Anterior lumbar compared to oblique lumbar interbody approaches for multilevel fusions to the sacrum in adults with spinal deformity and degeneration

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OBJECTIVE In adult spinal deformity and degenerative conditions of the spine, interbody fusion to the sacrum often is performed to enhance arthrodesis, induce lordosis, and alleviate stenosis. Anterior lumbar interbody fusion (ALIF) has traditionally been performed, but minimally invasive oblique lumbar interbody fusion (OLIF) may or may not cause less morbidity because less retraction of the abdominal viscera is required. The authors evaluated whether there was a difference between the results of ALIF and OLIF in multilevel anterior or lateral interbody fusion to the sacrum.

METHODS Patients from 2013 to 2018 who underwent multilevel ALIF or OLIF to the sacrum were retrospectively studied. Inclusion criteria were adult spinal deformity or degenerative pathology and multilevel ALIF or OLIF to the sacrum. Demographic, implant, perioperative, and radiographic variables were collected. Statistical calculations were performed for significant differences.

RESULTS Data from a total of 127 patients were analyzed (66 OLIF patients and 61 ALIF patients). The mean follow-up times were 27.21 (ALIF) and 24.11 (OLIF) months. The mean surgical time was 251.48 minutes for ALIF patients and 234.48 minutes for OLIF patients ($p = 0.154$). The mean hospital stay was 7.79 days for ALIF patients and 7.02 days for OLIF patients ($p = 0.159$). The mean time to being able to eat solid food was 4.03 days for ALIF patients and 1.30 days for OLIF patients ($p < 0.001$). After excluding patients who had undergone L5–S1 posterior column osteotomy, 54 ALIF patients and 41 OLIF patients were analyzed for L5–S1 radiographic changes. The mean cage height was 14.94 mm for ALIF patients and 13.56 mm for OLIF patients ($p = 0.001$), and the mean cage lordosis was 15.87° in the ALIF group and 16.81° in the OLIF group ($p = 0.278$). The mean increases in anterior disc height were 7.34 mm and 4.72 mm for the ALIF and OLIF groups, respectively ($p = 0.001$), and the mean increases in posterior disc height were 3.35 mm and 1.24 mm ($p < 0.001$), respectively. The mean change in L5–S1 lordosis was 4.33° for ALIF patients and 4.59° for OLIF patients ($p = 0.829$).

CONCLUSIONS Patients who underwent multilevel OLIF and ALIF to the sacrum had comparable operative times. OLIF was associated with a quicker ileus recovery and less blood loss. At L5–S1, ALIF allowed larger cages to be placed, resulting in a greater disc height change, but there was no significant difference in L5–S1 segmental lordosis.

<https://thejns.org/doi/abs/10.3171/2020.4.SPINE20198>

KEYWORDS oblique lumbar; anterior lumbar; interbody fusion; ALIF; CCI; Charlson Comorbidity Index; OLIF; prepoas; degenerative; deformity

IN long fusions to the sacrum for adult deformity or degenerative lumbar conditions, interbody fusion is often used to enhance arthrodesis, induce lordosis, and alleviate foraminal stenosis.¹ In the treatment of multilevel lumbar pathology, anterior lumbar interbody fusion (ALIF) has been shown to have advantages over trans-

foraminal lumbar interbody fusion (TLIF) with regard to improving lordosis and disc height.^{2–4} However, there can be significant approach-related morbidity caused by the manipulation of the great vessels and the abdominal viscera.^{5,6} Thus, minimally invasive surgical approaches to access the anterior lumbar spine have been developed—

ABBREVIATIONS ALIF = anterior lumbar interbody fusion; CCI = Charlson Comorbidity Index; LLIF = lateral lumbar interbody fusion; OLIF = oblique lumbar interbody fusion; PCO = posterior column osteotomy; TLIF = transforaminal lumbar interbody fusion.

SUBMITTED February 13, 2020. **ACCEPTED** April 9, 2020.

INCLUDE WHEN CITING Published online June 12, 2020; DOI: 10.3171/2020.4.SPINE20198.

most specifically, lateral lumbar interbody fusion (LLIF). Although LLIF is a good option to access lumbar pathology from L2 to L5, L5–S1 often is degenerated and needs to be included in the fusion construct. However, performing the LLIF from L2 to L5 and then performing an ALIF at L5–S1 requires repositioning the patient, reparation and draping of the patient, a separate skin incision, and mobilization of the abdominal viscera.^{7,8} Alternatively, an L5–S1 TLIF can be performed, but this may not be ideal if there is dorsal scar tissue, a clinical need for more lordosis than a TLIF can achieve, or pseudarthrosis requiring an anterior approach.

