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Clinical Study

Fusion technique does not affect short-term patient-reported outcomes for lumbar degenerative disease

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Abstract **BACKGROUND/CONTEXT:** Degenerative lumbar disease can be addressed via an anterior or posterior approach, and with or without the use of an interbody cage. Although several studies have compared the type of approach and technique, there is a lack of literature assessing patient-reported outcome measures (PROMs) and radiographic parameters between different fusion techniques.

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PURPOSE: To determine whether the surgical approach and fusion technique for lumbar degenerative disease had an effect on short-term PROMs and radiographic parameters.
STUDY DESIGN/SETTING: Retrospective Cohort Study.
PATIENT SAMPLE: Three hundred and ninety-one patients who underwent a 1−3 level lumbar spine fusion procedure at a high-volume academic center were retrospectively identified. Patients were divided into three groups based on the type of fusion they underwent: posterolateral fusion (PLF), anterior lumbar interbody fusion (ALIF), or transforaminal lumbar interbody fusion (TLIF).
OUTCOME MEASURES: PROMs: Short Form-12 (SF-12) Physical Component Score (PCS) and Mental Component Score (MCS), Oswestry Disability Index (ODI), Visual Analog Score (VAS) Back, VAS Leg. Spinopelvic measurements: Pelvic Tilt (PT), Sacral Slope (SS), Pelvic Incidence (PI), Lumbar Lordosis (LL), Segmental Lordosis (SL), PI−LL mismatch.
METHODS: Patients with less than 1-year follow-up were excluded from the cohort. Pre- and postoperative spinopelvic measurements were obtained for all patients. Univariate analysis (Chi-squared/Fisher's exact test or ANOVA test with post-hoc Bonferroni test) was used to compare among the three groups in the PROMs and radiographic spinopelvic parameters. Multiple linear regression was used to determine if fusion technique was an independent predictor of change in each patient outcome.
RESULTS: Two hundred and sixteen patients were included in the PLF group, 33 patients in the ALIF group, and 142 patients in the TLIF group. The PLF group was significantly older at baseline ($p<.001$) and had lower preoperative diagnosis rates of degenerative scoliosis and disc herniations ($p<.001$), whereas the ALIF group underwent a higher proportion of three-level fusions ($p<.001$). There was no significant difference in spinopelvic parameters preoperatively, however the ALIF group showed significantly more improvement in SL postoperatively ($p=.004$) than the PLF and TLIF groups. Within each group, SL improved for the PLF and ALIF groups ($p=.002$ for both), but not for the TLIF group ($p=.238$). Comparing patient outcomes, the ALIF group reported lower preoperative VAS Leg scores ($p=.031$), however, this difference resolved postoperatively. Stratifying for preoperative diagnosis, there were no significant differences in outcomes, except for a greater improvement in VAS Leg scores for degenerative scoliosis patients undergoing ALIF. Using multivariate analysis, fusion technique was not found to be a significant predictor of change in any patient outcome or in odds of revision.
CONCLUSIONS: Lumbar degenerative disease can be treated with several different fusion techniques, however, the relationship between type of fusion and PROMs is not established. Based on the findings in this study, the ALIF group showed greater improvement in SL compared with the PLF and TLIF groups, however, there was no difference noted in overall LL, PI−LL mismatch or other spinopelvic parameters. Despite these radiographic findings, patient outcome measures remained similar between all three fusion types.

Keywords: ALIF; Lumbar approach; Lumbar fusion; Patient reported outcome measures; PLF; PROM; Spinopelvic parameters; TLIF

Introduction

Lumbar fusion is one of the most common procedures performed annually in the United States. Each year, over 450,000 cases are performed and the rate of elective lumbar fusions is increased 32.1% over the last decade [1]. Lumbar decompression and fusion is a common technique for treatment of degenerative lumbar disease, including spondylolisthesis, degenerative scoliosis, and spinal stenosis. Traditionally, a posterior approach with posterolateral fusion (PLF) was the mainstay approach and technique [2]. First described by Watkins in 1953, PLF refers to obtaining fusion between lumbar motion segments by placing bone graft in the posterolateral aspect of the spine, lateral to the laminae, and dorsal to the transverse processes [3]. With the advent of hook constructs and subsequently pedicle screw fixation, the addition of segmental instrumentation has increased the rigidity of this construct and increased fusion rates [4].

