Medicine®

OPEN

Comparing stand-alone oblique lumbar interbody fusion with posterior lumbar interbody fusion for revision of rostral adjacent segment disease

A STROBE-compliant study

Guangduo Zhu, MD[a], Yingjie Hao, MD[a,*], Lei Yu, MM[a], Yingchun Cai, MD[a], Xiaowei Yang, MM[b]

Abstract

Spinal fusion has become a standard treatment for symptomatic intervertebral degenerative disc disease. The present study aimed to compare perioperative parameters, clinical outcomes, and radiographic results of stand-alone oblique lumbar interbody fusion (OLIF) with posterior lumbar interbody fusion (PLIF) for the revision of rostral adjacent segment disease (ASD) following prior posterior lumbar fusion.

Thirty-six patients who underwent revision surgeries for rostral ASD were retrospectively reviewed. Among them, 17 patients underwent stand-alone OLIF (OLIF group) and 19 patients underwent PLIF (PLIF group). The length of operation, intraoperative hemorrhage, bed rest duration, and length of hospital stay were compared between the 2 groups. Clinical results were evaluated with the Oswestry Disability Index (ODI) and visual analog scale (VAS). Radiological results were evaluated with disc height (DH), foraminal height (FH), retrolisthesis index (RI), and lumbar lordosis (LL), as well as the fusion rate and cage subsidence. Follow-up results at 1 week, 3 months, and 12 months postoperatively were compared between the 2 groups.

The OLIF group had less intraoperative blood loss, shorter operative time, bed rest time, and hospital stay than did the PLIF group ($P < .05$). The OLIF group had lower VAS scores for back pain than the PLIF group at 1 week and 3 months postoperatively ($P < .05$), and lower VAS scores for leg pain than the PLIF group at 1 week postoperatively ($P < .05$). The OLIF group had lower ODI than the PLIF group at 1 week and 3 months postoperatively ($P < .05$). No significant differences were found in DH and FH between the 2 groups preoperatively ($P > .05$); the OLIF group showed higher DH and FH than the PLIF group at all time points ($P < .05$). No significant differences were found in RI and LL between the 2 groups at any time point. All patients achieved fusion at 12 months postoperatively, and cage subsidence was not observed in either group.

OLIF is effective and safe for the treatment of rostral ASD following prior posterior lumbar fusion, and is superior to PLIF in terms of perioperative parameters, short-term clinical outcomes, and DH restoration, with similar fusion and reduction rates.

Abbreviations: ASD = adjacent segment disease, CT = computed tomography, DH = disc height, FH = foraminal height, LL = lumbar lordosis, ODI = Oswestry Disability Index, OLIF = oblique lumbar interbody fusion, PLIF = posterior lumbar interbody fusion, RI = retrolisthesis index, VAS = visual analog scale.

Keywords: adjacent segmental disease, disc protrusion, oblique lumbar interbody fusion, posterior lumbar interbody fusion, retrolisthesis

1. Introduction

Spinal fusion, initially described by Albee and Hibbs in 1911, has become a standard treatment for symptomatic intervertebral degenerative disc disease. With the development of surgical instruments and implants, the number of lumbar fusion surgeries has increased rapidly worldwide.[1] Nevertheless, the results of fusion can be compromised by the long-term postoperative complication of adjacent segment disease (ASD), which refers to clinically significant degenerative changes in the segments adjacent to previous fusion.[2,3]

Retrolisthesis of the rostral adjacent level is one of the most common radiological manifestations of ASD; it can be accompanied by lumbar disc herniation or stenosis, resulting in low back pain and weakness, numbness, or pain of the lower limbs.[4] When the symptoms are severe, surgical intervention may be warranted. One of the standard revision surgeries is posterior lumbar interbody fusion (PLIF), during which decompression and extension of previous fusion can both be accomplished; however, the risks of dural laceration and nerve injury are high, and broken posterior spinal structures may lead to the progression of ASD.[5,6]

Oblique lumbar interbody fusion (OLIF), as a minimally invasive retroperitoneal approach for intervertebral fusion, has increased in popularity in recent years.[7,8] During OLIF, the disc space is accessed from the interval of the psoas and abdominal

Editor: Yan Li.

Henan provincial key science and technology research project (No. 182102310621).

The authors have no conflicts of interest to disclose.

[a] Department of Orthopedics, [b] Department of SICU, The First Affiliated Hospital of Zhengzhou University, Zhengzhou, Henan, China.

[*] Correspondence: Yingjie Hao, Department of Orthopedics, The First Affiliated Hospital of Zhengzhou University, No. 1 Jianshe East Road, Zhengzhou, Henan 450052, China (e-mail: jackhao2006@126.com).

