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RESEARCH

Safety and biological effectiveness of transforaminal (TLIF) and oblique lumbar interbody fusion (OLIF): a retrospective cohort study including patients with significant comorbidity

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Abstract

Purpose The aim of the study was to compare the safety, perioperative outcomes, and radiographic fusion rate of oblique lumbar interbody fusion (OLIF) and transforaminal lumbar interbody fusion (TLIF) in patient population including highly comorbid patients who underwent lumbar fusion for degenerative pathology.

Methods This retrospective cohort study included 268 patients who underwent one- or two-level lumbar interbody fusion (L3–L5) between 2017 and 2021. 201 patients underwent TLIF and 67 received OLIF surgery. Demographic, operative, postoperative clinical, and radiographic data were collected. One-year CT and X-ray scans in a subset ($n=157$ and $n=174$) were used to evaluate bony fusion. Adverse Events (AEs) were categorized using the SAVES-V2 system. Multivariate logistic and linear regressions models were applied to identify predictors of AEs and LOS.

Results Baseline characteristics were comparable between groups. OLIF demonstrated significantly reduced intraoperative blood loss, minor perioperative decline in serum Hgb and shorter hospital stay, whereas TLIF had shorter operative times. Early postoperative AEs and reoperation rates did not differ significantly. High-comorbidity patients showed similar safety profiles. The overall one-year fusion rate was high in both groups (CT: 90.9% TLIF vs. 91.5% OLIF on CT- and 92.5% in TLIF, 87% in OLIF on X-ray based measurements). OLIF achieved fusion more frequently within the cage, whereas TLIF more often demonstrated fusion around the cage. Independent predictors of AEs included age, anthropometric factors, and intraoperative blood loss. The regression model showed good discriminatory ability (AUC = 0.735).

Conclusion Both OLIF and TLIF are safe and effective techniques for the surgical treatment of degenerative lumbar conditions also in medically complex patients. OLIF offers advantages in blood loss and LOS, while TLIF allows shorter operative times. Surgical approach should be individualized based on patient anatomy and surgeon expertise.

Keywords Lumbar fusion · OLIF · TLIF · Postoperative adverse events · Comorbidity · Radiographic fusion

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Introduction

Transforaminal Lumbar Interbody Fusion (TLIF) and Oblique Lateral Interbody Fusion (OLIF) are widely practiced approaches for lumbar spinal fusion [1–5]. TLIF is a posterior approach allowing direct decompression of neural elements through resection of compressive structures via an enlarged interlaminar window [1, 5, 6]. In contrast, OLIF uses a minimally invasive retroperitoneal approach to the intervertebral disc achieving indirect decompression by restoring disc height and foraminal space with a large interbody cage [2, 6].

Anatomical and procedural differences between TLIF and OLIF may lead to different safety and efficacy profiles. Previous comparative studies and meta-analyses have shown conflicting results and often did not separately analyse high-risk patients with substantial comorbidities [7–10]. Given their growing prevalence, further studies are warranted.

This study aimed to compare OLIF and TLIF regarding perioperative complications, mid-term adverse events and radiographic fusion outcomes in a retrospective cohort. As published data on frail patients remain limited, patients with comorbidities were analysed in detail.

Methods

Study cohort

This retrospective cohort study included patients who underwent one- or two-level lumbar interbody fusion at the L3–L5 levels for degenerative pathology at a tertiary spine center between 2017 and 2021. Indications included symptomatic segmental instability due to disc degeneration, degenerative spondylolisthesis, degenerative scoliosis and spinal canal stenosis, disc herniation. Exclusion criteria were prior lumbar stabilization, incomplete medical or imaging records, or non-degenerative pathologies such as trauma, tumor, or spinal infection.

67 eligible subjects who underwent OLIF were identified. To minimize confounding effects, a propensity score matching strategy was applied, and 201 subjects who underwent TLIF surgery were selected, so the final cohort consisted of 268 patients. TLIF was performed via a standard open posterior approach using PEEK or titanium interbody TLIF cage filled with autologous local bone graft, followed by transpedicular posterior screw-rod fixation. In OLIF procedures, discectomy(s) was performed via a standard left-sided retroperitoneal (anterior-to-psoas) approach. A PEEK OLIF cage filled with hydroxyapatite-based bone graft was inserted, finalized with either lateral plate or percutaneous transpedicular screw-rod fixation. All procedures used C-arm fluoroscopic guidance for visualization. The comorbid subgroup was defined based on the Charlson Comorbidity Index (CCI) [11]. Patients with a CCI score of 5 or higher were included in this sub-cohort [12, 13]. The study was approved by the Medical Research Council (29970/2015/EKU).

Data collection

Demographic, surgical, and clinical data were retrieved retrospectively from electronic records. Variables included patient demographics (age, sex, BMI), comorbidity scores (CCI, frailty index), surgical parameters (pathology, instrumentation, operative time, estimated blood loss, hospital, ICU stay), and postoperative outcomes (complications, adverse events, reoperations, radiographic fusion results) [14, 15]. Adverse events (AE) were graded by severity using the SAVES-V2 system (Spinal Adverse Events Severity System Version 2) [15].

