ABSTRACT

Objective: This study aimed to compare the radiological and clinical outcomes of oblique lumbar interbody fusion (OLIF) and posterior lumbar interbody fusion (PLIF) surgeries and to confirm the effects of additional partial laminectomy on the surgical outcomes of OLIF.

Methods: This retrospective study included 130 patients who underwent OLIF or PLIF for single-level fusion. Among them, 42 patients underwent PLIF and open pedicle screw fixation and 88 underwent OLIF and percutaneous pedicle screw fixation. In the OLIF group, 42 patients received additional neural decompression through partial laminectomy and discectomy (direct OLIF), whereas the remaining 46 patients did not (indirect OLIF). To measure the neurological deficits, the clinical outcomes were evaluated using a visual analog scale for back and leg pain and the Oswestry Disability Index. Radiologic outcomes were evaluated based on the disc and foraminal heights as well as the segmental lordotic and lumbar lordotic angles.

Results: The improvement in the clinical outcomes did not differ significantly among the 3 groups. Radiologically, the 2 OLIF groups showed statistically significant improvements in the disc and foraminal heights when compared with the PLIF group. The PLIF group showed a significant decrease in the disc height and segmental lordotic angle when compared with the OLIF group in the postoperative 1-year period.

Conclusion: Both OLIF and PLIF showed similar clinical outcomes in the single-level lumbar fusion. However, OLIF grafts showed an advantage over PLIF with respect to the radiographic outcomes and complication rates. Additionally, partial laminectomy did not significantly affect the radiological results.

Keywords: Neurologic deficits; Lumbar vertebrae; Spinal fusion; Spinal diseases

INTRODUCTION

The degenerative lumbar disease is a common chronic spinal problem that increases with population aging. These diseases cause back and radicular pains, and neurogenic
Conflict of Interest
The authors have no financial conflicts of interest.

Claudication due to degenerative changes in the lumbar structures, such as the spinal canals and neural foramen. Surgical treatment was considered in patients with no improvement with conservative treatment. Lumbar interbody fusion has been used as a conventional surgical tool to maintain segmental lordosis and recover the intervertebral disc height (DH). Traditionally, the surgical treatment of lumbar interbody fusion includes anterior and posterior lumbar interbody fusion (PLIF). Although these methods have proven useful in several studies, problems such as root injury and paravertebral muscle stripping have been reported.

To avoid nerve root injury during cage insertion, the mini-open anterior retroperitoneal lumbar interbody fusion technique was introduced by Silvestre. Recently, oblique lumbar interbody fusion (OLIF) has gained wide usage for degenerative spinal diseases and has exhibited clear advantages over PLIF. Unlike PLIF, OLIF passes the psoas muscle through the left abdomen without damaging the paravertebral space and reaches the intervertebral disc. Therefore, it may have the advantage of decreased posterior damage and bleeding than that associated with PLIF. Indirect decompression through OLIF has many advantages, such as the absence of an epidural scar or postoperative epidural hematoma.

Research on cage subsidence in PLIF has been adequately conducted and studies on cage subsidence in OLIF are also currently underway. However, no study has directly compared OLIF and PLIF for DH changes. Moreover, no studies have assessed how additional partial laminectomy affects the DH in OLIF surgery. This study aimed to compare the radiological and clinical outcomes of OLIF and PLIF and to confirm the effects of additional partial laminectomy on surgical outcomes.

MATERIALS AND METHODS

Patient demographics
We retrospectively investigated the medical records of 130 patients who had undergone single-level OLIF or PLIF between January 2016 and December 2020. The inclusion criteria were: 1) neurologic deficits such as back pain and radiculopathy lasting for 3 months diagnosed with degenerative lumbar disease on preoperative magnetic resonance imaging; 2) at least a 1-year follow-up period with postoperative radiological examinations performed in outpatient clinics; and 3) no history of fusion, infectious disease, traumatic injury, neoplasm, or congenital spinal deformity. All patients were targeted at a single level of degenerative lumbar disease. Of the 130 patients, 42 underwent PLIF and open pedicle screw fixation and 88 underwent OLIF and percutaneous pedicle screw fixation. Of the 88 patients who underwent OLIF, 42 underwent additional neural decompression through partial laminectomy and discectomy. We categorized the patients who underwent OLIF and partial laminectomy as the direct OLIF group and those who did not undergo additional laminectomy as the indirect group.