Oblique lumbar interbody fusion (OLIF), also known as an the antepsoas or prepsoas approach, is one type of LLIF, and the OLIF approach affords the ability to include the L5–S1 segment, unlike traditional LLIF, which historically has been limited to L5 or higher. However, adding an L5–S1 OLIF onto an L2–5 OLIF requires a separate skin incision, separate retractors, the assistance of a vascular surgeon, and different types of cages. One advantage of multilevel OLIF is that it does not require repositioning of the patient or reparation and re-draping.⁹ Although the L5–S1 OLIF can be done in the same position as an L2–5 OLIF, it is unclear if OLIF at L5–S1 is as good at restoring intervertebral disc height and lordosis as ALIF.^{10,11} It is also unclear if making two separate small incisions yields less morbidity than simply performing a multilevel ALIF through a single incision. Thus, in the current study, we compared multilevel ALIF and multilevel OLIF to the sacrum in patients with adult deformity and degenerative disease to evaluate perioperative and radiographic parameters.

Methods

We performed a retrospective review of patients undergoing multilevel ALIF and OLIF to the sacrum at the University of California, San Francisco, from 2013 to 2018 by 3 spine surgeons and 1 vascular surgeon. The study was approved by the institutional review board, and patient consent was not necessary for this retrospective research. The inclusion criteria included patients with adult degenerative scoliosis, degenerative lumbar conditions, age ≥ 18 years, a minimum 1-year follow-up, and multilevel lumbar interbody fusion (ALIF or OLIF), with all patients also undergoing L5–S1 ALIF or OLIF in the same surgical setting. Patients with tumors, infection, inadequate imaging, or trauma were excluded. Data collected were demographic variables, Charlson Comorbidity Index (CCI), operative time, blood loss, transfusion, time to solid food intake, length of hospital stay, and fusion rates. Operative times were calculated as skin-to-skin surgical times during the ALIF and OLIF portion, not the induction, patient positioning, or posterior surgery; blood loss and transfusions were analyzed in cases of anterior surgery only. Fusion rates were determined using either CT scans or radiographs, and arthrodesis was classified as fusion, no fusion, and indeterminate. Fusion rates were evaluated at each interbody graft level, and overall OLIF and ALIF fusion rates were compared. We also analyzed the radiographic changes at L5–S1 given the relative novelty

of the L5–S1 OLIF. Although patients with posterior column osteotomies (PCOs) at L5–S1 were included in the clinical analysis of approach-related morbidity, they were excluded from the radiographic analysis because of the osteotomy. Radiographic parameters such as L5–S1 disc height and segmental lordosis were measured on preoperative and immediate postoperative lateral radiographs. All measurements were performed by 2 attending spinal neurosurgeons and 1 orthopedic spine surgeon. Complications related to the anterior or oblique approach were collected. All patients were immediately placed on a clear liquid diet postoperatively, and once patients had a bowel movement, they were advanced to solid food. Ileus was defined as severe abdominal distension on clinical examination, dilated loops of bowel observed on upright abdominal radiographs, no flatus whatsoever, extreme abdominal discomfort precluding ambulation, and requirement of a hospitalist consultation confirming the diagnosis of ileus.

Categorical variables are presented as numbers, and continuous variables are presented as means with SDs. The Kolmogorov-Smirnov test was used to assess for normal distribution of the findings, and independent sample t-tests and chi-square tests were used to evaluate differences between ALIF and OLIF variables. Values of $p < 0.05$ were considered statistically significant, and all statistical analyses were performed using SPSS version 17.0.

Surgical Technique of Multilevel ALIF to the Sacrum

ALIFs were performed via anterior retroperitoneal approaches with a vascular surgeon. A lower paramedian incision was created and carried down to the anterior rectus sheath, which was incised longitudinally. The rectus muscle was mobilized laterally, the posterior rectus sheath incised, and the retroperitoneal space established. The peritoneum was then widely mobilized toward the patient's contralateral side. Dissection was carried up along the psoas muscle from the iliac artery up onto the aorta. Exposure of the L5–S1 interspace was done by working within the bifurcation of the great vessels. The middle sacral vessels were divided, the prevertebral space was established, and wide exposure of the L5–S1 disc was obtained. The recurrent iliolumbar vein was then divided to mobilize the iliac vein for the L4–5 disc space and higher. At this point, the spinal level was confirmed fluoroscopically, and ALIF was performed in the traditional manner^{12,13} (Figs. 1 and 2).

