CLINICAL ARTICLE

Acceptable Fusion Rate of Single-Level OLIF Using Pure Allograft Combined with Posterior Instrumentation through the Wiltse Approach: A 2-Year Follow-Up Study

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Objective: Autogenic bone grafts have shown successful fusion rates in the treatment of degenerative lumbar disorders, but taking too many autogenic bones may result in donor site ischemia or infection. This study aimed to evaluate the outcomes of single-level oblique lumbar interbody fusion (OLIF) using pure allograft combined with posterior pedicle screw instrumentation through the Wiltse approach.

Methods: A retrospective case analysis was performed on a series of consecutive patients who received a single-level OLIF procedure combined with posterior pedicle screw instrumentation through the Wiltse approach between July 1, 2017, and December 31, 2019, in which pure allogenic bone graft was used and filled in the large window of the cage. The patients were followed up as scheduled at 1 day and 3, 6, 12, 24 months after operation. Clinical outcome was assessed by multiple questionnaires, including Oswestry disability index (ODI), Japanese Orthopaedic Association (JOA) score rating system, short form-36 health survey (SF-36), and visual analog scale (VAS) for low back pain. Radiographic outcome was evaluated by measuring the parameters such as disc height, lumbar lordosis, and segmental angle on the standard standing lateral radiographs, and the space angle of the fusion level on the dynamic views of the lateral radiographs. Subsidence of the cage and intervertebral fusion status were evaluated on both the radiographic and CT scan images.

Results: A total of 34 patients were finally included in this study. At 2-year follow-up, the VAS for low back pain, ODI, JOA, and SF-36 scores all had significant improvement ($p < 0.001$). Substantial increase of anterior and posterior disc heights was observed ($p < 0.001$). Both lumbar lordosis and segmental angle became larger ($p < 0.05$). No visible change of the space angle of the fusion level was found on the dynamic views. The 1-year fusion rate of 73.5% on CT scans proceeded to 82.4% at 2-year follow-up. The fusion rate was as high as 91.2% according to Bridwell interbody fusion grading system on radiographic images. The clinical outcomes in patients with incomplete fusion were just as good as those with complete fusion. The six patients with cage subsidence had higher ODI ($p < 0.001$) and lower JOA ($p < 0.001$) and SF-36 PCS ($p = 0.011$) scores than those without cage subsidence.

Conclusion: The use of pure allograft in single-level OLIF resulted in an acceptable fusion rate and satisfactory clinical effect at 2-year follow-up. Supplementation of posterior pedicle screw through the minimally invasive Wiltse approach ensured the favorable outcomes both clinically and radiographically.

Key words: Allograft; Fusion; OLIF; Pedicle Screw; Wiltse Approach

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Introduction

Due to the high rate of pseudarthrosis formation following posterolateral fusion, interbody fusion has become the standard method for obtaining a reliable fusion of the lumbar spine. Oblique lateral lumbar interbody fusion (OLIF) was first described by Michael Mayer in 1997.[1] By using the natural space between the abdominal large vessels and the psoas muscle, it accesses the disc space of the lumbar spine. Unlike the traditional posterior approaches, such as posterolateral lumbar interbody fusion (PLIF) and transforaminal lumbar interbody fusion (TLIF), OLIF does not require stripping of spinal or paraspinal musculature, laminectomy, or facetectomy.[2] Additionally, it may improve neurological symptoms by restoring the height of foraminal canals and intervertebral disc. In a study of Fujibayshi et al., 130.2% of the cross-sectional area of the median canal was expanded following OLIF, which contributed to significant neurological improvement.[3] Therefore, OLIF facilitates minimally invasive surgery with rapid postoperative mobilization.[4–6] Recent years have seen OLIF techniques becoming more popular among clinicians due to their advantages such as reducing surgical bleeding, reducing surgical trauma, and shortening hospital stays.[7–9]

With OLIF, a big cage with a large window offers a huge advantage in bone grafting, but there is also a requirement for the amount of bone. Autologous bone grafting has been the gold standard[10,11]; however, taking too many autogenic bones will definitely lead to donor site morbidity. BMP-based artificial bone grafts are not always feasible due to their high cost or availability. Thus, allografts are commonly used to fill in the big cage in our clinical practice of OLIF technique. Although allogenic bone grafting was reported to have a satisfactory bone union in many situations,[12–14] it has its unique problems such as disease transmission, histocompatibility, and longer time for bone growth. OLIF has been associated with a number of complications, which the incidence of transient perioperative complications reached 18%–48% and majority resolved spontaneously,[4,5,15] posterior pedicle screw augmentation is now usually advocated. Insertion of the pedicle screw through the Wiltse approach is in its nature a minimally invasive procedure with little disturbance to the posterior musculature and almost no bleeding.[16]

The purpose of this study is as follows: (i) to summarize the clinical and radiographic outcomes of OLIF; (ii) to investigate bone fusion of the pure allograft after operation; and (iii) to discuss the validity of supplementation of posterior pedicle screw through the Wiltse approach.