Operative technique
Two techniques were used in this study. For the OLIF procedure, the patient was placed in the right-lateral decubitus position. Under fluoroscopic control, anatomical surfaces such as the rib cage, iliac crest, and target disc were marked on the skin. A 3–4-cm oblique skin incision was made in the left abdomen parallel to the external oblique muscle fibers. After dissecting the abdominal muscles using a blunt muscle-splitting technique, the peritoneal fat layer was...
confirmed. The peritoneal sac was anteriorly mobilized and the psoas muscle was retracted posteriorly. After touching the target disc, its level was confirmed using a fluoroscope. Subsequently, a tubular retractor was docked, and a self-tapping guide pin was inserted into the upper vertebral body to maintain the operative corridors to minimize potential segmental artery damage. We performed discectomy and removal of the adjacent cartilaginous endplate to avoid damaging the bony endplate. In all OLIF cases, the cage lordotic angle was 6°, and cage heights were appropriately determined using trials from 10 to 16 mm. We inserted a trapezoid-shaped cage (Clydesdale; Medtronic Inc., Minneapolis, MN, USA) packed with a demineralized bone matrix under fluoroscopy guidance. The dissected abdominal wall was sutured layer-by-layer. After cage placement, the patients were changed to the prone position. Posterior lumbar stabilization was performed after the anterolateral procedure with percutaneous pedicle screw fixation. In some cases, indirect decompression was performed, and additional surgical decompression with partial laminectomy was performed as follows: 1) prominent disc protrusion or sequestration with obvious segmental instability, 2) severe spinal stenosis (grade IV), 3) synovial cyst, and 4) severe facet degeneration.

The PLIF procedure was performed in accordance with previous studies. Interbody arthrodesis was performed by locating the bilateral cages, which were packed with demineralized bone matrix and autogenous bone blocks that had been trimmed from the excised spinous process, laminae, inferior facet, and superior facet. Posterior lumbar stabilization was achieved via open pedicle screw fixation.

Assessment of radiologic and clinical outcomes
All radiological assessments were performed by 2 independent neurological patients who were not involved in the study and were blinded to all clinical information. We analyzed radiologic changes for L3–4 or L4–5 single-level fusions. DH, foraminal height (FH), segmental lordotic angle (SLA), and lumbar lordotic angle (LLA) were measured preoperatively, postoperatively, and at the 12-month follow-up (postoperative day [POD] 1 year) on lateral radiographs. The DH was calculated as the distance between the midportion of the endplate at each disc space. The FH was measured as the distance between the inferior pedicle wall above the index disc space and the superior pedicle wall below. The SLA was measured from the inferior endplate of the superior vertebral body to that of the inferior vertebral body. The LLA was defined as the sagittal Cobb angle from the superior endplate of L1 to the inferior endplate of L5. We determined the extent to which the increased DH was preserved after surgery using the following formula: DH Reduction Ratio=ΔDH (Postoperative−POD 1 Year)/ΔDH (Postoperative−Preoperative)×100. These measurements are presented in FIGURES 1 & 2.

To measure neurological deficits, we evaluated the degree of pain in the lower back and leg according to the visual analog scale (VAS) and assessed functional disability due to lower back pain using the Oswestry Disability Index (ODI). Additionally, medical information was collected on the operation time, estimated blood loss (EBL), length of hospital stay, and perioperative complications (intraoperative, postoperative, and surgically unrelated).

Statistical analysis
Statistical analyses were performed using the SPSS version 18.0 (SPSS, Chicago, IL, USA). Statistical significance was set at p-values <0.05. Normally distributed data were compared using an unpaired t-test. Categorical data were analyzed using the Fisher’s exact test and the χ² test.
RESULTS

Clinical variable
A total of 130 patients (51 men, 79 women) were retrospectively analyzed. The mean patient age was 66 years. Our study comprised 42 patients in the PLIF group, 46 in the indirect OLIF group, and 42 in the direct OLIF group. According to the level of fusion operation, our cohort comprised 4 patients who were operated on at the L3/4 level and 126 at the L4/5 level. There was no significant difference in baseline patient characteristics between the 3 groups. The demographic characteristics of the 2 groups are shown in TABLE 1.