Interbody fusions were initially developed as a means of treatment for lumbar spondylolisthesis [5]. This technique has the added benefit of anterior column support to increase surface area for fusion. Theoretically, this leads to increased correction, lower rates of pseudarthrosis, and less hardware failure [5]. Among the different types of interbody fusion techniques, anterior lumbar interbody fusion (ALIF) and transforaminal interbody fusion (TLIF) are the most frequently used. The advantages of an ALIF include an anterior exposure to the lumbar spine that allows direct visualization of the pathologic disc space, anterior ligamentous release, and placement of an interbody device or allograft with the largest possible footprint without disruption of posterior stabilizing structures and without risking damage to the neural elements. Contrarily, TLIF involves a posterior approach and necessitates a facetectomy to allow for access to the interbody space with limited retraction on the neural elements. Compared with the ALIF, however, the TLIF approach minimizes the risk of vascular injury. Both of these techniques can indirectly decompress the neural foramen after placement of an interbody device, whereas PLF requires direct decompression of the lamina and foramen.

Although clinical outcomes such as complication rates and fusion rates for each technique have been widely reported, few studies have compared spinopelvic parameters between each technique and included patient reported outcome measures (PROMs) as a primary endpoint for patients with all types of lumbar disease. In the existing literature, ALIF has been shown to significantly increase lumbar lordosis (LL) compared with TLIF but have equivalent pain and disability outcomes [6,7]. When comparing TLIF with PLF, initial studies suggested better restoration of LL with TLIF, however, recent studies have shown no differences between the two methods [8−10]. To date, only one study has considered Pelvic Incidence (PI) and LL mismatch (PI−LL) as an outcome measure when analyzing the differences between fusion techniques but it did not consider PROMs [11]. Optimizing PI−LL mismatch and restoration of overall sagittal alignment is associated with improved patient outcomes and satisfaction rates in the spine deformity literature, but literature is lacking in short-segment fusions for degenerative disease [12]. The aim of this study is to analyze the differences in short-term PROMs and spinopelvic parameters after lumbar fusions for degenerative disease with three different techniques: ALIF, TLIF, and PLF.

Materials and methods

Institutional Review Board approval was obtained before the start of the study. Patients undergoing lumbar decompression and fusion surgery for degenerative disease between January 2016 and December 2017 at a high-volume, single-center academic hospital were retrospectively identified. Inclusion criteria for the study were patients over the age of 18 years undergoing fusion between 1 and 3 levels with an ALIF (with subsequent open or minimally invasive posterior fusion on the same day), TLIF, or PLF approach, those with simultaneous decompression at 1-5 levels, and those with a preoperative diagnosis of degenerative spondylolisthesis, degenerative scoliosis, or recurrent disc herniation were included. Patients with a history of previous surgery, active infection, tumor, or trauma and patients with less than 1-year follow-up were excluded. Basic demographic data including age, sex, body mass index, months followed-up, duration of preoperative lumbar symptoms (<3 months, 3−6 months, or >6 months), smoking status (never, current, and former), number of levels fused and decompressed, number of levels with interbody cage, and revision status were noted.

Outcomes data collected included both PROMs and radiographic measurements preoperative and postoperatively. PROMs collected included Short Form-12 Physical Component Score, Mental Component Score, Oswestry Disability Index (ODI), Visual Analog Scale Back pain score (VAS Back), and VAS leg pain score (VAS Leg). Recovery ratio (RR; %) for each outcome was calculated using (change in score/(optimal score − baseline score)) × 100, where optimal score was defined as 100 for Physical Component Score and Mental Component Score and 0 for ODI, VAS Back pain, and VAS Leg pain. The percentage of patients achieving Minimal Clinically Important Difference (MCID) for each outcome was also noted.

