Differences in radiographic and clinical outcomes of oblique lateral interbody fusion and lateral lumbar interbody fusion for degenerative lumbar disease: a meta-analysis

Hui-Min Li, Ren-Jie Zhang and Cai-Liang Shen

Abstract

Background: In the current surgical therapeutic regimen for the degenerative lumbar disease, both oblique lateral interbody fusion (OLIF) and lateral lumbar interbody fusion (LLIF) are gradually accepted. Thus, the objective of this study is to compare the radiographic and clinical outcomes of OLIF and LLIF for the degenerative lumbar disease.

Methods: We conducted an exhaustive literature search of MEDLINE, EMBASE, and the Cochrane Library to find the relevant studies about OLIF and LLIF for the degenerative lumbar disease. Random-effects model was performed to pool the outcomes about disc height (DH), fusion, operative blood loss, operative time, length of hospital stays, complications, visual analog scale (VAS), and Oswestry disability index (ODI).

Results: 56 studies were included in this study. The two groups of patients had similar changes in terms of DH, operative blood loss, operative time, hospital stay and the fusion rate (over 90%). The OLIF group showed slightly better VAS and ODI scores improvement. The incidence of perioperative complications of OLIF and LLIF was 26.7 and 27.8% respectively. Higher rates of nerve injury and psoas weakness (21.2%) were reported for LLIF, while higher rates of cage subsidence (5.1%), endplate damage (5.2%) and vascular injury (1.7%) were reported for OLIF.

Conclusions: The two groups are similar in terms of radiographic outcomes, operative blood loss, operative time and the length of hospital stay. The OLIF group shows advantages in VAS and ODI scores improvement. Though the incidence of perioperative complications of OLIF and LLIF is similar, the incidence of main complications is significantly different.

Keywords: Degenerative lumbar disease, OLIF, LLIF, XLIIF, DLIF

Background

Lumbar interbody fusion has been recognized as a powerful surgical tool for lumbar degenerative disease, including degenerative disc disease, spondylolisthesis, disc herniation, and deformity [1, 2]. Traditional techniques, such as anterior lumbar interbody fusion and posterior/transforaminal lumbar interbody fusion, have been successful with high patient satisfaction and fusion rates [1]. However, complications, such as excessive blood loss, iatrogenic muscle and soft tissue injury, muscular denervation, cannot be avoided [3]. To decrease surgical trauma, reduce operative bleeding and reduce hospital stay, minimally invasive spine (MIS) techniques such as oblique lateral interbody fusion (OLIF), lateral lumbar interbody fusion (LLIF), also known as extreme/direct lumbar interbody fusion (XLIIF / DLIF), is progressively gaining popularity [3–7]. The advantages of both XLIF and OLIF are potential to restore both segmental and global lordosis, the latter often possible with...
targeting multiple levels through a single incision with minimally invasive surgery. Another advantage is the possibility of indirect decompression, avoiding the need in many cases to open spinal canal or foramina directly. Although radiographic and clinical outcomes of LLIF or OLIF have been assessed in many studies, however, few studies have compared the results of OLIF and LLIF. In the present study, considering the increasing interest in these techniques, our meta-analysis is performed to find differences in the radiographic and clinical outcomes of OLIF and LLIF for degenerative lumbar disease and, thus, provide vital evidence-based guidance for clinicians.