Surgical Technique of Multilevel OLIF to the Sacrum

The patient was placed into the right lateral decubitus position (OLIF can only be performed from the left side in order to avoid the vena cava). L2–5 OLIF was performed before or after the L5–S1 portion of the procedure, depending on the availability of the vascular surgeon. For L5–S1, the disc space was marked out using fluoroscopy, and a horizontal line relative to the L5–S1 disc space was drawn on the skin. The incision was drawn approximately 2 finger breadths anterior to the iliac crest (Fig. 3). After skin incision, the dissection was then carried through the external oblique, internal oblique, and transversus abdominis, which were all bluntly separated in the direction of their fibers. The preperitoneal space was established,

FIG. 1. Illustration comparing OLIF and ALIF at L2–5 (A) and at L5–S1 (B). Figure is available in color online only.

and using blunt dissection, the peritoneum was mobilized toward the patient's right. Dissection was then carried out between the right and left iliac veins, the middle sacral vessels were divided, the prevertebral space was established, and exposure of the L5–S1 disc was obtained. The procedure was performed with the use of C-arm fluoroscopy.

For the L2–5 portion, a percutaneous reference arc was placed into the left iliac crest through a separate stab incision. An intraoperative CT scan was obtained (O-arm, Medtronic), and StealthStation navigation (Medtronic) was registered with the acquired images. A skin incision was made in an oblique fashion approximately 5 cm anterior to the lumbar vertebrae. The dissection was carried down through the external oblique, internal oblique, and transversus abdominis until retroperitoneal fat was identified. The navigational probe was then docked at the appropriate disc space anterior to the psoas. Dilators were placed, and the minimally invasive surgical retractor was placed. The lateral interbody fusion was carried out in the standard manner, described elsewhere in detail^{11,14,15} (Figs. 1 and 4).

The decision as to whether multilevel ALIF or OLIF would be performed was based on patient anatomy. For instance, if the patient had a left-sided concave scoliosis that needed L2–3 addressed, then a multilevel OLIF was chosen because of the ability to correct the scoliosis and address L2–3. If, however, the patient had a low L4–5 below the iliac crest, or if the patient only needed L4–S1 fused, the patient may have instead undergone an ALIF.

Results

Clinical Variables

A total of 127 patients (51 males, 76 females) met the inclusion criteria, with 66 OLIF patients and 61 ALIF patients (Table 1). The range of follow-up was 12–60 months. With the Kolmogorov-Smirnov test, the data followed a normal distribution except for blood loss.

The mean age was 63.73 ± 10.80 years. There were no significant differences between OLIF and ALIF patient ages ($p = 0.142$) or sex ($p = 0.364$). The mean CCI score for ALIF was 2.64 ± 1.95 and that for OLIF was 2.58 ± 1.67

($p = 0.845$). The mean follow-up was 27.21 ± 6.77 months for ALIF and 24.11 ± 6.93 months for OLIF ($p = 0.112$). For staging, 7 patients underwent anterior stand-alone fusion only, 58 patients underwent anterior-posterior fusion in 1 day, and 62 patients underwent anterior and poste-

FIG. 2. Lateral and anterior-posterior radiographs showing the change in height and lordosis at L5–S1 before (A and C) and after (B and D) ALIF surgery.

FIG. 3. Images showing the incision planning and the cage position of the L4–S1 OLIF. **A:** Marking the angle of the L5–S1 disc on the skin. **B:** A line horizontal to the spine is subsequently drawn on the skin. **C and D:** A vertical incision is drawn 2 fingerbreadths anterior to the iliac crest. **E:** A skin incision is made in an oblique fashion approximately 5 cm anterior to the L4 and L5 lumbar vertebrae using navigation. **F:** The positional relationship between L4–5 and L5–S1 skin incisions. **G:** Intraoperative C-arm fluoroscopy demonstrating the cage positions. Figure is available in color online only.

rior fusion on 2 separate days. There were no significant differences between OLIF and ALIF patients ($p = 0.237$) in terms of staged versus same-day cases. However, the mean days between anterior and posterior surgeries were

4.22 ± 3.07 days for ALIF and 1.93 ± 1.66 days for OLIF ($p = 0.002$). Sixty-five patients had anterior fusion from L4 to S1 (34 ALIF, 31 OLIF), 35 patients had anterior fusion from L3 to S1 (23 ALIF, 12 OLIF), and 27 patients had L2–S1 anterior fusion (4 ALIF, 23 OLIF). The mean surgical times were 251.48 ± 67.04 minutes and 234.48 ± 66.51 minutes for ALIF and OLIF ($p = 0.154$), respectively. We used a nonparametric test to analyze blood loss, and the mean blood losses for ALIF and OLIF were 387.92 ± 310.40 ml and 90.91 ± 98.12 ml ($p < 0.001$), respectively. The average time to solid food intake was 4.03 ± 2.55 days for ALIF and 1.3 ± 1.64 days for OLIF ($p < 0.001$). The mean hospital stay was 7.79 ± 3.46 days for ALIF and 7.02 ± 2.65 days for OLIF ($p = 0.159$). The radiographic interbody fusion rate was 80.4% (123/153 levels) for ALIF and 76.3% (145/190 levels) for OLIF, without a significant difference ($p = 0.364$). Posterior arthrodesis was not analyzed. Complications are shown in Table 1, and diagnoses are shown in Supplemental Table 1.