All radiographic measurements were performed on lateral lumbar radiographs using Sectra Workstation IDS7 18.2 (Sectra AB; Linköping, Sweden) and included four spinopelvic parameters: Pelvic Tilt, Sacral Slope, PI, LL, and Segmental Lordosis (SL). Pelvic Tilt was measured as the angle between the vertical line and the line joining the middle of the sacral plate to the center of the bicoxo-femoral axis. Sacral Slope was measured as the angle subtended by a line through the sacral endplate and a horizontal reference line. Pelvic Incidence was measured as the angle between the line perpendicular to the middle of the cranial sacral endplate and the line joining the middle of the cranial sacral endplate to the center of the bicoxo-femoral axis. LL was measured from the superior endplate of L1 to the superior endplate of S1. Segmental Lordosis was measured from the superior endplate of the cephalad fusion level to the inferior endplate of the caudal fusion level. The difference between PI and LL was designated as the PI−LL mismatch and was measured pre- and postoperatively. A single threshold for mismatch was not used to dichotomize, however the magnitude of mismatch was compared between patients on a continuous scale. Patients were separated into three groups based on the fusion technique: ALIF, TLIF, or PLF.

Standard descriptive statistics including mean and 95% confidence interval were used to represent demographic and outcomes data. Normality of the outcome scores was assessed using skewness, kurtosis, and the Shapiro-Wilk test. For normally distributed outcome scores, a one-way ANOVA test with a Bonferroni post-hoc test was used to compare means between groups and a paired *t* test was used to compare change in perioperative radiographic parameters within groups. For non-normally distributed outcome scores, a Kruskal-Wallis test with a Dunn post-hoc test was used to compare means between groups. Pearson's chi-squared test or Fisher's exact test were used to compare categorical outcomes. A multiple linear regression was done to determine the effect of fusion technique on patient outcomes and a multiple logistic regression was done to determine the effect of fusion technique on odds of revision controlling for all demographic and operative variables. All statistical analyses were performed using Statistical Package for the Social Sciences version 24 (IBM Corporation, Armonk, NY, USA). A p value <.05 was considered to be statistically significant.

Results

Patient population

A total of 391 patients were included, with 216 in the PLF group, 33 in the ALIF group, and 142 in the TLIF group. Average age for the entire cohort was 62.4 years, with average body mass index of 30.5, and average follow-up of 13.6 months. There were 179 women (45.8%) and 212 men (54.2%) included. Patients had an average number of 1.36 levels fused and 1.88 levels decompressed. Table 1 shows the baseline characteristics for all three groups. There was a significant difference between groups with respect to age, preoperative diagnosis, number of levels fused, and number of levels with interbody cage. Patients in the PLF group were significantly older than the ALIF group (64.7 years vs. 57.2 years, p=.006) as well as the TLIF group (64.7 vs. 61.1 years, p=.008). However, the ALIF and TLIF groups were not significantly different in age (57.2 vs. 61.1 years, p=.592). There was a significant difference between groups with regards to preoperative diagnosis (p<.001), with patients in the ALIF and TLIF groups having a higher rate of degenerative scoliosis (27.3% and 17.6%, respectively) and disc herniation (6.0% and 7.0%, respectively). A higher proportion of patients in the TLIF group had two-level fusions (33.8%), whereas a higher proportion of patients in the ALIF group had three-level fusions (36.4%; p≤.001). The ALIF group had a higher proportion of patients with interbody cages at three levels (p≤.001).