Medicine (2018) 97:40(e12680)

Received: 9 April 2018 / Accepted: 7 September 2018

http://dx.doi.org/10.1097/MD.0000000000012680

major vessels.[9] Several studies have reported promising results from OLIF for primary surgery of lumbar degenerative disease[8,10]; reports on the use of OLIF in revision of ASD are rare, and no study has directly compared OLIF with PLIF to evaluate their efficacy in the treatment of ASD.

The aim of this study was to compare OLIF and PLIF for the treatment of rostral ASD after previous PLIF in terms of perioperative parameters, clinical outcomes, and radiographic results.

2. Patients and methods

2.1. Patient population

Patients who underwent revision surgery of the lumbar spine in our department between October 2014 and October 2016 were retrospectively reviewed. Each patient had prior posterior lumbar fusion and internal fixations at our hospital or an outside hospital. Inclusion criteria were as follows: low back and lower limb pain unresponsive to conservative therapy for over 3 months; unstable retrolisthesis and disc protrusion at the rostral segment adjacent to prior fused segments, demonstrated by radiologic examinations; follow-up >12 months. Exclusion criteria were as follows: calcified or migrated disc herniation; failure of previous internal fixations; more than grade 2 spondylolisthesis of the adjacent segment; severe osteoporosis; history of retroperitoneal surgery in the previous year; body mass index >32 kg/m^2; <12 months follow-up. In total, 36 patients were included in this study. Among them, 17 patients underwent OLIF (OLIF group) and 19 patients underwent PLIF (PLIF group) for revision of ASD. All surgeries were conducted by the same senior surgeon. The health records and radiographic data of the 36 patients were summarized and analyzed. This study was approved by the Ethics Committee of the First Affiliated Hospital of Zhengzhou University.

2.2. Surgical procedures

2.2.1. Oblique lumbar interbody fusion. For the OLIF procedure, after general anesthesia, the patient was placed on their right side and the target disc was located and marked using a C-arm. A 4 to 6 cm skin incision was made at the left abdomen, which was in the same horizontal plane as the target disc (Fig. 1A). The abdominal wall muscles were dissected layer by layer (Fig. 1B). The retroperitoneum was entered by blunt separation with the fingers, then the psoas was retracted posteriorly and the abdominal vessels were retracted anteriorly; a guidewire was placed into the target disc with the help of a C-arm. Sequential dilators were placed over the guidewire (Fig. 1C), then a lighted retractor was placed over the dilators and fixed to the vertebral body with a pin, and the operation field was exposed; a window was made in the annulus fibrosis and the nucleus pulposus was removed with the nucleus pulposus clamp; then, the cartilage endplates were resected for exposure of the bony endplates; a wide and lordotic intervertebral fusion cage (Boomerang, Medtronic, Inc, Minneapolis, MN) packed with allograft bone was inserted into the target disc with the guidance of a C-arm, and a final impaction was done to center the cage

