Comparative Clinical Analysis of Oblique Lateral Interbody Fusion at L5/S1 versus Minimally Invasive Transforaminal Interbody Fusion (MIS-TLIF) for Degenerative Lumbosacral Disorders

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Abstract:

Introduction: Since 2015, we have performed minimally invasive oblique lateral interbody fusion (OLIF) at L5/S1 for various lumbosacral spine disorders using percutaneous pedicle screws. This study evaluated the clinical and radiologic results between OLIF at L5/S1 and minimally invasive transforaminal interbody fusion (MIS-TLIF) for single to multilevel degenerative lumbosacral disorders.

Methods: A total of 124 patients underwent either OLIF (62 cases) or MIS-TLIF (62 cases). The applied disorders were L5 isthmic spondylolisthesis, foraminal stenosis, pseudarthrosis, adjacent segment degeneration, a combination of L4/5 and L5/S1 pathology, and others. We performed OLIF with posterior percutaneous fixation in the same lateral position. MIS-TLIF was performed with modified cortical bone trajectory screws. The operation time (OT), estimated blood loss (EBL), JOABPEQ effectiveness rate (%),Visual Analog Scale (VAS), fusion rate, radiologic segmental alignment, and complications were evaluated.

Results: The average follow-up periods were 51 and 69 months (24-95) in the OLIF and MIS-TLIF groups, respectively. Furthermore, the average fused segments were 1.6 and 1.5 in each group, respectively. The OT and EBL per segment were 130 min and 56 mL and 100 min and 64 mL, respectively. The JOABPEQ effectiveness rate in the OLIF group demonstrated a statistically higher value in the domains of pain, low-back function, and gait than the MIS-TLIF group (P<0.01). The follow-up VAS of low-back pain (LBP) and lower extremity numbness had lower values in the OLIF group (P<0.05). The fusion rates were 98% and 90%, respectively. Segmental lordosis at L5/S1 was significantly larger in the OLIF group (15° vs. 11°, P<0.01).

Conclusions: The OLIF group demonstrated less pain as well as better low-back and gait functions at follow-up. The minimally invasive anterolateral fusion employing OLIF at L5/S1 using percutaneous screws serves as a viable and effective procedure with less residual LBP and high fusion rate.

Keywords:

Spine, Oblique lateral interbody fusion (OLIF), Lateral position surgery

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Introduction

After the introduction of anterior lumbar interbody fusion (ALIF) in 1960[1], the minimally invasive approach for ALIF was reported by Mayer in 1997[2], followed by direct lateral interbody fusion for the L2/3 to L4/5 levels in 2014[3,4]. In turn, Hynes et al. successfully minimized the conventional ALIF using the mini-retroperitoneal approach under the lateral decubitus position, which was named as oblique lateral interbody fusion[5]. The advantages of this approach are its minimal invasiveness, with about 35-mm incision, and the effective movement of abdominal organs away from the approaching plane in the lateral decubitus position. We started OLIF25 in 2012 and experienced over 800 cases. In 2015, we started OLIF at L5/S1 and experienced over 160 cases for single to multilevel degenerative lumbosacral spinal fusion in conjunction with OLIF at the L2-L5 levels. In this technique, we simultaneously employed posterior percutane-

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Table 1. Patient Background Demographics.

	OLIF	MIS-TLIF
Patient number	62	62
Average age at Surgery	66 (30–84)	65 (22–88)
Gender (Male:Female)	25:37	36:36
Disorders	L4 DS & 51 DDD: 14 L5/S1 FS: 11 L4 DS & L5/S1 FS: 7 L5 IS: 7 L5/S1 TLIF Pseudo: 6 L5/S1 Disc Herniation or DDD: 5 L5 DS: 3 Others: 9	L5 IS: 25 L5/S1 FS: 9 L4 DS & 51 DDD: 5 L4 DS & L5/S1 FS: 3 L5/S1 TLIF Pseudo: 1 Others: 19
Average fixed segments	1.6 (1–3)	1.5 (1–3)
Patient's # of fixed segments		
Single segment	32	39
Two segments	20	18
Three segments	10	5

Remarks: DS, Degenerative spondylolisthesis; DDD, Degenerative disc disease; IS, Isthmic spondylolisthesis; FS, Foraminal stenosis; 51, L5/S1; TLIF, Transforaminal interbody fusion; Pseudo, Pseudarthrosis

ous screw fixation in the same lateral position without a position change, which is referred to as "lateral position surgery."