Patient reported outcome measures

There were no significant differences between surgical groups with regards to PROMs, either pre- or postoperatively, except for preoperative VAS Leg scores (p=.031, Table 2). Post-hoc analysis showed that patients in the ALIF group had significantly lower pain scores (4.7) compared the TLIF group (6.4, p=.026) and a trend towards significance in lower pain levels compared with the PLF group

Table 1
Baseline characteristics

	PLF n = 216	ALIF n = 33	TLIF n = 142	p value
Age (y)	64.7 [63.3, 66.2]	57.2 [52.2, 62.1]	61.1 [59.1, 63.1]	.001*
Sex				
Males	119 (55.0%)	18 (54.5%)	75 (52.8%)	.914
Females	97 (45.0%)	15 (45.5%)	67 (47.2%)	
BMI	30.6 [29.8, 31.4]	29.8 [27.8, 31.8]	30.4 [29.4, 31.4]	.585
Smoking				
Never	154 (71.3%)	24 (72.7%)	86 (60.6%)	
Former	11 (5.1%)	2 (6.1%)	17 (12.0%)	.103
Current	51 (23.6%)	7 (21.2%)	39 (27.4%)	
Follow-up (mo)	13.8 [13.1, 14.6]	13.1 [12.6, 13.6]	13.2 [12.6, 13.7]	.773
Duration of symptoms				
<3 months	116 (53.7%)	16 (48.5%)	84 (59.2%)	
3−6 months	53 (24.5%)	10 (30.3%)	39 (27.5%)	.327
>6 months	47 (21.8%)	7 (21.2%)	19 (13.3%)	
Preoperative diagnosis				
Spondylolisthesis	191 (88.4%)	22 (66.7%)	107 (75.4%)	
Scoliosis	23 (10.6%)	9 (27.3%)	25 (17.6%)	<.001*
Disc herniation	2 (1.0%)	2 (6.0%)	10 (7.0%)	
Number of levels decompressed				
1	89 (41.2%)	12 (36.4%)	71 (50.0%)	
2	73 (33.8%)	9 (27.3%)	40 (28.2%)	
3	41 (19.0%)	10 (30.3%)	23 (16.2%)	.297
4	11 (5.1%)	1 (3.0%)	8 (5.6%)	
5	2 (0.9%)	1 (3.0%)	0 (0.0%)	
Number of levels fused				
1	171 (79.2%)	13 (39.4%)	91 (64.1%)	
2	36 (16.7%)	8 (24.2%)	48 (33.8%)	<.001*
3	9 (4.1%)	12 (36.4%)	3 (2.1%)	
Number of levels with interbody cage				
1	-	16 (48.5%)	113 (79.6%)	
2	-	5 (15.2%)	28 (19.7%)	<.001*
3	-	12 (36.3%)	1 (0.7%)	
Hybrid construct?#				
No	-	30 (90.9%)	120 (84.5%)	.421
Yes	-	3 (9.1%)	22 (15.5%)	
Revision				
No	196 (90.7%)	31 (93.9%)	128 (90.1%)	.793
Yes	20 (9.3%)	2 (6.1%)	14 (9.9%)	

* Indicates statistical significance (p<.05).
# Includes constructs with an interbody cage at one level and posterior fusion at other levels.

Table 2
Pre- and postoperative patient reported outcome measures between the three lumbar fusion techniques

