no significant differences in surgery time between the MIS and open groups across 40 studies involving 3,470 patients ($I^2 = 99\%$, Figure 5).

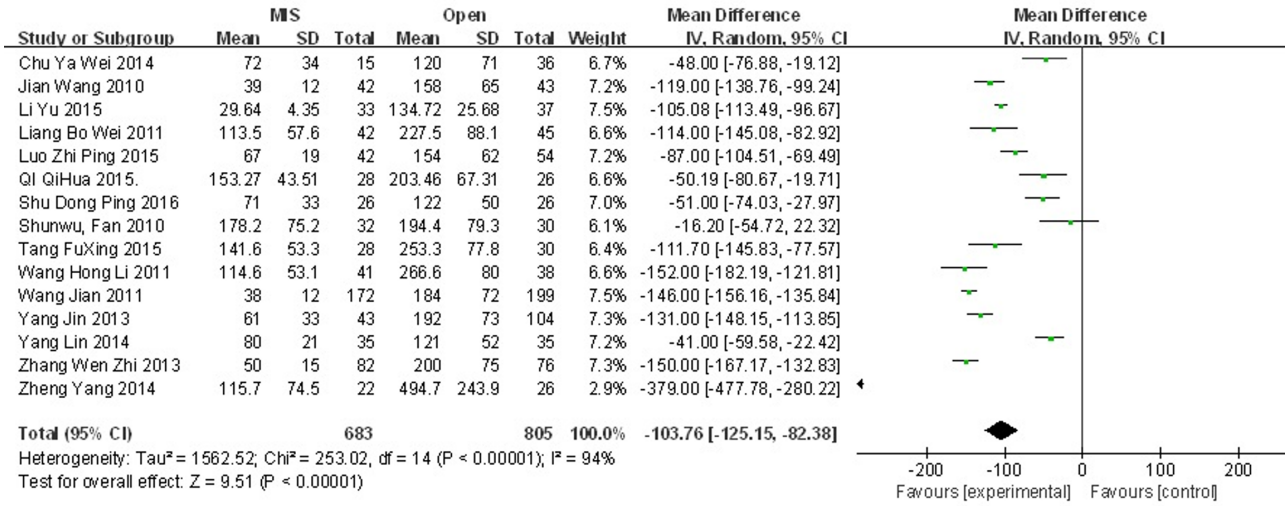

Figure 4: Postoperative drainage volume.

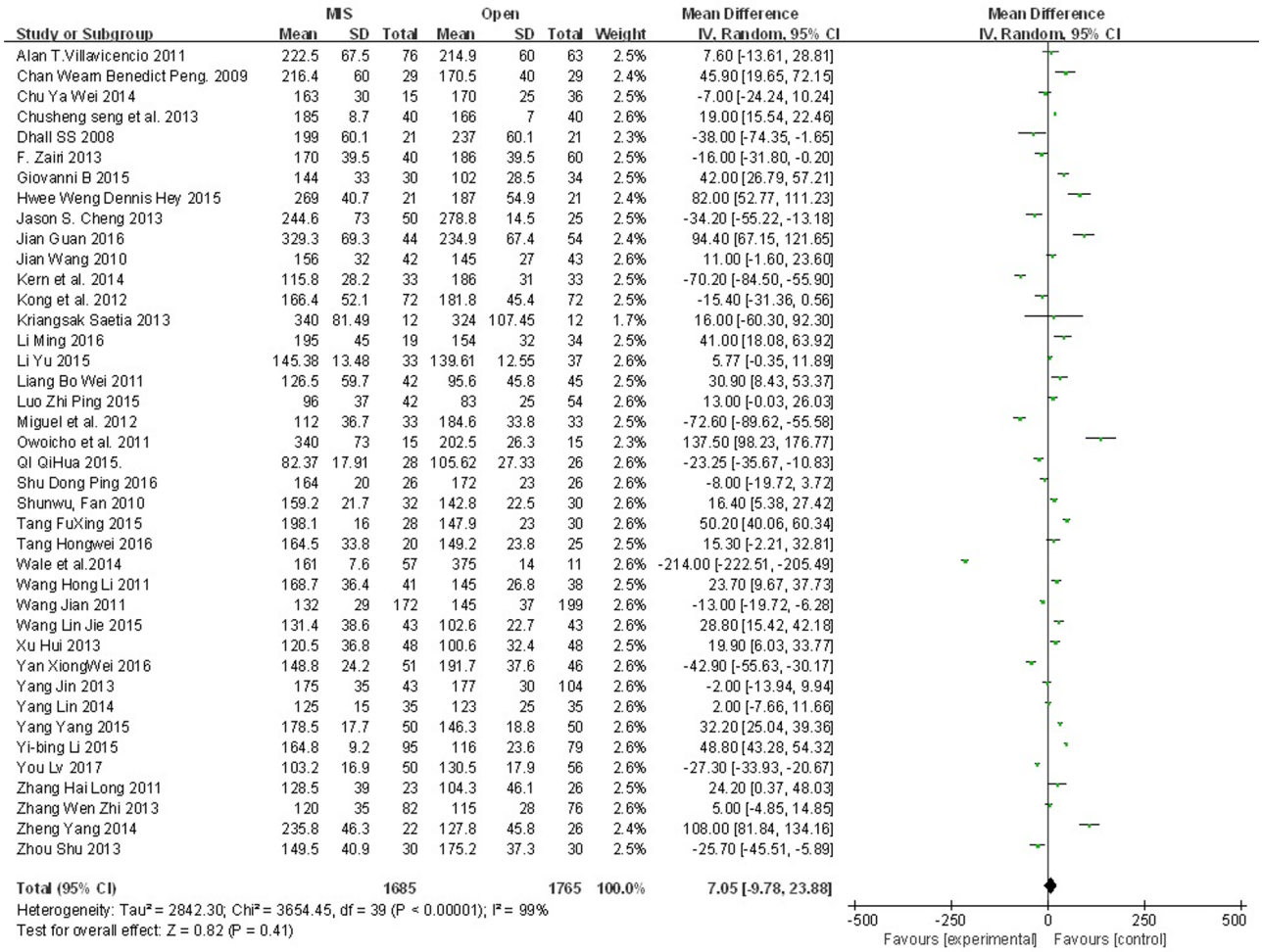

Figure 5: Surgery time comparison between MIS and open groups.

4.5 Length of Hospitalization

In 22 studies, including data from 15 studies that specifically compared the two groups, the MIS group demonstrated a shorter hospital stay by an average of 1.95 days compared to the open group (95% CI: -2.56 to -1.33, $P < 0.00001$). Significant heterogeneity was present in these findings (I^2 = 96%, Figure 6).

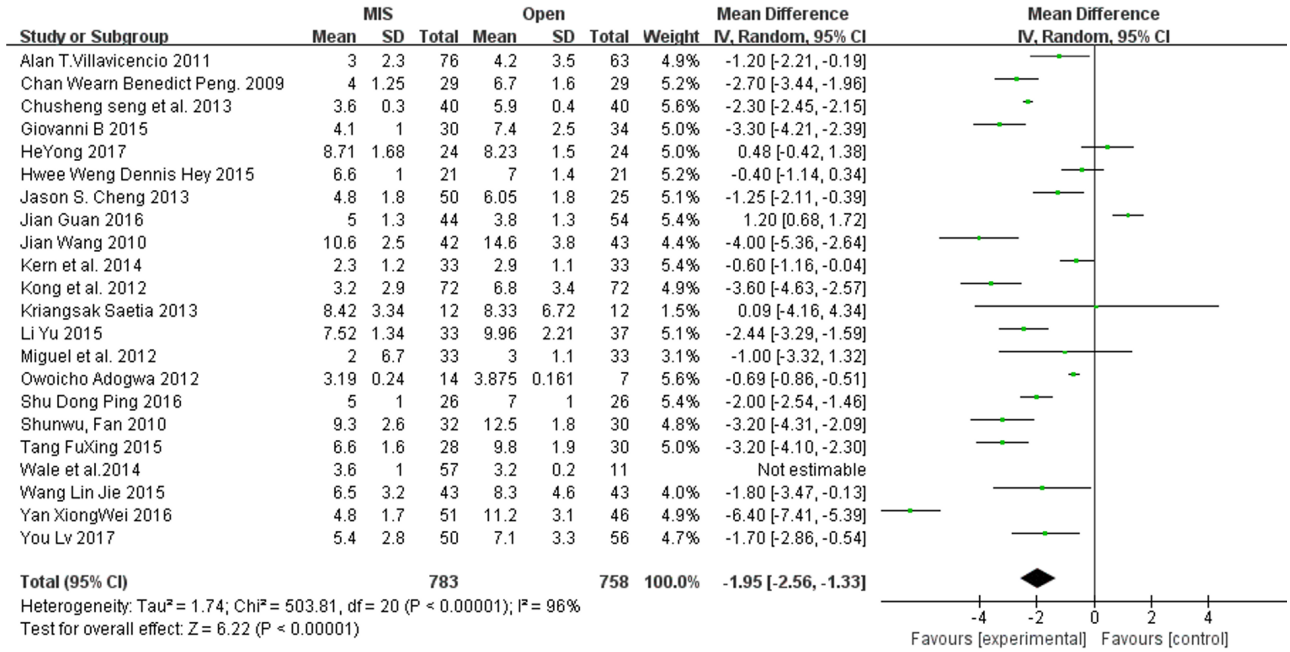

Figure 6: Length of hospitalization comparison between MIS and open groups.

4.6 Pain Outcomes Assessed by Visual Analog Scale (VAS)

4.6.1 Short-term Follow-up ($\leq$ 6 Months)

Data from 12 studies analyzing VAS scores for back pain demonstrated that the minimally invasive surgery (MIS) group reported significantly lower pain scores compared to the open group, with a weighted mean difference (WMD) of -0.63 points (95% CI: -0.95 to -0.31, $P = 0.001$), accompanied by substantial heterogeneity (I^2 = 92%). Additionally, VAS scores for leg pain, derived from 8 studies, showed a reduction of 0.49 points in the MIS group (WMD = -0.49; 95% CI: -0.82 to -0.19, $P = 0.004$), with notable heterogeneity (I^2 = 88%).

4.6.2 One-year Follow-up

Analysis of 8 studies on VAS scores for back pain at one year revealed that the MIS group experienced a further reduction in pain by 0.37 points (WMD = -0.37; 95% CI: -0.62 to -0.13, $P = 0.003$), with persistent high heterogeneity (I^2 = 93%). For leg pain at the same follow-up interval, data from 5 studies indicated no statistically significant differences between the MIS and

open groups (WMD = -0.02; 95% CI: -0.12 to 0.09, $P = 0.77$), with moderate heterogeneity (I^2 = 41%, Figure 7).

4.7 Long-term Pain Outcomes Assessed by Visual Analog Scale (VAS)

4.7.1 Two-Year Follow-up

In a meta-analysis of 13 studies evaluating back pain, the minimally invasive surgery (MIS) group demonstrated a statistically significant reduction in pain scores compared to the open group, with a weighted mean difference (WMD) of -0.31 points (95% CI: -0.44 to -0.17, $P < 0.00001$). This finding was associated with moderate heterogeneity (I^2 = 73%). For leg pain assessed at the same two-year follow-up, data from 8 studies indicated no statistically significant differences between the MIS and open groups, with a WMD of -0.10 (95% CI: -0.25 to 0.06, $P = 0.21$). This outcome also displayed moderate heterogeneity (I^2 = 54%, Figure 7).