Methods

Inclusion and Exclusion Criteria

A retrospective investigation was performed in a series of consecutive patients from July 2017 to December 2019 in our spine center who received an OLIF procedure for the treatment of degenerative lumbar diseases. We set the inclusion criteria as following: (i) discogenic low back pain, lumbar instability, and type I/II lumbar spondylolisthesis or spondylolysis without or with mild spinal stenosis; (ii) one single-level of OLIF was performed; (iii) pure cadaveric allogenic bone graft was used and filled in the window of the large cage; (iv) posterior pedicle screw instrumentation was applied for the fusion level through the Wiltse approach. All patients had plain radiographic findings of single-level disc disease and had undergone magnetic resonance imaging (MRI) and computed tomography (CT).

Exclusion criteria were as follows: (i) the L5-S1 level was not included in this study because of the difference of anatomical features and surgical techniques; (ii) lumbar spondylolisthesis of degree III and above; (iii) severe lumbar spinal canal stenosis that required direct posterior decompression of the spinal canal; (iv) severe osteoporosis or other metabolic bone diseases; (v) pregnancy; (vi) or any condition that required medications that could interfere with fusion. Besides, patients were excluded with the diagnosis of fracture, infection, or neoplasm. In order to improve the homogeneity of the data, patients with OLIF procedure performed in two or more levels were also excluded. This study was approved by the Ethic Committee of our university hospital (Approval No. XHEC-D-2022-105).

Surgical Procedure

Patients with symptomatic chronic low back pain and identification of level-specific degenerative changes on radiographical imaging underwent OLIF by the same surgeon at our institution. The operation began with a skin incision about 3 cm in length, 8–10 cm anterior to the midline of the lumbar vertebrae with the patient in the right lateral decubitus position. Retroperitoneal finger separation was used to assess the interval between the abdominal large vessels and the psoas muscle, and the indicated level was determined by fluoroscopy. After discectomy and careful preparation of the intervertebral space, a polyetheretherketone (PEEK) cage filled with pure allogeneic bone graft (Beijing XKC Medi & Tech Develope Co., Ltd., Beijing, China) was inserted. The size of the cage was determined to maximize the recovery of the disc height, but not too big to damage the endplates of the superior or inferior vertebral bodies. After changing to the prone position, posterior pedicle screw instrumentation was performed through the Wiltse approach under intraoperative fluoroscopic guidance. All patients started ward ambulation 1 day after the procedure with lumbar brace support recommended for 3 months. The patients were followed up as scheduled, and clinical and radiographic data were collected and analyzed at regular follow-ups after operation.

Clinical Outcome Assessment

The patients' demographic data and other factors such as body mass index and bone mineral density (BMD, measured

by dual X-ray absorptionmetry) were collected preoperatively. Clinical outcomes were assessed using outcome measures of multiple questionnaires, including the Oswestry Disability Index (ODI, 0–100 points),[17] Japanese Orthopaedic Association Scores rating system (JOA score, 0–29 points),[18] short form-36 health survey (SF-36, 0–100 points for both physical and mental component summaries),[19] and visual analog scale (VAS, 0–10 points)[20] for back pain. Spinal stenosis was so mild that leg pain was neglected in all these patients. These clinical parameters were recorded preoperatively and 3, 6, 12 and 24 months postoperatively.

Radiological Assessment

Standing anteroposterior and lateral radiographs of the lumbar spine before operation, 1 day and 3, 6, 12, 24 months after operation were collected from each patient. Dynamic views of lateral radiograph and computed tomography (CT) scans before operation and 12 and 24 months after operation were also collected. Results were determined by a spine surgeon who was blinded to the patient information. Measurement of radiological parameters was blinded from the clinical results.

Disc Height

Anterior and posterior disc height were measured on the standing neutral lateral radiographs. Anterior disc height was defined as the distance between the anterior tips, and posterior disc height as the distance between the posterior tips of the adjacent endplates of the target intervertebral space.

Lumbar Lordosis Angle and Segmental Angle

Lumbar lordosis angle and segmental angle were measured on the standing neutral lateral radiographs. Lumbar lordosis was measured as the Cobb' s angle between the inferior endplate of T12 and superior endplate of S1. Segmental angle was defined as the Cobb' s angle between the superior endplate of the upper vertebral body and the inferior endplate of the lower vertebral body at the operated level.

Space Angle

The change of the space angle was evaluated on the dynamic views of the lateral radiographs, and this space angle was defined as the angle formed by the adjacent superior and inferior endplates of the operated level.