The preoperative VAS and ODI scores for all groups were similar. The postoperative VAS and ODI scores of the 3 groups were significantly improved compared to the preoperative values.

FIGURE 1. DH and FH on a radiograph. The DH was calculated as the distance between the mid-portion of the endplate at each disc space. The FH was measured as the distance between the inferior pedicle wall above the index disc space and the superior pedicle wall below. DH: disc height, FH: foraminal height.

FIGURE 2. SLA and LLA on a radiograph. The SLA was measured from the inferior endplate of the superior vertebral body to that of the inferior vertebral body. The LLA was defined as the sagittal Cobb angle from the superior endplate of L1 to the inferior endplate of L5. SLA: segmental lordotic angle, LLA: lumbar lordotic angle.
In addition, there was no significant difference in the postoperative VAS and ODI scores when comparing the 3 groups. These clinical improvements were maintained during the follow-up period.

There was no significant difference in the EBL between the PLIF and direct OLIF groups. However, the indirect OLIF group showed significantly lower intraoperative blood loss than the other groups did. However, a significant difference was found in the operative time. The direct OLIF group showed a relatively longer operation time than the other 2 groups. There was no significant difference in the length of hospital stay between the 3 groups. The results are summarized in TABLE 2.

### Radiological analysis

No significant difference was found in the preoperative radiologic parameters between the 3 groups (TABLE 3). TABLE 4 presents the radiological changes in the 3 groups. There were significant differences in the parameters related to intraoperative changes, such as ΔDH (Postoperative−Preoperative) and ΔFH (Postoperative−Preoperative). Both OLIF groups showed a statistically significant increases in ΔDH and ΔFH (Postoperative−Preoperative) compared to those in the PLIF group.

### Table 1. Demographics characteristics

| Parameter       | PLIF (n=42) | Indirect OLIF (n=46) | Direct OLIF (n=42) | p-value |
|-----------------|-------------|----------------------|--------------------|---------|
| Age             | 65.4±7.95   | 65.0±6.90            | 66.2±8.30          | 0.764   |
| Sex (M:F)       | 16:26       | 15:31                | 20:22              | 0.348   |
| HT              | 27          | 19                   | 22                 | 0.098   |
| DM              | 12          | 9                    | 12                 | 0.592   |
| CKD             | 1           | 1                    | 0                  | 0.614   |
| RA              | 0           | 1                    | 0                  | 0.398   |
| Smoking         | 5           | 6                    | 2                  | 0.417   |
| BMI             | 25.0±3.37   | 25.5±3.08            | 26.4±3.28          | 0.142   |
| BMD             | 0.02±3.47   | −0.97±1.24           | −0.07±1.57         | 0.086   |
| Past operation hx | 4         | 3                    | 7                  | 0.338   |
| Fusion level    |             |                      |                    | 0.632   |
| L3–4            | 3           | 2                    | 4                  |         |
| L4–5            | 39          | 44                   | 38                 |         |

PLIF: posterior lumbar interbody fusion, OLIF: oblique lumbar interbody fusion, HT: hypertension, DM: diabetes mellitus, CKD: chronic kidney disease, RA: rheumatoid arthritis, BMI: body mass index, BMD: bone mineral density, hx: history.