4.8 Functional Outcomes as Assessed by the Oswestry Disability Index (ODI)

4.8.1 Short-Term and Long-Term Follow-Up

Functional outcomes were evaluated using the ODI, a measure of disability due to back pain. At the one-month follow-up, data from 5 studies indicated that the minimally invasive surgery (MIS) group reported significantly lower disability scores compared to the open group, with a weighted mean difference (WMD) of -3.21 points (95% CI: -4.65 to -1.77, $P < 0.0001$). High heterogeneity was observed (I^2 = 95%).

At six months, 11 studies reported a continued advantage for the MIS group, with a WMD of -0.79 points (95% CI: -1.21 to -0.37), also accompanied by significant heterogeneity (I^2 = 96%).

At the one-year mark, 14 studies demonstrated that the MIS group maintained improved functional outcomes, with a WMD of -1.18 points (95% CI: -1.58 to -0.77), indicating substantial heterogeneity (I^2 = 85%, Figure 8). Over a longer term, the two-year follow-up data from 20 studies showed that the MIS group's disability scores were consistently lower by 1.01 points (WMD = -1.01; 95% CI: -1.34 to -0.67), with moderate heterogeneity (I^2 = 72%, Figure 8).

4.9 Fusion Rates

Fusion success at grade 1 and grade 2 levels was assessed as a satisfactory outcome for lumbar fusion surgery. Analysis of the 6-month and 2-year fusion rates revealed no significant differences between the minimally invasive surgery (MIS) and open groups. At 6 months, the odds ratio (OR) was 0.90 (95% CI: 0.57 to 1.42, $P = 0.65$), and at 2 years, the OR was 0.86 (95% CI: 0.54 to 1.38, $P = 0.54$), with an overall effect showing an OR of 0.88 (95% CI: 0.64 to 1.22, $P = 0.45$). Chi-squared tests confirmed the absence of heterogeneity (I^2 = 0%, $P = 0.83$; Figure 9).

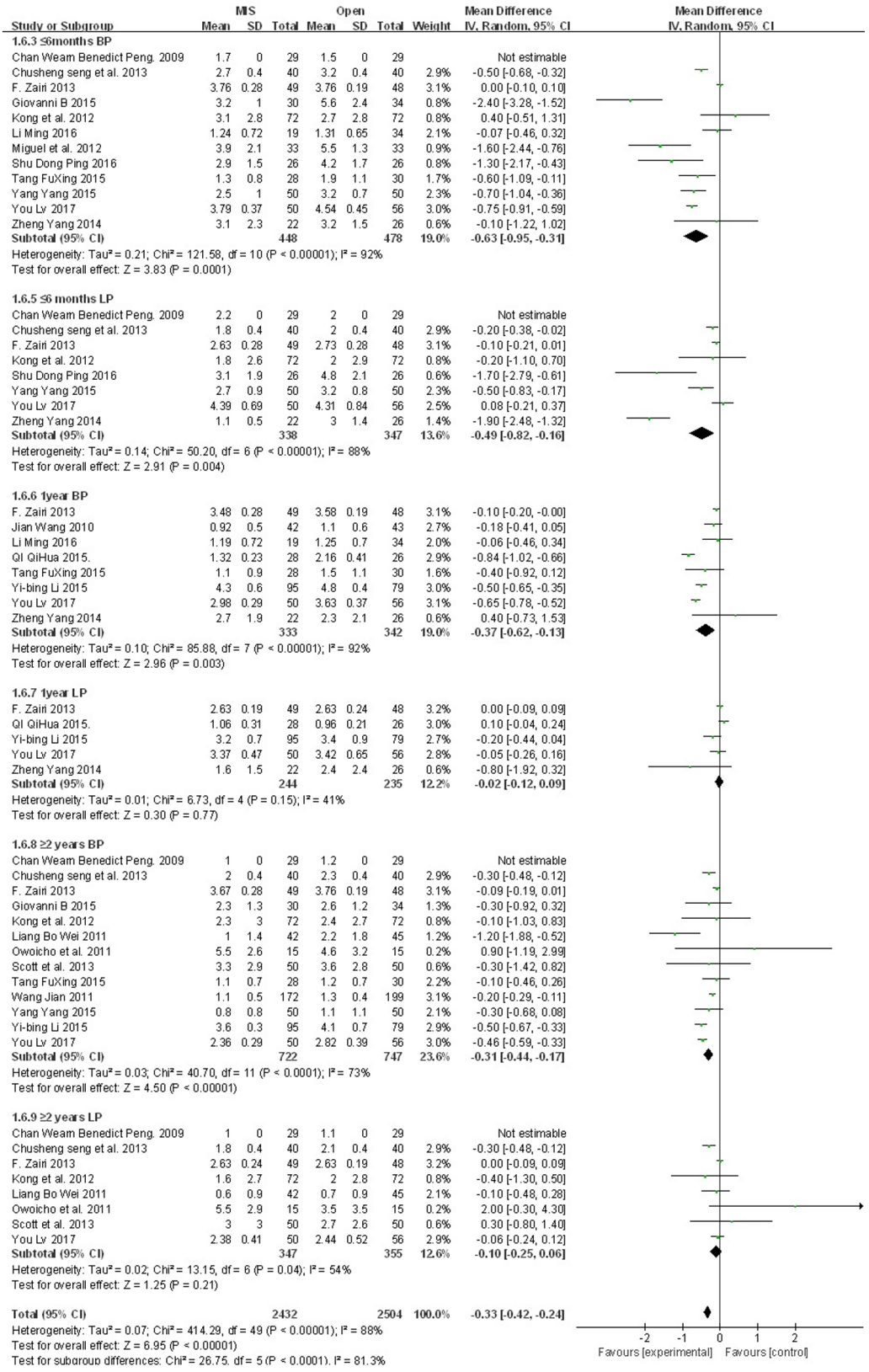

Figure 7: VAS scores comparison between MIS and open groups at different follow-up intervals.

4.10 Physical and Mental Component Scores

Physical component scores from four studies indicated that the MIS group scored on average 3.21 points higher than the open group (WMD = 3.21, 95% CI: 0.03 to 6.40, $P = 0.05$). In contrast,

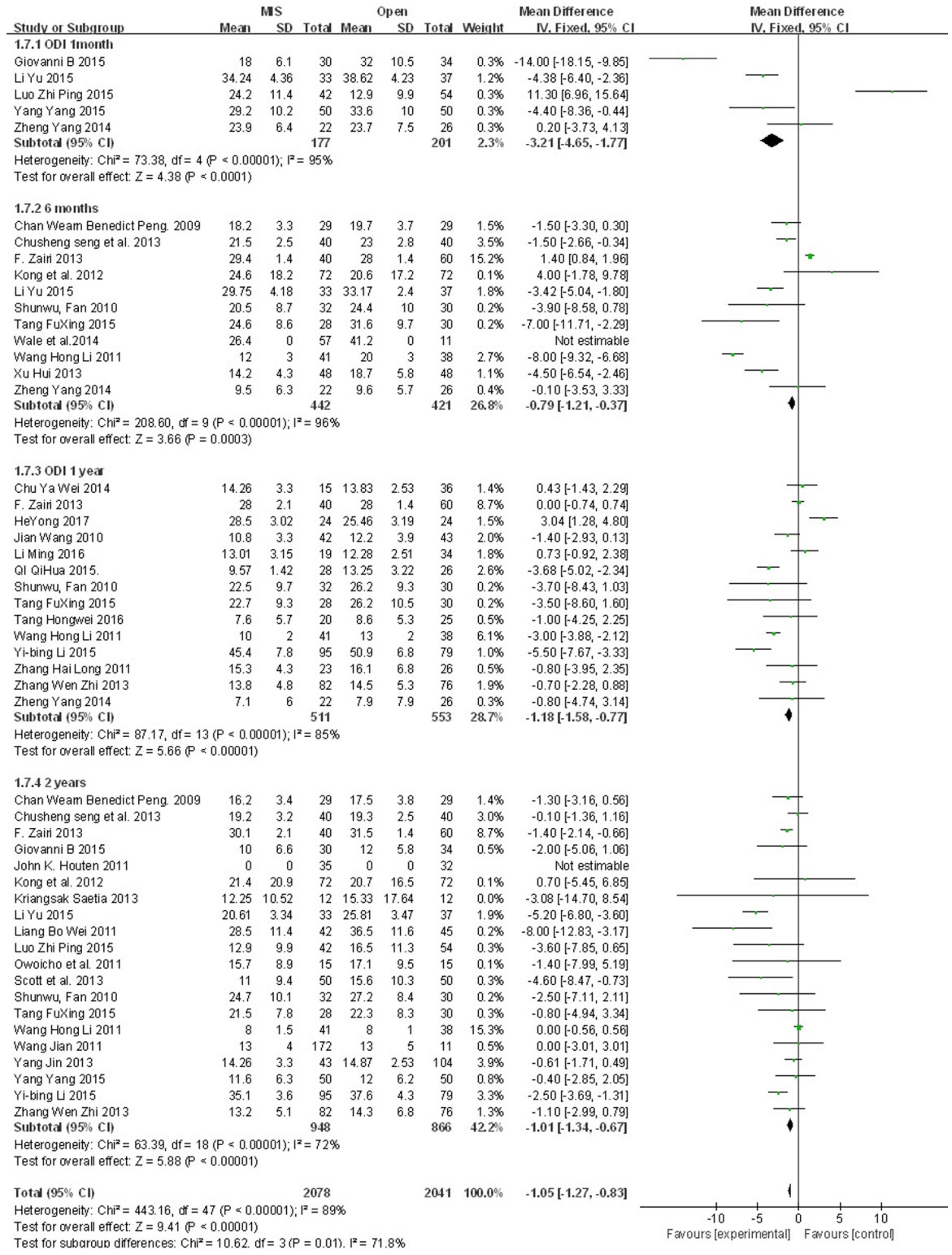

Figure 8: ODI scores comparison between MIS and open groups at different follow-up intervals.

data on mental component scores from four studies showed no statistically significant differences (Figure 10).