The transforaminal interbody fusion (TLIF) has been a well-accepted posterior interbody procedure for degenerative lumbosacral spinal disorders[6]. To minimize the invasiveness of this procedure, the minimally invasive TLIF (MIS-TLIF) has been developed by decreasing intraoperative bleeding, soft tissue damage, and postoperative pain for the patients[7,8]. The use of percutaneous screw and the rod assembly system as well as the advances in the retraction instruments contributed to the accomplishment of this process. We further utilized the cortical bone trajectory (CBT) screws instead of conventional pedicle screws to minimize the lateral exposure of the lumbar spine using single midline skin incision and increased screw insertion torque, which was reported by several authors[9,10].

In the previous study, we conducted a single-level comparison of OLIF at L5/S1 vs. MIS-TLIF for lumbosacral degenerative disorders[11]. This demonstrated a higher low-back function of the OLIF group in the JOABPEQ effectiveness rate than in the MIS-TLIF group (44% vs. 17%) at follow-up, as well as a higher fusion rate of 97% in the OLIF group (vs. 92% in MIS-TLIF). Furthermore, a greater segmental lordosis of 17° was observed in the OLIF group than in the MIS-TLIF group (11°).

In the multilevel lumbosacral fusion surgery, the combination of multiple OLIF and the use of lateral position surgery seems to be less invasive and improves patients' quality of life compared with multilevel MIS-TLIF.

We conducted a retrospective cohort study in a single to multilevel setting using OLIF vs. multilevel MIS-TLIF for lumbosacral degenerative disorders.

Materials and Methods

A total of 124 patients have received either OLIF (62 cases) or MIS-TLIF (62 cases) since 2013 (Table 1). The average ages at surgery were 65.7 (30-84) and 64.8 (27-88) years in the OLIF and MIS-TLIF groups, respectively. No gender differences were observed. The spinal disorders required for surgery in the OLIF group were foraminal stenosis at L5/S1 in 11 cases, L5 isthmic spondylolisthesis in 7, pseudarthrosis of TLIF in 6, disc herniation or degenerative disc disease (DDD) in 5, degenerative spondylolisthesis of L4 combined with former pathologies at L5/S1 in 21, and others. The disorders in the MIS-TLIF group included L5 isthmic spondylolisthesis in 25 patients, foraminal stenosis in 9, DDD at L5/S1 combined with L4 degenerative spondylolisthesis in 5, foraminal stenosis with L4 degenerative spondylolisthesis in 3, and others. The average fixed segments were 1.6 (1-3) and 1.5 (1-3) in the OLIF and MIS-TLIF groups, respectively. For multilevel spinal fusion, the conventional OLIF was applied to the L3/4 to L4/5 levels in the OLIF group.

Surgical procedures

The OLIF surgeries were performed according to the original technique developed by Hynes R[5]. The patient was positioned in the true right decubitus position, and a 35-mm oblique incision was made two to three fingers medial to the anterior-superior iliac spine (ASIS) (Fig. 1A). After carefully incising the abdominal muscle layers, transverse fascia was split bluntly, and the retroperitoneal space was exposed to-