Methods

Literature review

MEDLINE (1966 to May 1, 2019), Embase (1974 to May 1, 2019) and Cochrane (2003 to May 1, 2019) were searched to find relevant studies about OLIF or LLIF for treatment for the degenerative lumbar disease. Studies were eligible for inclusion if they met the following criteria: studies reported outcomes at least one of the following outcomes: disc height (DH), visual analog scale (VAS), Oswestry disability index (ODI), operative blood loss, operative time, length of hospital stay, fusion, and complications; and had sufficient data to extract and pool. The following search terms were used: “oblique lumbar interbody fusion” or “OLIF” or “lateral lumbar interbody fusion” or “LLIF” or “extreme lateral interbody fusion” or “XLIF” or “direct lateral interbody fusion” or “DLIF”. We have found 2097 results through the above databases. Two of the reviewers (H.M. L. and R.J. Z.) independently examined the data extraction using standardized data extraction forms. There were altogether 1337 potentially relevant studies identified from the electronic search, the abstracts, and full manuscripts were also reviewed. The reference list of all relevant retrieved manuscripts was searched manually to identify additional studies that might have been missed. A summary of the study selection process in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines was showed in Fig. 1.
Study design
This study involved 56 studies, including 21 on OLIF [2, 3, 7–25] and 36 on LLIF [4–6, 10, 26–57] were relevant and analyzed in this study. The publishing year of these studies was between 2009 and 2019. Three studies were prospective consecutive clinical series, 16 studies were retrospective comparative studies, and 37 studies were retrospective case series. Two reviewers, using standardized data collection tool, independently extracted data on age, publication year, follow-up, fusion level, disc height (DH), visual analog scale (VAS), Oswestry disability index (ODI), operative blood loss, operative time, length of hospital stay, fusion, and complications [58]. Fusion was defined as bridging trabecular bone and lack of luencies on plain radiographs and radiographic evidence of fusion was based on CT scans or flexion-extension radiographs. Any disagreements were resolved by discussion and consensus with a third party.

Statistical methods
When pooling the data from the included studies, the Stata software (version 14.0; TX 77845, USA) was used. The z-test was applied to the mantel-haenszel analysis, and standardized mean difference (SMD) and 95% confidence interval (CI) was estimated by the random-effects model [58]. The heterogeneity was assessed using the chi-square test. The potential effects of mean age and analysis on radiological and clinical outcomes were assessed by performing meta-regression. A p-value of 0.05 or less was considered statistically significant.

Results
Description of study
We have included fifty-six studies involving 2852 patients in this analysis. A total of 1304 patients aged 54.1–69 years (62.1 years on average) were included in the OLIF group. Follow-up was reported from 1 month to 24 months (10.5 months on average). Fusion levels have been reported to involve T10-T11 to L5-S1 (1 level: 154 patients; 2 levels: 192 patients, and ≥3 levels: 80 patients). A total of 1548 patients aged 51–74 years (62.2 years on average) were included in the LLIF group. Follow-up duration has been reported to range from 3 months to 35.4 months (17.7 months on average). Fusion levels have been reported to involve T12-L1 to L4-L5 (1 level: 278 patients, 2 levels: 139 patients, and ≥3 levels: 142 patients).

Disc height
Pooled analysis of six studies treated with OLIF [2, 8, 10, 14, 16, 23] showed that the pooled mean of DH did not vary across studies ($I^2 = 35.2\%$), and the pooled SMD was 2.20 (95% CI, 1.83–2.57). Pooled analysis of six studies treated with LLIF [5, 30, 31, 37, 43, 48] showed that the pooled mean of DH varies across studies ($I^2 = 93.3\%$), and the pooled SMD was 2.44 (95% CI, 1.26–3.61) (Fig. 2a and b).

Visual analog scale
Pooled analysis of eight studies treated with OLIF [3, 8–11, 14, 17, 22] showed that the pooled mean of VASs varies across studies ($I^2 = 91.7\%$), and the pooled SMD was 3.25 (95% CI, −3.80 to −2.70). Pooled analysis of seventeen studies treated with LLIF [26, 27, 30, 33, 34, 36–38, 46, 48, 49, 51–54, 57] showed that the pooled mean of VASs varies across studies ($I^2 = 75.8\%$), and the pooled SMD was −2.18 (95% CI, −2.47 to −1.88) (Fig. 3a and b).

Oswestry disability index
Pooled analysis of nine studies treated with OLIF [3, 8–11, 14, 16, 21, 22] showed that the pooled mean of ODIs varies across studies ($I^2 = 94.8\%$), and the pooled SMD was −3.06 (95% CI, −4.03 to −2.08). Pooled analysis of eighteen studies treated with LLIF [5, 10, 26, 27, 30, 33, 34, 36–38, 46, 48, 49, 51–54, 57] showed that the pooled mean of ODIs varies across studies ($I^2 = 83.9\%$), and the pooled SMD was −1.76 (95% CI, −2.08 to −1.43) (Fig. 4a and b).