All patients had standard pre- and postoperative radiographs. Interbody fusion was assessed on standing X-ray obtained at 1 year postoperatively (mean = 392.9 days) in 174 patients and graded on a three-level scale [16]. According to this scale, Grade 1 is complete fusion with a bone bridge between the adjacent vertebral bodies; Grade 2 means no visible bone bridge but no radiolucency around the cages with a thick fusion mass; and Grade 3 is non-union with radiolucency around the cages consistent with bone resorption/pseudoarthrosis. Achieved fusion was defined as Grade 1 or Grade 2 [16]. Although postoperative computed tomography (CT) is not routinely included in the institutional follow-up protocol, 154 patients (57.4%) had postoperative CT imaging at one year (mean = 354 days) available for detailed fusion analysis. Fusion was evaluated by the Bridwell classification in three anatomical locations: within the interbody cage, around the cage, and in the posterior column [14]. "Solid bony fusion" was defined as the presence of Bridwell Grade 1 remodelling in at least one region of the spinal segment.

Statistical analysis

Statistical analysis was performed using R-Commander and SPSS software. Continuous variables were tested for normality and compared with Welch's t-test or Mann-Whitney U-test. Categorical variables, including complication and fusion rates, were analyzed using Chi-square test or Fisher's exact test as appropriate. Risk factors for adverse events were assessed in a multivariate logistic regression model, and predictors of longer hospital stay was determined by a multivariate linear regression. A significance threshold of

$p < 0.05$ was used for all comparisons. Our total sample size was enough high to provide a 100% power to detect the difference in blood loss or operating time at alpha level of 0.05.

Results

Cohort demographics

Baseline characteristics did not differ significantly between TLIF ($n = 201$) and OLIF ($n = 67$) subgroups (Table 1). The cohort was typical for degenerative lumbar fusion population in our country, characterized by mean age of 62.7 ± 12.7 years, mean BMI was 28.8 ± 4.7 kg/m^2. Majority of patients were female in both groups (70.1%). Comorbidity burden was similar across groups, (mean Charlson Comorbidity Index (CCI) 2.49 ± 1.72). Frailty scores were comparable (0.3 ± 0.09 vs. 0.29 ± 0.11; $p = 0.77$). In the comorbid subcohort (CCI ≥ 5, $n = 32$), patients were older, but TLIF ($n = 24$) and OLIF ($n = 8$) subgroups remained demographically balanced (Supplementary Table 1).

Underlying degenerative pathologies justifying the lumbar fusion were mostly similar in TLIF and OLIF groups, with a few notable differences in prevalence (Table 1). Spinal canal stenosis was the most common indication overall and was significantly more frequent among TLIF patients (58.7%) compared to OLIF patients (43.3%; $p = 0.03$). Disc herniation was also more prevalent in the TLIF group (42.3% vs. 26.9%; $p = 0.02$). In contrast, degenerative spondylolisthesis was significantly more common in the OLIF group (55.2%) than in the TLIF group (32.8%; $p = 0.001$). Other findings were not significantly different. In the high-comorbidity subgroup (CCI ≥ 5, $n = 32$), the distribution of radiographic pathologies was more similar between TLIF and OLIF. Degenerative scoliosis was the only pathology, being significantly more prevalent in OLIF patients (50% vs. 0% in TLIF; $p < 0.002$).

Surgical characteristics

Operated-level distribution was identical between groups (Table 1). Single-level fusions accounted for 78.6% in the TLIF group and 77.6% in OLIF, the rest underwent two-level fusion. Prior decompression at the index level occurred in 22.9% of TLIF and 25.4% of OLIF patients ($p = 0.678$). Operative time and blood loss differed significantly between TLIF and OLIF. OLIF surgeries were significantly longer (mean operative time: 182.2 ± 42.2 min, compared to 135.3 ± 44.9 min for TLIF ($p < 0.001$). Conversely, TLIF procedures were associated with significantly greater