FIG. 4. Lateral and anterior-posterior radiographs showing the change in height and lordosis at L5–S1 before (**A and C**) and after (**B and D**) L5–S1 OLIF.

Radiographic Analysis in Patients Without PCOs at L5–S1

As shown in Table 2, there were 7 ALIF and 25 OLIF patients who underwent L5–S1 PCOs, leaving 54 ALIF and 41 OLIF patients for radiographic analysis at L5–S1. In these 95 patients, the mean ALIF cage height was 14.94 ± 1.56 mm for ALIF and 13.56 ± 2.11 mm for OLIF ($p = 0.001$). The mean cage lordosis was $15.87^\circ \pm 4.23^\circ$ for ALIF and $16.81^\circ \pm 3.71^\circ$ for OLIF ($p = 0.278$). The mean preoperative anterior disc height was 11.53 ± 3.46 mm for ALIF and 12.45 ± 4.08 mm for OLIF ($p = 0.234$). The mean postoperative anterior disc height was 18.87 ± 3.82 mm for ALIF and 17.17 ± 4.22 mm for OLIF ($p = 0.043$). The mean increase in anterior disc height was 7.34 ± 3.84 mm for ALIF and 4.72 ± 3.41 mm for OLIF ($p = 0.001$). The mean preoperative posterior disc height was 5.44 ± 2.07 mm for ALIF and 5.93 ± 1.95 mm for OLIF ($p =$

TABLE 1. Clinical information and perioperative factors

Variable	Total (n = 127)	ALIF (n = 61)	OLIF (n = 66)	p Value
Age (yrs)	63.73 ± 10.80	63.57 ± 9.83	63.88 ± 11.69	0.142
Sex				0.364
Male	51	27	24	
Female	76	34	42	
CCI score	2.61 ± 1.81	2.64 ± 1.95	2.58 ± 1.67	0.845
Follow-up time	25.63 ± 5.88	27.21 ± 6.77	24.11 ± 6.93	0.112
Surgical approach				0.237
Anterior only	7	5	2	
Anterior + posterior in 1 day	58	24	34	
Anterior + posterior in 2 days	62	32	30	
Days btwn anterior & posterior op	3.11 ± 3.04	4.22 ± 3.07	1.93 ± 1.66	0.002
Anterior levels				<0.001
L5–S1	0	0	0	
L4–S1	65	34	31	
L3–S1	35	23	12	
L2–S1	27	4	23	
>4 levels	0	0	0	
Posterior levels				0.712
L5–S1	2	0	2	
L4–S1	40	18	22	
L3–S1	25	12	13	
L2–S1	22	10	12	
>4 levels, w/ L5–S1	31	16	15	
PCO at L5–S1				
Yes	30	7	25	
No	95	54	41	
Surgical time (mins)	242.65 ± 67.04	251.48 ± 67.04	234.48 ± 66.51	0.154
Blood loss (ml)	232.34 ± 269.56	387.92 ± 310.40	90.91 ± 98.12	<0.001
Transfusion (ml)	78.76 ± 211.21	154.90 ± 285.71	9.55 ± 38.41	<0.001
Transfusion (n = 126)				<0.001
No	98	37	61	
Yes	28	23	5	
Time to solid food (days)	2.60 ± 2.52	4.03 ± 2.55	1.30 ± 1.64	<0.001
Time to solid food	126	60	66	<0.001
0 days	32	3	29	
1–3 days	52	24	28	
>3 days	42	33	9	
Hospital stay (days)	7.39 ± 3.08	7.79 ± 3.46	7.02 ± 2.65	0.159
Fusion rate	268/343 (78.1%)	123/153 (80.4%)	145/190 (76.3%)	0.364
L2–3	25/27 (92.6%)	4/4 (100%)	21/23 (91.3%)	
L3–4	49/62 (79.0%)	24/27 (88.9%)	25/35 (71.4%)	
L4–5	94/127 (74.0%)	47/61 (77.0%)	47/66 (71.2%)	
L5–S1	100/127 (78.7%)	48/61 (78.7%)	52/66 (78.8%)	
Complications				0.108
No	119	55	64	
Yes	8	6	2	
Complications				
Ileus		2	2	
Acute kidney injury		1	0	
Bilateral iliopsoas weakness		1	0	
Abdominal wound hematoma		2	0	

Values are presented as the number of patients (%) or as the mean ± SD.