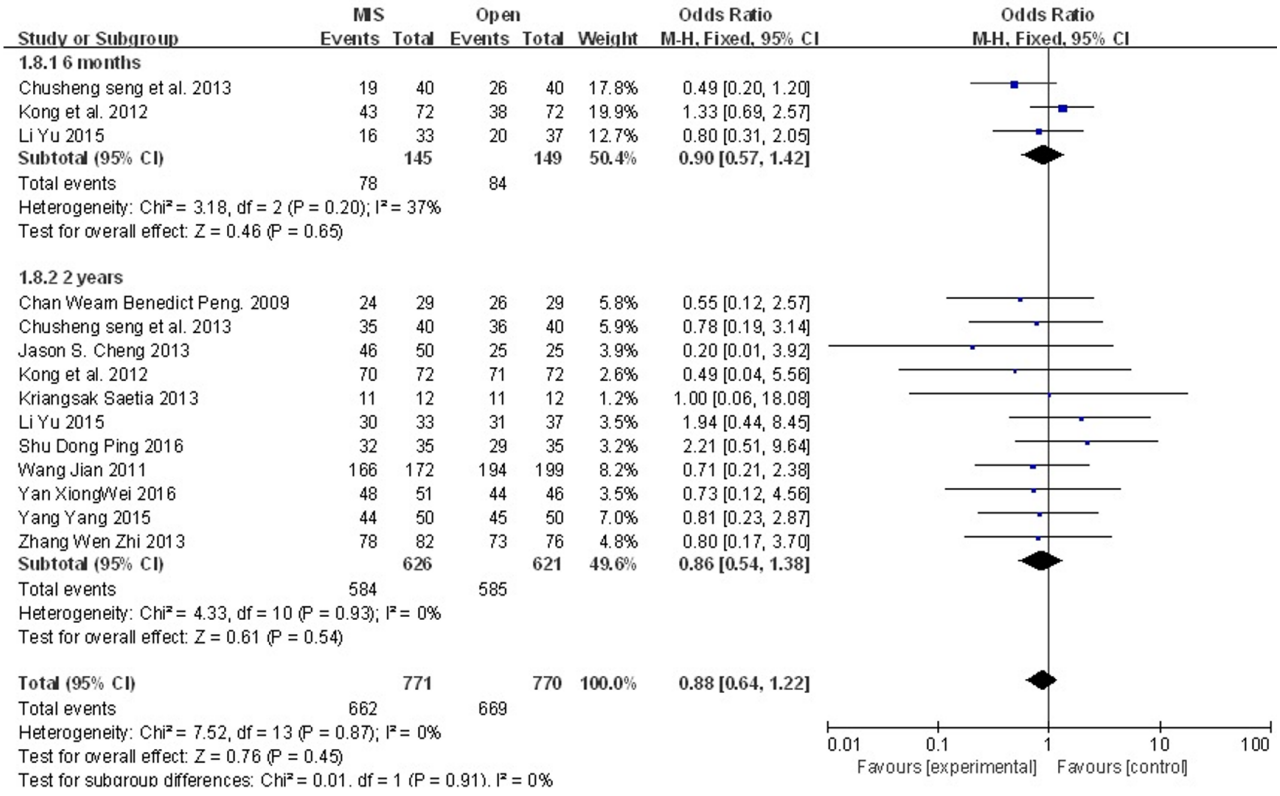

Figure 9: Fusion rate comparison between MIS and open groups.

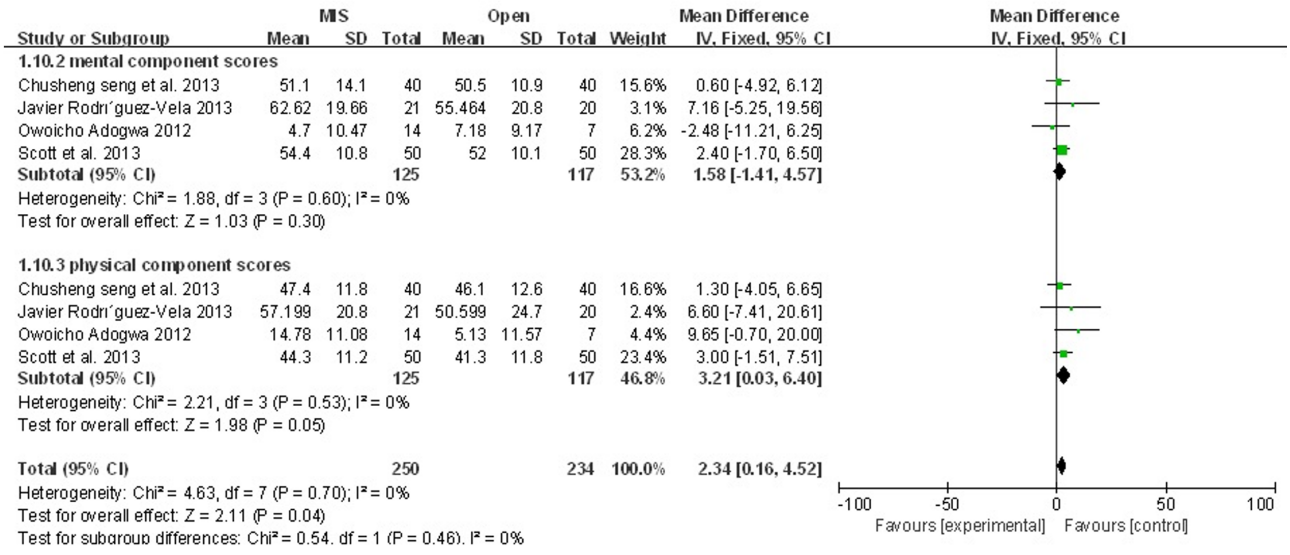

Figure 10: Short-form 36 physical and mental component scores.

4.11 Neurogenic Symptom Scores

At the 6-month follow-up, neurogenic symptom scores were reported in three studies. One of these showed statistically significant differences, with a mean difference (MD) of 1.87 (95% CI: 0.67 to 3.07). There was no evidence of heterogeneity (I^2 = 0%, P = 0.77; Figure 11). At

the 2-year follow-up, although no individual study reported significant differences, pooled data indicated that the open group had lower neurogenic symptom scores than the MIS group, with a WMD of -1.44 (95% CI: 0.50 to 2.38, $P = 0.003$). Again, there was no evidence of heterogeneity (I^2 = 0%, $P = 0.71$; Figure 11).

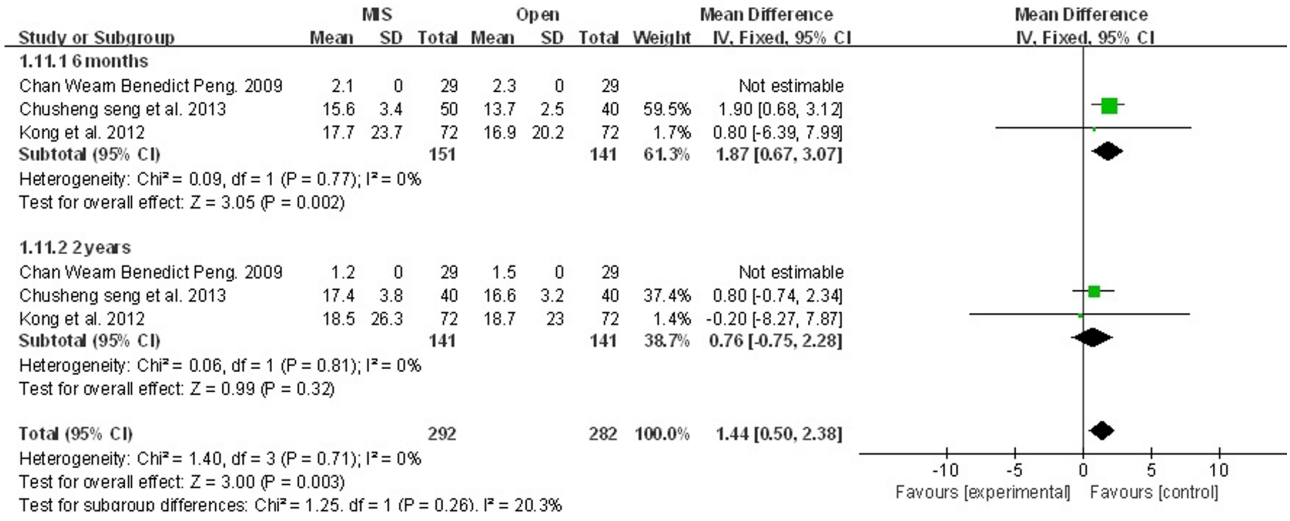

Figure 11: Neurogenic symptom scores at 6-month and 2-year follow-ups.

4.12 Biochemical Markers of Inflammation and Muscle Damage

4.12.1 C-reactive Protein (CRP)

CRP levels were measured in four studies at 24 hours post-operation. The minimally invasive surgery (MIS) group exhibited significantly lower CRP levels than the open group, with a weighted mean difference (WMD) of -17.20 ng/L (95% CI: -27.05 to -7.35), although significant heterogeneity was present (I^2 = 89%, random effects). At 7 days post-operation, CRP levels were reported in two studies, showing no significant differences between the groups (WMD = -3.51 ng/L; 95% CI: -16.17 to 9.16), with very high heterogeneity (I^2 = 98%). Overall, CRP levels in the MIS group were 12.45 ng/L lower than those in the open group (WMD = -12.45; 95% CI: -21.43 to -3.47), also displaying substantial heterogeneity (I^2 = 97%, Figure 12).

4.12.2 CK-MM

CK-MM levels recorded 24 hours after surgery in three studies showed that the MIS group had significantly lower levels than the open group by 178.62 IU/L (WMD = -178.62; 95% CI: -269.66 to -87.57), with evident heterogeneity (I^2 = 88%). At 7 days post-operation, CK-MM levels were lower in the MIS group by 16.60 IU/L (WMD = -16.60; 95% CI: -33.47 to 0.27), showing moderate heterogeneity (I^2 = 55%). Cumulatively, CK-MM levels in the MIS group were 87.64 IU/L lower than in the open group (WMD = -87.64; 95% CI: -136.10 to -39.17), with high heterogeneity (I^2 = 94%, Figure 13).

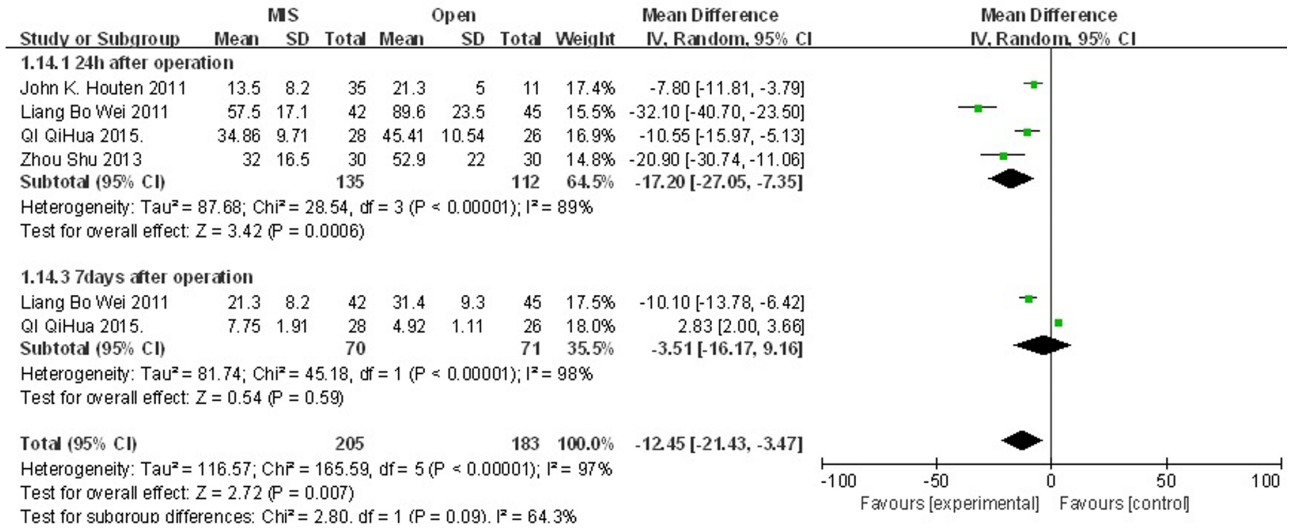

Figure 12: C-reactive protein (CRP) levels comparison between MIS and open groups.

