Meta-analysis of the clinical efficacy and safety of oblique lateral interbody fusion and transforaminal interbody fusion in the treatment of degenerative lumbar spondylolisthesis

Wen-xi Sun¹, Hao-nan Liu¹, Meng-tong Chen¹, Yong-peng Lin², Hong-shen Wang² and Bo-lai Chen¹,²

¹Guangzhou University of Chinese Medicine, Guangzhou, China
²Division of Spine Center, Guangdong Provincial Hospital of Chinese Medicine, Guangzhou, China

Objective: The aim of this study was to comprehensively evaluate the efficacy of oblique lateral interbody fusion (OLIF) and transforaminal lumbar interbody fusion (TLIF) in the treatment of degenerative lumbar spondylolisthesis by meta-analysis.

Methods: A computer-based search of PubMed, Cochrane Library, Embase, Web of Science Core Collection databases, the China National Knowledge Infrastructure, China Biology Medicine, and Wanfang Digital Periodicals was conducted from the time of inception of each database to December 2021. The review process was conducted according to the PRISMA guidelines and registered in the PROSPERO database. Meta-analysis was performed using RevMan 5.4 software provided by the Cochrane Library.

Results: Thirteen studies were included in the statistical analysis. One randomized controlled study and 12 cohort studies with 954 patients were included. In terms of operation time, intraoperative blood loss, Oswestry disability index score, intervertebral height, and complications, the OLIF group was better than the TLIF group, and the difference was statistically significant (P < 0.05). There was no significant difference between the two groups in terms of visual analogue scale score, lumbar lordosis or fused segment lordosis (P > 0.05).

Conclusion: Both OLIF and TLIF are effective surgical modalities in the treatment of degenerative lumbar spondylolisthesis. They achieve similar therapeutic effects, but OLIF is superior to TLIF in restoring intervertebral height. At the same time, OLIF has the advantages of short operation time and less intraoperative blood loss.

Lumbar spondylolisthesis can be defined based on the degree of slippage of the upper vertebral body relative to the lower vertebral body. Degenerative lumbar spondylolisthesis (DLS) is a common orthopaedic disease. The elderly population is the most commonly affected. The clinical manifestations include low back and leg pain, radiating pain in the affected limb, and intermittent sexual claudication, which are also the main causes of chronic pain (1). The past 30 years have seen tremendous progress in the advancement of spine and biomedical research and the development of a scientific basis for new clinical procedures. Currently, there are various techniques for the surgical treatment of DLS, ranging from decompression only to various types of interbody fusion. Many of these procedures have gained acceptance in the medical community and become useful treatments over time (2). To minimize the trauma to the spine and paravertebral muscles, a variety of surgical methods have been used, but the choice of a surgical method for the treatment of DLS is highly controversial (3). Transforaminal lumbar interbody fusion (TLIF) completes the removal of the intervertebral disc through the intervertebral foramen to achieve direct decomposition. TLIF is more popular than posterior lumbar interbody fusion (PLIF) due to less nerve traction (4). Oblique lateral interbody fusion (OLIF) uses an anterior approach to the extraperitoneal psoas major muscle and...
performs intervertebral fusion under direct vision through the channel, which effectively protects the lumbar and back muscles. OLIF can reduce the risk of conventional posterior surgery and achieve indirect decompression (5). TLIF is a relatively classic procedure, and OLIF is increasingly recognized by orthopaedic surgeons. They have gradually become widely used clinical procedures. However, there is still debate as to which of these two techniques is more advantageous (6). A meta-analysis of the clinical efficacy and safety of each surgical procedure was conducted, and the results are as follows.

**Materials and methods**

A systematic literature review was performed according to the Preferred Reporting Item for Systematic Reviews and Meta-Analyses guidelines (7), using RevMan 5.4 software provided by the Cochrane Library (RevMan version 5.4, Cochrane Collaboration, Oxford, UK). A meta-analysis was also performed. This study has been registered in the PROSPERO (Prospective Registry of International Systematic Reviews) database.