		PLF	ALIF	TLIF	p value[‡]	Multivariate analysis[§]
PCS-12	Pre-op	31.5 [30.3, 32.8]	29.0 [26.1, 31.9]	30.8 [29.4, 32.2]	.369	β 0.73 [−6.23, 7.69]
	Post-op	40.0 [38.6, 41.4]	39.9 [35.1, 44.7]	40.3 [38.6, 42.0]	.985	p=.834
	Δ	8.7 [7.1, 10.3]	11.0 [5.9, 16.2]	9.4 [7.7, 11.2]	.593	
	p value[†]	<.001*	<.001*	<.001*	-	
MCS-12	Pre-op	50.8 [49.2, 52.4]	48.7 [44.5, 52.8]	48.4 [46.5, 50.2]	.086	β 0.55 [−4.88, 5.98]
	Post-op	54.1 [52.9, 55.3]	52.2 [48.1, 56.3]	52.6 [50.9, 54.3]	.482	p=.841
	Δ	3.1 [1.6, 4.6]	4.1 [−0.3, 8.5]	3.9 [1.9, 5.9]	.823	
	p value[†]	<.001*	.065	<.001*	-	
ODI	Pre-op	40.9 [38.4, 43.4]	42.5 [37.3, 47.7]	42.1 [39.3, 44.8]	.501	β 0.78 [−10.3, 11.9]
	Post-op	20.9 [18.5, 23.2]	20.6 [13.3, 28.0]	22.3 [19.1, 25.5]	.672	p=.889
	Δ	−20.5 [−23.3, −17.6]	−21.3 [−30.1, −12.6]	−18.3 [−22.2, −14.3]	.543	
	p value[†]	<.001*	<.001*	<.001*	-	
VAS Back	Pre-op	5.8 [5.3, 6.2]	5.9 [4.9, 6.9]	6.1 [5.5, 6.6]	.512	β 0.14 [−1.43, 1.70]
	Post-op	2.8 [2.4, 3.1]	2.9 [1.9, 3.8]	3.2 [2.7, 3.6]	.325	p=.862
	Δ	−3.1 [−3.5, −2.6]	−3.0 [−4.3, −1.6]	−3.0 [−3.6, −2.4]	.984	
	p value[†]	<.001*	<.001*	<.001*	-	
VAS Leg	Pre-op	6.1 [5.7, 6.6]	4.7 [3.6, 5.9]	6.4 [5.8, 6.9]	.031*	β −0.81 [−2.49, 0.88]
	Post-op	2.4 [2.0, 2.8]	2.1 [1.1, 3.0]	2.6 [2.1, 3.0]	.393	p=.342
	Δ	−3.7 [−4.2, −3.2]	−2.8 [−4.0, −1.5]	−3.8 [−4.5, −3.2]	.265	
	p value[†]	<.001*	<.001*	<.001*	-	

PCS-12, Physical Component Score of SF-12; MCS-12, Mental Component Score of SF-12; ODI, Oswestry Disability Index; VAS, Visual Analog Scale.
* Indicates statistical significance (p<.05).
† Paired samples *t* test to assess change after surgery.
‡ One-way ANOVA or Kruskal-Wallis H test used to compare means.
§ Multiple linear regression model used to compare magnitude of change in patient reported outcomes from pre-op to post-op between the surgery groups.

(6.1, p=.064). Table 2 shows the pre- and postoperative PROMs for each group. Within each surgical group, each PROM improved significantly from baseline (p<.05). Table 3 shows RRs for each patient outcome with no differences between groups. In addition, there were no differences in the percentage of patients achieving MCID for each outcome measure. Multiple regression analysis showed that the type of fusion (PLF, ALIF, or TLIF) did not significantly affect any of the patient outcomes and was not a significant predictor of revision. A higher number of levels decompressed was found to decrease improvement in ODI (β −8.4, p=.030) and increasing age was found to decrease improvement in VAS Back scores (β −0.1, p=.049) on multivariate analysis.

Spinopelvic parameters

Preoperatively, there were no significant differences between groups with regards to any spinopelvic parameters (Table 4). Postoperatively, only SL was significantly different between groups (p=.002), with the ALIF group having a significantly higher SL (27.6°) compared with PLF (21.7°) and TLIF (21.7°) on post-hoc analysis. Overall increase in SL was also higher in the ALIF group (6.0°, p=.004). Segmental