### Table 2. Clinical data

| Parameter       | PLIF (n=42) | Indirect OLIF (n=46) | Direct OLIF (n=42) | p-value |
|-----------------|-------------|----------------------|--------------------|---------|
| VAS back score  |             |                      |                    |         |
| Preoperative    | 5.79±1.13   | 5.72±1.39            | 6.02±1.35          | 0.519   |
| Postoperative   | 2.64±0.98   | 3.09±1.09            | 3.19±1.22          | 0.056   |
| POD 1 year      | 2.52±1.27   | 3.00±1.32            | 3.14±1.51          | 0.097   |
| VAS leg score   |             |                      |                    |         |
| Preoperative    | 4.26±1.01   | 4.15±1.07            | 4.26±1.06          | 0.851   |
| Postoperative   | 2.12±0.92   | 2.02±1.09            | 2.33±0.98          | 0.334   |
| POD 1 year      | 2.00±1.01   | 1.96±1.07            | 2.10±1.36          | 0.849   |
| ODI score       |             |                      |                    |         |
| Preoperative    | 30.6±5.43   | 29.59±5.95           | 31.36±5.59         | 0.482   |
| Postoperative   | 17.86±4.29  | 17.70±4.42           | 19.26±4.92         | 0.219   |
| POD 1 year      | 15.33±5.00  | 14.87±3.95           | 15.98±5.16         | 0.546   |
| EBL             | 329.52±202.54 | 185.76±115.55         | 323.33±173.45      | <0.001 |
| Operative time  | 279.93±47.81 | 285.76±60.02          | 387.98±68.59       | <0.001 |
| Hospital day    | 18.69±7.43  | 16.04±5.39           | 17.21±7.32         | 0.187   |

PLIF: posterior lumbar interbody fusion, OLIF: oblique lumbar interbody fusion, VAS: visual analog scale, ODI: Oswestry Disability Index, EBL: estimated blood loss, POD: postoperative day.
When comparing radiographic changes 1 year after surgery, there was no significant difference between the 3 groups in ΔFH (Postoperative−POD 1 year) (p=0.147). However, the PLIF group showed a significant decrease in DH and SLA compared to both OLIF groups in the POD 1 year period.

Comparing the difference between the POD 1 year follow-up and preoperative radiologic parameters, the indirect OLIF and direct OLIF groups showed significant improvement compared to the PLIF group in all parameters except LLA. Unlike other parameters, there was no statistically significant difference in the LLA between the 3 groups at any time point.

Using these radiologic parameters, we evaluated the DH reduction ratio to confirm whether increased DH was maintained during the follow-up period (TABLE 4). The increased DH was significantly preserved in the indirect and direct OLIF groups than in the PLIF group (p<0.001).

**Complications**

The types and degrees of the complications are presented in **TABLE 5**. Minor complications did not alter the patient’s recovery or prolong the hospital stay. Major complications require prolonged hospitalization or revision. We found 4 major complications in the PLIF group. Two cases of dural tears, 1 case of cage migration, and one case of deep wound infection were confirmed. Among them, 2 cases of dural tears were resolved intraoperatively. However, patients with cage migration and deep wound infection require revision surgery. In the OLIF group, no major complications required extended hospital stay or reoperation. Minor
Complications were confirmed in 4, 5, and 4 cases in the PLIF, indirect OLIF, and direct OLIF groups, respectively. Transient psoas paresis was the most common minor complication in both OLIF groups, whereas urinary tract infection was the most common in the PLIF group.

**DISCUSSION**

With recent advances in surgical techniques and instrumentation, minimally invasive surgeries are being developed for spinal disorders. Minimally invasive lateral lumbar fusion is gaining increasing preference as an alternative to conventional posterior procedure. Among them, OLIF is an attractive method for spinal fusion and has various characteristic advantages. First, it permits intervertebral distraction using large-sized lordotic cages, so indirect decompression can be expected. Clinical improvement with indirect decompression has been proven in many studies. This result is similar to that of comparative studies using other surgical methods. Takaoka et al. conducted a comparative study between transforaminal lumbar interbody fusion and indirect OLIF, showing no difference in clinical outcome. Wu et al. conducted a comparative study between PLIF and indirect OLIF and reported similar results. Herein, we conducted a comparative study on 3 groups by adding a direct OLIF group that underwent additional laminectomy in the posterior position; however, there was no difference in clinical improvements between the 3 groups.