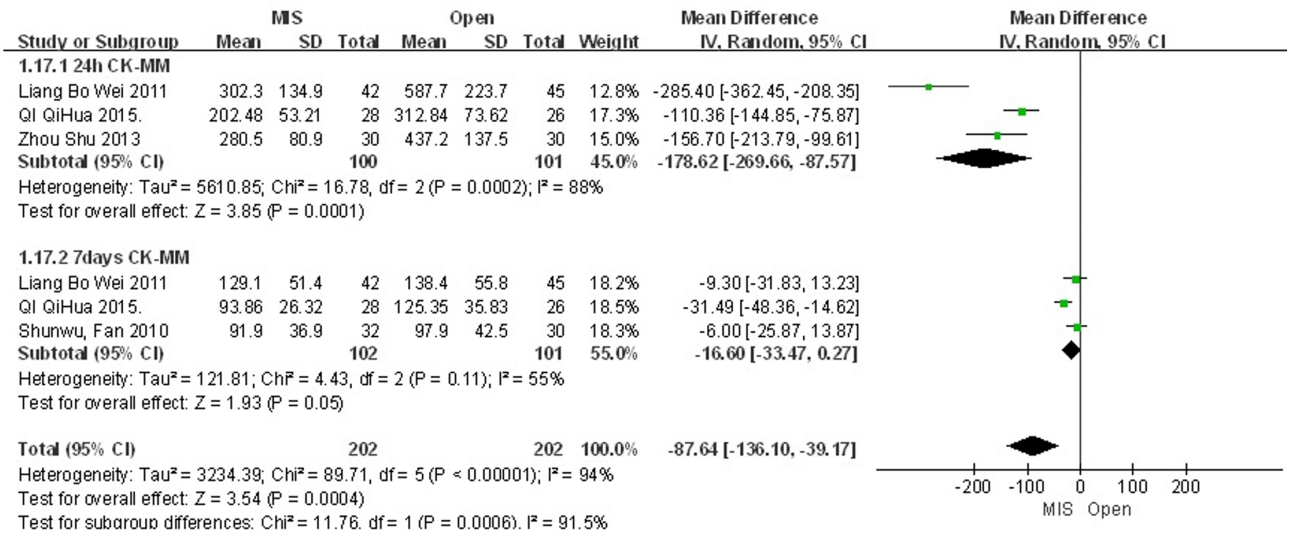

Figure 13: Creatine kinase-MM (CK-MM) levels comparison between MIS and open groups.

4.12.3 CPK Levels

CPK levels recorded 24 hours post-operation were available in three studies. The minimally invasive surgery (MIS) group had significantly lower CPK levels compared to the open group, with a weighted mean difference (WMD) of -84.17 IU/L (95% CI: -93.40 to -74.95, $P < 0.00001$). There was significant heterogeneity among the studies ($I^2 = 91\%$). At 7 days post-operation, data from two studies showed no statistically significant differences between the groups (WMD = -0.72, 95% CI: -4.95 to 3.51), with low heterogeneity ($I^2 = 43\%$). Overall, the MIS group had lower CPK levels by 15.24 IU/L compared to the open group (WMD = -15.24, 95% CI: -19.09 to -11.40), with substantial heterogeneity ($I^2 = 99\%$, Figure 14).

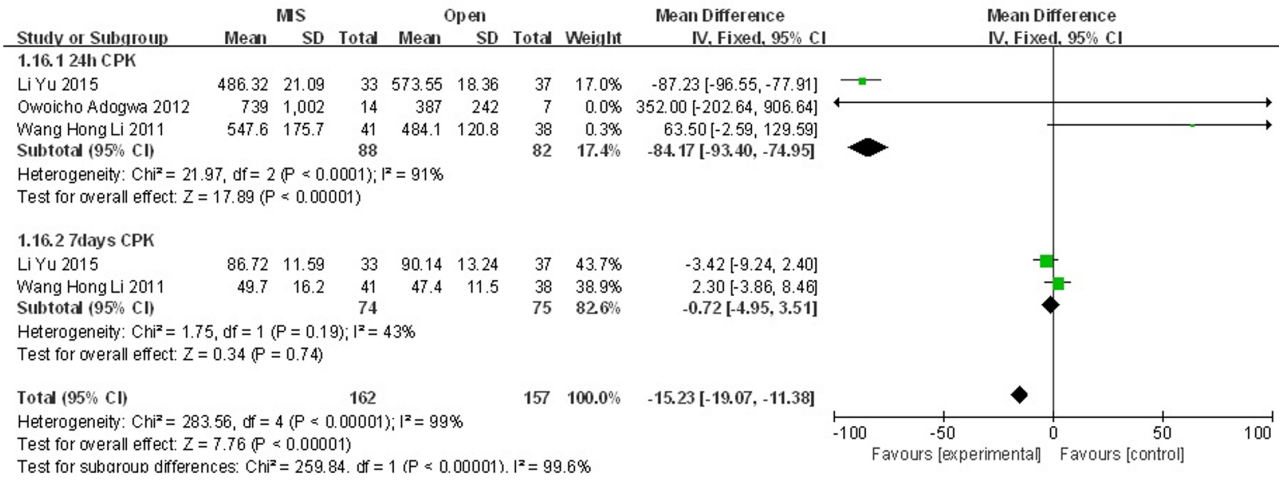

Figure 14: Creatine phosphokinase (CPK) levels comparison between MIS and open groups.

4.12.4 Complication Rates

Complication rates were reported in 13 studies. There were no statistically significant differences in complication rates between the MIS and open groups (I^2 = 12%, Figure 15).

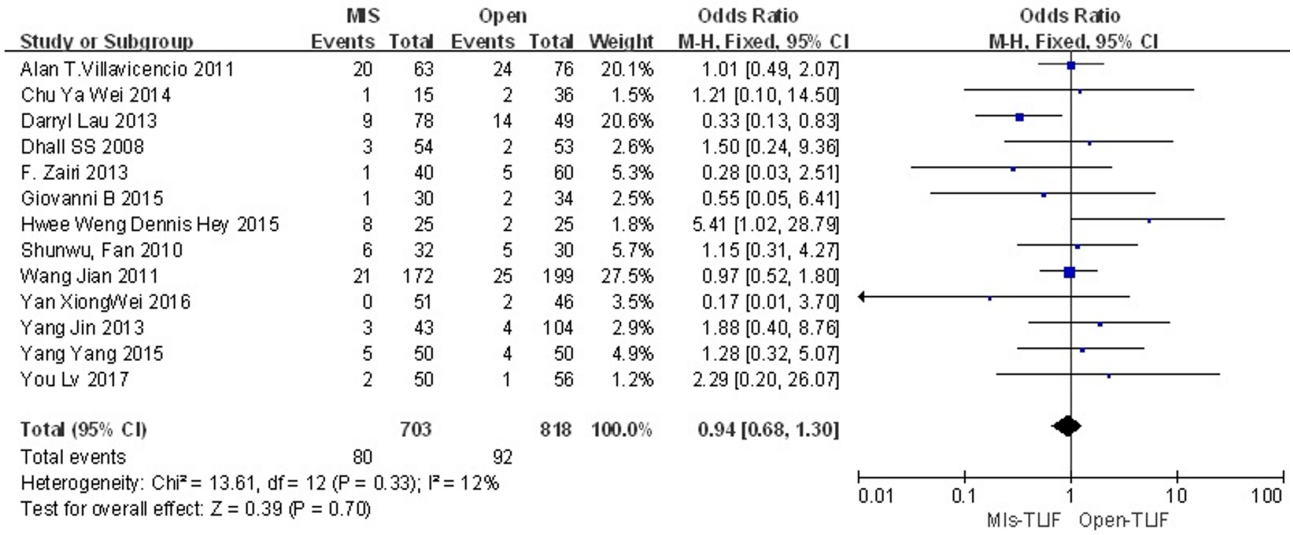

Figure 15: Comparison of complication rates between MIS and open groups.

5 Discussion

5.1 Advantages and Limitations of TLIF and MIS-TLIF

TLIF, an evolution of posterior lumbar interbody fusion (PLIF), was first introduced in 1998[15]. It offers several advantages over PLIF, including reduced epidural synechiae and decreased scar formation. However, TLIF has limitations in contralateral decompression and incomplete disc

removal[16]. On the other hand, PLIF may result in abnormal physiological motion of the fused lumbar segments, increased stress on adjacent segments, and accelerated degeneration[17].

With advancements in spine surgery, minimally invasive TLIF (MIS-TLIF) has emerged as a popular alternative. MIS-TLIF is associated with reduced intraoperative blood loss, faster recovery, and improved postoperative function[18]. However, it also has limitations, such as restricted working space, potentially leading to longer operative times and a steeper learning curve[19]. According to Lee et al.[20], surgeons must perform 44 MIS-TLIF procedures to reach proficiency. Additionally, MIS-TLIF has been reported to increase surgical risks by up to 31.37%[21], including cage misplacement, screw misalignment, and nerve root injury. A contentious issue surrounding MIS-TLIF is the increased intraoperative fluoroscopy exposures, challenging surgeons to choose between minimally invasive and open techniques[22].

5.2 Surgical Exposure and Long-Term Outcomes

One of the major drawbacks of MIS-TLIF is reduced surgical exposure and visualization, which can lead to insufficient neural decompression. This inadequate decompression may reduce the long-term efficacy of the surgery[5]. Although high-quality evidence supports the short-term benefits of MIS-TLIF, its long-term outcomes remain uncertain[18]. Our meta-analysis sought to compare the long-term clinical outcomes of MIS-TLIF and open-TLIF in treating single-level degenerative lumbar diseases, with follow-up periods exceeding two years.

Previous meta-analyses by Sun et al.[23], Tian et al.[24], and Nickalus et al.[25] found that MIS-TLIF resulted in less blood loss and shorter hospital stays compared to open-TLIF. However, these studies had limitations, including a lack of focus on VAS scores for leg pain and varying methodologies, potentially introducing bias. Additionally, these meta-analyses were restricted to English-language publications, potentially overlooking important data and contributing to publication bias[14,26].

5.3 Clinical Effectiveness of MIS-TLIF

Our meta-analysis confirmed that MIS-TLIF is associated with significantly lower blood loss and shorter hospital stays, with no significant difference in surgery time compared to open-TLIF. These findings align with previous studies[24]. Patients undergoing MIS-TLIF also showed less postoperative drainage volume. Regarding pain outcomes, MIS-TLIF led to better VAS back pain scores at follow-ups of ≤ 6 months, 1 year, and ≥ 2 years. However, the advantages for VAS leg pain were limited to the early postoperative period (≤ 6 months). No significant differences in VAS leg pain were observed at the 1-year and 2-year follow-ups.

5.4 Functional Outcomes and ODI Improvements

Our meta-analysis revealed superior early (1 month, 6 months) and mid-term (1 year, ⊡2 years) ODI score improvements in the MIS-TLIF group. However, the conclusions should be interpreted with caution. Although Sun et al.[23] found slight ODI improvement at 1-year follow-up,

Nickalus R et al.[25] reported no significant differences. Further high-quality studies are necessary to corroborate these findings.