Intervertebral Fusion Status

The status of interbody fusion was mainly evaluated on computed tomography scan images 12 and 24 months postoperatively. Complete fusion was defined as the presence of continuous bridging trabecular bone connecting the adjacent vertebral bodies through or around the implants.[21] Incomplete fusion was defined as an absence of continuous bridging bone between the adjacent vertebral bodies. At the same time, the Bridwell interbody fusion grading system based on plain radiographs (grade I, fused with remodeling and trabeculae; grade II, not fully remodeled and incorporated, but no lucency present; grade III, definite lucency present at the top or bottom of the graft; grade IV, definitely not fused with resorption of bone graft with collapse) was also used for fusion grading.[22] Grades I and II were considered successful and Grade III and IV unsuccessful.

Cage Subsidence

Subsidence of the cage was recognized as any breach of endplates adjacent to an intervertebral device and loosening of the pedicle screws was assessed on CT scan.

Statistical Methods

Statistical significance of the observed changes in preoperative and postoperative clinical scores and radiological measurement were assessed using paired two-sided *t*-tests and clinical outcomes of the two groups were compared using the Student *t* test for normally distributed data and the Mann–Whitney U-test otherwise. The differences of the outcomes among the changes over time were identified *via* one-way repeated measures analysis of variance. Statistical analysis was performed using SPSS Statistics version 25.0 software (IBM Corp, Armonk, New York). $p < 0.05$ was considered to have significant difference.

Results

General Results

During the study period, OLIF procedure was performed in 96 patients with a total of 189 levels for the treatment of degenerative lumbar diseases in our clinic. Among them, 42 patients met the inclusion criteria in whom one single-level OLIF was done using pure allogenic bone grafting combined with posterior pedicle screw instrumentation through the Wiltse approach. Eight cases were further excluded due to the application of this combined procedure in the L5/S1 level, in the patients with pyogenic discitis or with a vertebral fracture, or just lost to follow-up. Thirty-four patients were finally accepted into our study.

Among the 34 patients, nine were males and 25 were females with an average age of 56.3 years old (range, 43–70). The L4-5 level was the most common site (20 of 34), followed by L3-4 (12 of 34) and L2-3 (two of 34). The BMI of the patients was 24.6 ± 2.6 kg/m^2. The T-score of the patients was -0.3 ± 1.5 and 5 patients had osteoporosis with a *T*-score ≤ -2.5, but none of them had severe osteoporosis with a *T*-score ≤ -4.0. Of all patients, four had diabetes, 11 had hypertension, and three had history of tobacco use. All patients in the study were followed up as scheduled, and each patient had a minimum follow-up of 2 years.

Radiographic Outcomes

Radiographic measurements were shown in Table 1. Anterior and posterior disc height significantly increased from 11.8 ± 2.9 mm and 6.9 ± 1.6 mm preoperatively to 16.4 ± 2.1 mm ($p < 0.001$) and 10.7 ± 1.4 mm ($p < 0.001$) at 1 day following the OLIF procedure. Loss of both the

Table 1 Radiographic outcome of the patients

Time	ADH (mm)	PDH (mm)	LL (°)	SA (°)
Pre operation	11.8 ± 2.9	6.9 ± 1.6	40.8 ± 13.6	5.1 ± 2.3
PO 1 day	16.4 ± 2.1*	10.7 ± 1.4*	44.2 ± 11.6*	8.6 ± 2.0*
PO 3 months	16.0 ± 1.9*	10.4 ± 1.4*	44.0 ± 11.1*	8.5 ± 2.0*
PO 6 months	15.7 ± 2.0*	10.1 ± 1.4*	44.5 ± 11.0*	8.6 ± 1.9*
PO 12 months	15.0 ± 2.0*	9.5 ± 1.4*	44.3 ± 11.7*	8.2 ± 2.1*
PO 24 months	14.8 ± 2.0*	9.2 ± 1.3*	43.9 ± 11.4*	7.8 ± 2.0*
F value	20.048	30.428	7.497	14.888
p value	<0.001	<0.001	0.002	<0.001

Abbreviations: ADH, anterior disc height; LL, lumbar lordosis; PDH, posterior disc height; PO, postoperative; SA, segmental angle.; * $p < 0.05$ compared with preoperative value.

anterior and posterior heights happened during the follow-up period, but they (14.8 ± 2.0 mm and 9.2 ± 1.3 mm) were still significantly bigger at 2 years after operation than their preoperative values ($p < 0.001$) and less than the 1-day postoperative values ($p = 0.010$ and $p < 0.001$) (Fig. 1A).

Lumbar lordosis increased from 40.8° ± 13.6° to 44.2° ± 11.6° ($p = 0.001$), segmental angle increased from 5.1° ± 2.3° to 8.6° ± 2.0° ($p < 0.001$) at 1 day after operation, and there remained no significant change in the following 2-year period (Fig. 1B).