**Study search**

A computer-based search of the China National Knowledge Infrastructure, China Biology Medicine, Wanfang Digital Periodicals, PubMed, Cochrane Library, Embase, and Web of Science databases was performed on the literature on OLIF and TLIF in the treatment of DLS from the time of inception of each database to December 2021. The search language was limited to Chinese and English. The search terms were lumbar fusion, oblique lateral interbody fusion, OLIF, transforaminal lumbar interbody fusion, TLIF, and lumbar spondylolisthesis.

**Inclusion and exclusion criteria for the study**

The process of study inclusion is summarized in Fig. 1.

The inclusion criteria were as follows: (i) postoperative follow-up included at least two of the following reference indicators: operation time, intraoperative blood loss, visual analogue scale (VAS) score, Oswestry disability index (ODI) score, number of complications, intervertebral height (IH), lumbar lordosis (LL), and fused segment lordosis (FSL); (ii) the average age of the study subjects was ≥45 years old. Patients had lumbar spondylolisthesis with mild-to-moderate degeneration and had undergone OLIF or TLIF surgery. The main diagnosis was DLS, with or without lumbar spinal stenosis; (iii) the research design method was a randomized controlled trial (RCT) or a cohort study. At least two subgroups, an ‘OLIF group’ and a ‘TLIF group’, were included, and there was no significant difference in baseline data between the two groups; (iv) all subjects included in the study had single-segment or two-segment lumbar spondylolisthesis; and (v) the follow-up time was at least 6 months. The exclusion criteria were as follows: (i) studies except papers written in Chinese or English; (ii) the lumbar spondylolisthesis of the research subject was nondegenerative, such as isthmic or traumatic lumbar spondylolisthesis; (iii) the research subject had a history of spinal surgery or combined spine and pelvis deformities, spinal tumours, infections, rheumatic immune diseases, etc.

**Data extraction and quality assessment**

Two researchers independently reviewed the titles, abstracts, and (if necessary) full texts of eligible studies. The risk of bias for RCTs was assessed using the Physiotherapy Evidence Database scale. The risk of bias for cohort studies was assessed using the Newcastle–
Table 1  Summary of the studies included in the meta-analysis.

| Reference | Country | Research design and methods | Gender (men and women) | Operation formula | Cases | Mean follow-up time (months) | Average age (years) | Included reference indicators |
|-----------|---------|-----------------------------|------------------------|-------------------|-------|-----------------------------|-------------------|-----------------------------|
| Huang et al. (11) | China | Retro-CS | 33/23 | OLIF/TLIF | 26/30 | N/A (>24) | 60.33/61.04 | 0.00000000 |
| Li et al. (12) | China | Retro-CS | 15/48 | OLIF/TLIF | 28/35 | N/A (>6) | 57.5/59.3 | 0.00000000 |
| Qin et al. (15) | China | Retro-CS | 30/38 | OLIF/TLIF | 34/34 | 12.5* | 63.4* | 0.00000000 |
| Takaoaka et al. (13) | Japan | Retro-CS | 63/80 | OLIF/TLIF | 65/78 | 53.0* | 66/71 | 0.00000000 |
| Wang et al. (14) | China | Retro-CS | 23/45 | OLIF/TLIF | 33/35 | N/A (>12) | 62.76/58.51 | 0.00000000 |
| Zhang et al. (10) | China | Retro-CS | 13/17 | OLIF/TLIF | 15/15 | 8.5* | 50.2/51.5 | 0.00000000 |
| Qiu et al. (17) | China | Retro-CS | 28/12 | OLIF/MIS-TLIF | 20/20 | 13.5/14.1 | 50.3/51.7 | 0.00000000 |
| Sheng et al. (18) | China | Retro-CS | 29/64 | OLIF/MIS-TLIF | 38/55 | N/A (>12) | 65.29/60.62 | 0.00000000 |
| Kotani et al. (19) | Japan | Retro-CS | 63/79 | OLIF/MIS-TLIF | 92/50 | 31.0/57.2 | 72.0/70.0 | 0.00000000 |
| Ye et al. (9) | China | Retro-CS | 19/26 | OLIF/TLIF | 20/25 | 14.4/14.1 | 46.14/47.63 | 0.00000000 |
| Koike et al. (16) | Japan | Retro-CS | 38/48 | OLIF/MIS-TLIF | 38/48 | 18.1/22.5 | 72.1/70.1 | 0.00000000 |
| Li et al. (8) | China | RCT | 34/26 | OLIF/TLIF | 30/30 | 6* | 57.2/56.8 | 0.00000000 |
| Han et al. (20) | China | Retro-CS | 28/33 | OLIF/MIS-TLIF | 28/32 | 12* | 50.4/53.6 | 0.00000000 |

