Efficacy of Oblique Lateral Interbody Fusion in Treatment of Degenerative Lumbar Disease

Can Zhang, Kai Wang, Fengzeng Jian, Hao Wu

■ OBJECTIVE: **This study aimed to analyze the efficacy of oblique lumbar interbody fusion (OLIF) in the treatment of degenerative lumbar disease.**

■ METHODS: **Twenty-two patients with degenerative lumbar disease who underwent OLIF between October 2016 and January 2017 were included. Radiography, computed tomography, and magnetic resonance imaging were performed preoperatively and postoperatively. The cross-sectional area (CSA) of the dural sac, disk height, cross-sectional height of the intervertebral foramina, and intervertebral foramina CSA were measured. Scores from the visual analog scale, Oswestry Disability Index, and Medical Outcome Study 36-Item Short-Form Health Survey, obtained preoperatively, 1 week and 3 months postoperatively, and at the final follow-up, were compared.**

■ RESULTS: **Forty-five segments were fused in 22 patients using OLIF. Postoperatively, CSA increased from 0.79 ± 0.32 cm^2 to 1.40 ± 0.37 cm^2, disk height increased from 0.67 ± 0.24 cm to 1.15 ± 0.31 cm, cross-sectional height increased from 1.51 ± 0.25 cm to 2.01 ± 0.31 cm, and intervertebral foramina increased from 1.11 ± 0.28 cm^2 to 1.86 ± 0.38 cm^2 (P <0.01). The visual analog scale, Oswestry Disability Index, and 36-Item Short-Form Health Survey scores of all patients significantly improved postoperatively (P < 0.05). There were no complications involving injuries to spinal nerves, great vessels, abdominal viscera, or ureters. Only 1 patient experienced injury to the psoas major.**

■ CONCLUSIONS: **OLIF is a safe and effective minimally invasive procedure for the treatment of degenerative lumbar disease.**

INTRODUCTION

With extensive progress in lumbar fusion surgery, lumbar interbody fusion (LIF) has gradually become a commonly used technique in the treatment of lumbar degenerative disk disease.[1] Anterior lumbar interbody fusion (ALIF), posterior lumbar interbody fusion, and transforaminal lumbar interbody fusion have been effective in the treatment of lumbar degenerative disease.[2-4] However, iatrogenic injuries to spinal nerves, great abdominal vessels, abdominal viscera, ureters, and the autonomic nervous system have been reported.[5-7] Ozgur et al[8] described 2 minimally invasive lateral transpsoas approaches including extreme lateral interbody fusion (XLIF) and direct lateral interbody fusion. Both XLIF and DLIF are minimally invasive LIF techniques, whereby access to the intervertebral disk space is achieved using a lateral approach passing through the retroperitoneal fat and psoas major. Compared with conventional open surgery, these techniques have the advantages of less blood loss, shorter operative time, shorter hospital stays, and less perioperative pain.[8] However, complications involving nerve injury have been reported.[9,10] The oblique lateral interbody fusion (OLIF) technique allows access to the anterolateral margin of the vertebral body through the surgical space between the psoas major in the retroperitoneal space and abdominal aorta or inferior

Key words
- Decompression
- Disk degeneration
- Nerve injury
- Oblique lateral interbody fusion

Abbreviations and Acronyms
ALIF: Anterior lumbar interbody fusion
CSA: Cross-Sectional Area
CSAF: Cross-sectional area of intervertebral foramina
CSH: Cross-sectional height
CT: Computed tomography
DH: Disk height
MRI: Magnetic resonance imaging
ODI: Oswestry Disability Index
OLIF: Oblique lateral interbody fusion
SF-36: Study 36-Item Short-Form Health Survey
VAS: Visual analog scale
XLIF: Extreme lateral interbody fusion

Department of Neurosurgery, Xuanwu Hospital of Capital Medical University, China-INI, Xicheng District, P.R. China

To whom correspondence should be addressed: Hao Wu, M.D., Ph.D.
[E-mail: 13901397527@139.com]

Can Zhang and Kai Wang are co–first authors.

Fengzeng Jian and Hao Wu are co-corresponding authors.

Citation: World Neurosurg. (2019) 124:e17-e24.
https://doi.org/10.1016/j.wneu.2018.11.139