Operative blood loss, operative time, and length of hospital stay
Operative blood loss, operative time, and length of hospital stay have been reported in eleven studies of OLIF [2, 8–11, 16, 17, 21, 23–25] including 787 patients. OLIF combined with posterior fixation resulted in an average blood loss of 136 mL (49.7 for 1 operated level; 112.5 for 2 operated levels, 148.7 for 3 operated levels or more), an average operative time of 114 min (54.5 for 1 operated level; 67.2 for 2 operated levels, 119.5 for 3 operated levels or more), and an average length of hospital stay of 6.8 d (5.1 for 1 operated level; 6.4 for 2 operated levels, 7.9 for 3 operated levels or more) [58]. OLIF stand-alone [8, 11] resulted in an average operative blood loss of 83 mL, an average operative time of 104.2 min, and an average length of hospital stay of 6 d. Operative blood loss, operative time, and length of hospital stay have been reported in 29 studies of LLIF [6, 10, 26–32, 34, 35, 37–42, 44–46, 49, 51, 52, 54–57] including 1698 patients. LLIF combined with posterior fixation resulted in an average operative blood loss of 176 mL (71.6 for 1 operated level; 115 for 2 operated levels, 176 for 3 operated levels or more), an average operative time of 188 min (134.8 for 1 operated level; 174 for 2 operated levels, 253 for 3 operated levels or more), and an average length of hospital stay of 5.9 d (2 for 1 operated level; 3 for 2 operated levels, 4 for 3 operated levels or more). LLIF stand-alone [6, 30, 34, 40, 42, 46, 49, 52] resulted in an average operative blood loss of 76.4 mL, an average
operative time of 126.2 min, and an average length of hospital stay of 5 d (Table 1).

Fusion results and complications
Five studies about OLIF [8, 12, 19, 21, 22] with a total of 287 patients and fusion was reported in 278 patients. Twelve studies about LLIF [30, 38–40, 46, 47, 51, 52, 54, 55, 57] with a total of 584 patients and fusion was reported in 535 patients.

Seventeen studies about OLIF [2, 3, 7–10, 12, 14–23, 25] with a total of 1043 patients reported an incidence of perioperative complications of 26.7%. The most common perioperative complication was thigh pain/numbness or psoas weakness (8.8%). Other main perioperative complications included endplate fracture (5.2%), cage subsidence (5.1%), vascular injury (1.7%) and the details of perioperative complications of OLIF are shown in Table 3. Thirty-two studies about LLIF [4–6, 10, 26–32, 34, 35, 37–42, 44–47, 49–57] with a total of 1562 patients reported an incidence of perioperative complications of 27.8%. The most common perioperative complication was thigh pain/numbness or psoas

**Table 1**

| Study ID | SMD (95% CI) | Weight |
|----------|--------------|--------|
| Fujikawa et al (2014) | 2.05 (1.45, 2.70) | 19.33 |
| Heo et al (2017) | 2.69 (1.68, 3.50) | 19.39 |
| Saw et al (2017) | 2.61 (1.16, 3.99) | 13.61 |
| Jin et al (2018) | 1.54 (0.57, 2.50) | 29.19 |
| Jin et al (2018) | 1.50 (0.19, 2.80) | 16.49 |
| Duh et al (2018) | 1.17 (0.04, 2.30) | 49.18 |
| Overall (I² = 32.2%, p = 0.172) | 2.29 (0.53, 3.97) | 100.00 |

**Table 3**

| Study ID | SMD (95% CI) | Weight |
|----------|--------------|--------|
| Akiyama et al (2015) | 3.35 (2.30, 4.39) | 13.95 |
| Iizuka et al (2016) | 0.71 (0.16, 1.26) | 17.68 |
| Lee et al (2017) | 1.06 (0.54, 1.59) | 17.46 |
| Takeda et al (2017) | 2.86 (1.97, 3.73) | 16.62 |
| Kenev et al (2018) | 1.15 (0.44, 1.86) | 19.35 |
| Locke et al (2018) | 2.75 (1.80, 3.66) | 15.08 |
| Overall (I² = 93.5%, p = 0.000) | 2.80 (1.26, 3.44) | 100.00 |

Fig. 2 (A) Oblique lateral interbody fusion group, (B) lateral lumbar interbody fusion group. The positive and negative values of SMD represent disc height restoration and loss, respectively, after surgery. SMD, standard mean difference.
weakness (21.2%). Other main perioperative complications included cage subsidence (1.3%) and the details of perioperative complications of LLIF are shown in Table 2.