5.5 Intraoperative Radiological Exposure

MIS-TLIF procedures are associated with longer intraoperative radiological exposure. Chang Hyeun Kim et al.[29] demonstrated that MIS-TLIF patients were exposed to 2.4 times more radiation than open-TLIF patients, with higher lifetime risks of cancer and hereditary disorders. However, the use of navigation-assisted fluoroscopy has shown potential for reducing intraoperative radiation exposure in minimally invasive spine surgeries[30].

5.6 Learning Curve and Technical Challenges

The steep learning curve of MIS-TLIF can significantly affect surgery time and radiation exposure. With advancements in technology and surgeon proficiency, it is anticipated that intraoperative radiological exposure time will decrease[20]. Comparative studies have shown that radiation doses vary depending on surgical technique and individual anatomy[31,32].

5.7 Additional Clinical Outcomes and Fusion Rates

Our meta-analysis found no significant differences in SF-36 physical and mental component scores, nor in NASS scores for neurogenic symptoms, between MIS-TLIF and open-TLIF groups. Furthermore, fusion rates were comparable between the two procedures, consistent with prior research[34]. The complication rates were also similar between the two techniques[35].

5.8 Biochemical Markers of Inflammation and Muscle Damage

CRP and CK-MM levels, commonly used markers of inflammation and muscle damage, were lower in the MIS-TLIF group post-operation. Lower CRP levels in the early postoperative period suggest reduced inflammatory response following MIS-TLIF, although there were no significant differences at 7 days post-operation. Similarly, CK-MM and CPK levels were significantly lower in the MIS-TLIF group 24 hours post-operation, indicating less muscle damage compared to open-TLIF[36,37,38]. These findings suggest that MIS-TLIF is associated with less iatrogenic muscle injury than open-TLIF.

5.9 Limitations

There are several limitations to our study. Firstly, there was a scarcity of high-quality randomized controlled trials (RCTs), which are crucial for evaluating surgical treatments. Consequently, we had to include retrospective and prospective studies, which are susceptible to selection bias. Many of these studies had methodological defects, leading to significant heterogeneity when continuous outcomes were pooled. Secondly, we did not analyze complications by specific types because the nature of complications varied across studies; instead, we only analyzed the overall complication

rate. Thirdly, the data we collected were not discharge values, which would have provided greater confidence in our findings. Despite these limitations, our systematic review still offers valuable insights for clinicians.

Table 1. Information of the two groups in the finally included articles

Studies	Etiology	Participants：Group 1: MIS TLIF Group 2: Open TLIF	Study Design	Outcome Collection	Methodological Quality Assessment of Included Studies
Chan Wearn Benedict Peng 2009[39]	Spondylolisthesis + DDD	Group 1: 29 participants;mean age 54.1 year (26.4 –73.6 years), female:male 24:5 follow-up ≥2 years Group 2: 29 patients; mean age 54.1 year (26–73.6 years) follow-up ≥2 years, female:male 24:5	PCS	1.2.3.4.5.6.7.9	S:3+C:2+O:3=8
Owoicho Adogwa 2011[40]	Degenerative spondylolithesis	Group 1: 15 participants; mean age 50.8 year (SD age 7.9 years) female:male ratio of 8:7 follow-up ≥2 years Group2: 15 participants mean age 49.7 year (SD age 11.4 years) female:male ratio of 10:5 follow-up ≥2 years	RCS	2.3.5.6.	S:4+C:1+O:3=8
Miguel 2012[41]	Spondylolisthesis+ spinal stenosis+ DDD	Group 1：33 participants, mean age 51.67 ± 12.19, female:male 23:10 Follow-up for2 years ;follow-up rate unclear Group 2: 33 participants, mean age 49.85 ± 10.72, female:male 21:12, follow-up for 2 years, follow-up rate unclear	PCS	2.3.4.5.	S:4+C:2+O:2=8
Kong Hwee Lee 2012[42]	Spondylolisthesis+ recurrent prolapsed disc+ spinal stenosis+ degenerated collapsed disc	Group 1 :72 participants, age 52.2 ± 13.8 , femal:male 52:20, follow-up 2 years ; follow-up rate 95.8% Group 2:72 participants, age 56.6 ± 14.6, femal:male 50:22, follow-up 2 years, follow-up rate 91.7%	PCS	1.2.3.4.5.6.7.9.	S:4+C:2+O:3=9
scott 2014[43]	Spondylolisthesis	Group 1: 50 participants, age 53.5 ± 12.5 years, mean age 53.5 years (SD age 12.5), female:male 34:16, follow-up ≥2 year Group 2: 50 participants, age 52.6 ± 11.6 years, female:male 32:18, follow-up ≥2 year	PCS	5.6.8.	S:3+C:2+O:3=8
Kern Singh 2014[44]	Spondylolisthesis+ Spinal stenosis+ DDD	Group 1 : 33 participantsAge 51.67±11.12Female:male 10:23Follow-up ≥2 years Group 2: 33 participantsAge 49.85±10.72Female:male 12:21Follow-up ≥2 years	RCS	2.3.4	S:3+C:2+O:3=8
Wale 2014[45]	Spondylolisthesis	Group 1: 57 participants, Mean age 61.1, female:male 40:17, follow-up ≥1 years Group 2: 11 participants, mean age 56.7, female:male 7:4, follow-up ≥1 years	RCS	2.3.4.6	S:4+C:2+O:2=8
Seng 2013[46]	Spondylolisthesis+ DDD	Group 1: 40 participants, age 56.6 ± 1.63, female:male 33:7, follow-up ≥5 years Group 2: 40 participants, age 56.8 ± 1.67, female:male 33:7, follow-up ≥5 years	RCS	1.2.3.4.5.7.8.9	S:4+C:2+O:2=8
Alan T.Villavicencio 2010[47]	Spondylolisthesis + DDD+ Stenosis	Group1:76participants, age:50.5(19-91) , female:male:31:45, follow-up:37.5(26-52) Group2:63participants;age: 58.9(30-86); female:male 25:38;follow-up:37.5(26-52)	RCS	2.3.4.14	S:4+C:2+O:2=8
Dhall SS 2008[48]	Spondylolisthesis+ DDD	Group1:21participants;age:53,P:0.98;female:male:NA;follow-up:24(12-47), Group2:21participants, age:53,P:0.98,female:male:NA, follow-up:34(12-86)	RCS	2.3.14	S:4+C:2+O:2=8
F. Zairi 2013[49]	Spondylolisthesis+ DDD	Group1:40participants;age49.;P:0.723;female:male:20:20;follow-up:27(24-39), Group2:60participants, age:48,P:0.723,female:male:53:47, follow-up:30(24-48)	RCS	2.3.14	S:3+C:2+O:3=8
Giovanni B 2015[50]	Spondylolisthesis+ DDD	Group1:30participants;age:46(28-56);female:male:18:12;follow-up:23(12-38), Group2:34participants, age:51(32-58),female:male:20:14, follow-up:25(12-40)2	RCS	2.3.4.5.6.14	S:4+C:2+O:2=8
Hwee Weng Dennis Hey 2015[51]	NA	Group1:25participants;age44.4(19-69);female:male:12:13;follow-up:26.9 Group2:25participants, age:43.6(20-69),female:male:12:13, follow-up:29.3	PCS	2.3.4.14	S:3+C:2+O:2=7
Javier Rodrguez-Vela 2013[52]	DDD	Group1:21participants, age:41.8±8.7;female:male:7:14, follow-up:＞3 years Group2:20participants;age43.15±7.3;female:male:7:13;follow-up:＞3 years	PCS	8	S:3+C:2+O:2=7
Jian Wang 2010[53]	Degenerative spondylolisthes+ Isthmic spondylolisthes	Group1:42participants;age47.9±8.5;female:male:29:13;follow-up:26.3(13-35) Group2:43participants, age:53.2±10.6;female:male:27:13, follow-up:26.3(13-35)	PCS	2.3.4.5.6.10.14	S:4+C:2+O:2=8
Kriangsak Saetia 2013[54]	Spondylolisthesis	Group1:12participants;age63.1±6.84;female:male:11:1;follow-up:28(24-38) Group2:12participants;age:67.4±10.35;female:male:6:6, follow-up:28(24-38)	RCS	2.3.4.6.7.	S:4+C:2+O:2=8
Owoicho 2012[55]	Spondylolisthesis+ DDD	Group1:14participants;age48.14±13.21;female:male:10:4;follow-up:＞2years Group2:7participants;age:47.28±9.86;female:male:4:3, follow-up:＞2years	PCS	4.8	S:4+C:2+O:2=8
Shunwu, Fan 2010[56]	Spondylolisthesis+ DDD+ Stenosis	Group1:32participants;age51.4±7.2;female:male:14:18;follow-up:2years Group2:30participants;age:52.0±6.4;female:male:16:14, follow-up:2years	PCS	2.3.4.5.10.12.14	S:4+C:1+O:3=8
WANG Hong-li2011[57]	Single-level LDH+ Spinal stenosis+ Spondylolisthesis	Goup1:41participants;age51.4±13.3;female:male:17:24;follow-up:32.7(24-47) Group2:38participants;age:57.3±12.1,female:male:15:23;follow-up:32.7(24-47)	RCT	1.2.3.10.13	S:4+C:1+O:3=8
Yang Yang 2015[58]	Spinal stenosis + Spondylolisthesis + Disc herniation with segmental instability	Goup1:50participants;age58.0±13.4;female:male:32:18;follow-up:2years Group2:50participants;age:56.1±11.0;female:male:27:23;follow-up:2years	RCT	1.2.3.5.6.7.14	S:4+C:2+O:3=9
Yi-bing Li 2016[59]	Lumbar Instability+Lumbar stenosis+ Lumbar spondylolysis	Goup1:95participants;age56.0±7.8;female:male:46:43;follow-up:51.8±6.8 Group2:79participants;age:59±5.5;female:male:47:45;follow-up:54.8±5.7	PCS	3.6	S:3+C:2+O:3=8
Chu Ya Wei 2014[60]	DDD	Goup1:15participants; Group2:36participants; Mean age in all cases：53（40-76） Female：Male in all cases：17:34	RCS	2.3.6.10.14	S:3+C:2+O:3=8
Darryl Lau2013[61]	Spondylolisthesis+ Degenerative disc disease (DDD).	Group1:26participants; Group2:19participants; Mean age：Group1：50.5±13.4；Group2：57.4±12.6 Female/Male：Group1:14:12;Group2:11:8	RCS	14	S:3+C:2+O:3=8
Li Yu 2015[62]	Lumbar degenerative disease	Goup1:33participants;age51.83±4.16;female:male:15:18;follow-up:23.57±3.05 Group2:37participants;age:52.42±3.76;female:male:16:21;follow-up:24.67±3.48	PCS	2.3.4.6.7.10.13	S:4+C:2+O:2=8
Liang Bo Wei 2011[63]	Degenerative lumbar instability	Goup1:42participants;age49.8（41-62）;female:male:19:23;follow-up:32（27-52） Group2:45participants;age:51.3（38-65）;female:male:19:26;follow-up:33（26-51）	RCS	2.3.5.6.10.11	S:4+C:2+O:3=9
Luo Zhi Ping 2015[64]	LDH with instability; Lumbar stenosis+ Lumbar spondylolysis;	Goup1:42participants;age64.4±4.9;female:male:19:23;follow-up:26±7 Group2:54participants;age:66.5±7.6;female:male:22:32;follow-up:27±8	RCT	2.3.6.10.11	S:4+C:2+O:3=9
QI QI Hua 2015[65]	Spondylolisthesis+ DDD+ Stenosis	Goup1:28participants;age44.1（35-55）;female:male:12:16;follow-up:＞1year Group2:26participants;age:43.5（39-60）;female:male:11:15;follow-up:＞1year	RCS	2.3.5.6.10.11.12	S:4+C:2+O:3=9
Wang Jian 2011[66]	Spondylolisthesis	Goup1:172participants;age49±11;female:male:111:161;follow-up:32.7（12-58） Group2:199participants;age:50±13;female:male:126:73;follow-up:32.7（12-58）	RCS	1.2.3.5.6.7.10	S:3+C:2+O:3=8
Wang Lin Jie 2015[67]	Lumbar degenerative disease	Goup1:43participants;age50.0±5.4;female:male:21:22;follow-up:1year Group2:43participants;age50.5±4.6;female:male:19:24;follow-up:1year	RCS	2.3.4.	S:3+C:2+O:3=8
Xu Hui 2013[68]	Spondylolisthesis	Goup1:48participants;age:44.6;female:male:24:24;follow-up:6-12months Group2:48participants;age45.3;female:male:16:32;follow-up:6-12months	RCS	1.2.3	S:3+C:2+O:3=8
Yang Jin 2013[69]	Single-level lumbar degenerative disease	Goup1:43participants;age:55(36-79);female:male:28:15;follow-up:21months(18-26) Group2:104participants;age52(36-78);female:male:67:37;follow-up:23months(18-28)	RCS	1.2.3.6.10.14	S:4+C:2+O:2=8
Yang Lin 2014[70]	Lumbar degenerative disease	Goup1:35participants;age:52.2±3.3;female:male:10:25;follow-up:NA Group2:35participants;age51.2±3.5;female:male:11:24;follow-up:NA	PCS	2.3.10	S:4+C:2+O:1=7
Zhang Hai Long 2011[71]	Spondylolisth	Goup1:23participants;age:55(42-76);female:male:13:10;follow-up:11months(9-22) Group2:26participants;age56(38-72);female:male:10:16;follow-up:11months(9-22)	RCS	1.2.3.6	S:3+C:2+O:3=8
Zhang Wen Zhi 2013[72]	Lumbar degenerative disease	Goup1:82participants;age:52.4(42-65);female:male:38:44;follow-up:18months(12-28) Group2:76participants;age51.8(40-61);female:male:30:46;follow-up:18months(12-28)	RCS	1.2.3.6.7.10	S:3+C:2+O:3=8
Zheng Yang 2014[73]	Single level lumbar spine degenerative disease	Goup1:22participants;age:49.4±12.1;female:male:15:7;follow-up:12months（6months-24months） Group2:26participants;age50.7±11.8;female:male:15:11;follow-up:12months（6months-24months）	RCS	2.3.5.6.10	S:4+C:2+O:3=9
Jason S. Cheng2013[74]	Spondylosis+ Spondylolisthesis+ Foraminal stenosis	Goup1:50participants;age53.7±11.5;female:male:23:27; Group2:25participants;age54.3±11.1;female:male:11:14; The average follow-up for all patients was5.05±1.4 years	RCS	2.3.4.7	S:3+C:2+O:3=8
Jian Guan2016[75]	Degenerative instability + Deformitys	Goup1:44participants;age:44±10.1;female:male:25:19;follow-up:3-12months Group2:54participants;age45±11.2;female:male:24:30;follow-up:3-12months	RCS	2.3.4	S:3+C:2+O:3=8
You Lv2017[76]	One-segment lumbar disc herniation	Goup1:50participants;age:NA;female:male:NA;follow-up:3year Group2:56participants;ageNA;female:male:NA;follow-up:3year	PCS	2.3.4.5.14	S:4+C:2+O:2=8
He Yong2017[77]	Lumbar disc herniation	Goup1:24participants;age:52.42±8.44;female:male:14:10;follow-up:14.71±1.90 Group2:24participants;age53.42±9.50;female:male:11:13;follow-up:14.38±1.88	RCS	4.6	S:4+C:2+O:1=7
Li Ming2016[78]	Spondylolisth	Goup1:19participants;age:39-72;female:male:11:8;follow-up:3-12M Group2:34participants;age41-79;female:male:21:13;follow-up:3-12M	RCS	1.2.3.5.6	S:3+C:2+O:3=8
Shu Dong Ping2016[79]	Lumbar degenerative disease spondylolisthesis+ Foraminal stenosis	Goup1:20participants;age:55.7±8.3;female:male:10:16;follow-up:3-12M Group2:25participants;age55.4±8.6;female:male:11:15;follow-up:3-12M	RCS	2.3.4.5.7.10	S:3+C:2+O:3=8
Tang Hong Wei2016[80]	Lumbar degenerative disease	Goup1:20participants,age50.9(27-71);Female:male 10:10follow-up:24.4(14-38months) Group2:25participants,age50.2(36-72),Female:male 13:12Follow-up:24.4(14-38months)	RCS	2.3.6	S:4+C:1+O:2=7
Tang Fu Xing2015[81]	Discogenic Low Back Pain	Goup1:28participants;age:44.7(37-66);female:male:13:15;follow-up:36months（32-47months） Group2:30participants;age45.5(35-68);female:male:13:17;follow-up:39months（35-51months）	RCS	1.2.3.4.5.6.10	S:3+C:2+O:3=8
Yan Xiong Wei2016[82]	Lumbar degenerative disease	Goup1:51participants;age:62.8±8.7;female:male:28:23;follow-up:48.7±21.8M Group2:46participants;age61.9±11.3;female:male:25:21;follow-up:48.6±19.7M	PCS	2.3.4.7.14	S:4+C:2+O:2=8