*Merger of narrative; ①VAS score; ②ODI score; ③complication cases; ④operation time (min); ⑤intraoperative blood loss (mL); ⑥lumbar lordosis; ⑦fused segment lordosis; ⑧inter vertebral height.

Retro-CS, retrospective cohort study; RCT, randomized controlled trial.

Quality scores for the included studies

The RCT scored 8 points (8). The NOS score results for the 12 cohort studies were as follows: 3 articles scored 5 points (9, 10, 11), 5 articles scored 6 points (12, 13, 14, 15, 16), 3 articles scored 7 points (17, 18, 19), and 1 article scored 8 points (20).

Evaluation of clinical efficacy

VAS score

A total of nine studies (8, 9, 10, 11, 12, 14, 15, 17, 20) reported the VAS score at the last follow-up. A total of 485 patients were included, including 234 patients in the OLIF group and 251 patients in the TLIF group. There was no significant difference between the two groups (P = 0.03, I² = 53%), and a random effect model was used for the meta-analysis. The analysis results showed (Fig. 2) that there was no significant difference in VAS score between the two groups (WMD = -0.11, 95% CI (-0.26, 0.03), P = 0.12).

Table 2  Complications reported in the studies included in the meta-analysis.

| Complications                      | OLIF (n = 467) | TLIF (n = 487) |
|-----------------------------------|----------------|----------------|
| Approach-related                  |                |                |
| Cerebrospinal fluid leak          | 1 (0.2%)       | 12 (2.5%)      |
| Dural tear                        | 0              | 2 (0.4%)       |
| Nerve damage                      | 9 (1.9%)       | 4 (0.8%)       |
| Arterial injury                   | 2 (0.4%)       | 0              |
| Waist/leg weakness/numbness       | 24 (5.1%)      | 12 (2.5%)      |
| Low back/lower extremity pain     | 1 (0.2%)       | 7 (1.4%)       |
| Approach-unrelated                |                |                |
| Infection                         | 0              | 9 (1.8%)       |
| Screw misalignment                | 0              | 3 (0.6%)       |
| Endplate fracture/subsidence      | 16 (3.4%)      | 2 (0.4%)       |
| Haematoma                         | 0              | 1 (0.2%)       |
| Pain in the extraction area       | 1 (0.2%)       | 0              |
| Cage shift                        | 1 (0.2%)       | 1 (0.2%)       |
| Sensory disturbance               | 2 (0.4%)       | 2 (0.4%)       |
| Total                             | 57 (12.2%)     | 55 (11.8%)     |
ODI score
A total of nine studies (8, 9, 10, 11, 12, 14, 15, 17, 20) reported the ODI score at the last follow-up. A total of 485 patients were included, including 234 patients in the OLIF group and 251 patients in the TLIF group. The heterogeneity between the two groups was high (P < 0.1, I² = 60%), and a random-effect model was used for the meta-analysis. The results showed (Fig. 3) that there was a statistically significant difference in the ODI score between the two groups (WMD = −1.02, 95% CI (−1.79, −0.25), P < 0.05). The ODI score in the OLIF group was lower than that in the TLIF group.

Lumbar lordosis
A total of five studies (9, 12, 13, 14, 17) reported the postoperative LL. A total of 359 patients were included, including 166 patients in the OLIF group and 193 patients in the TLIF group. There was high heterogeneity between the two groups (P < 0.1, I² = 72%), and a random-effect model was used for the meta-analysis. The results showed (Fig. 4) that there was no significant difference in LL between the two groups (WMD = 0.94, 95% CI (−2.64, 4.52), P = 0.61).