Table 1 Characterization of the cohort

	Total cohort ($n = 268$)	TLIF ($n = 201$)	OLIF ($n = 67$)
Age (year, mean ± SD)	62.7 ± 12.7	62.6 ± 12.77	62.8 ± 12.67
Weight (kg, mean ± SD)	81.2 ± 15.5	81.6 ± 16.29	81.2 ± 16.14
Height (m, mean ± SD)	1.68 ± 0.10	1.67 ± 0.09	1.66 ± 0.11
BMI (mean ± SD)	28.8 ± 4.7	29.08 ± 4.43	29.19 ± 4.33
Female (%)	188 (70.4%)	141 (70.1%)	47 (70.1%)
Male (%)	80 (29.6%)	60 (29.9%)	20 (29.9%)
Charlson Comorbidity Index (mean ± SD)	2.49 ± 1.72	2.45 ± 1.68	2.58 ± 1.84
Frailty score (mean ± SD)	0.30 ± 0.10	0.3 ± 0.09	0.29 ± 0.11
Morphological indication for surgery			
Spinal canal stenosis	147 (54.9%)	118 (58.7%)	29 (43.3%) *
Anterolisthesis	103 (38.4%)	66 (32.8%)	37 (55.2%) *
Retrolisthesis	4 (1.5%)	2 (0.9%)	2 (2.9%)
Disc herniation	103(38.4%)	85 (42.3%)	18 (26.9%) *
Degenerative scoliosis	39 (14.6%)	31 (15.4%)	8 (11.9%)
Disc degeneration	48 (17.9%)	36 (17.9%)	12 (17.9%)
Surgical details			
Previous decompression at index level	63 (23.5%)	46 (22.9%)	17 (25.4%)
Single level fusion	210 (78.4%)	158 (78.6%)	52 (77.6%)
Two-level fusion	58 (21.6%)	43 (21.4%)	15 (22.4%)
Operation time (minutes, mean ± SD)	147.0 ± 48.6	135.3 ± 44.93	182.2 ± 42.21**
Intraoperative blood loss (mL, mean ± SD)	320.5 ± 250.8	381.7 ± 255.56	133.9 ± 96.96**
Δ Hgb (g/L, range)	−16.5 (0- −84.0)	−18.8 (0- −84.0)	−9.24 (0- −40.0)*
Δ Htc (range)	−0.043 (0- −0.142)	−0.048 (0- −0.142)	−0.028 (0- −0.12)
Length of ICU stay (days, mean ± SD)	0.85 ± 0.91	1.19 ± 3.83	0.85 ± 1.18
Length of hospital stay (days, mean ± SD)	7.12 ± 3.17	7.33 ± 3.22	6.47 ± 2.92*

* $p < 0.05$, ** $p < 0.01$ comparing TLIF to OLIF

intraoperative blood loss (mean ± SD was 381.7 ± 255.6 mL vs. 133.9 ± 97.0 mL in OLIF group, $p < 0.001$). The postoperative decline (Δ) in serum haemoglobin (Hgb, g/L) and haematocrit (Hct) values were − 16.5 g/L and − 0.048 for the TLIF and −9.24 g/L and −0.028 for the OLIF cohort. The difference between TLIF and OLIF cohort was significant in change of the Hgb level ($p = 0.035$). The mean postoperative length of hospital stay was longer in TLIF patients (7.33 ± 3.22 days) compared to OLIF (6.47 ± 2.92 days; $p = 0.044$). Intensive care unit (ICU) utilization was minimal and similar in both groups (TLIF: 1.19 ± 3.83 days, OLIF: 0.85 ± 1.18 days; $p = 0.268$). In the comorbid subgroup (CCI ≥ 5), blood loss was higher in TLIF (519.6 ± 377.8 mL vs. 200.1 ± 113.1 mL; $p = 0.019$). In this frail subcohort, the mean operation time (TLIF: 151.46 ± 53.58, OLIF: 193.75 ± 49.19; $p = 0.059$) and the hospital length of stay (TLIF: 9.17 ± 5.02, OLIF: 8.88 ± 5.01; $p = 0.89$) did not differ significantly. ICU stays remained low in the comorbid subgroup (TLIF: 1.38 ± 0.8 vs. OLIF: 2 ± 2.65; $p = 0.53$).

Intraoperative complications and postoperative adverse events

Intraoperative complications were rare in both techniques. Dural tears occurred in 6 TLIF cases (3%) and none of the OLIF cases. No direct nerve root injuries occurred. Importantly, there were no intraoperative major vascular or visceral injuries in the OLIF group. (Table 2.)

Early postoperative (within 40 days) adverse event (AE) rates did not differ significantly between groups. In the total cohort, and 35 TLIF patients (17.4%) and 9 OLIF patients (13.4%) experienced at least one early postoperative adverse event. New or worsened motor symptoms occurred in 15 patients (5.6%) − 12 TLIF (5.9%) and 3 OLIF (4.5%) cases. New or worsened sensory symptoms occurred in 10 patients (3.7%) − 7 in the TLIF (3.5%) and 3 in the OLIF group (4.5%). Clinically significant postoperative radicular pain was more prevalent in the TLIF group (6.5%) compared to OLIF (1.5%) but did not differ significantly. Most resolved conservatively, but a few required reoperations (details later). Surgical site infections occurred in 8