*Journal homepage: **www.journals.elsevier.com/world-neurosurgery***

*Available online: **www.sciencedirect.com***

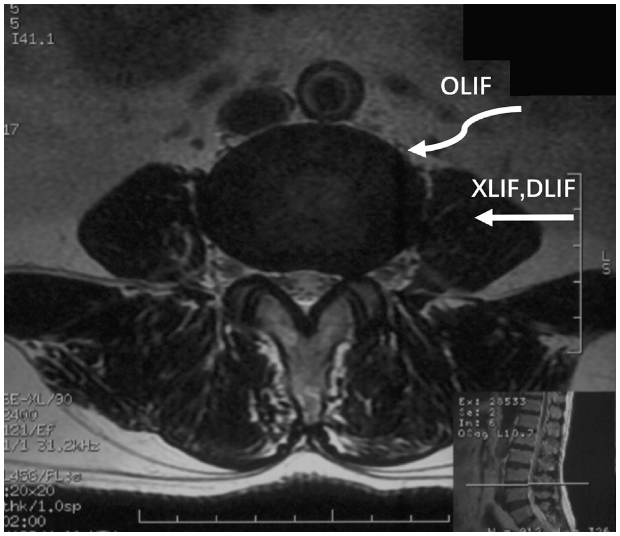

Figure 1. Surgical pathway of oblique lumbar interbody fusion (OLIF). Approaches to OLIF, extreme lateral interbody fusion (XLIF), and direct lateral interbody fusion (DLIF). DLIF and XLIF access the lateral side of vertebral body though psoas muscles, while the corridor of OLIF is between psoas muscles and the aorta abdominalis.

vena cava (Figure 1). As such, OLIF can avoid injury to the lumbar plexus within the psoas major, abdominal aorta, and inferior vena cava. This technique combines the advantages of ALIF and XLIF, while compensating for their respective shortcomings (potential risks of vascular injury in ALIF and nerve injury in XLIF).[1,11] The present study analyzes the efficacy and related complications of OLIF using a retrospective review of relevant information of patients with lumbar degenerative disk disease who underwent OLIF at our institution.

MATERIALS AND METHODS

Clinical Data

Twenty-two patients with lumbar degenerative disk disease who were admitted to the Department of Neurosurgery, Xuanwu Hospital of Capital Medical University between October 2016 and January 2017 were retrospectively included in the study. Medical histories and imaging data of each patient were collected.

Inclusion criteria were patients who were diagnosed with degenerative scoliosis, degenerative lumbar spinal stenosis, diskogenic low back pain, degenerative lumbar spondylolisthesis, a need for revision surgery, refractory back pain, or radiating pain to the lower extremities that could not be effectively treated conservatively; had progressively worsening nerve compression symptoms that severely affected daily life and work; and had undergone OLIF (DePuy Spine, Raynham, Massachusetts, USA) at our institution. Exclusion criteria were patients diagnosed with traumatic injuries, tumors, or infections.

This study was carried out in accordance with Declaration of Helsinki and approved by the Capital Medical University, Beijing, China. Institutional Review Board approval was obtained before medical records were accessed.

Oblique Lateral Interbody Fusion Procedure

OLIF (DePuy Synthes, Raynham, Massachusetts, USA) surgery was performed in all patients. The general technique of OLIF has been previously described.[1,12] Blunt dissection was performed through the plane between the retroperitoneal fat and psoas muscle in the retroperitoneal space to access the lumbar spine, allowing for psoas preservation and avoiding the lumbar plexus. Sufficiently wide cages were selected to prevent subsidence. If restoration of sagittal lumbar lordosis was required, angled cages were selected. Navigation-guided posterior percutaneous pedicle screw fixation was performed in patients who had degenerative scoliosis, had undergone fusion of $\geq$3 levels, or whose imaging data indicated the presence of lumbar spondylolisthesis or spondylolysis, as well as the first patient who underwent the OLIF procedure.

Imaging Evaluation

All patients underwent preoperative lumbar spine radiography in the anteroposterior, lateral, anteflexion, retroflexion, and oblique positions. Lumbar spine radiography in the anteroposterior and lateral positions, computed tomography (CT) scans and 3-dimensional reconstruction of the lumbar spine, and lumbar spine magnetic resonance imaging (MRI) were performed 2 days postoperatively, 3 months postoperatively, and at the final follow-up. The Picture Archiving Communication System was used to measure the cross-sectional area of the dural sac (CSA) in axial T2-weighted MRI scans. Disk height (DH), cross-sectional height of the intervertebral foramina (CSH), and cross-sectional areas of the intervertebral foramina (CSAF) were assessed in sagittal CT scans (Figure 2).

Clinical Indices, Efficacy Evaluation, and Follow-up

Relevant patient descriptors including age, body mass index, operative time, intraoperative blood loss, length of postoperative hospital stay, and complications were collected and statistically analyzed. Scores using the visual analog scale (VAS), Oswestry Disability Index (ODI), and Medical Outcome Study 36-Item Short-Form Health Survey (SF-36) were obtained preoperatively, 1 week postoperatively, 3 months postoperatively, and at the final follow-up. A 6- to 8-month follow-up was conducted in patients after surgery in which the pedicle screw position and fusion rate were assessed by CT, and extent of decompression was assessed by CT and MRI.

Postoperative Complications

Data on perioperative and postoperative complications in the patients were collected and statistically analyzed.