The fusion rate was 14.7% (5 of 34) and 44.1% (15 of 34) at 3- and 6-month follow-ups according to Bridwell interbody fusion grading system based on plain radiographs. It was 91.2% (31 of 34) at both 12- and 24-month follow-ups (Fig. 2). However, based on the CT scan at 1 year after operation, as many as nine patients (26.5%) had incomplete interbody fusion (Fig. 3A), whereas the other 25 patients (73.5%) had complete fusion (Fig. 3B). It's worth noting that three patients with incomplete fusion at 1-year follow-up (Fig. 3C) proceeded to complete fusion at 2-year follow-up (Fig. 3D), and the bone fusion rate on CT scan increased to 82.4% at 2 years after operation.

On the dynamic views of the lumbar spine at 2-year follow-up, the space angle in all the 34 patients was 7.4° ± 1.3° in flexion position and 8.0° ± 1.3° in extension position ($p = 0.060$). In the six patients with incomplete fusion on CT scan, this angle was 7.6° ± 1.3° in flexion position and 8.1° ± 1.4° in extension position ($p = 0.412$). No visible change of the space angle was observed during movement of the lumbar spine, not even in any of the patients with incomplete fusion (Fig. 4).

None of the patients had screw loosening on CT scan. Cage subsidence was found in six patients (17.6%) at 2 years after operation.

Clinical Outcomes

Clinical outcome evaluations were shown in Table 2. All of the patients were satisfied with the result of the operation and would be willing to do the operation again if they were asked. At 1-year and 2-year follow-ups, the clinical outcomes in the patients with complete fusion and in the patients with incomplete fusion on CT scans were shown in Table 3. The outcomes as evaluated by ODI, JOA score, VAS for back pain, SF-36 PCS, and SF-36 MCS in the patients with

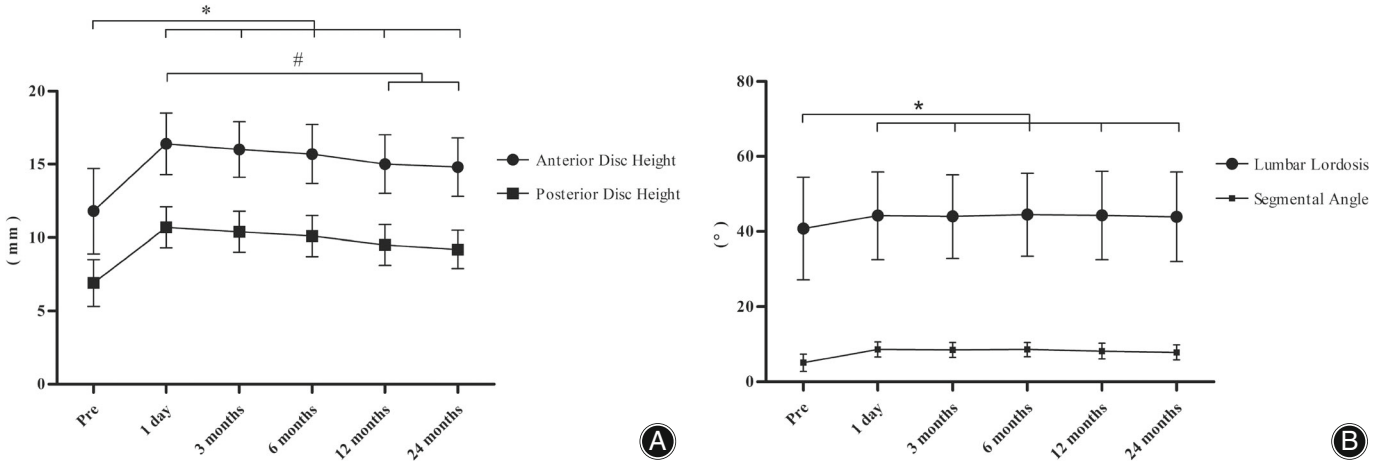

Fig. 1 Radiographic outcome of the patients. (A) anterior and posterior disc height. (B) lumbar lordosis and segmental angle. *, postoperative value compared with preoperative value, $p < 0.05$; #, postoperative value compared with 1-day value, $p < 0.05$