1Intraoperative radiological exposure
2Blood loss
3Surgury time
4Hospitalization
5VAS
6ODI
7Fusion rate
8Short-form36
9Neurogenic symptom scores
10Postoperative drainage volume
11CRP
12CK-MM
13CPK
14Complication
RCT: randomized controlled trial；
PCS: prospective cohort study；
RCS: retrospective cohort study
DDD: Degenerative disc diseases
S: Selection C:Comparability O: Outcome

6 Conclusion

Our meta-analysis suggests that compared to TLIF, MIS-TLIF is associated with increased intraoperative radiological exposure but results in significantly less intraoperative blood loss, reduced postoperative drainage volume, shorter hospital stays, and lower overall VAS and ODI scores. Additionally, MIS-TLIF is linked to lower levels of CRP, creatine kinase-MM (CK-MM), and CPK postoperatively. However, no significant differences were observed between the two techniques in terms of operative time, fusion rate, and physical and mental recovery.

Article History

Received: July 3, 2024 **Accepted:** July 10, 2024 **Published:** September 30, 2024

References

[1] J. Allain, T. Dufour, Anterior lumbar fusion techniques: ALIF, OLIF, DLIF, LLIF, IXLIF, Orthop Traumatol Surg Res, vol. 106, pp. S149-S157, 2020.

[2] S. Arif, Z. Brady, Y. Enchev, N. Peev, E. Encheva, Minimising radiation exposure to the surgeon in minimally invasive spine surgeries: A systematic review of 15 studies, Orthop Traumatol Surg Res, vol. 107, p. 102795, 2021.

[3] I. Caelers, S. L. de Kunder, K. Rijkers, W. van Hemert, R. A. de Bie, S. Evers, et al, Comparison of (Partial) economic evaluations of transforaminal lumbar interbody fusion (TLIF) versus Posterior lumbar interbody fusion (PLIF) in adults with lumbar spondylolisthesis: A systematic review, PLoS One, vol. 16, p. e0245963, 2021.

[4] A. F. Cannestra, M. D. Peterson, S. R. Parker, T. F. Roush, J. V. Bundy, A. W. Turner, MIS Expandable Interbody Spacers: A Literature Review and Biomechanical Comparison of an Expandable MIS TLIF With Conventional TLIF and ALIF, Spine (Phila Pa 1976), vol. 41, Suppl 8, pp. S44-S49, 2016.

[5] A. Chandel, K. Brusher, V. Hall, R. S. Howard, P. A. Clark, Diagnosis and Management of Rhabdomyolysis in the Absence of Creatine Phosphokinase: A Medical Record Review, Mil Med, vol. 184, pp. 820-825, 2019.

[6] S. L. de Kunder, S. van Kuijk, K. Rijkers, I. Caelers, W. van Hemert, R. A. de Bie, et al, Transforaminal lumbar interbody fusion (TLIF) versus posterior lumbar interbody fusion (PLIF) in lumbar spondylolisthesis: a systematic review and meta-analysis, Spine J, vol. 17, pp. 1712-1721, 2017.

[7] G. Fan, T. Wang, S. Hu, X. Guan, X. Gu, S. He, Isocentric Navigation of Percutaneous Endoscopic Transforaminal Discectomy at the L5/S1 Level in Difficult Puncture Cases: A Technical Note, Pain Physician, vol. 20, pp. E531-E540, 2017.

[8] C. Fleege, M. Rickert, M. Rauschmann, [The PLIF and TLIF techniques. Indication, technique, advantages, and disadvantages], Orthopade, vol. 44, pp. 114-123, 2015.

[9] H. Funao, K. Ishii, S. Momoshima, A. Iwanami, N. Hosogane, K. Watanabe, et al, Surgeons' exposure to radiation in single- and multi-level minimally invasive transforaminal lumbar

interbody fusion; a prospective study, PLoS One, vol. 9, p. e95233, 2014.

[10] B. Garg, N. Mehta, Minimally invasive transforaminal lumbar interbody fusion (MI-TLIF): A review of indications, technique, results and complications, J Clin Orthop Trauma, vol. 10, pp. S156-S162, 2019.

[11] J. D. Harris, C. E. Quatman, M. M. Manring, R. A. Siston, D. C. Flanigan, How to write a systematic review, Am J Sports Med, vol. 42, pp. 2761-2768, 2014.

[12] X. Hu, L. Yan, X. Jin, H. Liu, J. Chai, B. Zhao, Endoscopic Lumbar Interbody Fusion, Minimally Invasive Transforaminal Lumbar Interbody Fusion, and Open Transforaminal Lumbar Interbody Fusion for the Treatment of Lumbar Degenerative Diseases: A Systematic Review and Network Meta-Analysis, Global Spine J, vol. 14, pp. 295-305, 2024.

[13] S. E. Kelly, D. Moher, T. J. Clifford, Quality of conduct and reporting in rapid reviews: an exploration of compliance with PRISMA and AMSTAR guidelines, Syst Rev, vol. 5, p. 79, 2016.

[14] N. R. Khan, A. J. Clark, S. L. Lee, G. T. Venable, N. B. Rossi, K. T. Foley, Surgical Outcomes for Minimally Invasive vs Open Transforaminal Lumbar Interbody Fusion: An Updated Systematic Review and Meta-analysis, Neurosurgery, vol. 77, pp. 847-874, 2015.