Table 2 Intra and early postoperative (≤40 days) adverse events

	Total cohort			Comorbid subcohort		
	All patients (n = 268)	TLIF (n = 201)	OLIF (n = 67)	All patients (n = 32)	TLIF (n = 24)	OLIF (n = 8)
Number of surgeries with AEs (%)	45 (16.8%)	40 (19.9%)	9 (13.4%)	9 (28.1%)	9 (37.5%)	0
Number of intraoperative AEs	6	6	0	1	1	0
Dural tear	6 (2.2%)	6 (2.9%)	0	1 (3.1%)	1 (4.2%)	0
Nerve root injury	0	0	0	0	0	0
Vascular injury	0	0	0	0	0	0
Visceral injury	0	0	0	0	0	0
Number of surgeries with AEs (%)	44 (16.4%)	35 (17.4%)	9 (13.4%)	8 (25.0%)	8 (33.3%)	0
Number of early postoperative AEs	67	52	15	14	14	0
Surgical site infection	8 (2.9%)	7 (3.5%)	1 (1.5%)	2 (6.3%)	2 (8.3%)	0
Wound hematoma	1 (0.4%)	0 (0.0%)	1 (1.5%)	0	0	0
Peritoneal pain	1 (0.4%)	0 (0.0%)	1 (1.5%)	0	0	0
Motor symptoms	15 (5.6%)	12 (5.9%)	3 (4.5%)	3 (9.4%)	3 (12.5%)	0
Sensory symptoms	10 (3.7%)	7 (3.5%)	3 (4.5%)	1 (3.1%)	1 (4.2%)	0
Radicular pain (treated at least conservatively)	14 (5.2%)	13 (6.5%)	1 (1.5%)	4 (12.5%)	4 (16.7%)	0
Blood loss indicating transfusion	8 (3.0%)	6 (3.0%)	2 (3.0%)	2 (6.3%)	1 (4.2%)	1 (12.5%)
UTI	2 (0.7%)	2 (0.9%)	0	0	0	0
Dyspnoea	1 (0.4%)	1 (0.5%)	0	0	0	0
Deep vein thrombosis	0	0	0	0	0	0
Pulmonary embolism	0	0	0	0	0	0
Retroperitoneal fluid (seroma)	1 (0.4%)	0	1 (1.5%)	0	0	0
Implant related complications						
Screw malposition	4 (1.5%)	2 (1.5%)	2 (2.9%)	1 (3.1%)	1 (4.2%)	0
Screw loosening/pull out	3 (1.1%)	3 (1.5%)	0	1 (3.1%)	1 (4.2%)	0
Cage/plate subsidence/loosening	4 (1.5%)	2 (1.0%)	2 (4.5%)	1 (3.1%)	1 (4.2%)	0
Autograft migration	1 (0.4%)	1 (0.5%)	0	0	0	0
Severity of early postoperative AEs (SAVES-V2)						
1	16	11	5	1	1	0
2	20	16	4	4	4	0
3	31	25	6	9	9	0

Table 3 Significant predictors of early postoperative AEs

Predictors of early postoperative AEs	Multivariate logistic regression (Enter method)				Multivariate logistic regression (Backward stepwise method)			
	B (SE)	Wald	OR	*p*	B (SE)	Wald	OR	*p*
TLIF vs. OLIF	−0.065 (0.628)	0.011	0.938	0.918				
Age (year)	0.058 (0.027)	4.77	1.060	**0.029**	0.059 (0.018)	10.54	1.06	**0.001**
Sex	0.012 (0.554)	0.000	1.012	0.983				
Height (cm)	−0.241 (0.119)	4.27	0.000	**0.039**	−0.218 (0.114)	3.69	0.000	0.055
Weight (kg)	0.258 (0.118)	4.73	1.294	**0.030**	0.228 (0.113)	4.06	1.26	**0.044**
BMI (kg/m2)	−0.734 (0.337)	4.75	0.480	**0.029**	−0.666 (0.33)	4.24	0.514	**0.040**
CCI	0.139 (0.211)	0.435	1.149	0.510				
Frailty score	−4.291 (2.711)	2.51	0.014	0.113				
ASA score	−0.049 (0.508)	0.009	0.952	0.923				
Single vs. two-level fusion	0.167 (0.448)	0.139	1.182	0.709				
Operation time (min)	−0.002 (0.005)	0.252	0.998	0.616				
Blood loss (every 100 ml)	0.2 (0.1)	4.87	1.2	**0.027**	0.2 (0.1)	8.395	1.2	**0.004**
Transfusion (RBC)	0.255 (0.876)	0.085	1.290	0.771				

patients (2.9 (7 (3.5%) TLIF and 1 (1.5%) OLIF cases). Urinary tract infections and transfusion-requiring postoperative blood occurred in 2 TLIF cases (0.9%), and none in the OLIF group. Other rare events - wound hematoma ($n=1$), peritoneal pain ($n=1$), retroperitoneal seroma ($n=1$) - were reported only in the OLIF cohort and one TLIF patient had dyspnoea. No cases of deep vein thrombosis or pulmonary embolism were observed in either group.

Objectively verifiable implant-related complications were documented 12 times in the total cohort. Cage subsidence/loosening was identified in 4 patients (2 TLIF, 2 OLIF), screw malposition was seen in 4 cases (2 TLIF, 2 OLIF). Screw loosening or pull out was noted only in the TLIF group (3 cases, 1.5%), as well as autograft migration to the spinal canal occurred in one TLIF case (0.5%). Regarding the categorization of AEs by SAVES-V2, the ratio of grades did not show significant difference. Most AEs were low-grade and self-limiting (1st, 2nd grade), some were moderate (3rd grade). No severe (4th −6th grade) AE occurred in the cohort.

AEs were more frequent in the comorbid subcohort (25% vs. 16.4% in patients with CCI≥5 vs. patients with CCI<5) but this difference was not significant (Chi-square=1.95, $p=0.163$). All AEs in this subcohort occurred in the TLIF subgroup (8 TLIF patients vs. 0 OLIF patient).