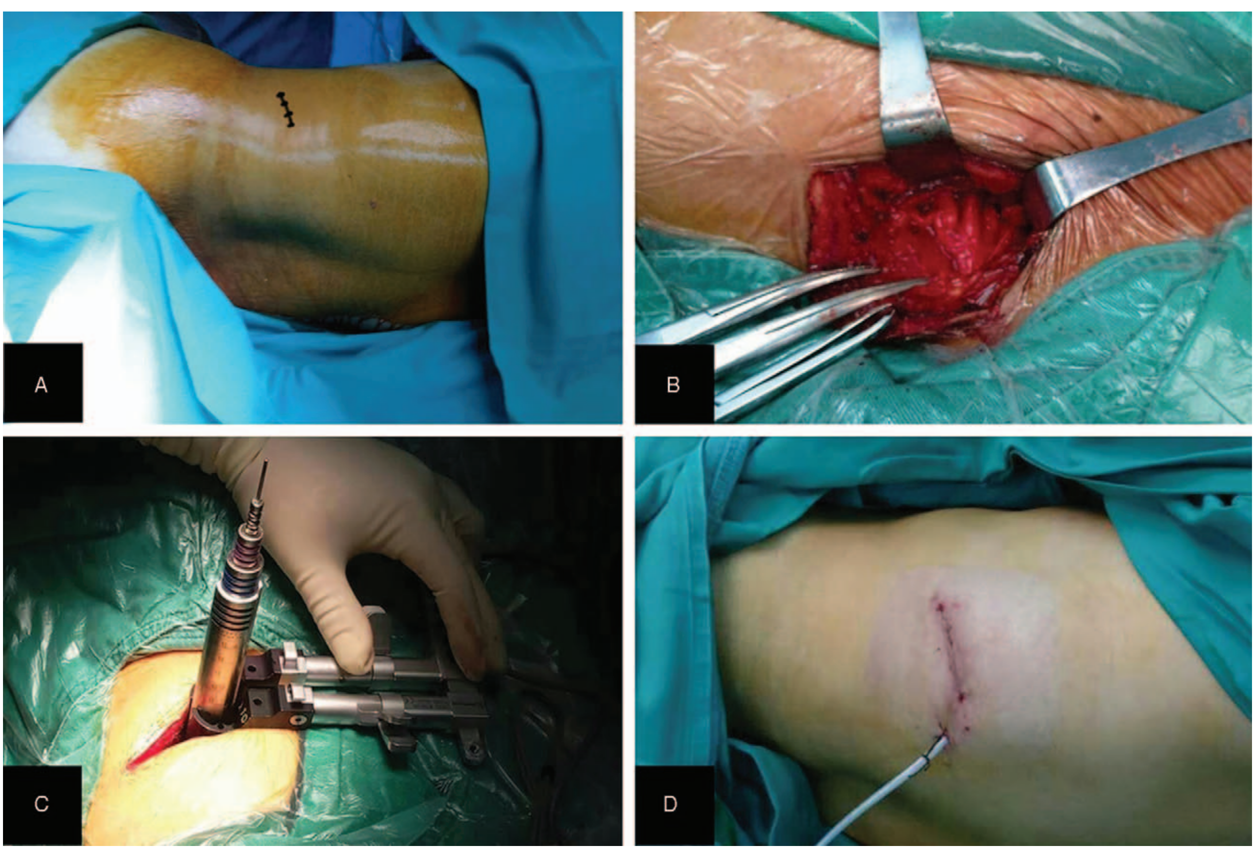

Figure 1. Procedures of OLIF operation. (A) The incision was marked on the skin before surgery; (B) the abdominal wall muscles were dissected sequentially; (C) sequential dilators were used intraoperatively; (D) skin closure and drainage was performed. OLIF=oblique lumbar interbody fusion.

Figure 2. A typical case of a 62-year-old man who underwent OLIF for rostral adjacent segment disease. (A) Preoperative anteroposterior X-rays; (B) preoperative lateral X-rays; (C, D) preoperative flexion and extension X-rays; (E) preoperative MRI; (F) preoperative CT; (G) postoperative anteroposterior X-rays; (H) postoperative lateral X-rays. CT = computed tomography, MRI = magnetic resonance imaging, OLIF = oblique lumbar interbody fusion.

within the disc space. Then, the abdominal wall muscles and the incision were closed sequentially after a drainage tube was placed (Fig. 1D). A typical case of OLIF is shown in Fig. 2.

2.2.2. Posterior lumbar interbody fusion. During the PLIF procedure, the patient was placed in the prone position after general anesthesia. The original incision scar was incised; all previously implanted nuts and screw rods were exposed and removed, then the rostral adjacent vertebra was exposed, and 2 pedicle screws were inserted. Bilateral laminotomies and medial facetectomies were performed using an osteotome or rongeur; subsequently, the thecal sac and nerve roots were exposed and mobilized medially. Bilateral annular windows were made using a scalpel, the nucleus pulposus was removed with the nucleus pulposus clamp, and a combination of shavers, curettes, and rongeurs was used to perform a thorough discectomy down to the exposed endplate. Autologous bone was then implanted into the disc space, and a proper sized cage packed with bone autograft was inserted. Bilateral pedicle screws were connected with new elongated screw rods and fixed with nuts. A drainage tube was placed and the incision was closed sequentially. A typical case of PLIF is shown in Fig. 3.

2.3. Assessment of clinical and radiographic outcomes

The duration of the operation, volume of intraoperative hemorrhage, length of bed rest, length of hospital stay, and complications were recorded for all patients. Clinical and radiographic outcomes were evaluated preoperatively and at 1 week, 3 months, and 12 months postoperatively. Clinical evaluation included symptoms and signs, visual analog scale (VAS) for back and leg pain, and Oswestry Disability Index (ODI).