Statistical Methods

Statistical processing and analysis of data were performed using SPSS 23.0. Data that followed a normal distribution were expressed as $\bar{x} \pm s$. The Student's *t*-test was used to perform pairwise comparisons, while analysis of variance was used for the comparison of data in multiple groups. Multiple linear regression was used to analyze the factors related to CSA improvement and

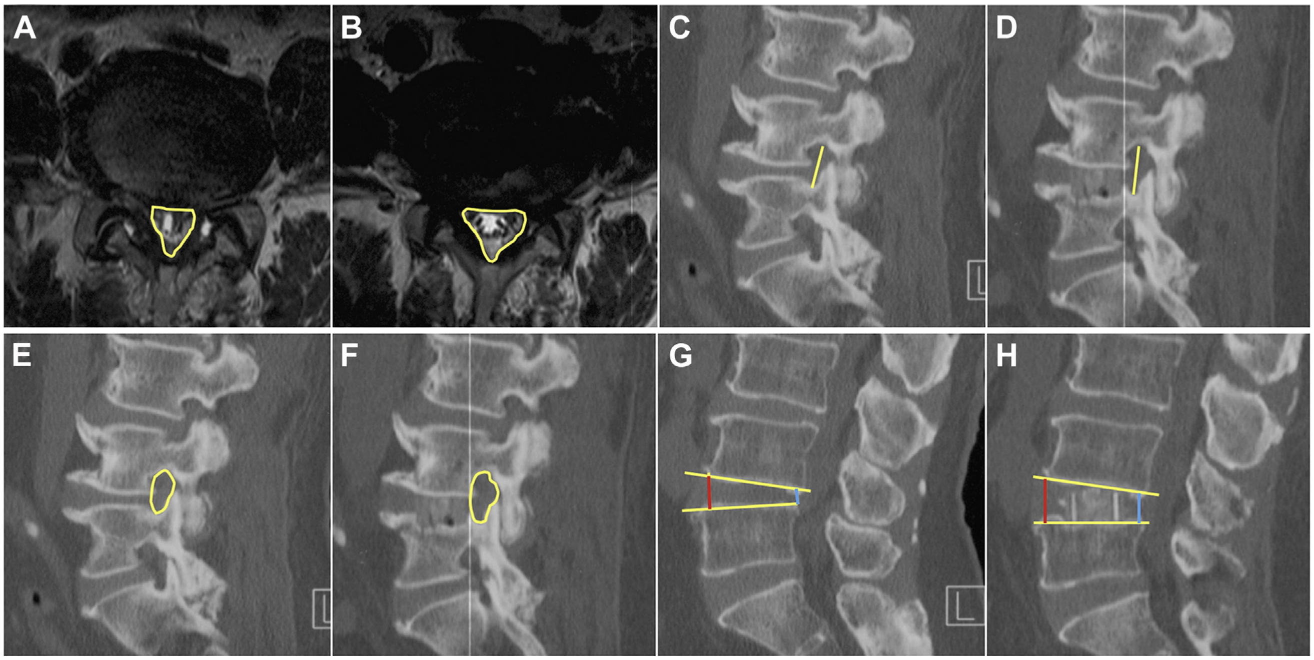

Figure 2. Measurement of cross-sectional area (CSA), disk height (DH), cross-sectional height (CSH), and cross-sectional areas of the intervertebral foramina (CSAF). Measurements of CSA, DH, CSH, and CSAF in the Picture Archiving Communication System (PACS) before the operation and at the last follow-up. (**A** and **B**) CSA was measured in the axial sections of T2-weighted imaging. The central canal (including the thecal sac and epidural fat) was outlined in PACS to get the area of CSA. (**C** and **D**) CSH was measured in the sagittal planes of bilateral foramen in computed tomography (CT) images. The length between the upper and lower edges is CSH. (**E** and **F**) In the same plane of CT, the foramen was outlined to read the CSAF. (**G** and **H**) The distance between the anterior/posterior edges of the upper vertebrae and the end plate of the lower vertebrae is called the anterior/posterior disk height. The average value of anterior disk height (marked red) and posterior disk height (marked blue) is DH.

CSAF improvement. Differences were considered statistically significant when $P < 0.05$.

RESULTS

Surgical Efficacy

Twenty-two patients were included, 10 of whom were male and 12 were female. Patients had a mean age of 67.5 ± 8.1 years (52–80 years) and a mean body mass index of 26.1 ± 3.7 kg/m^2. The patients' diagnoses included the following: degenerative scoliosis (6 cases), degenerative lumbar spinal stenosis (21 cases), lumbar spondylolisthesis (1 case), diskogenic low back pain (1 case), and a need for revision surgery (1 case). The chief complaints of patients included intermittent claudication (17 cases) and pain (16 cases). A total of 45 segments from L2-L5 were fused using the OLIF procedure. One-level fusions were performed in 5 patients, 2-level fusions were performed in 11 patients, and 3-level fusions were performed in 6 patients. The mean operative time was 239.3 ± 165.3 min (90–586 minutes), and intraoperative blood loss was 226.4 ± 310.2 mL (40–1200 mL). For patients who underwent