Meta-regression analyses and publication bias
Results of meta-regression demonstrated that the follow-up period had no effect on DH, VAS, or ODI, and mean age had no effect on DH or VAS in both surgical groups. However, the mean age was negatively correlated with decreasing ODI score in the OLIF group (Table 3).

No publication bias for DH or ODI was observed in either group, but publication bias for VAS was observed for the LLIF group (Fig. 5).

Discussion
Our meta-analysis was designed to explore differences in radiographic and clinical outcomes of OLIF and LLIF. The importance of restoring sagittal balance and lumbar lordosis is increasingly recognized in any spinal reconstruction surgery. The most important factor affecting lumbar lordosis recovery is DH restoration [59]. In the
present study, very similar results about restorations of DH (2.20 versus 2.44) were observed between the OLIF and LLIF techniques. Most studies have shown OLIF and LLIF could restore the DH [8, 43, 48], and some researchers have found that the OLIF group showed a significant increase of posterior disk space compared with the LLIF group (40.2% vs. 31.6%, respectively), which may be explained by the fact that the orthogonal maneuver provides the controllability of cage position, and earlier change of direction from oblique to direct lateral makes the anterior position of the cage to obtain a large segmental angle for the kyphosis correction [10]. However, other study demonstrated that OLIF might make no difference in restoring the DH, as more than half of the patients without applying posterior supplemental fixation in their study [11]. And considering the heterogeneity of this meta-analysis, meta-regression was applied for exploring the cause of heterogeneity of the potential

![Fig. 4](image-url) (A) Oblique lateral interbody fusion group, (B) lateral lumbar interbody fusion group. The negative and positive values of SMD represent Oswestry disability index improvement and loss, respectively, after surgery. SMD, standard mean difference.
effect of mean age and follow-up on DH restoration, but we found that the follow-up period and mean age did not affect DH in both groups.

According to previous studies, both OLIF and LLIF presented lower postoperative VAS and ODI scores compared with preoperative values [8, 9, 38, 39], which is consistent with our results. Furthermore, we have found the postoperative VAS and ODI scores in the OLIF group were better than those in the LLIF group (−3.25 versus −2.18; −3.06 versus −1.76, respectively), probably due to complications related to the psoas muscle injury in the LLIF group. Besides, meta-regression has shown that the mean age was negatively correlated with decreasing ODI score in the OLIF group.

This meta-analysis suggests that OLIF showed similar operative blood loss, operative time, and hospital stay than those compared with LLIF. This may be because the OLIF and LLIF techniques are performed through the retroperitoneal space and by blunt dissection. Besides, the number of manipulations during surgery is decreased especially when radiographs are required, as no microscope or other specific complex ancillary is used in both groups.

The meta-analysis also suggests that OLIF achieves a similar fusion rate (>90%) compared with that of LLIF.

Table 1 Operative blood loss, operative time and length of hospital stay of the study

| Fusion Level | Operative blood loss (ml) | Operative time (min) | length of hospital stays (days) |
|--------------|--------------------------|----------------------|--------------------------------|
| OLIF Alone   | OLIF + Posterior Fixation | LLIF Alone           | LLIF + Posterior Fixation     | LLIF Alone           | LLIF + Posterior Fixation | LLIF Alone           | LLIF + Posterior Fixation | LLIF Alone           |
| 1            | 49.7                     | NR                   | 71.6                           | NR                   | 54.5                     | NR                   | 134.8                           | NR                   |
| 2            | 112.5                    | NR                   | 115                            | NR                   | 67.2                     | NR                   | 174                             | NR                   |
| ≥3           | 148.7                    | NR                   | 176                            | NR                   | 119.5                    | NR                   | 253                             | NR                   |
| Mean         | 136                      | 83                   | 176                            | 76.4                 | 114                      | 104.2                | 188                             | 126.2                |

OLIF oblique lateral interbody fusion; LLIF lateral lumbar interbody fusion; NR not reported