Radiographic examination included X-ray, computed tomography (CT), and magnetic resonance imaging. Lumbar lordosis (LL), disc height (DH), foraminal height (FH), and retrolisthesis index (RI) at the operated level were measured. LL was defined as the angle between the upper endplate of the L1 and S1 vertebra using the Cobb method. DH was calculated as the mean value of the anterior and posterior margin heights of the affected disc. FH was measured as the maximal interval between the lower border of the upper pedicle and the upper border of the lower pedicle. RI was calculated as the ratio of retrolisthesis length of the upper vertebra to the antero-posterior length of the lower vertebra. Fusion was identified by the formation of continuous bone trabeculae at the interface between the bone grafts and endplates

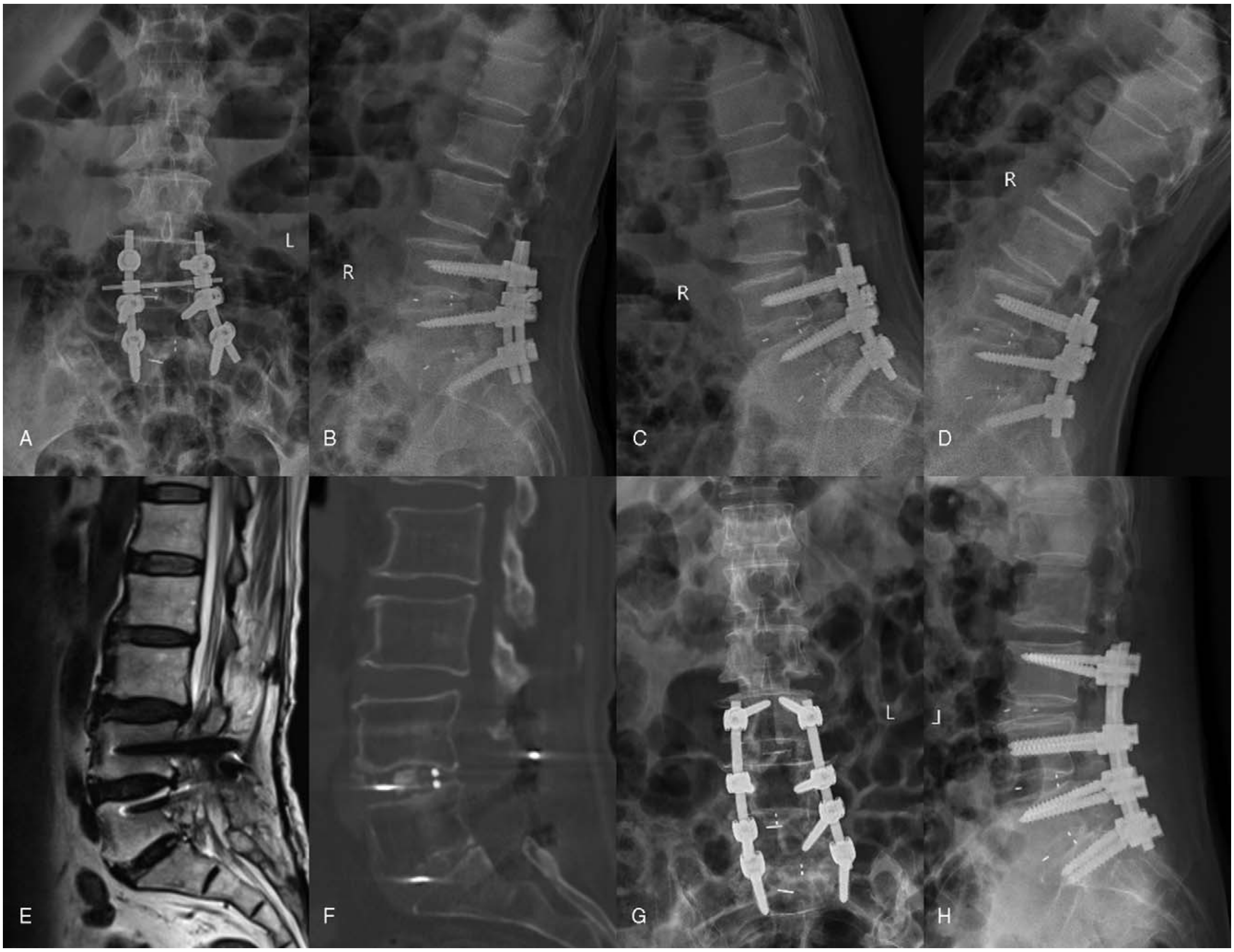

Figure 3. A typical case of a 64-year-old woman who had PLIF for treating rostral adjacent segment disease. (A) Preoperative anteroposterior X-rays; (B) preoperative lateral X-rays; (C, D) preoperative flexion and extension X-rays; (E) preoperative MRI; (F) preoperative CT; (G) postoperative anteroposterior X-rays; (H) postoperative lateral X-rays. CT=computed tomography, MRI=magnetic resonance imaging, PLIF=posterior lumbar interbody fusion.

on X-ray or CT at final follow-up. Cage subsidence was identified by the compromise of bony endplates visible on X-ray or CT. All images in this study were assessed by 2 independent researchers and the measurements were averaged.