Table 1. Comparison of Clinical Indices Before and After Operation

Time Point	VAS	ODI	SF-36 PCS	SF-36 MCS
① Preoperative	6.9 ± 1.6	52.1 ± 11.0	58.8 ± 9.7	61.4 ± 11.3
② 1 week postoperatively	3.3 ± 1.4	43.7 ± 6.3	72.5 ± 8.5	78.2 ± 12.5
③ 3 months postoperatively	2.1 ± 0.6	19.2 ± 4.7	84.1 ± 9.9	81.7 ± 11.9
④ Final follow-up	1.3 ± 0.5	12.2 ± 3.7	88.9 ± 8.4	84.8 ± 9.5
F value	110.7	218.8	20.1	18.5
P value	<0.001	<0.001	<0.001	<0.001

N = 22 for all time points. Mean value ± SD.
VAS, visual analog scale; ODI, Oswestry Disability Index; SF-36, Medical Outcome Study 36-Item Short-Form Health Survey; PCS, physical component score; MCS, mental component score.

Table 2. Pairwise Comparisons of Clinical Indices Before and After Operation

	VAS		ODI		SF-36 PCS		SF-36 MCS	
Pairwise Comparison	*T*	*P*	*t*	*P*	*t*	*P*	*T*	*P*
①:②	10.1	<0.001	5.9	<0.001	−7.0	<0.001	−8.6	<0.001
①:③	12.8	<0.001	14.1	<0.001	−11.8	<0.001	−10.7	<0.001
①:④	15.6	<0.001	18.5	<0.001	−19.2	<0.001	−14.5	<0.001

VAS, visual analog scale; ODI, Oswestry Disability Index; SF-36, Medical Outcome Study 36-Item Short-Form Health Survey; PCS, physical component score; MCS, mental component score.

posterior internal fixation, the mean operative time including both lateral and posterior stage for the fusion of each level was 217.4 ± 92.1 minutes (62–362 minutes) and intraoperative blood loss was 240.6 ± 153.8 mL (33–400 mL). For patients who did not undergo posterior internal fixation, the mean operative time for each level was 75.3 ± 32.5 min (33–164 minutes). The operative time for single-level fusion in 1 particular patient was significantly longer (164 minutes) than that of other patients due to an extremely thick psoas major, which made operative exposure difficult; the mean intraoperative blood loss was 38.1 ± 14.1 mL (17–60 mL). Patients who underwent posterior internal fixation experienced longer operative time for single-level fusion compared with those who did not ($P < 0.001$) due to the need for position change and navigation during percutaneous pedicle screw fixation. The mean length of postoperative hospital stay was 5.1 ± 2.1 days (2–11 days). All 22 patients received follow-up for 6–8 months, with a mean follow-up time of 7.0 ± 0.9 months. At the final follow-up, VAS and ODI scores were lower compared with the preoperative scores, while SF-36 physical and mental component scores were higher compared with the preoperative scores (all P values <0.001, Tables 1 and 2).

Imaging Results

The extent of decompression in all surgical segments was assessed using images, and results indicated that postoperative CSA, DH, CSH, and CSAF improved compared with the preoperative measurements (P values <0.01, Table 3). A fusion rate of 100% and good positioning of pedicle screws were achieved in all patients.

Multiple linear regression analysis indicated that DH and CSA improvement (ΔCSA) were negatively correlated, while CSH improvement (ΔCSH) and ΔCSA were positively correlated. Preoperative CSAF was the only independent variable that was correlated with CSAF improvement (ΔCSAF), and the 2 variables were found to be negatively correlated (Tables 4 and 5).

Surgical Complications

One patient developed symptoms of injury to the psoas major, which were manifested as a reduction of flexion strength in the left thigh; the symptoms gradually subsided 2 weeks postoperatively. Two patients experienced local tearing in the vertebral venous plexus during surgery. From image data collected during follow-up, cage subsidence was observed in a total of 15 fused segments, with single-level subsidence occurring in 10 fused segments and 2-level subsidence occurring in 5 fused segments. One particular patient with 2-level subsidence experienced transient aggravation of pain; however, at the final follow-up, the pain had been significantly relieved, and improved VAS, ODI, and SF-36 scores were achieved. No patients experienced infection or injuries to the great abdominal vessels, abdominal viscera, ureters, or lumbar plexus.

DISCUSSION

The OLIF procedure was first reported by Mayer et al[12] in 1997, while the official name and acronym of the procedure was coined by Silvestre et al[1] in 2012. OLIF is a novel minimally invasive surgical technique for the treatment of lumbar degenerative disease. Compared with conventional techniques, it has the advantages of less blood loss, smaller wounds, shorter recovery time, shorter hospital stays, and lower infection rates. The present study retrospectively reviewed the efficacy and related complications of OLIF in the treatment of lumbar degenerative disease.