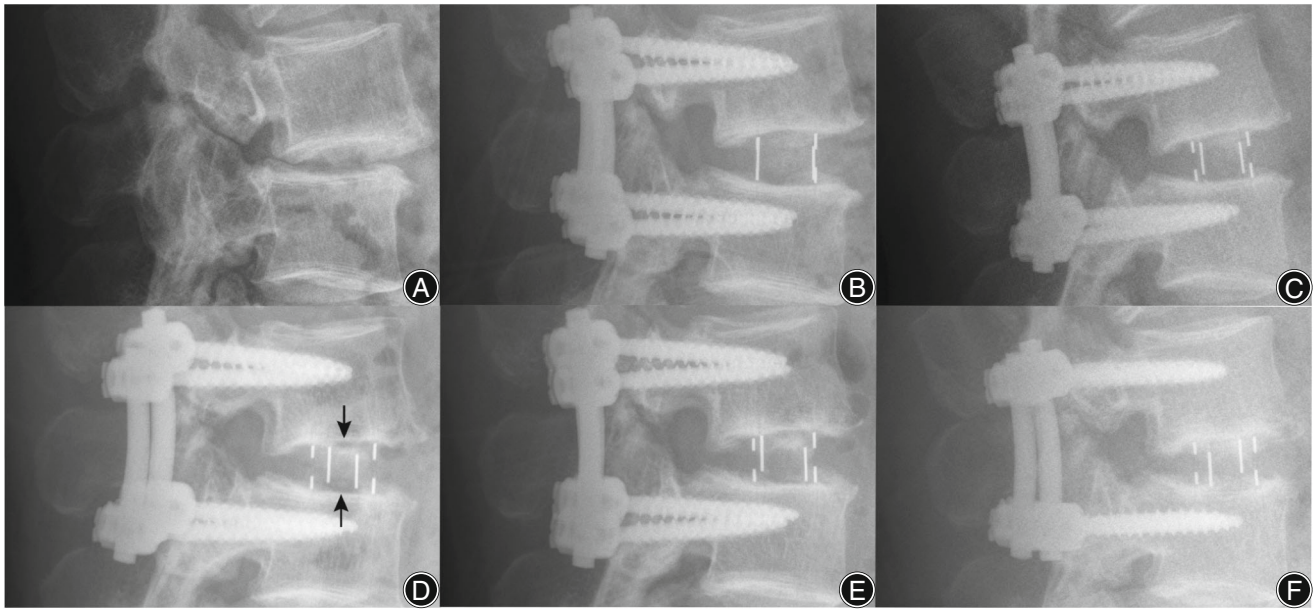

Fig. 2 Lateral radiographic images of a 50-year-old male who had the operation at L3-4 level. (A) preoperative. (B) 1-day postoperative. (C) 3-month postoperative. (D) 6-month postoperative, Bridwell grade III fusion: non-continuous bony incorporation within the cage and definite lucency present at the top or bottom of the graft (arrows). (E) 12-month postoperative, Bridwell grade II fusion: bone not fully remodeled and incorporated, but no lucency present. (F) 24-month postoperative, Bridwell grade I fusion: continuous bone fused with remodeling and trabeculae

incomplete fusion were just as good as those in the patients with complete fusion at regular follow-ups (Fig. 5A). However, the clinical outcomes in the patients with cage subsidence were not as good as those in the patients without cage subsidence. At 2-year follow-up, higher ODI ($p < 0.001$) and lower JOA ($p < 0.001$) and SF-36 PCS ($p = 0.011$) scores were observed in the patients with cage subsidence (Fig. 5B).

Complications

Complications such as surgical site infection, neurovascular injury, transmission of infectious diseases and rejection reaction to the allograft did not happen in any of the cases. No revision surgery was performed for any of the patients within the study period.

Discussion

This study retrospectively evaluated the curative effects of single-level OLIF using pure allograft combined with posterior pedicle screw instrumentation through the Wiltse approach at a 2-year follow-up. Good clinical and radiographic outcomes with acceptable fusion rate were achieved in our patients. The use of pure allograft in one single-level

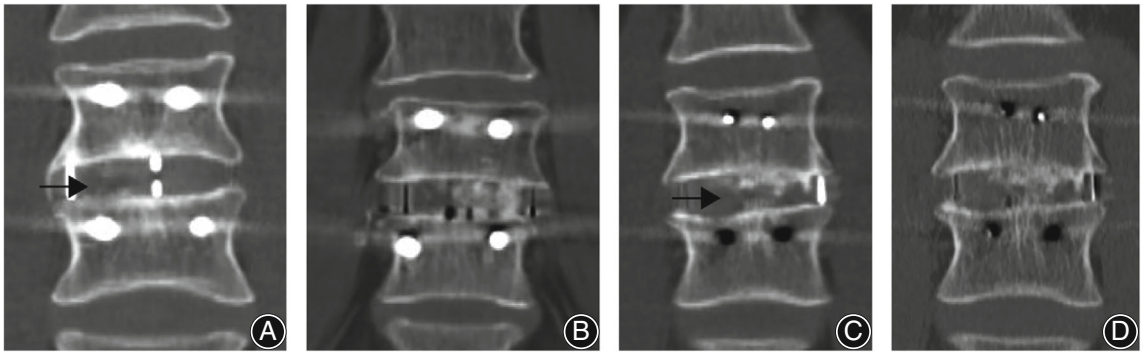

Fig. 3 CT evaluation for fusion. At 1-year follow-up, (A) incomplete fusion: absence of continuous bridging bone connecting the adjacent vertebral bodies (arrows). (B) complete fusion: continuous bridging trabecular bone connecting the adjacent vertebral bodies through or around the implants. (C) incomplete fusion at 1-year follow-up in a 59-year-old male who had the operation at L3-4 level proceeded to (D) complete fusion at 2-year follow-up