Although indirect decompression has been proposed as an effective method, the patient selection remains controversial. Oliveira et al. insisted that central canal stenosis might be a contraindication for indirect decompression and Wang et al. concluded that bony lateral recess stenosis is a risk factor for indirect decompression. According to a recent systemic study, the effects of indirect decompression on severe central stenosis or lateral recess stenosis were poorly supported, and posterior direct decompression was recommended for these conditions. We determined the operative criteria for direct decompression based on previous studies and did not require additional revision surgery because of remnant radicular pain. With the addition of personal experience, we tended to gradually increase the proportion of patients who chose indirect decompression compared with the initial states when OLIF surgery was first attempted. For patients with ambiguous criteria boundaries, we carefully performed OLIF with indirect decompression, and obtained good results.

Our study confirmed that radiologic parameters such as DH, FH, and segmental lordosis in the OLIF group were improved and well-maintained compared to those in the PLIF group, and partial laminectomy did not significantly affect the radiological outcomes. These results are similar to those reported in previous studies. To determine the extent to which the increased DH was preserved after surgery, we introduced the DH reduction ratio. The underlying concept is that the ratio of DH increase by surgery and DH loss during the follow-up period

| Complication                  | PLIF (8 cases)                          | Indirect OLIF (5 cases) | Direct OLIF (5 cases) |
|-------------------------------|----------------------------------------|-------------------------|-----------------------|
| Major complication            | Deep wound infection (n=1)              | Cage migration (n=1)    | Dura tear (n=2)       |
| Minor complication            | Delirium (n=1)                         | Ileus (n=1)             | Ileus (n=1)           |
|                               | Insomnia (n=1)                         | Transient psoas paresis (n=3) |                           |
|                               | UTI (n=2)                              | Paravertebral hematoma (n=1) |                       |

PLIF: posterior lumbar interbody fusion, OLIF: oblique lumbar interbody fusion, UTI: urinary tract infection.
slightly differs from the cage subsidence. The concept of cage subsidence was concentrated on the graft penetrating the vertebral endplate, and it did not consider the improved DH through the operation. The OLIF group showed superior results in terms of parameters such as the degree of increase in DH and the degree of graft penetration, which led to a significant difference in the DH reduction ratio compared to the PLIF group. Restoration of the DH is associated with positive clinical outcomes\(^5\) and OLIF surgery has greater value and improved curative effects when applied to patients with localized conditions.

OLIF surgery has shown low surgical complications in several studies.\(^2,10,23\) These results originate from the benefits of minimally invasive surgery, such as less soft tissue disruption, decreased blood loss, and preservation of the posterior tension band. Similar results were obtained in this study. Unlike the PLIF group, major compliance did not occur in either OLIF group. Among the minor complications, transient psoas was the most common. Excessive retraction and inappropriate dissection of the psoas muscle led to transient psoas paresis. In a meta-analysis of OLIF-related complications, transient psoas paresis was the most common complication.\(^10\) A previous study reported that this complication is associated with the early stages of the learning curve.\(^12\) Although it has not been a clinical problem in all cases undergoing the OLIF procedure, informed consent is required before surgery.

Our study had some limitations. First, it was a small retrospective study conducted at a single institution, and the follow-up period was relatively short. Second, the choice of surgical method was based on the surgeon’s preference. This might have resulted in a selection bias. Third, retrospective risk factor analysis was not performed for numerous factors causing graft penetration. Fourth, we used different fusion materials for OLIF and PLIF. We can use DBM and autogenous bone as Fusion materials in PLIF; however, OLIF only has DBM. Nevertheless, the advantages of OLIF in terms of radiologic outcomes have been confirmed. Fifth, in our PLIF cases a relatively longer operation time and more complications than other studies. But our hospital is an academic training hospital, and many beginner operators are going through a learning curve. Therefore, the operation time may be longer than those reported in other hospitals, and the complication rate may be higher. Since OLIF was also performed under the same conditions, the comparison seems meaningful.

Our study was designed such that various variables were relatively uniformly controlled before surgery. Multicenter prospective studies with a long follow-up periods are required to confirm the efficacy of OLIF compared with that of PLIF.

CONCLUSION

Both OLIF and PLIF showed similar clinical outcomes in a single-level lumbar fusion. However, OLIF exhibited an advantage over PLIF in terms of radiographic outcomes and complication rates. Additional partial laminectomy did not significantly affect the radiological results.

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