Table 3. Comparison of Preoperative and Postoperative Measurements

	Preoperative	Postoperative	*t* (paired Student's *t*-test)	*P*
CSA (cm^2)	0.79 + 0.32	1.40 + 0.37	−13.68	0.00
DH (cm)	0.67 + 0.24	1.15 + 0.31	−9.72	0.00
CSH (cm)	1.51 + 0.25	2.01 + 0.31	−14.24	0.00
CSAF (cm^2)	1.11 + 0.28	1.86 + 0.38	−17.01	0.00

CSA, cross-sectional area; DH, disk height; CSH, cross-sectional height of the intervertebral foramina; CSAF, cross-sectional areas of the intervertebral foramina.

Table 4. Regression Analysis Results for ΔCross-Sectional Area

	Multiple Linear Regression Analysis				
	β	SE	Standardized β	t	*P*
ΔDH	−0.03	0.14	−0.04	−0.22	0.83
Preoperative DH	−0.41	0.18	−0.34	−2.26	0.03
Preoperative CSA	−0.15	0.13	−0.16	−1.19	0.24
Preoperative CSH	0.04	0.18	0.03	0.22	0.83
ΔCSH	0.01	0.00	0.44	3.23	0.00

Adjusted $R^2 = 0.27$, $P = 0.00$.
SE, standard error; DH, disk height; CSA, cross-sectional area; CSH, cross-sectional height.

Efficacy of OLIF in Treatment of Lumbar Degenerative Disease

The efficacy of surgery in the treatment of lumbar degenerative disease is primarily determined by the extent of decompression achieved. In conventional surgery, which adopts a posterior approach to the spine, direct decompression is achieved primarily by the excision of the lamina and hypertrophic ligaments and bone. In OLIF, indirect decompression in the intervertebral foramina and spinal canal is achieved by interbody fusion and intervertebral height restoration. With the use of the lateral approach, OLIF enables the implantation of larger fusion cages,[13] excision of herniated intervertebral disks, better restoration of intervertebral height, stretching and thinning of the ligamentum flavum, and indirect spinal canal decompression without excision of the posterior ligaments (Figure 3).[14,15]

For patients with degenerative scoliosis, in order to achieve a better and long-lasting surgical result, spinal canal decompression alone is not enough and they have to consider treatment for the improvement of spinal alignment in the coronal and sagittal planes to correct spinal deformities.[11] Patients with degenerative scoliosis have stiff spines and poor flexibility, and conventional techniques of posterior correction through a pedicle screw-rod system have limited effectiveness. To achieve better correction, osteotomy is usually required, which results in extended operative time, large surgical wounds, and increased blood loss, thereby increasing the instability factors in the spine.[16] With the help of OLIF and minimally invasive surgery−transforaminal lumbar interbody fusion techniques, the release of intervertebral spaces and leveling of the last instrumented vertebra can be achieved concurrently during disk excision and the implantation of cages in multiple disk spaces enables stepwise adjustment of the spinal curvature. After the implantation of pedicle screws and insertion of titanium rods, further correction can be achieved by compression and distraction while maintaining the balance in coronal and sagittal planes, which results in positive outcomes.[17,18] Compared with posterior surgery, the lateral approach used in OLIF facilitates the insertion of larger cages, thereby achieving more significant corrections of spinal alignment in the coronal and sagittal planes in patients with degenerative scoliosis (Figure 4).[13]

In the present study, postoperative VAS, ODI, and SF-36 scores of patients improved compared with the preoperative scores. This indicates that the procedure is effective in the treatment of lumbar spinal stenosis and lumbar degenerative disease.

Imaging Evaluation

Indirect decompression is achieved by OLIF through intervertebral height restoration. Results of the paired Student's *t*-test indicated

Table 5. Regression Analysis Results for ΔCross-Sectional Areas of Intervertebral Foramina

	Multiple Linear Regression Analysis				
	β	SE	Standardized β	t	*P*
ΔDH	0.23	0.18	0.20	1.32	0.19
Preoperative DH	−0.15	0.26	−0.10	−0.59	0.56
ΔCSH	−0.00	0.01	−0.04	−0.27	0.79
Preoperative CSH	−0.00	0.24	0.00	−0.00	1.00
ΔCSA	0.35	0.20	0.27	1.71	0.10
Preoperative CSA	0.18	0.17	0.14	1.04	0.30
Preoperative CSAF	−0.54	0.20	−0.40	−2.73	0.01

Adjusted $R^2 = 0.22$, $P = 0.00$.
SE, standard error; DH, disk height; CSH, cross-sectional height of the intervertebral foramina; CSA, cross-sectional area; CSAF, cross-sectional areas of the intervertebral foramina.