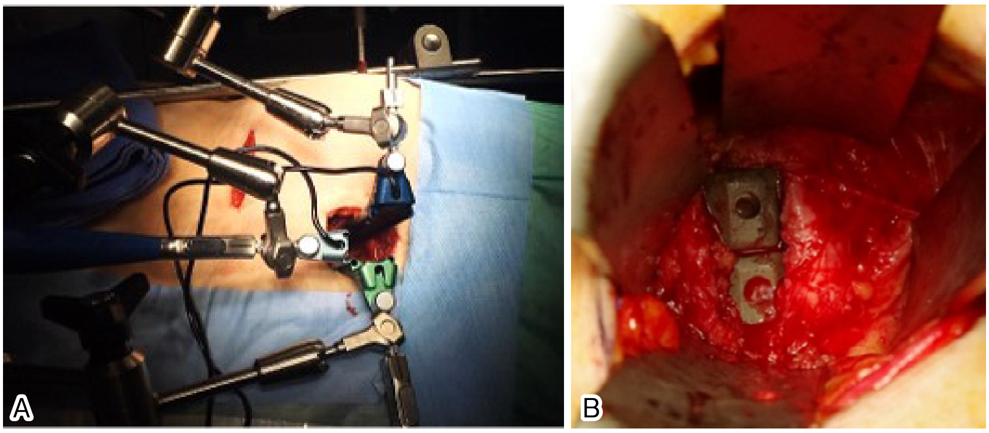

Figure 1. A: Setup for OLIF at L5/S1. In the right decubitus position, a 3.5-cm oblique incision was made at two to three fingers medial from the ASIS. Using a retroperitoneal approach, the L5/S1 disc was safely exposed by retracting all vascular tissues. B: After an extensive release of the L5/S1 disc, a massive bone graft and two titanium-coated PEEK cages were successfully placed.

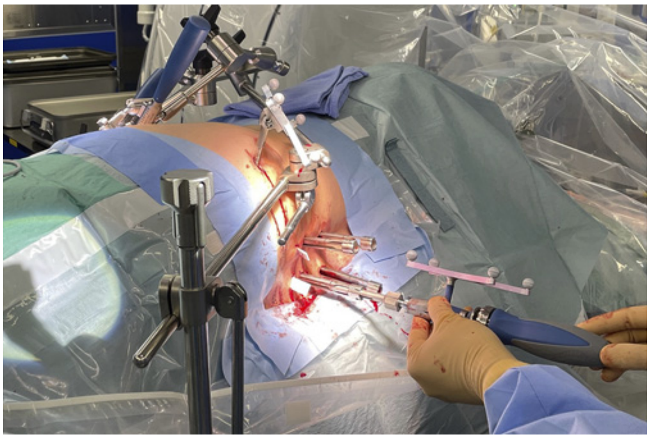

Figure 2. After OLIF at L5/S1, posterior percutaneous screw fixation was simultaneously performed in the same lateral position.

ward the posterior direction. After exposing the anterior aspect of the psoas muscle, the approach was extended to the medial side, and the left common iliac artery and vein were identified. With great care for the left ureter, both vessels were retracted to the left side, and the L5/S1 intervertebral disc was exposed. After extending the exposure to both the cephalad and right border of the L5/S1 disc, the retractor was placed to prevent injury of the surrounding vessels, ureter, and peritoneum. After removing the anterior annulus in a rectangular fashion, whole nucleotomy was performed. The cartilaginous endplates were removed, and an allograft was placed at the posterior portion of the disc. Two titanium-coated PEEK cages with 10° of lordosis (MectaLIF, Medacta, Switzerland) were finally placed obliquely in the disc space (Fig. 1B). For additional multilevel fusions, conventional OLIF was performed with additional single transverse incision cephalad to the previous one. For posterior fixation, simultaneous percutaneous screw fixations were performed using modified cortical CBT screws[10] in the same lateral position (Fig. 2).

MIS-TLIF was performed with a single midline incision of 35 mm (Fig. 3)[10]. After subperiosteally exposing the contiguous laminae and facet joint at the L5/S1 level, modified CBT screws were inserted into the L5 and S1 pedicles[10]. Under continuous distraction applied to the unilateral CBT screws, discectomy was performed after unilateral complete facetectomy. After the meticulous removal of the cartilaginous endplates, a boomerang-type PEEK cage and allograft fragments were placed in the disc space. Finally, the proper compression force was applied between the contiguous screws to enhance the segmental stability.

Data analysis

For the operative and perioperative analysis, the number of fixed spinal segment, operation time (OT, minute) and estimated blood loss (EBL, mL) were recorded. The OT and EBL were also normalized to a single segment (min/seg and mL/seg). The serum C-reactive protein (CRP) and creatine phosphokinase (CK) were recorded at postoperative day 1 and day 6. For radiologic analysis, the disc angle (degree) and posterior disc height (mm) were measured preoperatively and at the final follow-up. For the clinical outcome and quality of life evaluation, the Japanese Orthopedic Association Back Pain Evaluation Questionnaire (JOABPEQ) score and visual analog scale (VAS) of low-back pain (LBP), lower extremity pain, and numbness were recorded preoperatively and at the final follow-up[12]. The JOABPEQ questionnaire consisted of five domains, namely, pain, low-back function, gait, social parameter, and psychogenic parameter, and its effectiveness rate (%) was statistically compared between two surgical groups.