Table 3
Recovery ratios and % MCID between the three lumbar fusion techniques

	Recovery ratios				% MCID			
	PLF	ALIF	TLIF	p[†]	PLF	ALIF	TLIF	p[‡]
PCS-12	11.8% [9.5, 14.2]	15.0% [7.9, 22.1]	13.1% [10.6, 15.6]	.571	66.3%	74.2%	75.6%	.183
MCS-12	3.4% [0.5, 6.3]	6.0% [−2.6, 13.4]	5.4% [1.9, 9.0]	.709	25.6%	22.6%	26.8%	.890
ODI	35.9% [19.0, 53.3]	30.9% [−10.7, 72.5]	38.2% [26.3, 50.1]	.581	71.8%	62.5%	69.1%	.550
VAS Back	46.3% [37.4, 55.1]	23.3% [−30.1, 77.4]	31.5% [15.9, 47.2]	.488	57.0%	50.0%	56.5%	.772
VAS Leg	54.2% [46.9, 61.4]	47.5% [22.2, 72.7]	53.7% [43.7, 63.7]	.993	37.6%	32.3%	41.5%	.599

PCS-12, Physical Component Score of SF-12; MCS-12, Mental Component Score of SF-12; ODI, Oswestry Disability Index; VAS, Visual Analog Scale.
Recovery Ratios: Δ Score divided by (Optimal Score − Baseline Score). Optimal Scores: PCS-12 and MCS-12—100 points; ODI, VAS Back and Leg − 0 points.
MCID Cutoffs: PCS-12—2.5 points; MCS-12—10.1 points; ODI—8.2 points; VAS Back—2.2 points; VAS Leg: 5.0 points.
PROMs reported as: Mean [95% Confidence Interval].
* Indicates statistical significance (p<.05).
† One Way ANOVA or Kruskal-Wallis H used to compare means.
‡ Pearson chi-square analysis used to compare % MCID achieved after surgery.

Table 4
Pre-op and Post-op spinopelvic measurements between the three lumbar fusion techniques

		PLF	ALIF	TLIF	p value‡
Pelvic Tilt (PT)	Pre-op	23.8 [22.5, 25.1]	24.9 [20.8, 28.9]	23.3 [21.8, 24.9]	.909
	Post-op	24.7 [23.5, 25.9]	24.4 [20.8, 28.0]	23.9 [22.5, 25.2]	.476
	Δ	0.7 [−0.2, 1.6]	−1.2 [−4.0, 1.7]	0.6 [−0.7, 1.8]	.443
	p value†	.119	.409	.371	-
Sacral Slope (SS)	Pre-op	36.2 [35.0, 37.5]	37.4 [33.5, 41.4]	35.9 [34.2, 37.6]	.835
	Post-op	36.0 [34.8, 37.3]	41.0 [37.1, 44.8]	35.8 [34.2, 37.3]	.052
	Δ	−0.5 [−1.4, 0.4]	3.1 [−0.2, 6.5]	−0.2 [−1.7, 1.2]	.094
	p value†	.275	.067	.762	-
Pelvic Incidence (PI)	Pre-op	59.9 [58.4, 61.4]	62.3 [57.3, 67.4]	59.3 [57.2, 61.3]	.644
	Post-op	60.5 [59.0, 62.1]	65.3 [59.9, 70.7]	59.7 [57.6, 61.8]	.112
	Δ	0.3 [−0.2, 0.8]	1.9 [−0.1, 3.9]	0.4 [−0.7, 1.5]	.563
	p value†	.272	.058	.490	-
Lumbar Lordosis (LL)	Pre-op	40.3 [38.4, 42.2]	41.1 [34.1, 48.1]	38.7 [36.4, 41.1]	.580
	Post-op	40.8 [39.0, 42.6]	44.0 [38.5, 49.4]	38.1 [35.7, 40.5]	.183
	Δ	0.3 [−0.9, 1.5]	2.2 [−3.1, 7.5]	−0.6 [−2.4, 1.1]	.437
	p value†	.610	.397	.481	-
Segmental Lordosis (SL)	Pre-op	20.2 [18.9, 21.4]	21.5 [17.3, 25.7]	20.7 [19.0, 22.5]	.695
	Post-op	21.7 [20.4, 23.0]	27.6 [24.3, 30.8]	21.7 [20.1, 23.3]	.002*
	Δ	1.5 [0.5, 2.4]	6.0 [2.5, 9.6]	0.8 [−0.5, 2.1]	.004*
	p value†	.002*	.002*	.238	-
PI−LL	Pre-op	19.6 [17.8, 21.4]	21.2 [15.4, 27.0]	20.5 [18.3, 22.8]	.501
	Post-op	19.8 [18.1, 21.5]	21.3 [16.5, 26.1]	21.7 [19.4, 23.9]	.600
	Δ	0.0 [−1.2, 1.2]	−0.3 [−5.2, 4.6]	1.0 [−1.0, 3.0]	.570
	p value†	.965	.899	.316	-