TABLE 2. Radiographic parameters of patients who did not undergo L5–S1 PCO

Variable	Total (n = 95)	ALIF (n = 54)	OLIF (n = 41)	p Value
Mean cage height (mm)	14.35 ± 1.93	14.94 ± 1.56	13.56 ± 2.11	0.001
Mean cage lordosis (°)	16.21 ± 4.03	15.87 ± 4.23	16.81 ± 3.71	0.278
Anterior disc height (mm)				
Preop	11.92 ± 3.74	11.53 ± 3.46	12.45 ± 4.08	0.234
Postop	18.15 ± 4.06	18.87 ± 3.82	17.17 ± 4.22	0.043
Change	6.22 ± 3.87	7.34 ± 3.84	4.72 ± 3.41	0.001
Posterior disc height (mm)				
Preop	5.65 ± 2.02	5.44 ± 2.07	5.93 ± 1.95	0.242
Postop	8.09 ± 2.61	8.78 ± 2.60	7.17 ± 2.36	0.002
Change	2.44 ± 2.70	3.35 ± 2.87	1.24 ± 1.90	<0.001
L5–S1 segmental lordosis (°)				
Preop	11.66 ± 5.60	11.52 ± 5.76	11.85 ± 5.46	0.775
Postop	16.11 ± 5.49	15.85 ± 5.74	16.44 ± 5.20	0.608
Change	4.44 ± 5.60	4.33 ± 5.87	4.59 ± 5.29	0.829

Values are presented as the mean ± SD.

0.242). The mean postoperative posterior disc height was 8.78 ± 2.60 mm for ALIF and 7.17 ± 2.36 mm for OLIF ($p = 0.002$). The mean increase in posterior disc height was 3.35 ± 2.87 mm for ALIF and 1.24 ± 1.90 mm for OLIF ($p < 0.001$). The mean preoperative L5–S1 segmental lordosis was $11.52^\circ \pm 5.76^\circ$ for ALIF and $11.85^\circ \pm 5.46^\circ$ for OLIF ($p = 0.775$). The mean postoperative L5–S1 segmental lordosis was $15.85^\circ \pm 5.74^\circ$ for ALIF and $16.44^\circ \pm 5.20^\circ$ for OLIF ($p = 0.608$). The mean change in the L5–S1 segmental lordosis was $4.33^\circ \pm 5.87^\circ$ for ALIF and $4.59^\circ \pm 5.29^\circ$ for OLIF ($p = 0.829$).

Subgroup Analysis of Patients With L4–S1 Fusions

As shown in Table 3, there were 34 patients (17 males, 17 females) who underwent L4–S1 ALIF and 31 patients who underwent L4–S1 OLIF. Age and sex were not different between the two groups. The mean surgical time was 233.53 ± 72.56 minutes for ALIF and 212.74 ± 66.65 minutes for OLIF ($p = 0.235$). The mean blood loss for ALIF patients was 386.76 ± 353.19 ml and that for OLIF patients was 104.84 ± 123.39 ml ($p < 0.001$). The mean time to solid food intake was 3.18 ± 1.78 days for ALIF patients and 1.45 ± 1.69 days for OLIF patients ($p < 0.001$). The average hospital stay was 6.56 ± 2.904 days for ALIF patients and 6.55 ± 2.84 days for OLIF patients ($p = 0.988$).

There were 31 ALIF and 22 OLIF patients without L5–S1 PCOs in the L4–S1 fusion subgroup. The mean cage height was 14.74 ± 1.48 mm for ALIF patients and 13.68 ± 2.06 mm for OLIF patients ($p = 0.034$), and the mean cage lordosis was $15.03^\circ \pm 4.66^\circ$ for the ALIF group and $16.70^\circ \pm 3.50^\circ$ for the OLIF group ($p = 0.069$). The mean increase in anterior disc height was 7.25 ± 4.22 mm for ALIF patients and 4.63 ± 3.16 mm for OLIF patients ($p = 0.019$). The mean increase in posterior disc height was 3.37 ± 2.86 mm for ALIF patients and 1.16 ± 1.88 mm for OLIF patients ($p = 0.003$). The mean change in L5–S1 segmental lordosis was $4.19^\circ \pm 6.13^\circ$ for ALIF patients and $4.41^\circ \pm 5.95^\circ$ for OLIF patients ($p = 0.899$).