The spinal fusion status was examined at 6 months, 12 months, and final follow-up with CT scan. The bony continuity between two contiguous vertebrae appeared over three slices in both coronal and sagittal scans were regarded as a solid fusion. The surgical complications and details of re-

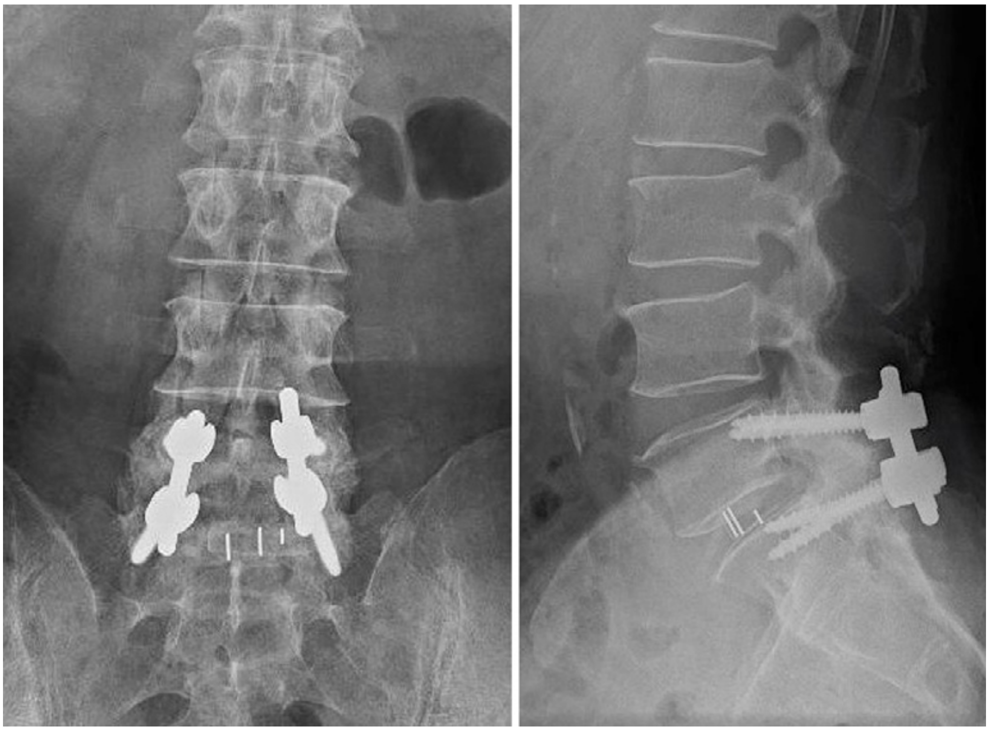

Figure 3. MIS-TLIF using modified cortical bone trajectory screws. This requires a 4-cm single incision and exposure the lamina medial to the facet joint.

Table 2. Descriptive Summarized Results in Two Groups.

	OLIF	MIS-TLIF	Significance
Average follow-up period (months)	51 (24–72)	61 (51–95)	
Average operation time (min)	189 (65–326)	131.5 (75–237)	p<0.01
Operation time/segment (min)	130 (65–263)	100 (50–237)	p<0.01
Average estimated blood loss (mL)	84 (10–530)	89.5 (10–340)	NS
Estimated blood loss/segment (mL)	55.8 (10–265)	64.9 (10–240)	NS
Average serum CRP at postop day 1	3.6	2.0	p<0.01
Average serum CRP at postop day 6	2.6	2.4	NS
Average serum CK at postop day 1	931	407	p<0.01
Average serum CK at postop day 6	175	96.8	p<0.01
Fusion rate (%)	98%	90%	
Surgical site infection (SSI; %)	0%	1.6%	
Neurovascular complications (%)	1.6%	0%	

Statistical difference was shown on the right column at the P<0.01 level. NS, no statistical difference; CRP, C-reactive protein; CK, Creatinine phosphokinase

operation were recorded.

For the statistical analysis, either the *t*-test or the Cochran and Cox tests were conducted after the test for equal variance between two surgical groups. For the comparison of the JOABPEQ effectiveness rates, chi-squared test was conducted between two surgical groups. The statistical significance was set to P=0.05 in each test. StatMate V (Atoms, Co., Tokyo Japan) was utilized for all statistical analyses. This research has been approved by the institutional review board of the authors' affiliated institution.