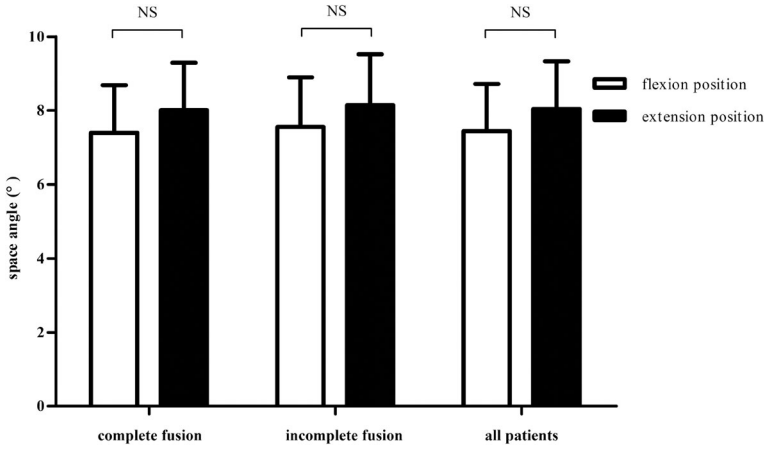

Fig. 4 The space angle measured on the dynamic views of the lumbar spine at 2-year follow-up. No visible change of the space angle was observed during movement of the lumbar spine, not even in any of the patients with incomplete fusion ($p > 0.05$). NS, not statistically significant

OLIF with degenerative disorders resulted in 73.5% fusion rate on CT scans at 1-year and 82.4% at 2-year follow-ups. Simultaneous supplementation of posterior pedicle screws through the minimally invasive Wiltse approach ensured the favorable outcomes both clinically and radiographically.

OLIF Has Good Clinical Efficacy

With the ability to restore disc height, to indirectly decompress the neural elements and to correct the sagittal and coronal deformities, minimally invasive OLIF is being used increasingly as an alternative to conventional posterior procedures in the treatment of degenerative lumbar diseases. The inclusion of only single-level OLIF cases contributed to case consistency and data homogeneity in our study. Actually, in the cases with two or more levels of OLIF, we usually mixed the allograft with autogenous bone graft in order to promote bone union and fusion rate. In these cases, direct decompression is frequently needed for more severe spinal stenosis or neurological symptoms, and posterior pedicle screw instrumentation was done after routine dissection of the musculature from the vertebral laminae. In our study, we restricted our patients to only one single-level OLIF with pure allogenic bone filled in the cage. In these patients, direct decompression was not necessary. The good clinical effects of OLIF, mainly manifested in VAS and ODI scores, have been demonstrated in other published articles.[5,9,12] We collected the data of the patients who received one single-level OLIF using pure allograft combined with posterior pedicle screw augmentation through the Wiltse approach in recent years in our spine center. As we wished, significant improvement in clinical and functional outcomes evaluated by VAS, ODI, JOA, and SF-36 health survey scores and high patient satisfaction with the surgery were achieved in our patients at regular follow-ups.

The Fusion Rate Increased at 2-Year Follow-Up

OLIF is assumed to have high fusion rate due to the use of a big cage with a large window for bone grafting.[23] For most types of bone graft procedures, autologous bone from the iliac crest has been considered the gold standard because of high bioactivity and lack of immunity reaction. It is reported that successful and rapid lumbar fusion rates with the autogenous iliac crest bone grafts have been reported higher than 90%.[24,25] However, taking too many autogenic bones will definitely lead to donor site morbidity and insufficiency of local bone will lead to poor rate of bone union.[24] Thus, allografts are commonly used to fill in the big cage in our clinical practice of OLIF technique. In this study, the complete

Table 2 Clinical outcome of the patients

Time	VAS	ODI	JOA	SF-36 PCS	SF-36 MCS
Pre operation	7.3 ± 1.1	54.6 ± 9.8	18.4 ± 3.5	13.1 ± 7.1	26.4 ± 7.0
PO 3 months	2.1 ± 0.8*	20.2 ± 7.7*	23.5 ± 1.9*	42.5 ± 6.7*	43.9 ± 6.7*
PO 6 months	1.5 ± 0.8*	14.1 ± 6.0*	25.1 ± 1.7*	55.7 ± 5.9*	65.7 ± 5.8*
PO 12 months	1.2 ± 0.7*	10.1 ± 4.0*	26.0 ± 1.4*	70.7 ± 8.1*	80.3 ± 6.7*
PO 24 months	1.3 ± 0.7*	9.2 ± 3.3*	26.2 ± 1.3*	73.6 ± 8.5*	82.8 ± 6.0*
F value	323.326	271.372	76.341	374.261	446.029
p value	<0.001	<0.001	<0.001	<0.001	<0.001

Abbreviations: JOA, Japanese Orthopaedic Association scores rating system; MCS, mental component summary; ODI, Oswestry disability index; PCS, physical component summary; PO, postoperative; SF-36, 36-item short form survey; VAS, visual analog scale.; * $p < 0.001$ compared with preoperative value.