Predictors for AEs and longer hospital stay

Effect of 13 perioperative variables on the risk of AEs were analyzed in multivariate logistic regression models (Table 3). Applying enter method, older age, height, weight, BMI and intraoperative blood loss showed significant risk and the same predictors consisted of the final backward stepwise model (Table 3). Using the predicted individual

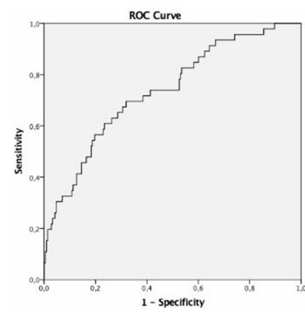

Fig. 1 ROC curve representing the discriminating power of the final regression model

values from the final significant regression model (Chi-square=30.73, df=5, $p<0.001$), a ROC (Receiver Operating Curve) analysis was conducted. AUC (Area Under the Curve) was 0.735 demonstrating a clinically applicable and significant ($p<0.001$) risk prediction capability (Fig. 1).

The occurrence of any AE was the only significant predictor for longer hospital stay in the multiple linear regression model built by enter method. The final backward stepwise model consisted of 3 more predictors namely CCI, ASA score and intraoperative blood loss (F=22.47, $p<0.001$ for the final model) (Table 4).

Reoperations

Early reoperation rates (within 40 days) did not differ significantly between groups. In the total cohort, 8 TLIF patients (4.0%) underwent a reoperation compared to 3 OLIF patients (4.5%) ($p=1$) (Table 5). Wound related reoperations (superficial debridement and re-suture) were needed in 2 TLIF cases. Additional decompression for residual stenosis or disc herniation was performed in 3 TLIF patients and 1 OLIF patient. Implant or bone graft related indication occurred in 3 TLIF and 1 OLIF cases and one OLIF patient

Table 4 Result of multiple liner regression models on LOS

Predictors of LOS	Multiple linear regression (Enter method)			Multiple linear regression (Backward stepwise method)		
	B(SE)	t	*p*	B(SE)	t	*p*
(Constant)	3.257	0.160	0.873	6.24 (0.882)	7.08	0.000
Surgery with AE	2.09 (0.468)	4.480	**0.000**	2.16 (0.452)	4.78	**<0.001**
TLIF vs. OLIF	0.465 (0.577)	0.806	0.421			
Age (year)	0.039 (0.027)	1.466	0.144			
Sex	−0,656 (0.535)	−1.227	0.221			
Height (cm)	0.008 (0.118)	0.068	0.946			
Weight (kg)	−0.014 (0.117)	−0.118	0.906			
BMI (kg/m2)	0.061 (0.33)	0.185	0.853			
CCI	0.365 (0.208)	1.757	0.080	0.645 (0.11)	5.88	**<0.001**
Frailty score	2.103 (2.47)	0.852	0.395			
ASA score	−0.858 (0.471)	−1.821	0.070	−0.833 (0.446)	−1.87	0.063
Single vs. two-level fusion	−0.070 (0.456)	−0.153	0.879			
Operation time (min)	−0.002 (0.005)	−0.493	0.623			
Blood loss (every 100 ml)	0.153 (0.097)	1.580	0.115	0.183 (0.068)	2.69	**0.008**
Transfusion (RBC)	0.381 (1.007)	0.379	0.705			

Table 5 Reoperations in the study cohort

	Total cohort (*n*=268)	TLIF (*n*=201)	OLIF (*n*=67)
Reoperation less than 40 days after the surgery	11 (4.1%)	8 (3.0%)	3 (4.5%)
Re-suture the dehiscence	2 (0.7%)	2 (0.9%)	0 (0.0%)
Decompression	4 (1.5%)	3 (1.5%)	1 (1.5%)
Implant revision			
Malposition	2 (0.7%)	1 (0.5%)	1 (1.5%)
Cage subsidence	1 (0.3%)	1 (0.5%)	0 (0.0%)
Autograft migration	1 (0.3%)	1 (0.5%)	0 (0.0%)
Additional transpedicular fixation	1 (0.3%)	0 (0%)	1 (1.5%)
Reoperation between the 40-365th days	13 (4.8%)	11 (5.5%)	2 (3.0%)
Fusion extension	6 (2.2%)	4 (1.9%)	2 (3.0%)
Decompression	3 (1.1%)	3 (1.5%)	0 (1.5%)
Restabilization/refusion	2 (0.7%)	2 (0.9%)	0 (0%)
Implant revision			
Malposition	1 (0.3%)	1 (0.5%)	0 (0.0%)
Loosening	1 (0.3%)	1 (0.5%)	0 (0.0%)

No significant difference between TLIF and OLIF cohort

stabilized with an anterior plate had to get an additional transpedicular fixation.

In longer term (between the postoperative 40th day and 1 st year), the cumulative reoperation incidence remained comparable ($p=0.548$). 11 further reoperations (5.5% of 201) occurred in TLIF group and 2 reoperations (3% of 67) in OLIF patients. The most common indication was extension of the fusion to adjacent levels due to adjacent segment degeneration (4 TLIF patients (2.0%) and 2 OLIF patients (3.0%)). Decompression at the index or adjacent level was done in 3 TLIF (1.5%). 2 TLIF patients (1.0%) underwent restabilization/refusion procedure and 2 other TLIF patients required a revision of the implants. Overall reoperation rate within one year was similar in case of the two fusion techniques (9.4% in TLIF and 7.4% in OLIF subgroups, Chi-square=0.244, $p=0.621$).