Results

The average follow-up periods were 44 (24-63) and 61 months (39-95) in the OLIF and MIS-TLIF groups (Table 2), respectively. The average OTs were 189 min (65-326) and 131.5 min (75-237) in the OLIF and MIS-TLIF groups, respectively (P<0.01). The average OTs per segment were 130.9 min (65-263) and 100.2 min (50-237), respectively (P <0.01). The EBL was 84.1 mL(10-530) and 89.5 mL (10-340), respectively (NS). The EBL per segment was 55.8 mL (10-265) and 64.9 mL (10-240), respectively (NS). The average serum CRP values were 3.6 and 2.0 at day 1 (P<0.01) and 2.6 and 2.4 at day 6 (NS). The average serum CK val-

Table 3. Radiologic and Clinical Parameter Results.

	OLIF	MIS-TLIF	Significance
Segmental lordotic angle at L5/S1 (degree): Preop	9.9 (−4.5–25)	9.6 (−5–20)	
Segmental lordotic angle at L5/S1 (degree): Fup	14.8 (4–36)	11.0 (1–23)	p<0.01
Posterior disc height (mm) at L5/S1: Preop	4.1 (0.8– 8.1)	4.3 (0–9.0)	
Posterior disc height (mm) at L5/S1: Fup	5.3 (2.0– 9.7)	5.5 (0–12.0)	
JOABPEQ effectiveness rate (%): Pain	84.6	65.7	p<0.01
JOABPEQ effectiveness rate (%): LB function	43.6	28.6	p<0.01
JOABPEQ effectiveness rate (%): Gait	69.2	48.6	p<0.01
JOABPEQ effectiveness rate (%): Social	41.0	60.0	p<0.01
JOABPEQ effectiveness rate (%): Psycho	28.2	42.9	p<0.01
Visual analogue scale (mm): LBP, Preop	64.2 (0–100)	59.8 (0–100)	
Visual analogue scale (mm): LBP, Fup	23.5 (0–85)	35.7 (0–100)	p<0.01
Visual analogue scale (mm): LE pain, Preop	63.3 (0–100)	54.8 (0–100)	
Visual analogue scale (mm): LE pain, Fup	23.9 (0–85)	29.1 (0–100)	
Visual analogue scale (mm): LE numbness, Preop	63.4 (0–100)	56.3 (0–100)	
Visual analogue scale (mm): LE numbness, Fup	18.9 (0–93)	29.9 (0–100)	p<0.05

Statistical difference was shown on the right column at the $P<0.01$ or 0.05 level.
Preop, Preoperative; Fup, Follow-up; LB, Low back; Psycho, Psychological; LBP, Low back pain; LE, Lower extremity

ues were 931 and 407 at day 1 ($P<0.01$) and 175 and 96.8 at day 6 ($P<0.01$), respectively. The radiologic disc angles in average at L5/S1 were 9.9° and 9.6° preoperatively and 14.8° and 11.0° at follow-up in the OLIF and MIS-TLIF groups, respectively (Table 3). The disc angle of OLIF at follow-up was statistically larger than that of MIS-TLIF at the L5/S1 level ($P<0.01$). The posterior disc heights (mm) in average were 4.1 and 4.3 mm preoperatively and 5.3 and 5.5 mm at follow-up (Table 3). No statistical difference was observed between the two group values. The overall fusion rates evaluated *via* CT were 98% and 90% in the OLIF and MIS-TLIF groups, respectively.

The JOABPEQ effectiveness rates of the pain domain at follow-up were 84.6% and 65.7% in the OLIF and MIS-TLIF groups, respectively, which was statistically significant ($P<0.01$) (Table 3). The rates of the lumbar function domain were 43.6% and 28.6%, respectively, which was statistically significant ($P<0.01$). The gait domain also had rates of 69.2% and 33.1%, respectively, which was statistically significant ($P<0.01$). The rates of the social domain were 41% and 60% inversely ($P<0.01$), and those of the psychogenic domain were 28.2% and 42.9%, respectively ($P<0.05$). The VAS of the LBP, lower extremity pain, and numbness all improved at follow-up when compared with the preoperative values. The VAS of the LBP, lower extremity pain, and numbness at follow-up were 23.5 vs. 35.7 ($P<0.01$), 23.9 vs. 29.1 (NS), and 18.9 vs. 29.9 ($P<0.05$) in the OLIF and MIS-TLIF groups, respectively (Table 3).