Table 3 Clinical outcomes in patients with complete fusion and incomplete fusion at 1-year and 2-year follow-ups

	1-year follow-up			2-year follow-up		
Variable	Complete fusion ($n = 25$)	Incomplete fusion ($n = 9$)	p value	Complete fusion ($n = 28$)	Incomplete fusion ($n = 6$)	p value
VAS	1.2 ± 0.7	1.4 ± 0.5	0.435	1.2 ± 0.7	1.6 ± 0.7	0.293
ODI	9.1 ± 3.0	12.2 ± 5.3	0.109	8.6 ± 2.9	11.0 ± 4.0	0.099
JOA	26.0 ± 1.4	26.1 ± 1.5	0.686	26.4 ± 1.2	25.6 ± 1.7	0.132
SF-36 PCS	71.9 ± 8.1	68.1 ± 7.8	0.417	75.2 ± 8.3	68.3 ± 7.4	0.087
SF-36 MCS	80.5 ± 5.7	79.9 ± 8.9	0.829	83.6 ± 5.7	80.6 ± 6.6	0.165

Abbreviations: JOA, Japanese Orthopaedic Association scores rating system; MCS, mental component summary; ODI, Oswestry disability index; PCS, physical component summary; SF-36, 36-item short form survey; VAS, visual analog scale.

fusion rate based on CT scan in our study was 73.5% at 1-year follow-up. It is much lower than the 90%–98% bone fusion rate reported in many other studies with OLIF procedure.[2,26,27] This could be the result of the large amount of pure allogenic bone graft we used. The status of lumbar interbody fusion is usually evaluated at 6 to 12 months after surgery in most published literature; however, pure allogenic bone graft may require more time for bone ingrowth and integration. Thus, we followed up our patients for a longer time and found that the bone fusion rate increased to 82.4% at 24 months after operation. Meanwhile, complete fusion was defined on CT scan in our study as the presence of continuous bridging trabecular bone connecting the adjacent vertebral bodies through or around the implants. The evidence of this CT-based evaluation of fusion is stronger than the judging criteria of fusion based on plain radiographic films.[28] As a matter of fact, our patients had a fusion rate of 91.2% according to Bridwell interbody fusion grading system based on plain radiographs images. This reflects the high sensitivity of CT in detecting bone fusion. Therefore, for pure allogenic bone graft, 1-year follow-up on CT is insufficient to evaluate the rate of bone fusion, which may lead to low bone fusion rate.

The result of complete fusion rate based on CT was not so idealized, but in terms of clinical outcomes, all of the patients were satisfied with the result of the operation. It's worth noting in our study that the clinical outcomes of the patients with incomplete fusion on CT scans were not different from those with complete fusion, which were the same at 1-year and 2-year follow-ups. It showed that the patient's treatment effect was acceptable and helpful for the improvement of symptoms and quality of life of patients.

Cage Subsidence Led to Poorer Clinical Results

The cage in the OLIF procedure rests on the outer rings of lower and upper endplates of the adjacent vertebral bodies with relative strong cortical bone support. Theoretically, the cage should have a lower rate of subsidence. However, cage subsidence was one of the most common complications with an incidence of about 5%–30% of OLIF procedure in literature.[26,29,30] The rate of cage subsidence in our patients was also as high as 17.6%. It's worth noting that in our study the clinical outcomes of the patients with cage subsidence were not as good as the patients without cage subsidence. Inability to fully recover the disc height in these patients should be the most probable culprit of the unsatisfactory clinical results. In general, the high incidence was caused by too large cages and damage to the endplates of the outer cortical rings during vertebral space preparation and cage insertion during OLIF procedure.[15,30] Osteoporosis is also a risk factor