Subgroup Analysis of Patients With L2–S1 and L3–S1 Fusions

There were only 4 patients who underwent L2–S1 fusion, and these patients were combined with the L3–S1 fusion cohort (Table 4). There were 62 patients (ALIF 27, OLIF 35), and the mean age was 67.47 ± 8.61 years ($p = 0.207$). The mean follow-up was 27.15 ± 6.96 months for ALIF patients and 24.56 ± 7.02 months for OLIF patients ($p = 0.268$). The mean surgical time for all patients was 262.60 ± 57.84 minutes, and there was no significant difference between ALIF and OLIF patients ($p = 0.172$). The mean blood loss for ALIF and OLIF patients was 389.42 ± 250.42 ml and 78.57 ± 68.10 ml, respectively ($p < 0.001$). The mean transfusion volume for ALIF patients was 192.50 ± 301.02 ml and that for OLIF was 13.71 ± 49.35 ml ($p = 0.006$). The mean time to solid food intake was 5.07 ± 2.97 days for ALIF patients and 1.17 ± 1.60 days for OLIF patients ($p < 0.001$). The mean hospital stay was 9.33 ± 3.53 days for ALIF patients and 7.43 ± 2.43 days for OLIF patients ($p = 0.015$).

There were 23 ALIF and 19 OLIF patients who did not undergo L5–S1 PCOs in the L3–S1 and L2–S1 subgroups of patients. The mean cage height was 15.24 ± 1.67 mm for ALIF and 13.41 ± 2.24 mm for OLIF patients ($p = 0.007$), and the mean cage lordosis was $17.10^\circ \pm 3.22^\circ$ for the ALIF group and $16.24^\circ \pm 3.98^\circ$ for the OLIF group ($p = 0.466$). The mean increase in anterior disc height was 7.46 ± 3.35 mm for ALIF patients and 4.81 ± 3.76 mm for OLIF patients ($p = 0.020$). The mean increase in posterior disc height was 3.32 ± 2.94 mm for ALIF and 1.34 ± 1.97 mm for OLIF ($p = 0.017$). The mean change in L5–S1 segmental lordosis was $4.52^\circ \pm 5.63^\circ$ for ALIF patients and $4.79^\circ \pm 4.57^\circ$ for OLIF patients ($p = 0.868$).

Discussion

To our knowledge, this is the first report directly comparing multilevel OLIF and ALIF to the sacrum.⁸ Both

TABLE 3. Perioperative parameters of patients who underwent ALIF and OLIF at L4–S1 only

Variable	Total (n = 65)	ALIF (n = 34)	OLIF (n = 31)	p Value
Age (yrs)	60.17 ± 11.51	61.74 ± 9.61	58.45 ± 13.24	0.261
Sex				0.360
Male	29	17	12	
Female	36	17	19	
Follow-up time (mos)	25.23 ± 6.89	27.26 ± 6.87	23.63 ± 6.90	0.245
Surgical time (mins)	223.62 ± 70.05	233.53 ± 72.56	212.74 ± 66.65	0.235
Blood loss (ml)	252.31 ± 302.65	386.76 ± 353.19	104.84 ± 123.39	<0.001
Transfusion (ml)	69.36 ± 206.78	126.15 ± 274.47	4.84 ± 19.81	0.015
Time to solid food (days)	2.34 ± 1.93	3.18 ± 1.78	1.45 ± 1.69	<0.001
Time to solid food		33	31	0.007
0 days	16	3	13	
1–3 days	31	18	13	
>3 days	17	12	5	
Hospital stay (days)	6.55 ± 2.85	6.56 ± 2.90	6.55 ± 2.84	0.988
Radiographic Variables of L5–S1 (w/o L5–S1 PCO)	Total (n = 53)	ALIF (n = 31)	OLIF (n = 22)	p Value
Mean cage height (mm)	14.3 ± 1.80	14.74 ± 1.48	13.68 ± 2.06	0.034
Mean cage lordosis (°)	15.85 ± 4.34	15.03 ± 4.66	17.30 ± 3.50	0.069
Anterior disc height (mm)				
Preop	12.28 ± 3.89	11.87 ± 3.65	12.88 ± 4.24	0.364
Postop	18.47 ± 4.25	19.12 ± 4.33	17.51 ± 4.04	0.184
Change	6.19 ± 4.01	7.25 ± 4.22	4.63 ± 3.16	0.019
Posterior disc height (mm)				
Preop	5.86 ± 2.12	5.69 ± 2.15	6.10 ± 2.10	0.494
Postop	8.31 ± 2.83	9.06 ± 2.92	7.26 ± 2.36	0.020
Change	2.45 ± 2.71	3.37 ± 2.86	1.16 ± 1.88	0.003
L5–S1 segmental lordosis (°)				
Preop	11.43 ± 5.97	11.19 ± 5.90	11.77 ± 6.19	0.731
Postop	15.72 ± 5.94	15.39 ± 6.04	16.18 ± 5.92	0.636
Change	4.28 ± 6.00	4.19 ± 6.13	4.41 ± 5.95	0.899

Values are presented as the number of patients (%) or as the mean ± SD.