Fused segment lordosis
A total of four studies (12, 13, 14, 17) reported the postoperative FSL. A total of 316 patients were included, including 148 patients in the OLIF group and 168 patients in the TLIF group. The heterogeneity between the two groups was high (P < 0.1, I² = 88%), and the results showed (Fig. 5) that there was no significant difference in FSL between the two groups (WMD = 1.55, 95% CI (−1.56, 4.66), P = 0.33).

Intervertebral height
A total of 7 studies (9, 10, 13, 16, 17, 19, 20) reported the postoperative IH, including 546 patients, 278 patients in the OLIF group and 268 patients in the TLIF group. The heterogeneity between the two groups was high (P < 0.1, I² = 75%), and the results showed (Fig. 6) that the difference in IH between the two groups was statistically significant (WMD = 1.38, 95% CI (0.80, 1.97), P < 0.05). The postoperative IH in the OLIF group was higher than that in the TLIF group.

Safety evaluation
Operation time
A total of 12 studies (8, 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, 20) reported the operation time. A total of 811 patients were included, including 402 patients in the OLIF group and 409 patients in the TLIF group. The heterogeneity between the two groups was high (P < 0.1, I² = 98%), and the results showed (Fig. 7) that the difference between the two groups was statistically significant (WMD = −14.36, 95% CI (−27.30, −1.42), P < 0.05). The operative time in the OLIF group was shorter than that in the TLIF group.

Intraoperative blood loss
A total of 12 studies (8, 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, 20) reported intraoperative blood loss. A total of 811 patients were included, including 402 patients in the OLIF group and 409 patients in the TLIF group. The heterogeneity between the two groups was high (P < 0.1, I² = 100%), and the analysis showed (Fig. 8) that the difference between the two groups was statistically significant (WMD = −103.93, 95% CI (−171.27, −36.59), P < 0.05). The intraoperative blood loss in the OLIF group was less than that in the TLIF group.
Complications

A total of 11 studies (9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 20) reported the number of complications at the last follow-up. A total of 808 patients were included, including 407 patients in the OLIF group and 401 patients in the TLIF group. There was no significant heterogeneity between the two groups ($P=0.27$, $I^2=18\%$), and a fixed-effect model was used for the meta-analysis. The results indicated (Fig. 9) that there was no significant difference between the two groups (OR=1.09, 95% CI (0.74, 1.61), $P=0.67$).

Heterogeneity and sensitivity analysis

The results of this analysis showed that the heterogeneity of the ODI score, LL, FSL, IH, operation time, and intraoperative blood loss was high. So we used a random-effect model to partially eliminate the effect of heterogeneity. To exclude the effect of MIS-TLIF (transforaminal lumbar interbody fusion using minimally invasive spine surgery), the five studies we excluded (16, 17, 18, 19, 20) were reanalysed, and the heterogeneity was still high. To exclude the effect of follow-up time on the heterogeneity of the ODI score, we excluded studies (9, 12, 15, 20) and performed the meta-analysis again. The results showed that the heterogeneity was still high, but the difference between the two groups was not statistically significant. This shows that the results of this meta-analysis are relatively reliable, and the heterogeneity may come from the technical level of the surgeons. To exclude the influence of the heterogeneity of the included studies, a sensitivity analysis of the ODI score, operation time, and intraoperative blood loss was performed. After excluding the RCT study, a meta-analysis was performed again, and the results of the analysis were consistent with those obtained before the exclusion of the RCT, indicating that heterogeneity had little impact on the results of this study.

Bias analysis

Funnel plots were constructed to assess publication bias, and the results were largely symmetrical, indicating acceptable publication bias in our analysis (Supplementary Fig. 1, see section on supplementary materials given at the end of this article). However, the distribution of ODI score, VAS score, operation time, and intraoperative blood loss was significantly asymmetric at the last follow-up, suggesting that publication bias is likely (Supplementary Fig. 2).