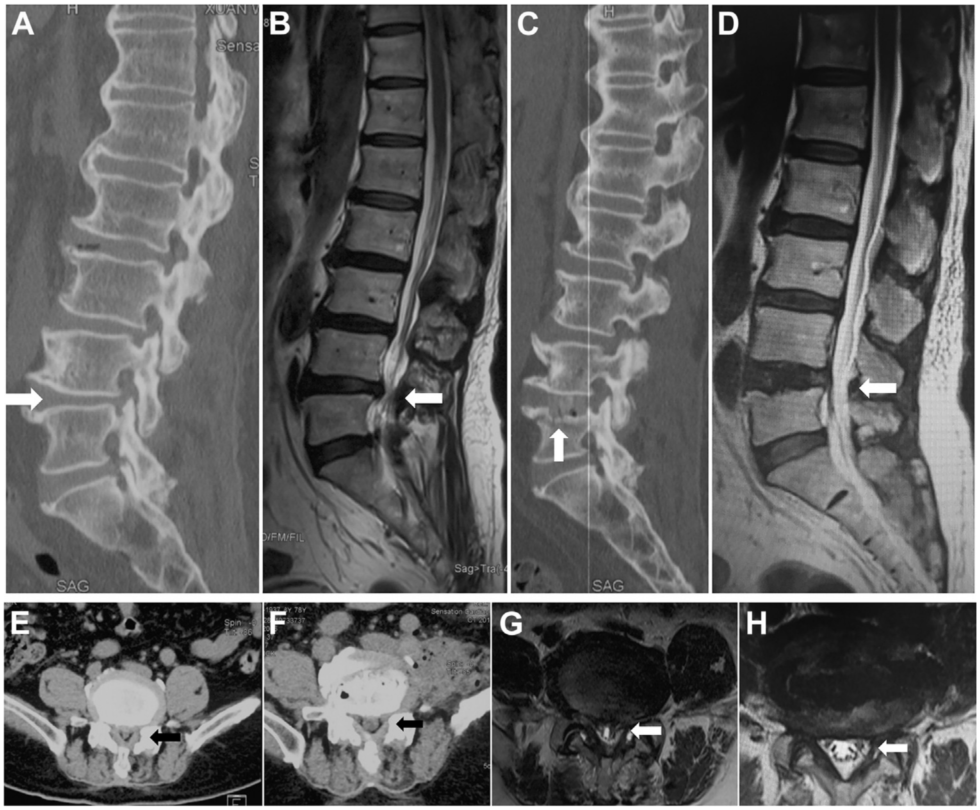

Figure 3. A case of higher cage insertion. A 78-year-old male suffered from low back pain and intermittent claudication, accompanied by pain and numbness of the dorsal part of bilateral feet. L4-5 stand-alone OLIF was performed. (**A**) Preoperative sagittal computed tomography (CT) showed narrowing of intervertebral space of L4-5 (*white arrow*). (**B**) Preoperative sagittal T2-weighted imaging (T2WI) magnetic resonance imaging (MRI) showed compressing of the dura sac and narrowing of the spinal canal of L4-5 (*white arrow*); (**C**) Postoperative sagittal CT showed the intervertebral space of L4-5 had been restored (*white arrow*). (**D**) Postoperative sagittal T2WI MRI showed indirect decompression spinal canal of L4-5 (*white arrow*). (**E**) Preoperative axial CT showed narrowing of spinal canal (*black arrow*). (**F**) Postoperative axial CT showed indirect decompression of the spinal canal (*black arrow*). (**G**) Preoperative axial T2WI MRI showed narrowing of spinal canal (*white arrow*). (**H**) Postoperative axial T2WI showed indirect decompression of the spinal canal (*white arrow*).

a significant increase in postoperative DH in patients compared with preoperative DH ($P = 0.00$), a significant improvement in postoperative CSA compared with the preoperative values, and good decompression effects in the central canal ($P = 0.00$), which are consistent with results reported by Fujibayashi et al[15] and Sato et al.[14], Fujibayashi et al[15] reported an increase of CSA from 0.996 $\pm$ 0.465 cm^2 before surgery to 1.343 $\pm$ 0.468 cm^2, while the preoperative CSA of the present study was 0.79 + 0.32 cm^2, which indicates the presence of more severe central stenosis compared with the aforementioned study. The postoperative CSA measured in the present study was comparable with that reported in the literature.[15] Multiple linear regression analysis revealed a negative correlation between preoperative DH and CSA improvement (ΔCSA) and a positive correlation between CSH improvement (ΔCSH) and ΔCSA. In other words, better postoperative decompression effects in the central canal were achieved in narrower preoperative disk spaces. Aside from the restoration of disc space, which is the primary reason for central canal decompression, the resolution of degenerative posterior disk herniation and restoration of sagittal alignment in the spine also contributed to central canal decompression. Therefore there was no statistical relationship between ΔDH and ΔCSA. On the other hand, a positive correlation existed between ΔCSH and ΔCSA, indicating that a higher level of improvement in intervertebral foraminal height led to a higher level of improvement in imaging data of the central canal. Intraoperative fluoroscopic observations of changes in intervertebral foraminal height may possibly replace myelography and function as a noninvasive imaging indicator for the prediction of decompression effects in the central canal.