Radiographic fusion outcome

Both TLIF and OLIF achieved high overall fusion rates on CT scans by 1 year, but the location of solid bony fusion (inside vs. around the cage) differed markedly between the fusion techniques (Table 6). Solid intervertebral fusion was confirmed in 90.9% of TLIF and 91.5% of OLIF patients. Complete fusion inside the cage was observed in 83.0% of OLIF cases but only 47.3% of TLIF cases. In contrast, TLIF patients more frequently developed solid fusion around the cage in the intervertebral space (72.7% of TLIF cases compared to 34.0% of OLIF cases. The incidence of fusion at the posterior elements was high in both groups and did not differ significantly (71.8% of TLIF and 82.9% of OLIF patients).

Interbody fusion at 1-year follow-up was achieved in vast majority of the cases based on the X-ray measurements (Table 7) (92.5% in the TLIF group and 87.0% in the OLIF group). However, when fusion status was stratified by grade on X-rays, the distribution differed significantly. Grade 1 fusion at 1-year follow-up was more frequent after TLIF (86.7%) than OLIF (62.9%) ($p<0.001$), whereas Grade 2 fusion occurred more often after OLIF (24.1%) than TLIF (5.8%) ($p<0.001$). The proportion of non-union (Grade 3) was numerically higher in the OLIF cohort (13.0%) than in the TLIF cohort (6.7%), but this difference did not reach statistical significance ($p=0.1710$).

Table 6 Fusion Outcome on 1-year-postoperative CT ($N=157$)

	TLIF ($n=110$)	OLIF ($n=47$)	Chi-square	p-value
Solid fusion*	100 (90.9%)	43 (91.5%)	0.014	0.906
fusion in the cage **	52 (47.3%)	39 (83.0%)	17.23	**<0.001**
fusion around the cage **	80 (72.7%)	16 (34.0%)	20.74	**<0.001**
posterior column fusion **	79 (71.8%)	39 (82.9%)	2.19	0.138

*Bridwell I in any of the regions ** Bridwell I or II

Table 7 Interbody fusion Outcome on 1-year postoperative X-ray ($N=174$)

	TLIF ($n=120$)	OLIF ($n=54$)	Chi-square	p-value
Achieved fusion	111 (92.5%)	47 (87%)	1.33	0.2486
Grade 1	104 (86.7%)	34 (62.9%)	12.75	**<0.001**
Grade 2	7 (5.8%)	13 (24.1%)	12.18	**<0.001**
Non-union (Grade 3)	8 (6,7%)	7 (13.0%)	1.87	0.1710

Discussion

The safety and biological effectiveness of TLIF and OLIF were not significantly different in this retrospective cohort study. No significant differences were found in complication, adverse events, reoperation, and one-year radiographic fusion rate. AEs rate was not significantly higher in the comorbid patient group suggesting that both fusion approaches are similarly safe in frail patients too. OLIF was associated with significantly lower intraoperative blood loss, significantly smaller perioperative decline of serum Hgb level and shorter hospital stay, TLIF was performed with significantly shorter operative time. These results align with prior studies showing OLIF's perioperative advantages—less blood loss and shorter hospitalization—due to its minimally invasive, indirect decompression approach [9, 17–19]. However, these advantages do not appear to translate into superior overall outcomes, complication rates, or fusion success [7, 9]. In our cohort, OLIF patients stayed approximately one day less in the hospital than TLIF patients. LOS is a multifactorial parameter which is important and relevant both medically and financially. Analyzing the predictors for longer hospital stay, we revealed that LOS was not influenced by the surgical technique, but the patients' general health status (CCI/ASA score), the occurrence of any AE and the intraoperative blood loss. Thus, OLIF's reduced blood loss may partly explain its shorter LOS.

AEs had a significant influence on LOS in our general lumbar fusion patient population but again, risk for any AE was not related to the type of surgical procedure in the multivariate models. Risk for any AE was associated with the age of the patient, the body shape, and the intraoperative blood loss. This multivariate model showed good clinical discriminatory power characterized by an AUC of 0.735. Based on the detailed analysis of general, common surgical and procedure specific AEs, we can conclude that both surgical techniques are safe, characterized by very low percentage of serious complications (0% of SAVES 4–6). The same similarly low complications profile was observed in patients characterized by high comorbidity [20–23].

Several meta-analyses have reported equivalent or longer operative times for TLIF compared to OLIF [7, 9, 10, 23]. In contrast, the shorter operative times observed for TLIF in our study may reflect also to local circumstances, especially the patient-repositioning-time and the use of intraoperative navigation/visualization system. Despite these procedural differences, both surgical approaches demonstrated equivalent safety profiles and fusion efficacy.

Both TLIF and OLIF have excellent efficiency for achieving arthrodesis in degenerative lumbar conditions. The notable difference was in how the fusion was achieved, OLIF patients more often had solid fusion through the interbody cage, whereas TLIF patients more often had fusion bridging outside the cage in the interbody space. When considering posterior elements, facet joints, there was no significant difference in success. This suggests that both surgical techniques frequently achieved fusion as well between the posterior column elements, such as the facet joints. The fusion rates observed in our study (CT: 90.9% in TLIF and 91.5% in OLIF, X-ray: 92.5% in TLIF, 87% in OLIF) are consistent with the high rates reported in the literature for both techniques [9, 24].