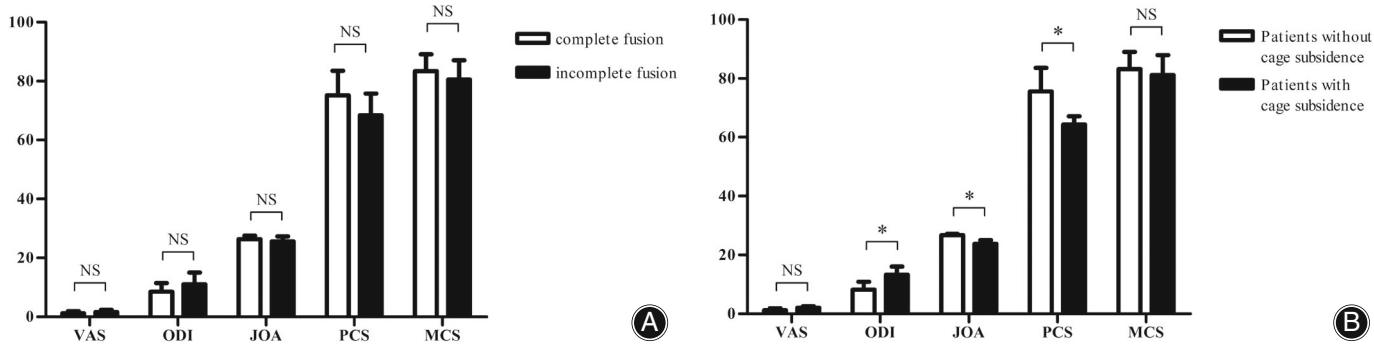

Fig. 5 Clinical outcomes of the patients at 2-year follow-up. (A) comparison between the patients with complete and incomplete fusion. (B) comparison between the patients with and without cage subsidence. NS, not statistically significant. * $p < 0.05$

for cage subsidence,[31,32] which may have contributed to the occurrence of high sedimentation rates in the study. Insertion of a cage with appropriate size and careful excision of the disc and preparation of the disc space are highly recommended in the OLIF procedure. Bone mineral density measurement is also recognized as routinely performed preoperatively to exclude severe osteoporosis in the patients and predict cage subsidence after operation.

Supplementation of Posterior Pedicle Screw through the Wiltse Approach Ensured the Favorable Outcomes

Afraid of the initial stability of the stand-alone cage and non-fusion of the allograft, we augmented the cage with posterior pedicle screw instrumentation simultaneously. These screws could be inserted with percutaneous method, but we chose the posterior Wiltse approach because of its minimally invasive nature. On the other hand, the Wiltse approach did not require frequent fluoroscopic guidance for pedicle screws insertion, so excessive radiation exposure was avoided. OLIF procedure is characterized by its capability to restore the height of the disc space. In all our patients, substantial increase of both the anterior and posterior disc heights was observed right after the operation, and the disc heights remained significantly increased at 2-year follow-up although they were lost a little bit probably because of osteoporosis or endplate damage. By increasing disc height, the lateral recess, intervertebral foramen, and spinal canal were indirectly decompressed. The unchanged space angles during flexion and extension in the dynamic views of the lumbar spine at 2-year follow-up reflected that the operated segments of the lumbar spine in these patients were stable. The good clinical outcomes in the patients with incomplete fusion on CT scans should be attributed to the initial and final stability provided by the one-stage posterior augmentation of the pedicle screws, which indicated that clinical results of OLIF are related to the effect of the stabilization.

Strengths and Limitations

This study evaluated the outcomes of single-level OLIF using pure allograft combined with posterior pedicle screw instrumentation through the Wiltse approach. Although using pure allogeneic bone cannot achieve satisfactory bone fusion effect in a short period of time, good clinical and radiographical outcomes were obtained in our patients at 2-year follow-up. This proved to be a procedure that reduced patient trauma and was worth generalizing. However, there are several limitations to this study. First, the patients were followed up for 24 months. Whether the good clinical outcomes are kept in these patients needs to be monitored in the future. Second, this was a retrospective study with a relatively small number of patients. Further studies especially prospective randomized controlled ones in multi-centers are necessary to validate our findings. Lastly, other methods in promoting the bone ingrowth and integration of the allograft in short time such as adding bone-morphogenetic proteins or platelet-rich plasma are worth considering.

Conclusion

The postoperative clinical and radiographic outcomes had satisfactory effect in our study. The use of pure allograft in single-level OLIF resulted in an acceptable fusion rate at 2-year follow-up. In comparison with the 1-year follow-up, there was an increase in bone union. Supplementation of posterior pedicle screw through the minimally invasive Wiltse approach ensured the favorable outcomes.

Author Contributions

Qingyin Xu and Zeyu Lu put forward the concept of the study and prepared the manuscript. Pengbo Chen and Bo Li contributed to the data acquisition. Xinfeng Zheng analyzed the data and interpretation. Shengdan Jiang and Leisheng Jiang checked all of the data used in the manuscript and reviewed the manuscript. All authors read and approved the final manuscript.

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Conflict of Interest

The authors declare no conflict of interest.

Ethics Statement

This study was conducted according to the Declaration of Helsinki and approved by the Shanghai Jiaotong University School of Medicine Xinhua Hospital Medical Science Research Ethics Committee (approval number: XHEC-D-2022-105).

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