The postoperative CSAF in patients of the present study also significantly improved compared with preoperative measurements ($P = 0.00$), which indicates that the restoration of intervertebral height also resulted in nerve decompression in the intervertebral

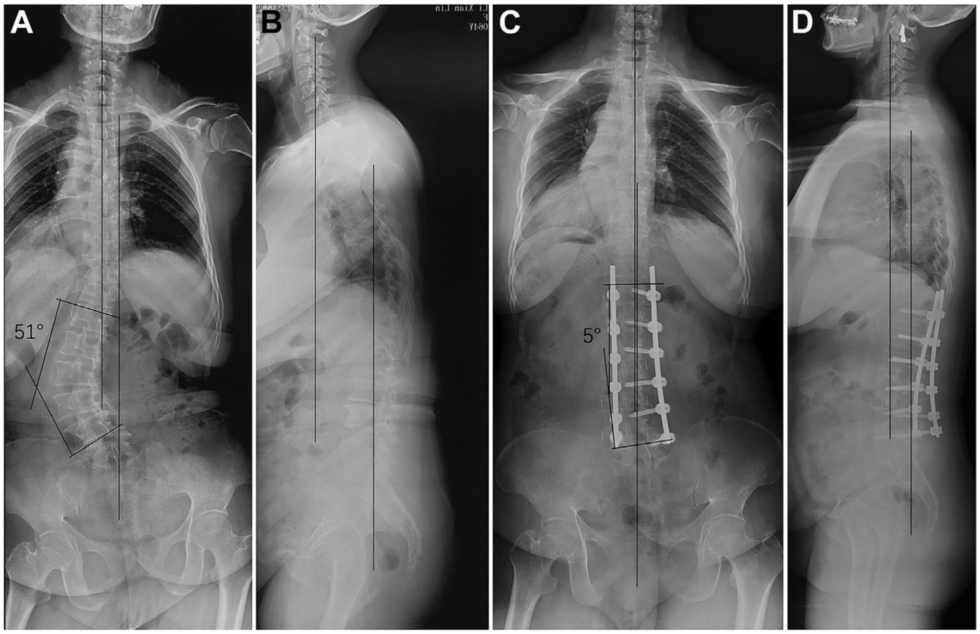

Figure 4. A case of spinal alignment restoration. A 64-year-old female suffered from low back pain and intermittent claudication for 14 years, which was aggravated by numbness of the lateral calf and dorsal left foot. L2-5 oblique lumbar interbody fusion with posterior percutaneous pedicle screw fixation. (**A**) Anteroposterior (AP) view of preoperative standing full-length spinal radiograph showed scoliosis. The Cobb angle was 51 degrees, with trunk shift and rotation of apical vertebrate. (**B**) Lateral view of preoperative standing full-length spinal radiograph showed sagittal malalignment of the patient. (**C**) AP view of postoperative standing full-length spinal radiograph showed correction of scoliosis. The Cobb angle was 5 degrees, with little trunk shift and derotation of apical vertebrate. (**D**) Lateral view of postoperative standing full-length spinal radiograph showed realignment of sagittal plane.

foramina. Multiple linear regression analysis demonstrated the existence of a negative correlation between CSAF and ΔCSAF. As such, a smaller preoperative CSAF resulted in a greater postoperative decompression in the intervertebral foramina. As OLIF merely achieved indirect decompression through expansion without resolving articular process hypertrophy and other factors that cause lateral stenosis, the degree of articular process hypertrophy varied among patients. ΔDH was not statistically correlated with ΔCSH or ΔCSAF.

Application of Stand-Alone Technique

The stand-alone technique refers to interbody fusion through the anterior approach without supplemental posterior internal fixation. It is applied in both XLIF and OLIF procedures and has achieved good results such as solid arthrodesis and improvements in pain and functional scores in patients.[11,19] Through the imaging evaluation of patients who underwent stand-alone XLIF and OLIF, it was observed that the spinal canal and intervertebral foramina of patients were expanded after surgery. This result indicated good surgical effects. Only a small minority of patients required subsequent posterior decompression and internal fixation.[14,20] Although OLIF provides good effects in the restoration of intervertebral height and sagittal alignment in the spine, cage subsidence occurred postoperatively in some patients. As a result, patients may experience limited relief or transient aggravation of clinical symptoms. Therefore some researchers have recommended single-stage posterior internal fixation in all patients undergoing the OLIF procedure.[11] For the patients who underwent stand-alone OLIF in the present study, imaging data collected during follow-up revealed cage subsidence in a total of 15 fused segments, with 2-level subsidence occurring in 5 of the segments. However, at the final follow-up, symptoms in all patients had been alleviated and improved pain and functional scores were achieved. Such results indicate that for patients who require 1- to 2-level interbody fusion and with imaging data excluding lumbar spondylolisthesis, spondylolysis, or degenerative scoliosis, the use of the stand-alone OLIF technique may be safe and effective. However, adequate communication with the patients must be carried out before surgery. Posterior decompression and internal fixation may be performed depending on the extent of decompression and symptomatic relief after surgery. Further studies are required to ascertain the indications for single-stage or multistage internal fixation and posterior decompression.