Importantly, our study included a cohort of medically complex patients, a population that is often underrepresented in spine surgery trials. The comparable complication rates in this subgroup suggest that both lumbar fusion techniques could be safe and effective options for patients with multiple comorbidities, expanding their applicability in clinical practice [25]. The difference in the LOS between TLIF and OLIF has been diminished in this comorbid subgroup underlying that LOS after lumbar fusion can be more related to the patient's general status and comorbidities than the surgical technique [26].

Clinical implications

Although anatomical access differences between TLIF and OLIF could theoretically influence adverse events and fusion patterns, our data did not support this assumption. Given similar complication, reoperation, and fusion rates, choice between OLIF and TLIF may depend on individual surgeon expertise and patient-specific anatomical factors. OLIF may benefit patients suited for a minimally invasive anterior approach or require realignment, whereas TLIF is preferable when direct decompression or posterior access is needed.

These findings support a personalized surgical approach, confirming both techniques are safe and effective when appropriately selected.

Strengths and limitations

Key strengths of this study include its relatively large sample size and the one-year X-ray and CT-based fusion assessment using defined criteria. Additionally, all surgeries were performed in a high-volume center, which likely minimized variability in technique and perioperative care. However, the retrospective study design inherently limits control of confounders and bias. Despite balanced baseline, unmeasured factors, such as surgeon preference and anatomical case selection, cannot be excluded. Long-term functional outcomes (pain relief, quality of life scores) were not systematically collected and remain areas for future investigation.

Conclusion

This study demonstrated that both TLIF and OLIF are safe and effective fusion techniques for treating lumbar degenerative instability. Despite differences in surgical parameters, such as reduced blood loss, less decline in Hgb level and shorter hospital stay with OLIF, shorter operative time with TLIF, no significant differences were observed in complication rates, reoperation frequency, or one-year radiographic fusion success.

Results were consistent in patients with high comorbidity (CCI$\geq$5), suggesting both techniques could be feasible and safe even in medically complex populations. Given comparable safety profiles and fusion outcomes, the choice between OLIF and TLIF should depend on surgeon expertise and the patient specific anatomical considerations to optimize individual surgical care.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Conflict of interests The authors declare no competing interests.

References

1. Mobbs RJ, Phan K, Malham G, Seex K, Rao PJ et al (2015) Lumbar interbody fusion: techniques, indications and comparison of interbody fusion options including PLIF, TLIF, MI-TLIF, OLIF/ATP, LLIF and ALIF. J Spine Surg 1(1):2–18. https://doi.org/10.3978/j.issn.2414-469X.2015.10.05
2. Wong AXJ, Tang DH, Kaliya-Perumal AK, Oh JYL (2024) The evolution of lateral lumbar interbody fusion: a journey from past to present. Medicina 60(3):378. https://doi.org/10.3390/medicina60030378
3. Silvestre C, Mac-Thiong JM, Hilmi R, Roussouly P (2012) Complications and morbidities of mini-open anterior retroperitoneal lumbar interbody fusion: oblique lumbar interbody fusion in 179 patients. Asian Spine J 6(2):89–97. https://doi.org/10.4184/asj.2012.6.2.89
4. Mayer HM (1997) A new microsurgical technique for minimally invasive anterior lumbar interbody fusion. Spine (Phila Pa 1976) 22:691–700. https://doi.org/10.1097/00007632-199703150-00023
5. Schnake KJ, Rappert D, Storzer B, Schreyer S, Hilber F, Mehren C (2019) Lumbar fusion—indications and techniques. Orthopade 48:50–58. https://doi.org/10.1007/s00132-018-03670-w
6. Yoshihara H (2017) Indirect decompression in spinal surgery. J Clin Neurosci 44:63–68. https://doi.org/10.1016/j.jocn.2017.06.061
7. Lin GX, Xu WB, Kotheeranurak V, Chen CM, Deng ZH, Zhu MT (2023) Comparison of oblique and transforaminal approaches to lumbar interbody fusion for lumbar degenerative disease: an updated meta-analysis. Front Surg 9:1004870. https://doi.org/10.3389/fsurg.2022.1004870
8. Xiao X, Duan H, Pan X, Zhao H (2024) Fusion rate and complications of oblique lumbar interbody fusion and transforaminal lumbar interbody fusion in the treatment of lumbar degenerative diseases: a meta-analysis. Front Surg 11:1374134. https://doi.org/10.3389/fsurg.2024.1374134
9. Shi J, Wu H, Li F, Zheng J, Cao P, Hu B (2024) Meta-analysis of the efficacy and safety of OLIF and TLIF in the treatment of degenerative lumbar spondylolisthesis. J Orthop Surg Res 19:4703. https://doi.org/10.1186/s13018-024-04703-1
10. Yang W, Pan X, Wang Y, Chen W (2022) Comparative meta-analysis of the effects of OLIF and TLIF in lumbar spondylolisthesis