The surgical complication in the OLIF group demonstrated a transient lower extremity edema in five, cage displacement in two, and rod dislodgement, ileus, sagittal imbalance, and micro-hole vascular injury in one each. In the cases of lower extremity edema, there was no venous thrombosis under sonography, and they spontaneously resolved within a month under oral dosing of anticoagulant agent. One case of cage displacement required revision of TLIF at 5 months postoperatively, finally leading to fusion. The ileus patient had a tendency of constipation by nature and developed an ileus postoperatively without a peritoneal injury. After the placement of ileus tube, scopic release was finally required by the general surgeon for the intractable course. One case developed proximal junctional kyphosis with sagittal imbalance, which required fusion extension. The patient with micro-hole vascular injury had severe adhesion of the left common iliac vein (CIV) to the L5/S1 disc intraoperatively. Even with the careful release between them, the micro-hole injury of CIV occurred. However, the micro-hole was solely repaired using the tissue sealing sheet without the suture. The MIS-TLIF group demonstrated six cases of pseudarthrosis (9.7%) and one case of surgical site infection (SSI; 1.6%). Two of the six patients with pseudarthrosis required revision of TLIF and OLIF, respectively. The SSI case was successfully treated conservatively.

Case presentations

Case: A 67-year-old male, L5 isthmic spondylolisthesis

The patient complained of unilateral leg pain, numbness, and LBP causing significant disability of daily living due to typical grade II isthmic spondylolisthesis. The wide preoperative vascular window was revealed by MR angiography (Fig. 4A). Successful OLIF at L5/S1 and percutaneous screw fixation in the lateral position were conducted with an OT of 146 min and EBL of 100 mL (Fig. 4B). The successful bony fusion was achieved at 1 year postoperatively without any residual symptoms.