Discussion

We included eight reference indicators, including operation time, intraoperative blood loss, VAS score, ODI score, complications, IH, LL, and FSL, for statistical analysis. In terms of pain relief, OLIF has a lower ODI score than TLIF; VAS seems to have a lower score, but there is no statistical significance between the two. OLIF achieves the effect of nerve decompression through indirect decompression, and TLIF can directly decompress the nerve and restore the stability of the lumbar spine, both of which can relieve pain. From a radiographic perspective, the LL and FSL of OLIF appeared to be greater, but there was also no significant difference between the two. This is related to the operator’s skills and surgical concept. It can be achieved by positioning the cage close to the anterior edge of the vertebral body and using the curved rod technique. The analysis results show that the IH after OLIF is higher than that after TLIF, which may be related to the surface area of the OLIF cage being much larger than that of the TLIF cage, and it is placed on the two sides of the vertebral endplates. The strongest point of the vertebral body is related (21, 22). The analysis showed that the OLIF group had less intraoperative blood loss and a shorter operation time, which was consistent with several previous studies (18, 23, 24). OLIF does not require resection of the intervertebral disc, and it uses indirect decompression without direct decompression of the spinal canal, which can shorten the operation time and reduce the amount of intraoperative blood loss. This is because OLIF does not require resection of the disc, through indirect decompression without direct decompression.
of the spinal canal. There was no significant difference in the number of complications. Similarly, Lin et al. (22) reported similar complication rates (32% vs 36%) for the two surgical approaches. Although our results did not find a significant difference in complications between the two procedures, it is worth mentioning that OLIF seems to have a higher risk of potential nerve and vascular damage (25). OLIF also has risks such as retrograde ejaculation and damage to the abdominal aorta (26).

Clinically, DLS can lead to lumbar spinal stenosis in the corresponding segment; that is, DLS and lumbar spinal stenosis coexist (26). However, not all DLS is associated with lumbar spinal stenosis. In this meta-analysis, we included DLS patients with and without lumbar spinal stenosis (distinguished from developmental lumbar spinal stenosis), which may have had a certain impact on the analysis results. The studies included in this meta-analysis were all focused on single-segment or two-segment slippage, and there was no significant difference in the extent of laminectomy and nerve decompression. However, the types of fusion materials were not reported in detail, and the number of studies included in this meta-analysis was small; only 1 was an RCT study, and the remaining 12 were cohort studies. The quality of the literature was not high, and some studies did not include long-term follow-up, which leads to certain deficiencies in this meta-analysis. Therefore, large-sample, multicentre clinical controlled studies, especially high-quality RCTs, and long-term follow-up results are needed to provide strong evidence.

**Conclusion**

Our study showed that OLIF and TLIF did not differ significantly in terms of postoperative VAS scores, LL, or FSL in the treatment of DLS, and the clinical efficacy was equivalent. OLIF is superior to TLIF in terms of ODI score and restoration of IH, and some of its therapeutic effects are better. In terms of surgical safety, the operation time and intraoperative blood loss are less than those in TLIF. The safety of OLIF is higher, but overall, there was no significant difference in the number of complications.

In summary, in the treatment of DLS, both OLIF and TLIF are effective surgical modalities. They can achieve similar therapeutic effects as TLIF, but OLIF is superior to TLIF in restoring IH. At the same time, OLIF has the characteristics of short operation time and...
less intraoperative blood loss, potentially giving it an advantage.

**Supplementary materials**
This is linked to the online version of the paper at https://doi.org/10.1530/EOR-22-0042.

**ICMJE Conflict of Interest Statement**
The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

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**Author contribution statement**
Wen-xi Sun: Conceptualization, Investigation, Data curation, Formal analysis, Writing the original draft. Hao-nan Liu: Investigation, Data curation, Formal analysis. Meng-tong Chen: Investigation, Data curation. Yong-peng Lin: Resources, Reviewing and editing. Hong-shen Wang: Methodology, Reviewing and editing. Bo-lai Chen: Supervision, Reviewing and editing.

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