central nerve injury. Comput Intell Neurosci 2022:6861749. https://doi.org/10.1155/2022/6861749
11. Charlson ME, Pompei P, Ales KL, MacKenzie CR (1987) A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. J Chronic Dis 40:373–383. https://doi.org/10.1016/0021-9681(87)90171-8
12. Khechen B, Haws BE, Bawa MS, Patel DV, Cardinal KL, Guntin JA et al (2019) The impact of comorbidity burden on complications, length of stay, and direct hospital costs after minimally invasive transforaminal lumbar interbody fusion. Spine (Phila Pa 1976) 44:363–368. https://doi.org/10.1097/brs.0000000000002834
13. Lenga P, Gülec G, Bajwa AA, Issa M, Kiening K, Ishak B et al (2022) Spinal meningioma surgery in octogenarians: functional outcomes and complications over a 2-year follow-up period. Medicina 58:101481. https://doi.org/10.3390/medicina58101481
14. Bridwell KH, Lenke LG, McEnery KW, Baldus C, Blanke K (1995) Anterior fresh frozen structural allografts in the thoracic and lumbar spine: do they work if combined with posterior fusion and instrumentation in adult patients with kyphosis or anterior column defects? Spine (Phila Pa 1976) 20(12):1410–1418
15. Rampersaud YR, Anderson PA, Dimar JR, Fisher CG (2016) Spinal adverse events severity system, version 2 (SAVES-V2): inter- and intraobserver reliability assessment. J Neurosurg Spine 25:256–263. https://doi.org/10.3171/2016.1.spine14808
16. Ito Z, Imagama S, Kanemura T, Hachiya Y, Miura Y, Kamiya M, Yukawa Y, Sakai Y, Katayama Y, Wakao N, Matsuyama Y, Ishiguro N (2013) Bone union rate with autologous iliac bone versus local bone graft in posterior lumbar interbody fusion (PLIF): a multicenter study. Eur Spine J 22(5):1158–1163. https://doi.org/10.1007/s00586-012-2593-4
17. Ahmad SR, Jain M, Sahoo A, Mishra NP, Singh N, Dansana SK (2024) A comparative study of perioperative pain, blood loss, and hospital stay in an Indian population undergoing mini-open oblique lumbar interbody fusion versus open transforaminal lumbar interbody fusion. Int J Crit Illn Inj Sci 14:37–42. https://doi.org/10.4103/ijciis.ijciis_59_23
18. Huang Q, Zhu W, Cui P, Wang S, Han D, Wang P et al (2025) A retrospective cohort study comparing perioperative clinical outcomes and radiographic results between patients undergoing TLIF and OLIF surgeries. BMC Surg 25:2920. https://doi.org/10.1186/s12893-025-02920-x
19. Li R, Shao X, Li X, Liu Y, Jiang W (2021) Comparison of clinical outcomes and spino-pelvic sagittal balance in degenerative lumbar spondylolisthesis: minimally invasive oblique lumbar interbody fusion (OLIF) versus transforaminal lumbar interbody fusion (TLIF). Medicine 100:e23783. https://doi.org/10.1097/md.0000000000023783
20. Jin C, Jaiswal MS, Jeun SS, Ryu KS, Hur JW, Kim JS (2018) Outcomes of oblique lateral interbody fusion for degenerative lumbar disease in patients under or over 65 years of age. J Orthop Surg Res 13:38. https://doi.org/10.1186/s13018-018-0740-2
21. Pham MH, Hassan O, Diaz-Aguilar LD, Lehman RA (2021) Complications associated with oblique lumbar interbody fusion at L5-S1: a systematic review of the literature. Neurosurg Open 2:okab018. https://doi.org/10.1093/neuopn/okab018
22. Wu J, Ao J, Xu Z, Li G, Ge T, Wang Y et al (2023) Comparisons of oblique lumbar interbody fusion and transforaminal lumbar interbody fusion for degenerative spondylolisthesis: a prospective cohort study with a 2-year follow-up. Front Surg 10:1115823. https://doi.org/10.3389/fsurg.2023.1115823
23. Chang MC, Kim GU, Choo YJ, Lee GW (2021) Transforaminal lumbar interbody fusion (TLIF) versus oblique lumbar interbody fusion (OLIF) in interbody fusion technique for degenerative spondylolisthesis: a systematic review and meta-analysis. Life 11:696. https://doi.org/10.3390/life11070696
24. Chen D, Liu T, Du K, Zhu Z (2024) Comparative analysis of the efficacy of oblique lateral interbody fusion versus transforaminal lumbar interbody fusion in the treatment of lumbar disc herniation. Sci Rep 14:81261. https://doi.org/10.1038/s41598-024-81261-w
25. Lee YM, Son DW, Oh BK, Lee SH, Lee JS, Kim YH et al (2023) Outcomes and complications of oblique lateral interbody fusion as a surgical option in elderly patients (over 70 years old) with degenerative spinal disease. Nerve 9:109–117. https://doi.org/10.21129/nerve.2023.00346
26. Baek W, Park SY, Kim Y (2023) Impact of frailty on the outcomes of patients undergoing degenerative spine surgery: a systematic review and meta-analysis. BMC Geriatr 23:4448. https://doi.org/10.1186/s12877-023-04448-2