CONCLUSIONS

We evaluated OLIF with or without posterior fixation for patients with degenerative lumbar disease. The results proved that OLIF can improve intervertebral height, cross-sectional area of the central canal, and cross-sectional areas of the intervertebral foramina in imaging data, which are indicative of good nerve decompression effects based on imaging data. Significant improvements in postoperative pain and functional scores of patients, as well as a lower risk of complications involving vascular and nerve injury, were also achieved. Therefore based on our limited experience, OLIF is a safe and efficient technique in the treatment of lumbar degenerative disease.

REFERENCES

1. Silvestre C, Mac-Thiong JM, Hilmi R, Roussouly P. 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.
2. Gill K, Blumenthal SL. Posterior lumbar interbody fusion. A 2-year follow-up of 238 patients. *Acta Orthop Scand Suppl*. 1993;251:108-110.
3. Ishihara H, Osada R, Kanamori M, et al. Minimum 10-year follow-up study of anterior lumbar interbody fusion for isthmic spondylolisthesis. *J Spinal Disord*. 2001;14:91-99.
4. Chastain CA, Eck JC, Hodges SD, Humphreys SC, Levi P. Transforaminal lumbar interbody fusion: a retrospective study of long-term pain relief and fusion outcomes. *Orthopedics*. 2007;30:389-392.
5. Sasso RC, Best NM, Mummaneni PV, Reilly TM, Hussain SM. Analysis of operative complications in a series of 471 anterior lumbar interbody fusion procedures. *Spine (Phila Pa 1976)*. 2005;30:670-674.
6. Okuda S, Miyauchi A, Oda T, Haku T, Yamamoto T, Iwasaki M. Surgical complications of posterior lumbar interbody fusion with total facetectomy in 251 patients. *J Neurosurg Spine*. 2006;4:304-309.
7. Takahashi K, Kitahara H, Yamagata M, et al. Long-term results of anterior interbody fusion for treatment of degenerative spondylolisthesis. *Spine (Phila Pa 1976)*. 1990;15:1211-1215.
8. Ozgur BM, Aryan HE, Pimenta L, Taylor WR. Extreme lateral interbody fusion (XLIF): a novel surgical technique for anterior lumbar interbody fusion. *Spine J*. 2006;6:435-443.
9. Bergey DL, Villavicencio AT, Goldstein T, Regan JJ. Endoscopic lateral transpsoas approach to the lumbar spine. *Spine (Phila Pa 1976)*. 2004;29:1681-1688.
10. Cummock MD, Vanni S, Levi AD, Yu Y, Wang MY. An analysis of postoperative thigh symptoms after minimally invasive transpsoas lumbar interbody fusion. *J Neurosurg Spine*. 2011;15:11-18.
11. 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;56:1051-1059.
12. Mayer HM. A new microsurgical technique for minimally invasive anterior lumbar interbody fusion. *Spine (Phila Pa 1976)*. 1997;22:691-699.
13. 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;9:565-572.
14. 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;26:671-678.
15. Fujibayashi S, Hynes RA, Otsuki B, Kimura H, Takemoto M, Matsuda S. Effect of indirect neural decompression through oblique lateral interbody fusion for degenerative lumbar disease. *Spine (Phila Pa 1976)*. 2015;40:E175-E182.
16. Lee SH, Kim KT, Suk KS, Lee JH, Seo EM, Huh DS. Sagittal decompensation after corrective osteotomy for lumbar degenerative kyphosis: classification and risk factors. *Spine (Phila Pa 1976)*. 2011;36:E538-E544.
17. Acosta FL, Liu J, Slimack N, Moller D, Fessler R, Koski T. Changes in coronal and sagittal plane alignment following minimally invasive direct lateral interbody fusion for the treatment of degenerative lumbar disease in adults: a radiographic study. *J Neurosurg Spine*. 2011;15:92-96.
18. Manwaring JC, Bach K, Ahmadian AA, Deukmedjian AR, Smith DA, Uribe JS. Management of sagittal balance in adult spinal deformity with minimally invasive anterolateral lumbar interbody fusion: a preliminary radiographic study. *J Neurosurg Spine*. 2014;20:515-522.
19. Youssef JA, McAfee PC, Patty CA, et al. Minimally invasive surgery: lateral approach interbody fusion: results and review. *Spine (Phila Pa 1976)*. 2010;35(suppl 26):S302-S311.
20. Oliveira L, Marchi L, Coutinho E, Pimenta L. A radiographic assessment of the ability of the extreme lateral interbody fusion procedure to indirectly decompress the neural elements. *Spine (Phila Pa 1976)*. 2010;35(suppl 26):S331-S337.

Conflict of interest statement: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. The authors have declared that there is no conflict of interest.

Received 19 July 2018; accepted 16 November 2018

Citation: World Neurosurg. (2019) 124:e17-e24.
https://doi.org/10.1016/j.wneu.2018.11.139

Journal homepage: ***www.journals.elsevier.com/world-neurosurgery***

Available online: ***www.sciencedirect.com***