Table 2 Comparison of clinical complications between both groups

|                     | OLIF Alone [8] (n = 17) | OLIF + Posterior Fixation (n = 1056) | OLIF Total (n = 1043) | LLIF Alone [6, 30, 34, 49, 52] (n = 249) | LLIF + Posterior Fixation (n = 1313) | LLIF Total (n = 1562) |
|---------------------|-------------------------|--------------------------------------|-----------------------|------------------------------------------|-------------------------------|-----------------------|
| vascular complications | 18                     | 18                                   | 0                     | 0                                       | 0                             | 0                     |
| Neurological injury       | 0                        | 3                                    | 2                     | 1                                       | 3                             | 3                     |
| thigh pain/numbness, psoas weakness | 0                        | 1                                    | 0                     | 4                                       | 4                             | 4                     |
| permanent                | 1                        | 90                                   | 91                    | 50                                      | 277                           | 327                   |
| impermanent             | 1                        | 50                                   | 50                    | 50                                      | 256                           | 256                   |
| gastrointestinal and urinary complications | 0                        | 26                                   | 26                    | 1                                       | 21                            | 22                    |
| wound complications | 18                      | 18                                   | 0                     | 11                                      | 11                            | 11                    |
| infections              | 0                        | 3                                    | 3                     | 0                                       | 11                            | 11                    |
| Hematoma                | 0                        | 4                                    | 4                     | 0                                       | 4                             | 4                     |
| Seroma                  | 0                        | 1                                    | 1                     | 1                                       | 1                             | 1                     |
| wound pain              | 2                        | 3                                    | 5                     | 0                                       | 1                             | 1                     |
| Revision Surgery        | 0                        | 12                                   | 12                    | 3                                       | 10                            | 13                    |
| Hardware failure        | 0                        | 4                                    | 4                     | 0                                       | 1                             | 1                     |
| Failure of Operation | 54                      | 54                                   | 54                    | 0                                       | 2                             | 2                     |
| EndPlate Fracture        | 0                        | 2                                    | 2                     | 0                                       | 3                             | 3                     |
| Vertebral fracture       | 53                      | 53                                   | 53                    | 15                                      | 5                             | 20                    |
| Cage subsidence         | 0                        | 0                                    | 0                     | 0                                       | 2                             | 2                     |
| Rupture of ALL          | 0                        | 0                                    | 0                     | 0                                       | 2                             | 2                     |
| complications not directly related to surgical access | 0                        | 1                                    | 1                     | 2                                       | 1                             | 3                     |
| pulmonary/ respiratory  | 0                        | 1                                    | 1                     | 7                                       | 10                            | 17                    |
| cardiac                 | 0                        | 1                                    | 1                     | 7                                       | 10                            | 17                    |

OLIF oblique lateral interbody fusion; LLIF lateral lumbar interbody fusion; ALL anterior longitudinal ligament
However, a high rate of perioperative complications was observed related to OLIF and LLIF, and there were differences between the two groups. Higher rates of nerve injury and psoas weakness were reported for LLIF, while higher rates of cage subsidence, endplate damage, and vascular injury were reported for OLIF. Direct injury to the lumbar plexus is the greatest risk from LLIF, as it has the potential to result in sensory and motor deficits. According to previous studies, the incidence of thigh dysfunction and numbness after LLIF has been reported to range from 0.7 to 30%, and the incidence of motor weakness ranged from 3.4 to 23.7% [6, 47, 60, 61]. In our study, we have found the incidence of anterior thigh numbness and leg weakness was high at 21.2%. Although most of those symptoms are transient and completely recovered by time in most studies, there are still some studies reported that some patients presented with the permanent damages [10, 62]. The possible reason for