2.4. Statistical analysis

All quantitative variables are presented as means ± standard deviations. SPSS 18.0 software (SPSS Inc, Chicago, IL) was used to conduct all statistical analyses. The Fisher exact test or chi-squared test was used to compare qualitative variables between groups, and the independent *t* test or Wilcoxon rank-sum test was used to compare quantitative variables between groups. $P<.05$ was considered statistically significant.

3. Results

The mean follow-up duration for the OLIF and PLIF groups was 17.2 ± 3.5 and 18.0 ± 3.0 months, respectively. No significant differences were found between the 2 groups in terms of baseline patient characteristics, including age, sex, body mass index, operated levels, and previously fused levels (Table 1).

As shown in Table 2, the operative duration was shorter and intraoperative hemorrhage was less in the OLIF group compared with the PLIF group (52.24 ± 6.24 vs. 134.32 ± 15.84 minutes; 34.94 ± 4.05 vs. 340.68 ± 25.27 mL; respectively, both $P<.01$).

Table 1

Baseline characteristics of patients in OLIF group and PLIF group.

	OLIF group (n=17)	PLIF group (n=19)	*P*
Age, y	60.47 ± 6.07	58.63 ± 6.17	.375
Gender			
Male	7	9	.749
Female	10	10	
Body mass index	20.98 ± 1.78	20.62 ± 1.68	.529
Operated level			
L2/3	9	11	.905
L3/4	4	5	
L4/5	4	3	
Previously fused levels			.901
Single-level	6	5	
Double-level	9	11	
Triple-level	2	3	

OLIF=oblique lumbar interbody fusion, PLIF=posterior lumbar interbody fusion.

Table 2

Comparison of perioperative parameters between OLIF group and PLIF group.

	OLIF group (n=17)	PLIF group (n=19)	*P*
Operative duration, min	52.24±6.24	134.32±15.84	<.001
Intraoperative hemorrhage, mL	34.94±4.05	340.68±25.27	<.001
Bed rest time, d	2.47±0.51	6.95±0.91	<.001
Hospital stay, d	6.00±1.12	13.10±1.40	<.001

OLIF=oblique lumbar interbody fusion, PLIF=posterior lumbar interbody fusion.

The OLIF group had a shorter bed rest time and shorter hospital stay than did the PLIF group ($P<.01$).

VAS scores of both groups decreased postoperatively (Table 3, Fig. 4). The OLIF group had lower VAS scores for back pain than the PLIF group at 1 week and 3 months postoperatively ($P<.01$), and lower VAS scores for leg pain than the PLIF group at 1 week postoperatively ($P<.05$). No significant differences in VAS scores were found at other follow-up time points between the 2 groups (Table 3). Preoperative ODI were 53.88±7.48 and 54.00±6.36 points in the OLIF and PLIF groups, respectively ($P>.05$), which both decreased postoperatively. The OLIF group had a lower ODI than the PLIF group at 1 week and 3 months postoperatively ($P<.05$). No significant difference in ODI was found at 1-year follow-up (Table 3).

Concerning radiographic parameters (Table 4), no significant differences in DH and FH between the 2 groups were seen preoperatively ($P>.05$). The OLIF showed higher DH and FH than the PLIF group at all time points after surgery ($P<.05$). Both groups showed reduction of retrolisthesis and increased LL after surgery, while no significant differences in RI and LL were found between the 2 groups at any follow-up time point (Table 4). Based on CT results, all patients achieved fusion at 12 months postoperatively, and cage subsidence was not observed in either group.

Table 3

Comparison of clinical outcomes between OLIF group and PLIF group.

	OLIF group	PLIF group	*P*
VAS (back pain)			
Preoperative	6.76±0.83	6.58±0.69	.531
7 d postoperative	2.53±0.51	3.10±0.66	.019
3 mo postoperative	1.65±0.49	2.21±0.54	.015
12 mo postoperative	1.06±0.66	1.21±0.42	.573
VAS (leg pain)			
Preoperative	4.70±0.69	4.47±0.51	.397
7 d postoperative	1.82±0.39	2.32±0.48	.025
3 mo postoperative	1.35±0.49	1.42±0.51	.731
12 mo postoperative	0.88±0.49	0.79±0.54	.661
ODI, %			
Preoperative	53.88±7.48	54.00±6.36	.960
7 d postoperative	22.29±3.20	28.74±2.02	<.001
3 mo postoperative	15.71±2.59	17.58±2.22	.026
12 mo postoperative	12.82±2.88	11.84±1.71	.452

ODI=Oswestry Disability Index, OLIF=oblique lumbar interbody fusion, PLIF=posterior lumbar interbody fusion, VAS=visual analog scale.