[15] C. H. Kim, C. H. Lee, K. P. Kim, How High Are Radiation-related Risks in Minimally Invasive Transforaminal Lumbar Interbody Fusion Compared With Traditional Open Surgery?: A Meta-analysis and Dose Estimates of Ionizing Radiation, Clin Spine Surg, vol. 29, pp. 52-59, 2016.

[16] C. W. Kim, Y. P. Lee, W. Taylor, A. Oygar, W. K. Kim, Use of navigation-assisted fluoroscopy to decrease radiation exposure during minimally invasive spine surgery, Spine J, vol. 8, pp. 584-590, 2008.

[17] K. H. Lee, W. Yeo, H. Soeharno, W. M. Yue, Learning curve of a complex surgical technique: minimally invasive transforaminal lumbar interbody fusion (MIS TLIF), J Spinal Disord Tech, vol. 27, pp. E234-E240, 2014.

[18] S. Lener, C. Wipplinger, R. N. Hernandez, I. Hussain, S. Kirnaz, R. Navarro-Ramirez, et al, Defining the MIS-TLIF: A Systematic Review of Techniques and Technologies Used by Surgeons Worldwide, Global Spine J, vol. 10, pp. 151S-167S, 2020.

[19] J. Lim, W. Yeo, J. Chen, Preoperative Leg Pain Score Predicts Patient Satisfaction After Transforaminal Lumbar Interbody Fusion Surgery, Global Spine J, vol. 8, pp. 354-358, 2018.

[20] A. V. Margulis, M. Pladevall, N. Riera-Guardia, C. Varas-Lorenzo, L. Hazell, N. D. Berkman, et al, Quality assessment of observational studies in a drug-safety systematic review, comparison of two tools: the Newcastle-Ottawa Scale and the RTI item bank, Clin Epidemiol, vol. 6, pp. 359-368, 2014.

[21] R. J. Mobbs, K. Phan, G. Malham, K. Seex, P. J. Rao, Lumbar interbody fusion: techniques, indications and comparison of interbody fusion options including PLIF, TLIF, MI-TLIF, OLIF/ATP, LLIF and ALIF, J Spine Surg, vol. 1, pp. 2-18, 2015.

[22] A. A. Momin, M. P. Steinmetz, Evolution of Minimally Invasive Lumbar Spine Surgery, World Neurosurg, vol. 140, pp. 622-626, 2020.

[23] K. Phan, P. J. Rao, A. C. Kam, R. J. Mobbs, Minimally invasive versus open transforaminal lumbar interbody fusion for treatment of degenerative lumbar disease: systematic review and meta-analysis, Eur Spine J, vol. 24, pp. 1017-1030, 2015.

[24] I. Propadalo, M. Tranfic, I. Vuka, O. Barcot, T. P. Pericic, L. Puljak, In Cochrane reviews, risk of bias assessments for allocation concealment were frequently not in line with Cochrane's Handbook guidance, J Clin Epidemiol, vol. 106, pp. 10-17, 2019.

[25] J. Rathbone, M. Rackham, D. Nielsen, S. M. Lee, W. Hing, S. Riar, et al, A systematic review of anterior lumbar interbody fusion (ALIF) versus posterior lumbar interbody fusion (PLIF), transforaminal lumbar interbody fusion (TLIF), posterolateral lumbar fusion (PLF), Eur Spine J, vol. 32, pp. 1911-1926, 2023.

[26] B. W. Ren, H. M. Zhao, J. H. Wu, B. C. An, Z. C. Han, Y. H. Liu, et al, Comparison of Fusion Rate and Clinical Outcomes in Minimally Invasive and Conventional Posterior Fusion for Lumbar Degenerative Disease: A Network Meta-Analysis, World Neurosurg, 2024.

[27] S. A. Rizo-Téllez, M. Sekheri, J. G. Filep, C-reactive protein: a target for therapy to reduce inflammation, Front Immunol, vol. 14, p. 1237729, 2023.

[28] F. Roberti, K. Arsenault, Direct Pars Defect Tubular Decompression and TLIF for the Treatment of Low-Grade Adult Isthmic Spondylolisthesis: Surgical Challenges and Nuances of a Muscle-Sparing Minimally Invasive Approach, Minim Invasive Surg, 2020, p. 5346805.

[29] A. J. Sayari, D. V. Patel, J. S. Yoo, K. Singh, Device solutions for a challenging spine surgery: minimally invasive transforaminal lumbar interbody fusion (MIS TLIF), Expert Rev Med Devices, vol. 16, pp. 299-305, 2019.

[30] W. H. Shuman, R. B. Baron, S. N. Neifert, M. L. Martini, E. K. Chapman, A. J. Schupper, et al, MIS-TLIF Procedure is Improving With Experience: Systematic Review of the Learning Curve Over the Last Decade, Clin Spine Surg, vol. 35, pp. 376-382, 2022.

[31] D. Stogiannis, F. Siannis, E. Androulakis, Heterogeneity in meta-analysis: a comprehensive overview, Int J Biostat, vol. 20, pp. 169-199, 2024.

[32] Z. J. Sun, W. J. Li, Y. Zhao, G. X. Qiu, Comparing minimally invasive and open transforaminal lumbar interbody fusion for treatment of degenerative lumbar disease: a meta-analysis, Chin Med J (Engl), vol. 126, pp. 3962-3971, 2013.

[33] J. H. Tan, G. Liu, R. Ng, N. Kumar, G. Liu, Is MIS-TLIF superior to open TLIF in obese patients?: A systematic review and meta-analysis, Eur Spine J, vol. 27, pp. 1877-1886, 2018.

[34] L. Tang, M. Pan, F. Wu, Diagnostic Accuracy of Creatine Kinase Isoenzyme-MM Test in Newborn Screening for Duchenne Muscular Dystrophy: A Systematic Review and Meta-Analysis, Pediatr Neurol, vol. 153, pp. 84-91, 2024.

[35] N. F. Tian, Y. S. Wu, X. L. Zhang, H. Z. Xu, Y. L. Chi, F. M. Mao, Minimally invasive versus open transforaminal lumbar interbody fusion: a meta-analysis based on the current evidence, Eur Spine J, vol. 22, pp. 1741-1749, 2013.

[36] M. Vazan, J. Gempt, B. Meyer, N. Buchmann, Y. M. Ryang, Minimally invasive transforaminal lumbar interbody fusion versus open transforaminal lumbar interbody fusion: a technical description and review of the literature, Acta Neurochir (Wien), vol. 159, pp. 1137-1146,

2017.

[37] J. Wang, Y. Zhou, Perioperative complications related to minimally invasive transforaminal lumbar fusion: evaluation of 204 operations on lumbar instability at single center, Spine J, vol. 14, pp. 2078-2084, 2014.

[38] K. Wasinpongwanich, T. Nopsopon, K. Pongpirul, Surgical Treatments for Lumbar Spine Diseases (TLIF vs. Other Surgical Techniques): A Systematic Review and Meta-Analysis, Front Surg, vol. 9, p. 829469, 2022.

[39] C. W. Peng, W. M. Yue, S. Y. Poh, W. Yeo, S. B. Tan, Clinical and radiological outcomes of minimally invasive versus open transforaminal lumbar interbody fusion, Spine (Phila Pa 1976), vol. 34, no. 13, pp. 1385-1389, 2009.

[40] O. Adogwa, S. L. Parker, A. Bydon, J. Cheng, M. J. McGirt, Comparative effectiveness of minimally invasive versus open transforaminal lumbar interbody fusion: 2-year assessment of narcotic use, return to work, disability, and quality of life, Journal of Spinal Disorders & Techniques, vol. 24, no. 8, pp. 479-484, 2011.

[41] M. A. Pelton, F. M. Phillips, K. Singh, A comparison of perioperative costs and outcomes in patients with and without workers' compensation claims treated with minimally invasive or open transforaminal lumbar interbody fusion, Spine (Phila Pa 1976), vol. 37, no. 22, pp. 1914-1919, 2012.

[42] K. H. Lee, W. M. Yue, W. Yeo, H. Soeharno, S. B. Tan, Clinical and radiological outcomes of open versus minimally invasive transforaminal lumbar interbody fusion, European Spine Journal, vol. 21, no. 11, pp. 2265-2270, 2012.

[43] S. L. Parker, S. K. Mendenhall, D. N. Shau, et al, Minimally invasive versus open transforaminal lumbar interbody fusion for degenerative spondylolisthesis: comparative effectiveness and cost-utility analysis, World Neurosurgery, vol. 82, no. 1-2, pp. 230-238, 2014.

[44] K. Singh, S. V. Nandyala, A. Marquez-Lara, et al, A perioperative cost analysis comparing single-level minimally invasive and open transforaminal lumbar interbody fusion, Spine Journal, vol. 14, no. 8, pp. 1694-1701, 2014.

[45] W. A. Sulaiman and M. Singh, Minimally invasive versus open transforaminal lumbar interbody fusion for degenerative spondylolisthesis grades 1-2: patient-reported clinical outcomes and cost-utility analysis, Ochsner J, vol. 14, no. 1, pp. 32-37, 2014.

[46] C. Seng, M. A. Siddiqui, K. P. Wong, et al, Five-year outcomes of minimally invasive versus open transforaminal lumbar interbody fusion: a matched-pair comparison study, Spine (Phila Pa 1976), vol. 38, no. 23, pp. 2049-2055, 2013.

[47] A. T. Villavicencio, S. Burneikiene, C. M. Roeca, E. L. Nelson, A. Mason, Minimally invasive versus open transforaminal lumbar interbody fusion, Surg Neurol Int, vol. 1, pp. 12, 2010.

[48] S. S. Dhall, M. Y. Wang, P. V. Mummaneni, Clinical and radiographic comparison of mini-open transforaminal lumbar interbody fusion with open transforaminal lumbar interbody fusion in 42 patients with long-term follow-up, J Neurosurg Spine, vol. 9, no. 6, pp. 560-565, 2008.

[49] F. Zairi, A. Arikat, M. Allaoui, R. Assaker, Transforaminal lumbar interbody fusion: com-

parison between open and mini-open approaches with two years follow-up, J Neurol Surg A Cent Eur Neurosurg, vol. 74, no. 3, pp. 131-135, 2013.

[50] G. B. Brodano, K. Martikos, F. Lolli, et al, Transforaminal Lumbar Interbody Fusion in Degenerative Disk Disease and Spondylolisthesis Grade I: Minimally Invasive Versus Open Surgery, Journal of Spinal Disorders & Techniques, vol. 28, no. 10, pp. E559-E564, 2015.

[51] H. W. Hey and H. T. Hee, Open and minimally invasive transforaminal lumbar interbody fusion: comparison of intermediate results and complications, Asian Spine J, vol. 9, no. 2, pp. 185-193, 2015.

[52] J. Rodriguez-Vela, A. Lobo-Escolar, E. Joven, J. Munoz-Marin, A. Herrera, J. Velilla, Clinical outcomes of minimally invasive versus open approach for one-level transforaminal lumbar interbody fusion at the 3- to 4-year follow-up, European Spine Journal, vol. 22, no. 12, pp. 2857-2863, 2013.

[53] J. Wang, Y. Zhou, Z. F. Zhang, C. Q. Li, W. J. Zheng, J. Liu, Comparison of one-level minimally invasive and open transforaminal lumbar interbody fusion in degenerative and isthmic spondylolisthesis grades 1 and 2, European Spine Journal, vol. 19, no. 10, pp. 1780-1784, 2010.