Discussion

MIS-TLIF has been a well-accepted surgical procedure

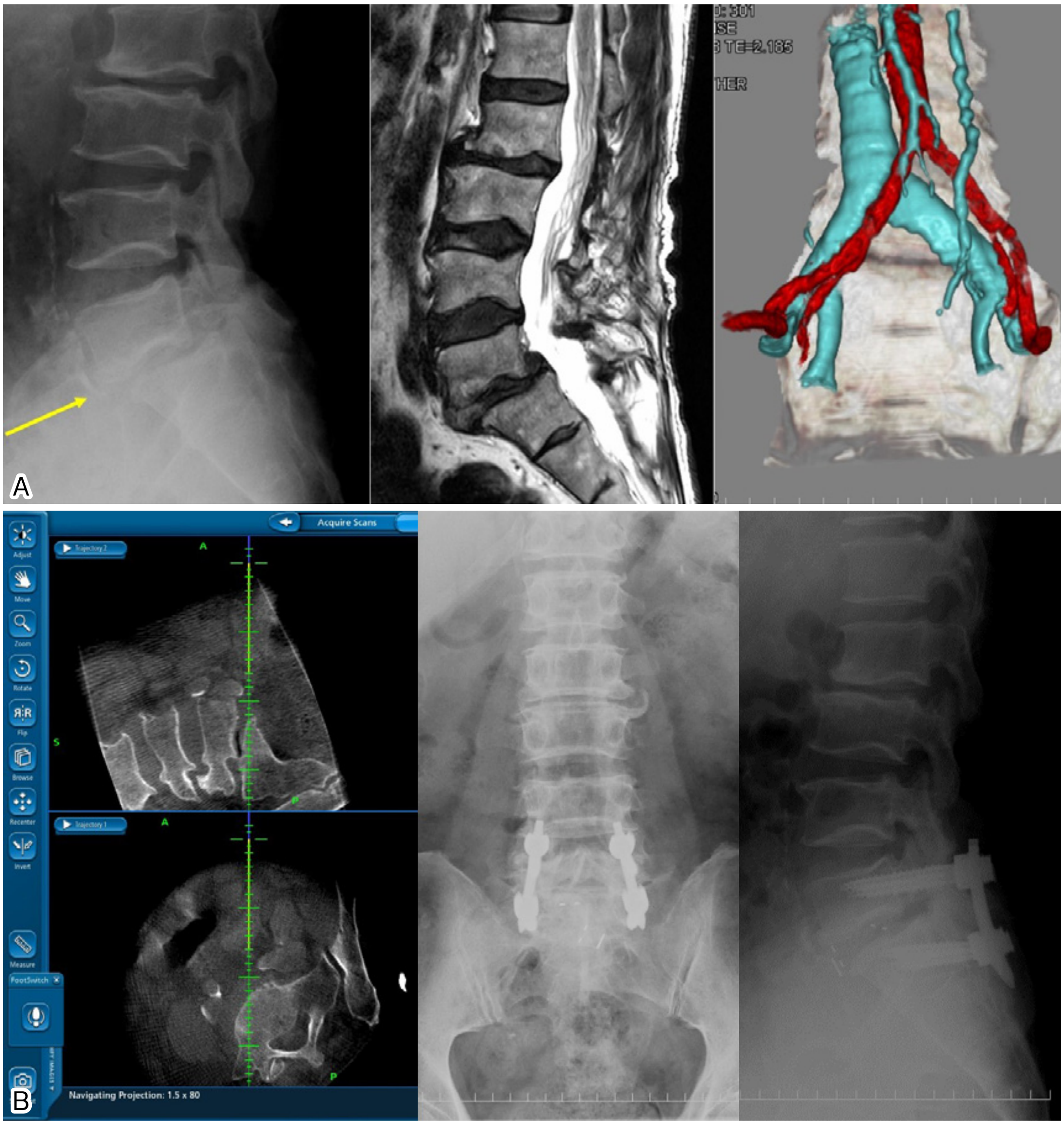

Figure 4. A: A 67-year old male, L5 isthmic spondylolisthesis. B: Successful OLIF at L5/S1 was performed using simultaneous posterior percutaneous screw fixation. The vein enhanced intraoperative CT helped the surgical approach effectively.

for degenerative lumbosacral fusion[7,8]. Compared with the conventional TLIF, it is less invasive in terms of pain, blood loss, and injury to the back muscles. However, there have still been several limitations of bony fusion and cage subsidence in elderly patients with severe osteoporosis as well as residual back pain at the lumbosacral area due to lumbosacral fascial injury. OLIF at L5/S1 is expected to reduce these problems due to the larger footprint of the cage, broad bone graft area, and posterior fixation using percutaneous screws. Consequently, this study was conducted to compare the clinical and radiologic results of OLIF and MIS-TLIF in single to multilevel lumbosacral fusion for degenerative disorders.

The results of the present study indicated the relative perioperative invasiveness of the OLIF group compared with the MIS-TLIF group in terms of longer OT and serological inferiority of the CRP and CK level postoperatively. It was explained by the relative difficulty of the technique and multiple incisions in OLIF. There was a significant learning curve in OLIF at L5/S1; however, after 20 cases experienced and careful case selection in terms of vascular anatomy, the OT was significantly shortened. In turn, several superiorities of OLIF at L5/S1 were demonstrated in terms of radiologic alignment, fusion rate, residual pain, and quality of life parameters. First, segmental lordosis at follow-up was larger in OLIF at L5/S1 (14.8° vs. 11°) despite the use of a 10° lordotic cage. This can be explained by the fact that the sufficient anterior release and anteriorly positioned cage helped create more lordosis in OLIF. Second, a higher fusion rate of 98% was achieved in OLIF at L5/S1 compared with 90% in MIS-TLIF (Fig. 5). In OLIF at L5/S1, the significant large annular window can be created followed by extensive discectomy and creation of a broad bone graft area. The interbody cage in OLIF covered the anterior endplate rim,

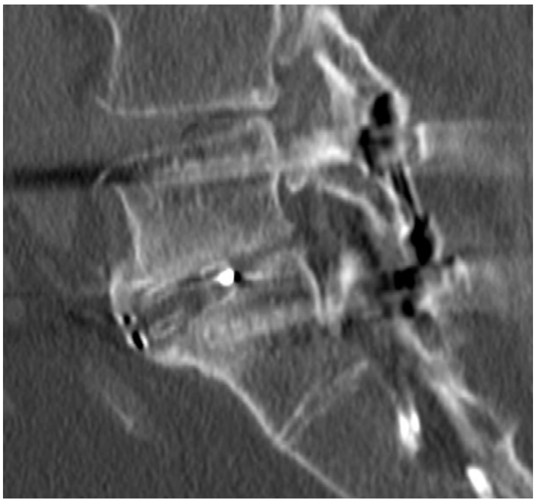

Figure 5. Representative sagittal CT image of OLIF at L5/S1 after one year postoperatively, showing successful anterior bridging bone formation.

contributing superior biomechanical stability at the segment.