Two patients experienced incisional pain and 1 patient experienced ipsilateral transient groin numbness postoperatively in the OLIF group, which all alleviated within 3 days after surgery. Superficial incision infection occurred in 2 patients in the PLIF group, which was treated with dressing change and antibiotics.

4. Discussion

ASD is a common complication after spinal fusion and may present with various symptoms and signs, including low back pain, radiculopathy, instability, or stenosis.[2,11] According to previous studies, patient-related risk factors for ASD include advanced age (>60 years), female sex, menopause, osteoporosis,

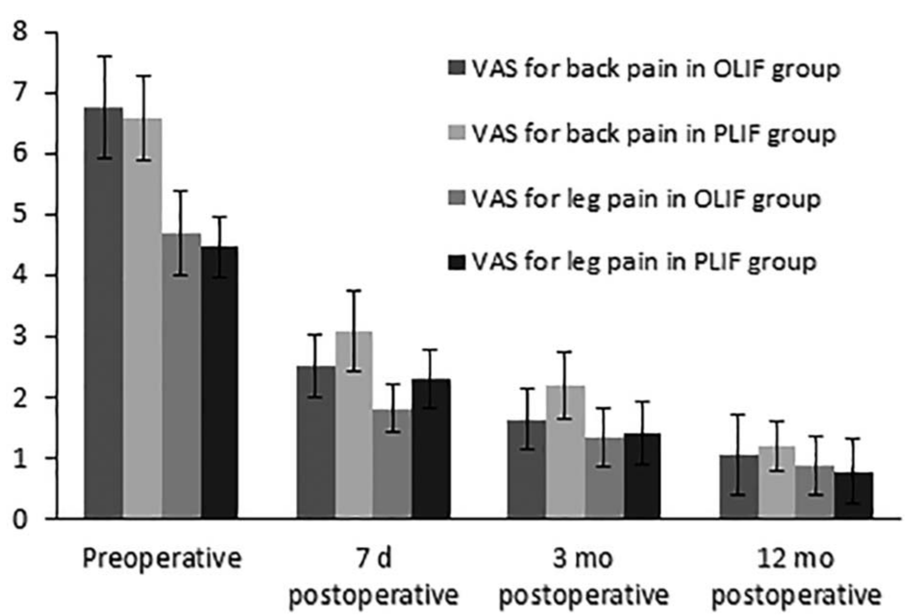

Figure 4. VAS scores for back pain and leg pain of the OLIF group and PLIF group preoperatively and at 1 week, 3 months, and 12 months postoperatively. OLIF=oblique lumbar interbody fusion, PLIF=posterior lumbar interbody fusion, VAS=visual analog scale.

Table 4

Comparison of radiologic parameters between OLIF group and PLIF group.

	OLIF group	PLIF group	P
DH, mm			
Preoperative	8.79±1.24	9.24±0.56	.531
7 d postoperative	13.08±1.38	12.07±0.89	.016
3 mo postoperative	13.00±1.42	11.67±1.23	.005
12 mo postoperative	12.96±1.39	11.87±0.90	.008
FH, mm			
Preoperative	15.10±0.87	14.98±0.54	.778
7 d postoperative	18.08±0.98	16.89±0.62	<.001
3 mo postoperative	18.06±0.97	16.77±0.62	<.001
12 mo postoperative	17.98±1.00	16.69±0.64	<.001
RI, %			
Preoperative	12.52±1.45	12.21±0.82	.457
7 d postoperative	2.63±0.79	2.39±0.54	.510
3 mo postoperative	2.56±0.78	2.16±0.52	.208
12 mo postoperative	2.45±0.78	2.07±0.50	.232
LL, °			
Preoperative	40.83±4.18	40.13±3.22	.570
7 d postoperative	45.47±3.88	44.61±3.18	.470
3 mo postoperative	45.50±3.88	44.48±3.20	.395
12 mo postoperative	45.53±3.97	44.41±3.19	.352

DH=disk height, FH=foraminal height, LL=lumbar lordosis, OLIF=oblique lumbar interbody fusion, PLIF=posterior lumbar interbody fusion, RI=retrolisthesis index.

and previous surgery-related factors including prior decompression at the adjacent level, floating or long fusion, and altered alignment of the spine.[12–14]

Revision surgery may be needed when the symptoms of ASD are severe. Surgical methods reported in the literature include simple decompression, decompression and extension of fusion, or decompression and artificial disc replacement[15–17]; the most appropriate method depends largely on the patient's individual condition. In this study, the 36 patients enrolled primarily presented with retrolisthesis, instability, and stenosis of the rostral adjacent segment, thus decompression and fusion were indicated.