### Table 3 Meta-regression of potential effect of follow-up and mean age on the radiographic and clinical indexes

|                | Follow-up |          | Mean age |          |
|----------------|-----------|----------|----------|----------|
|                | OLIF      | LLIF     | OLIF     | LLIF     |
| Disc height    | Coefficient (95% CI) | $P > t$ | Coefficient (95% CI) | $P > t$ | Coefficient (95% CI) | $P > t$ | Coefficient (95% CI) | $P > t$ |
|                | 0.01(−0.79 to 0.09) | 0.88     | −0.07(−0.31 to 0.16) | 0.44     | −0.09(−0.32 to 0.15) | 0.36     | 0.11(−0.67 to 0.89) | 0.73     |
| Visual analogue scale | 0.01(−0.23 to 0.24) | 0.94     | −0.01(−0.05 to 0.04) | 0.84     | 0.36(−0.05 to 0.78) | 0.08     | −0.04(−0.17 to 0.09) | 0.54     |
| Oswestry Disability Index | −0.08(−0.28 to 0.12) | 0.38     | 0.02(−0.02 to 0.06) | 0.34     | 0.46 (0.18 to 0.74) | 0.01*    | −0.06(−0.15 to 0.02) | 0.14     |

OLIF oblique lateral interbody fusion; LLIF lateral lumbar interbody fusion; $^{*}P < 0.05$ is considered as the factor that contributes to the heterogeneity of effect. If coefficient interval goes across both negative and positive values, it means that no evidence supports that the factor contributes significantly to the heterogeneity of effect.

Fig. 5 Funnel plot of publication bias. (a) Disc height of oblique lateral interbody fusion (OLIF), (b) disc height of lateral lumbar interbody fusion (LLIF), (c) visual analogue scale of OLIF, (d) visual analogue scale of LLIF, (e) Oswestry disability index of OLIF, and (f) Oswestry disability index of LLIF. No publication bias for DH or ODI was found in either group. Publication bias was found for VAS for the LLIF group.
this phenomenon may be ascribed to direct injury to lumbar plexus, ilioinguinal nerve or hypogastric nerve that are situated within the abdominal wall, and injury to the genitofemoral nerve on the psoas muscle during the surgical approach. Although thigh pain/numbness and psoas weakness were observed in OLIF group, the incidence of these complications was lower compared to LLIF. However, higher rates of cage subsidence (5.1%), endplate damage (5.2%) and vascular injury (1.7%) were reported for OLIF. The presence of a damaged endplate, an embedded cage, cage sedimentation, and shifting correlated highly, mainly because of endplate lesions [58]. The high risk of cage subsidence after OLIF may be also due to the smaller interbody grafts limited by the discectomy corridor [61]. Besides, vascular injury was a noteworthy complication of OLIF, and the incidence of vascular injury has been reported to range from 1.1 to 2.8% [3, 25, 61]. Although the incidence of major vascular injury was low, careful preoperative radiological evaluation of vascular anatomy should be conducted to avoid these complications [62].

One limitation of this review is that most of the studies included were retrospective studies with incomplete outcome reporting. Secondly, we did not compare segmental lordosis, global lordosis as more studies need to be included. Thirdly, the fusion result of both techniques may be influenced by the kind of graft material. Another limitation is that all the included studies are searched through an online database but not included unpublished studies, which might have led to publication bias in our meta-analysis. Finally, the interpretation of thigh symptoms was controversial, as surgeons have gradually realized that thigh symptoms disappeared spontaneously 2–3 weeks after surgery, so the definition of this symptom was changed to recognize it as an access-related symptom but not as a complication. However, any meta-analysis has the risk of publication, and we believe that our final result is convincing.

Conclusions
The two groups are similar in terms of radiographic outcomes, operative blood loss, operative time and the length of hospital stay. The OLIF group shows advantages in VAS and ODI scores improvement. Though the incidence of perioperative complications of OLIF and LLIF is similar, the incidence of main complications is significantly different.

Abbreviations
DH: Disc height; OLIF: Direct lumbar interbody fusion; LLIF: Lateral lumbar interbody fusion; ODI: Oswestry Disability Index; OLIF: Oblique lateral interbody fusion; VAS: Visual analog scale; XLIF: Extreme lumbar interbody fusion

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Authors’ contributions
C.L.S., H.M.L., and R.J.Z. conceived and coordinated the study, designed, performed, and analyzed the experiments, and wrote the paper. H.M.L. carried out the data collection, data analysis, and revised the paper. R.J.Z. designed the study, carried out the data analysis, and revised the paper. All authors reviewed the results and approved the final version of the manuscript.

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Availability of data and materials
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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