[54] K. Saetia, A. Phankhongsab, V. Kuansongtham, S. Paiboonsirijit, Comparison between minimally invasive and open transforaminal lumbar interbody fusion, J Med Assoc Thai, vol. 96, no. 1, pp. 41-46, 2013.

[55] O. Adogwa, K. Johnson, E. T. Min, et al, Extent of intraoperative muscle dissection does not affect long-term outcomes after minimally invasive surgery versus open-transforaminal lumbar interbody fusion surgery: A prospective longitudinal cohort study, Surg Neurol Int, vol. 3, no. Suppl 5, pp. S355-S361, 2012.

[56] F. Shunwu, Z. Xing, Z. Fengdong, F. Xiangqian, Minimally invasive transforaminal lumbar interbody fusion for the treatment of degenerative lumbar diseases, Spine (Phila Pa 1976), vol. 35, no. 17, pp. 1615-1620, 2010.

[57] H. L. Wang, F. Z. Lu, J. Y. Jiang, X. Ma, X. L. Xia, L. X. Wang, Minimally invasive lumbar interbody fusion via MAST Quadrant retractor versus open surgery: a prospective randomized clinical trial, Chin Med J (Engl), vol. 124, no. 23, pp. 3868-3874, 2011.

[58] Y. Yang, B. Liu, L. M. Rong, et al, Microendoscopy-assisted minimally invasive transforaminal lumbar interbody fusion for lumbar degenerative disease: short-term and medium-term outcomes, International Journal of Clinical and Experimental Medicine, vol. 8, no. 11, pp. 21319-21326, 2015.

[59] Y. B. Li, X. D. Wang, H. W. Yan, D. J. Hao, Z. H. Liu, The Long-term Clinical Effect of Minimal-Invasive TLIF Technique in 1-Segment Lumbar Disease, Clin Spine Surg, vol., pp.2016.

[60] Y. W. Chu, L. Cheng, J. M. Zhu et al, Comparison of the curative effect of minimally invasive tranforaminal lumber interbody fusion via channel and traditional operation in treating single-level lumber degenerative disease, Chuang Shang Wai Ke Za Zhi, vol. 16, no. 8, pp. 307-310, 2014

[61] D. Lau, A. Khan, S. W. Terman, T. Yee, F. La Marca, P. Park, Comparison of perioperative outcomes following open versus minimally invasive transforaminal lumbar interbody fusion in obese patients, Neurosurgical Focus, vol. 35, no. 2, pp. E10, 2013.

[62] Y. Li, Y. D. Zhan,H. B. Li et al, Effect comparison between minimally invasive surgery transforaminal lumbar interbody fusion and conventional open surgery in treatment of lumbar degenerative disease, Shi Yong Lin Chuang Yi Liao Za Zhi, Vol. 19, no. 5, PP 67-70, 2015

[63] B. Liang, G. Yin, J. Zhao, N. Li, Z. Hu, [Surgical treatment of degenerative lumbar instability by minimally invasive transforaminal lumbar interbody fusion], Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi, vol. 25, no. 12, pp. 1449-1454, 2011.

[64] Z. Luo, H. Rao, D. Huang, et al, [Comparison of minimally invasive using a tubular retraction system versus open transforaminal lumbar interbody fusion for the treatment of lumbar degenerative diseases], Zhonghua Yi Xue Za Zhi, vol. 95, no. 33, pp. 2681-2685, 2015.

[65] Q. Qi, Q. Xiao, L. Deng, C. Li, X. Dong, [COMPARISON OF EFFECTIVENESS BETWEEN PARA-MEDIAN INCISION MINIMALLY INVASIVE AND OPEN TRANSFORAMINAL LUMBAR INTERBODY FUSION FOR SINGLE SEGMENTAL LUMBAR DEGENERATIVE DISEASE], Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi, vol. 29, no. 10, pp. 1253-1258, 2015.

[66] J. Wang, Y. Zhou, Z. F. Zhang, et al, [Clinical study on lumbar spondylolisthesis treated by minimally invasive transforaminal lumbar interbody fusion], Zhonghua Wai Ke Za Zhi, vol. 49, no. 12, pp. 1076-1080, 2011.

[67] L. J. Wang, G. S.Sun, W. C. Sheng, et al, Analysis of effect of minimally invasive transforaminal interbody fusion and open surgery in treatment lumbar degenerative disease, Zhong Wai Yi Liao, vol. No.27, pp. 62-63, 2015

[68] H. Xu, L. J.Xiao, W. G. Chen, A comparison between minimally invasive and open transforaminal interbody fusion in the treatment of lumbar spondylolisthesis, Hebei Yi Xue, vol.19, no.1, pp. 48-51, 2013

[69] J. Yang, Q. C. Kong, Y. M. Song, et al, Comparison of short-term effectiveness between minimally invasive surgery- and open-transforaminal lumbar interbody fusion for single-level lumbar degenerative disease, Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi,vol. 27, no. 3, pp. 262-267, 2013

[70] L. Yang, X. Q. Liao, X. J. Zhao, et al, Analysis of efficacy of minimally invasive transforaminal lumbar interbody fusion in the treatment of 35 cases of lumbar degenerative disease, Guide of China Medicine, vol. 12, no. 22, pp. 53-54, 2014

[71] H. L. Zhang, X. Gu, S. S. Gu, et al, Minimally invasive transforaminal lumbar interbody fusion versus posterior open-surgery in treatment of lumbar spondylolisthesis., Zhong Hua Gu Ke Za Zhi, vol. 31, no. 10, pp. 1088-1092, 2011

[72] W. Z. Zhang, L. Q. Duan, X. F. Shang, et al,Effectiveness of minimally invasive transforaminal lumbar interbody fusion assisted with microscope in treatment of lumbar degenerative disease, Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi, vol., no. 03, pp. 268-273, 2013.

[73] Y. Zheng, W. S. Li, Z. Q. Chen, et al, The minimal invasive posterior transforaminal lum-

bar interbody fusion versus open transforaminal lumbar interbody fusion in the treatment of single level lumbar spine degenerative diseases, Zhongguo Ji Zhu Ji Sui Za Zhi, vol. 24, no. 12, pp. 1064-1071, 2014.

[74] J. S. Cheng, P. Park, Le H, L. Reisner, D. Chou, P. V. Mummaneni, Short-term and long-term outcomes of minimally invasive and open transforaminal lumbar interbody fusions: is there a difference? Neurosurgical Focus, vol. 35, no. 2, pp. E6, 2013.

[75] J. Guan, E. F. Bisson, A. T. Dailey, R. S. Hood, PM. H. Schmidt, Comparison of Clinical Outcomes in the National Neurosurgery Quality and Outcomes Database for Open Versus Minimally Invasive Transforaminal Lumbar Interbody Fusion, Spine, vol. 41, no. 7, pp. E416-E421, 2016.

[76] Y. Lv, J. Chen, J. Chen, et al, Three-year postoperative outcomes between MIS and conventional TLIF in1-segment lumbar disc herniation, Minim Invasive Ther Allied Technol, vol., pp. 1-12, 2017.

[77] Y. He, G. J. Wei, J. Huang, et al, Influence of Paraspinal Muscle by Open and Minimally Invasive Transforaminal Lumbar Interbody Fusion for Treating Lumbar Disc Herniation, ZHONG GUO ZHONG YI GU SHANG KE ZA ZHI, vol. 25, no. 1, pp. 26-29, 2017.

[78] M. Li, H. Y. Xu, L. Ju, et al, Effect comparison between open TLIF and Mis-TLIF in the treatment of degenerative lumbar instability, LIN CHUANG GU KE ZA ZHI, vol. 19, no. 5, pp. 534-537, 2016.

[79] D. P. Shu, S. G. Li, H. H. Deng, et al, Efficacy of minimal invasive posterior transforaminal lumbar interbody fusion and tranditional Open transforaminal lumbar interbody fusion in the treatment of single level lumbar degenerative disease, LIN CHUANG HE SHI YAN YI XUE ZA ZHI, vol. 15, no. 12, pp. 1195-1197, 2016.

[80] H. W. Tang, W. J. Wu, X. K. Zhang, et al, Quantitative injury of the minimally invasive transforaminal lumbar interbody fusion compared with an open approach, GUO JI GU KE XUE ZA ZHI, vol. 37, no. 5, pp. 326-330, 2016.

[81] F. X. Tang, C. Q. Zhou, J. Y. Zhong, et al, Comparison between Minimally Invasive Transforaminal Lumbar Interbody Fusion and Open Surgery in treatment of Discogeinc Low Back Pain, SHI YONG GU KE ZA ZHI, vol. 21. no. 10, pp. 869-913, 2015.

[82] X. W. Yan, K. Lian, H. Lu, et al, Efficacy comparison of minimally invasive and open transforaminal lumbar interbody fusion for treatment of single segment degenerative lumbar disease, LIN CHUANG GU KE ZA ZHI, vol. 19, no. 3, pp. 298-301, 2016.

Industry-Education Cooperation and Supply-Demand Matching to Deepen the Integration of Industry and Education: Creative Education Technology (Shenzhen) Co., Ltd. Serving Higher Education

Creative Education Technology (Shenzhen) Co., Ltd. focuses on academic journal publishing, educational software development, and laboratory construction as its core business activities. Under the guidance of the Ministry of Education, the company carries out the Ministry of Education's Industry-University Cooperative Education Projects and the Supply-Demand Matching Employment Education Projects. In addition, the company organizes the *Preservation and Innovative Development of Traditional Chinese Medicine competition*.

Academic Journals and Book Publishing

Creative Publishing Co., Limited (ISBN 978-988-79866), based in Hong Kong, China, publishes Chinese (bilingual in Chinese and English) academic journals, including *Theory and Practice of Social Sciences*, *Research on Industry-Education Integration*, *Research on Rural Revitalization and County Economy*, *Research on Art and Culture*, *Digital Economy and Digital Education*, *Chinese Culture*, *Basic Education Research*, as well as English journals like *Integration of Industry and Education Journal*, *Do Business and Trade Facilitation Journal*, *Costume and Culture Studies*, *Medical Research*, and *Journal of Rural Revitalization and County Economy*. These journals are indexed in databases such as CNKI, Google Scholar, Crossref, and Airiti, and are imported to mainland China through China National Publications Import & Export (Shanghai) Corporation.

Software Development and Sales, Laboratory Construction, Teacher Training

The company develops various educational and commercial software, including the Aircraft Structure Management System (ASMC) used by companies like China Southern Airlines, SF Airlines, and China Shipbuilding Industry Corporation, and acts as a distributor for other domestic and international software and equipment. In the field of education, the company has provided software development and laboratory construction services to universities such as Xi' an Technological University, Northwestern Polytechnical University, Minjiang University, Shenzhen Technology University, Qilu University of Technology, Sichuan Normal University, Wuyi University, Guangdong University of Foreign Studies, Mudanjiang Normal University, Civil Aviation Flight University of China, and Southwest University of Political Science and Law. It has also provided teacher training services to institutions like China People's Police University. Webstie: https://cpcl.hk, https://mrhk.cc.Email:wtocom@gmail.com, kycbshk@gmail.com. WhatApp: 95688358 Tel:+86-18565685800 +852-95688358