The OLIF group demonstrated less pain (85% vs. 66%) and better low-back function (44% vs. 29%) and gait (69% vs. 33%) in the JOABPEQ score evaluation at the final follow-up. The superiority in less LBP was also demonstrated in the follow-up VAS (23 vs. 35). This was explained by the fact that the use of percutaneous screws effectively decreased the invasiveness of lumbosacral fascia and paravertebral muscles when compared with posterior open surgery. In terms of surgical complications, there were apparent contrasts in the variation between two modalities. Even without major complications, OLIF at L5/S1 has the possibility to face vascular injury when adhesions exist between the intervertebral disc and vascular tissue. Therefore, surgeons require the basic repair technique of minor vascular injury as well as supporting systems by cardiovascular surgeons. We experienced two cases of anterior cage displacement in OLIF at L5/S1, because the cage we used did not have integrated screws. One case of revision was required; however, we did not experience any cage dislodgement. Contrarily, MIS-TLIF demonstrated higher pseudarthrosis rate (9.7%) and SSI rate (1.6%). This was explained by the smaller bone graft area due to the small annular window and unavoidable dead-space creation in MIS-TLIF.

Through this comparative study, we confirmed several advantages of OLIF at L5/S1 in comparison with MIS-TLIF: higher fusion rate (98% vs. 90%), better low-back function, and less residual LBP. This was explained by the larger bone graft area and superior biomechanical support provided by OLIF. We have not observed cage sinking in the OLIF group, in which the anteriorly placed cage covers the anterior cortical rim of the vertebral body. The better fusion capacity of OLIF could be attributed to the extensive anterior release and huge graft bone amount. Furthermore, in OLIF, the posterior instrumentation procedure can be performed using percutaneous screws, minimizing the damage to the paravertebral muscle and lumbosacral fascia. This seems to contribute to less pain and better low-back function of the OLIF group in the JOABPEQ score evaluation at follow-up.

The OLIF procedure at L5/S1 has several limitations and pitfalls. First, there were several anatomical variations of vascular tissue, especially in the venous system. The wide vascular window is required for OLIF, and at least 20-mm window was considered as the minimum value for a safe procedure according to the author's personal experience. In addition, the early branching of the internal iliac vein is a typical variation disturbing the OLIF procedure. Second, the adhesion between the outer annulus of the disc and common iliac vein sometimes disturbs this approach. The preoperative evaluation of adhesion on MR imaging and the careful detachment procedure are important for a successful surgery.

Finally, this study had several limitations. The study used a non-randomized cohort design. There were biased selections of the surgical procedure; either OLIF or MIS-TLIF, according to vascular anatomy, previous abdominal surgery, and required additional adjacent neural decompression. In addition, there were variations in the preoperative pathologies between the two groups. The pathology of isthmic spondylolisthesis was dominant in the MIS-TLIF group; however, there were various pathologies blended in the OLIF group. Finally, the MIS-TLIF procedure we performed in this study was "Mini-open TLIF using modified CBT screws," referred to as "MIDLF." The use of a more minimally invasive procedure, such as tubular or endoscopic TLIF using percutaneous screws, may change the comparative results in this study.

Conclusions

The present study was conducted to compare the clinical and radiologic results of oblique lateral interbody fusion (OLIF) and minimally invasive transforaminal interbody fusion (MIS-TLIF) in single to multilevel lumbosacral fusion for degenerative disorders. In lieu of a relatively longer OT, the OLIF group demonstrated less residual pain as well as better low-back and gait function at follow-up than the MIS-TLIF group. The single to multilevel lateral position surgery employing OLIF at L5/S1 using percutaneous screws serves as a viable and effective procedure with less residual LBP and high fusion rate.

Conflicts of Interest: The authors declare that there are no relevant conflicts of interest.

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Atsushi Ikeura (Study design, Data management)

Takanori Saito (Study design adviser, Manuscript revision)

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