OLIF is a modification of the retroperitoneal approach for microsurgical anterolateral lumbar interbody fusion, which was first described by Mayer in 1997.[18] In contrast to lateral lumbar interbody fusion, OLIF accesses the target disc from the window between the abdominal major vessels and the psoas, thus the risk of lumbar plexus injury is greatly reduced; few studies have reported the use of OLIF for the treatment of ASD.[7,19]

In this study, we found that the OLIF group had less intraoperative blood loss and shorter operative time, bed rest duration, and hospital stay than the PLIF group. This is reasonable because, in PLIF, the paravertebral muscles were dissected, scar tissues were removed, and the lamina was resected, increasing blood loss, and subsequent muscle atrophy. Meanwhile, the unclear operative field and removal of previous internal fixations both prolonged the operative time.

Potentially because of the absence of back muscle injury in OLIF, we also found that the OLIF group had lower VAS scores for back pain and ODI than the PLIF group at 1 week and 3 months postoperatively. Additionally, the OLIF group had lower VAS scores for leg pain than the PLIF group at 1 week postoperatively, possibly because direct traction of nerve roots was avoided in OLIF.[20]

In terms of radiographic outcomes, the OLIF group showed higher DH and FH than the PLIF group postoperatively. This is reasonable, because we inserted a relatively larger cage into the target disc in OLIF. No differences were found between the 2 groups in RI or LL at any follow-up time point. It is thought that RI and LL could be improved conveniently in PLIF, with the aid of extended internal fixations, while in OLIF, the reduction of retrolisthesis may be driven mainly by intervertebral distraction, FH restoration, tensioning of longitudinal ligaments, and the improvement of LL may be driven by the tapered cage and reduction of the upper vertebra.[21] Moreover, nonfusion and cage subsidence were not observed in either group. We thought that the wide cages used in OLIF and the posterior fixations used in PLIF were both beneficial for improving the fusion rate and decreasing the subsidence rate.[22,23]

Access-related complications of OLIF include injury of the sympathetic chain, vessels, or ureter,[7,24–26] which did not occur in this study. We recommend using a fingertip to access the retroperitoneal space and locate the target disc.

Several limitations of this study should be mentioned. First, this a small-sized, retrospective study. Second, the inclusion criteria were rather restrictive and may have introduced selection bias. Third, the follow-up period was short. Prospective, cohort studies with more patients and longer follow-up time are needed to further compare the efficacy of OLIF with PLIF in treating ASD.

In conclusion, OLIF is effective and safe for the treatment of rostral ASD following prior posterior lumbar fusion, and is superior to PLIF in terms of perioperative parameters, short-term clinical outcomes, and DH restoration, with similar fusion and reduction rates as compared to PLIF.

Author contributions

Conceptualization: Yingjie Hao.
Data curation: Guangduo Zhu, Xiaowei Yang.
Formal analysis: Guangduo Zhu.
Funding acquisition: Yingjie Hao.
Investigation: Lei Yu.
Methodology: Lei Yu.
Project administration: Yingchun Cai.
Software: Guangduo Zhu.
Supervision: Yingjie Hao.
Validation: Guangduo Zhu.
Visualization: Xiaowei Yang.
Writing – original draft: Guangduo Zhu.
Writing – review & editing: Yingjie Hao.

References

[1] Yavin D, Casha S, Wiebe S, et al. Lumbar fusion for degenerative disease: a systematic review and meta-analysis. Neurosurgery 2017;80: 701–15.
[2] Virk SS, Niedermeier S, Yu E, et al. Adjacent segment disease. Orthopedics 2014;37:547–55.
[3] Scemama C, Magrino B, Gillet P, et al. Risk of adjacent-segment disease requiring surgery after short lumbar fusion: results of the French Spine Surgery Society Series. J Neurosurg Spine 2016;25:46–51.
[4] Chen BL, Wei FX, Ueyama K, et al. Adjacent segment degeneration after single-segment PLIF: the risk factor for degeneration and its impact on clinical outcomes. Eur Spine J 2011;20:1946–50.
[5] Lee CW, Yoon KJ, Ha SS, et al. Which approach is advantageous to preventing development of adjacent segment disease? Comparative analysis of 3 different lumbar interbody fusion techniques (ALIF, LLIF, and PLIF) in L4-5 spondylolisthesis. World Neurosurg 2017;105: 612–22.