ALIF and LLIF can improve the height and lordosis of the disc space with an acceptable rate of complications.¹⁶ ALIF is generally easier to perform from L4 to S1 because of a single incision, while LLIF has historically been used to treat L2 to L5 because it is harder to access L2–3 via ALIF.¹ When performing multilevel interbody fusions down to the sacrum, ALIF is often used because of its single incision and exposure of the entire spine. However, because of the minimally invasive approach and ease of access at L2–3 and L3–4, some surgeons have used LLIF in combination with ALIF at L5–S1, using two incisions and repositioning the patient. On the other hand, the L5–S1 OLIF allows access to the L5–S1 disc space in the lateral position. This not only affords concomitant access from L2 to L5, but it also obviates the need to reposition and re-drape the patient.^{11,17,18}

With regard to previously published reports of OLIF complications, the overall complication rates have ranged from 4% to 15.5%, and the ileus rates have ranged from 2.1% to 9.8%.^{9–11,19} With regard to previously published reports on ALIF, the overall complication rates have ranged

from 9.61% to 26.47%, and the ileus rates have ranged from 1.93% to 13.90%.^{20,21} With regard to our study, our overall complication rates were comparable to previously published reports (3.03% for OLIF and 9.84% ALIF), and postoperative ileus rates were 3.03% for OLIF and 3.28% for ALIF. Because of the proximity to the iliac vessels, anterior surgery at L5–S1 has a higher risk of intraoperative vascular injury regardless of whether the procedure is an ALIF or OLIF approach.^{22,23} With regard to ileus rates after anterior surgery, it is thought that visceral manipulation results in temporary palsy and dysfunction of parasympathetic innervation of the abdominal viscera during ALIF and OLIF, leading to postoperative ileus colonic pseudo-obstruction.^{24,25} Thus, one reason that the OLIF patients may have had a quicker recovery time from ileus is less dissection and manipulation of the abdominal viscera. With regard to the observation that ALIF had longer times between stages than OLIF, if a patient had severe abdominal distension secondary to ileus, the second stage may have been postponed until the patient recovered from the ileus. This would have resulted in delay in the second

TABLE 4. Perioperative parameters of patients who underwent ALIF and OLIF at L2–S1

Variable	Total (n = 62)	ALIF (n = 27)	OLIF (n = 35)	p Value
Age	67.47 ± 8.61	63.89 ± 9.79	68.69 ± 7.49	0.207
Sex				0.822
Male	22	10	12	
Female	40	17	23	
Follow-up time (mos)	26.05 ± 6.99	27.15 ± 6.96	24.56 ± 7.02	0.268
Surgical time (mins)	262.60 ± 57.84	274.07 ± 52.31	253.74 ± 61.02	0.172
Blood loss (ml)	211.07 ± 229.74	389.42 ± 250.42	78.57 ± 68.10	<0.001
Transfusion (ml)	89.92 ± 216.98	192.50 ± 301.02	13.71 ± 49.35	0.006
Time to solid food (days)	2.87 ± 3.00	5.07 ± 2.97	1.17 ± 1.60	<0.001
Time to solid food				<0.001
0 days	16	0	16	
1–3 days	21	6	15	
>3 days	25	21	4	
Hospital stay (days)	8.26 ± 3.08	9.33 ± 3.53	7.43 ± 2.43	0.015
Radiographic Variables at L5–S1 (w/o L5–S1 PCO)	Total (n = 42)	ALIF (n = 23)	OLIF (n = 19)	p Value
Mean cage height (mm)	14.42 ± 2.13	15.24 ± 1.67	13.41 ± 2.24	0.007
Mean cage lordosis (°)	16.71 ± 3.56	17.10 ± 3.22	16.24 ± 3.98	0.466
Anterior disc height (mm)				
Preop	11.48 ± 3.54	11.08 ± 3.20	11.97 ± 3.95	0.422
Postop	17.74 ± 3.83	18.54 ± 3.06	16.78 ± 4.50	0.140
Change	6.26 ± 3.74	7.46 ± 3.35	4.81 ± 3.76	0.020
Posterior disc height (mm)				
Preop	5.38 ± 1.89	5.09 ± 1.95	5.73 ± 1.79	0.281
Postop	7.80 ± 2.32	8.41 ± 2.09	7.07 ± 2.42	0.061
Change	2.42 ± 2.71	3.32 ± 2.94	1.34 ± 1.97	0.017
L5–S1 segmental lordosis (°)				
Preop	11.95 ± 5.17	11.96 ± 5.68	11.95 ± 4.62	0.996
Postop	16.60 ± 4.88	16.48 ± 5.38	16.74 ± 4.36	0.867
Change	4.64 ± 5.12	4.52 ± 5.63	4.79 ± 4.57	0.868