[6] Huang YP, Du CF, Cheng CK, et al. Preserving posterior complex can prevent adjacent segment disease following posterior lumbar interbody fusion surgeries: a finite element analysis. PLoS ONE 2016;11:e0166452.
[7] Silvestre C, Mac-Thiong JM, Hilmi R, et al. Complications and morbidities of mini-open anterior retroperitoneal lumbar interbody fusion: oblique lumbar interbody fusion in 179 patients. Asian Spine J 2012;6:89–97.
[8] Ohtori S, Orita S, Yamauchi K, et al. Mini-open anterior retroperitoneal lumbar interbody fusion: oblique lateral interbody fusion for lumbar spinal degeneration disease. Yonsei Med J 2015;56:1051–9.
[9] Davis TT, Hynes RA, Fung DA, et al. Retroperitoneal oblique corridor to the L2-S1 intervertebral discs in the lateral position: an anatomic study. J Neurosurg Spine 2014;21:785–93.
[10] Ohtori S, Mannoji C, Orita S, et al. Mini-open anterior retroperitoneal lumbar interbody fusion: oblique lateral interbody fusion for degenerated lumbar spinal kyphoscoliosis. Asian Spine J 2015;9:565–72.
[11] Radcliff KE, Kepler CK, Jakoi A, et al. Adjacent segment disease in the lumbar spine following different treatment interventions. Spine J 2013;13:1339–49.
[12] Lee JC, Kim Y, Soh JW, et al. Risk factors of adjacent segment disease requiring surgery after lumbar spinal fusion: comparison of posterior lumbar interbody fusion and posterolateral fusion. Spine (Phila Pa 1976) 2014;39:E339–45.
[13] Nakashima H, Kawakami N, Tsuji T, et al. Adjacent segment disease after posterior lumbar interbody fusion: based on cases with a minimum of 10 years of follow-up. Spine (Phila Pa 1976) 2015;40:E831–41.
[14] Wang H, Ma L, Yang D, et al. Incidence and risk factors of adjacent segment disease following posterior decompression and instrumented fusion for degenerative lumbar disorders. Medicine (Baltimore) 2017;96: e6032.
[15] Telfeian AE. Transforaminal endoscopic surgery for adjacent segment disease after lumbar fusion. World Neurosurg 2017;97:231–5.
[16] Aichmair A, Alimi M, Hughes AP, et al. Single-level lateral lumbar interbody fusion for the treatment of adjacent segment disease: a retrospective two-center study. Spine (Phila Pa 1976) 2017;42:E515–22.
[17] Tobert DG, Antoci V, Patel SP, et al. Adjacent segment disease in the cervical and lumbar spine. Clin Spine Surg 2017;30:94–101.
[18] Mayer HM. A new microsurgical technique for minimally invasive anterior lumbar interbody fusion. Spine (Phila Pa 1976) 1997;22:691–9.
[19] Phan K, Mobbs RJ. Oblique lumbar interbody fusion for revision of non-union following prior posterior surgery: a case report. Orthop Surg 2015;7:364–7.
[20] Fujibayashi S, Hynes RA, Otsuki B, et al. Effect of indirect neural decompression through oblique lateral interbody fusion for degenerative lumbar disease. Spine (Phila Pa 1976) 2015;40:E175–82.
[21] Sato J, Ohtori S, Orita S, et al. Radiographic evaluation of indirect decompression of mini-open anterior retroperitoneal lumbar interbody fusion: oblique lateral interbody fusion for degenerated lumbar spondylolisthesis. Eur Spine J 2017;26:671–8.
[22] Miwa T, Sakaura H, Yamashita T, et al. Surgical outcomes of additional posterior lumbar interbody fusion for adjacent segment disease after single-level posterior lumbar interbody fusion. Eur Spine J 2013;22: 2864–8.
[23] Li JX, Phan K, Mobbs R, et al. Oblique lumbar interbody fusion: technical aspects, operative outcomes, and complications. World Neurosurg 2017;98:113–23.
[24] Woods KR, Billys JB, Hynes RA. Technical description of oblique lateral interbody fusion at L1-L5 (OLIF25) and at L5-S1 (OLIF51) and evaluation of complication and fusion rates. Spine J 2017;17:545–53.
[25] Phan K, Maharaj M, Assem Y, et al. Review of early clinical results and complications associated with oblique lumbar interbody fusion (OLIF). J Clin Neurosci 2016;31:23–9.
[26] Lee HJ, Kim JS, Ryu KS, et al. Ureter injury as a complication of oblique lumbar interbody fusion. World Neurosurg 2017;102:693.e7–14.