Values are presented as the number of patients (%) or as the mean ± SD.

stage, and because ALIF had a higher rate of ileus, this may have partially accounted for our observation. With regard to the reasons that ALIF had longer times than OLIF to solid food intake, there are probably 2 main reasons for this observation. First is that there is less bowel retraction and manipulation of the parasympathetic plexus in OLIF, not only because the OLIF approach is off to one side, but also because the abdominal contents have shifted to the contralateral side, requiring less retraction and manipulation to access the disc space. Second, ALIF patients did have a higher rate of ileus, and these outliers probably skewed the mean time to solid food intake.

With regard to radiographic analysis of the L5–S1 segment, we excluded patients with PCOs because osteotomies can affect lordosis and disc height (through posterior release). Even though patients who had L5–S1 PCOs were excluded from the radiographic assessment, they were included in the clinical assessment of approach-related morbidity and complications. After excluding L5–S1 PCO cases, the mean L5–S1 cage height for ALIF patients (14.94 mm) was higher than that for OLIF patients (13.56

mm) ($p = 0.001$). We found that placing larger cages with L5–S1 in ALIF procedures also had better restoration of anterior and posterior disc height. Because radiographic measurements at L5–S1 were in a lordotic segment, the mean cage height (15 mm) was smaller than the mean anterior disc height (18 mm) but larger than the mean posterior disc height (8 mm). However, the lordosis of L5–S1 cages was similar between ALIF and OLIF groups (15.87° and 16.81° , respectively; $p = 0.278$) and the increase of lordosis at L5–S1 was similar between the two groups. Thus, our results showed that although there was no significant difference in segmental lordosis at L5–S1 between ALIF and OLIF, there was better disc height restoration with ALIF.

There are limitations to this study. First, this is a single-institution retrospective series. Second, although the mean follow-up times for ALIF and OLIF groups were 27.21 and 24.11 months, respectively, a minimum 2-year follow-up for all patients would have been ideal for a rigorous study. Third, this article did not compare the functional outcomes and subsidence rates, mainly because reports have shown that subsidence rates and functional outcomes

in both LLIF and OLIF are comparable to those in ALIF.²⁶ Fourth, although there was no difference in hospital stay, this may not be an accurate number because of the variability of the posterior surgery. If a patient had undergone L3–S1 surgery compared to T3–S1 surgery, their hospital stay could have been profoundly affected, but we were not able to control for this. However, since we focused on the perioperative factors of the anterior approach alone (ileus, anterior-only blood loss, and disc height only at L5–S1), this should have been less of a factor in terms of assessing the differences in the ALIF and OLIF approaches. Nonetheless, despite these limitations, we believe that the uniqueness of this direct comparison may be useful to help surgeons understand the pros and cons of each approach when contemplating multilevel interbody fusions to the sacrum.

Conclusions

Patients who underwent multilevel OLIF to the sacrum appear to have comparable operative times and hospital stays to those who underwent ALIF. ALIF afforded larger cage placement at L5–S1, resulting in better disc height restoration but comparable lordosis induction with OLIF. OLIF had less blood loss, and there may be faster recovery from postoperative ileus after OLIF owing to less bowel manipulation than is required in ALIF.

Acknowledgments

Dr. Chang received funding from Yen Tjing Ling Medical Foundation, a nongovernment foundation that has no association with any implant or with the pharmaceutical industry.

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Disclosures

Dr. Chou reports being a consultant for Globus and Medtronic; he receives royalties from Globus. Dr. Mummaneni reports being a consultant for DePuy Synthes, Globus, and Stryker; he owns stock in Spinicity/ISD; he receives royalties from DePuy Synthes, Thieme Publishers, and Springer Publishing; and he receives support of non-study-related clinical or research efforts that he oversees from the following: AO Spine, NREF, and ISSG. Dr. Eichler reports being a consultant for Medtronic and NuVasive. Dr. Burch reports being a consultant for Medtronic and Zimmer Biomet.

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Conception and design: Xi. Acquisition of data: Xi, Eichler. Analysis and interpretation of data: Xi. Drafting the article: Xi. Critically revising the article: Chou, Mummaneni. Reviewed sub-

mitted version of manuscript: Chou, Mummaneni, Chang, Burch. Statistical analysis: Chou. Administrative/technical/material support: Mummaneni, Ruan, Chang, Burch.

Supplemental Information

Online-Only Content

Supplemental material is available with the online version of the article.

Supplemental Table 1. <https://thejns.org/doi/suppl/10.3171/2020.4.SPINE20198>.

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