* Indicates statistical significance (p<.05).
† Paired samples *t* test to assess change in outcome from pre- to postoperative measures within groups.
‡ One-way ANOVA test or Kruskal-Wallis test used to compare means used to compare means between groups with Bonferroni or Dunn multiple pairwise comparison post-hoc testing, respectively.

Lordosis within the PLF and ALIF groups improved significantly from baseline to postoperatively (p=.002 for both), whereas the TLIF group did not (p=.238). Overall, there were no differences in PI−LL mismatch pre- or postoperatively between or within groups.

Stratifying by diagnosis

When stratifying the cohort by diagnosis type, either degenerative spondylolisthesis or degenerative scoliosis, there were no significant differences in patient outcomes except for change in VAS Leg pain in the ALIF group (Table 5). Patients undergoing ALIF in the degenerative scoliosis showed a much bigger average improvement in VAS Leg scores postoperatively compared with patients with spondylolisthesis (−4.6 [−6.9, −2.4] vs. −1.3 [−3.4, −0.8], respectively; p=.025). There were no significant differences between diagnosis groups in terms of RR or % MCID. When analyzing radiographic parameters, patients with scoliosis had significantly less preoperative LL in all three fusion groups and significantly less postoperative LL in the PLF and TLIF groups (p<.05). Similarly, there was a higher degree of PI−LL mismatch in the scoliosis patients pre- and postoperatively in the PLF group and preoperatively in the ALIF group (p<.05).

Discussion

Degenerative lumbar disease is a highly prevalent condition with an increasing incidence in the United States secondary to the aging population. Posterolateral fusion is a common and straightforward approach that offers the benefits of decreased operative time, cost, and risk of overall complications compared with performing an interbody fusion [13−15]. However, unlike an interbody fusion, PLF does not restore disc height to create indirect decompression, reduce slippage, or confer a load bearing surface to the anterior column. Due to these reasons, interbody fusions have been increasingly incorporated in lumbar procedures over the last decade, especially for spondylolisthesis [15]. Two of the most common types of lumbar interbody fusion include ALIF and TLIF. Performing an ALIF allows for greater correction of segmental lordosis and placement of a larger interbody device, however it is also associated with a higher rate of vascular injury, sexual dysfunction, and overall complications [6,16]. On the other hand, TLIF requires a smaller cage to be inserted into the disc space and has a higher rate of neurologic injury. Currently, there is conflicting literature regarding improvement in radiographic parameters and patient outcomes between these three different fusion techniques [17,18]. The purpose of this study was to assess the relationship between type of lumbar

Table 5
Analysis comparing patient reported outcomes and changes in radiographic parameters when stratifying by diagnosis

PROM		Spondylolisthesis vs. scoliosis			Radiographic parameter		Spondylolisthesis vs. scoliosis		
		PLF	ALIF	TLIF			PLF	ALIF	TLIF
PCS-12	Pre-op	0.732	0.428	0.489	Pelvic Tilt (PT)	Pre-op	0.546	0.811	0.845
	Post-op	0.621	0.726	0.817		Post-op	0.529	0.666	0.667
	Δ	0.843	0.777	0.798		Δ	0.930	0.056	0.780
MCS-12	Pre-op	0.595	0.533	0.239	Sacral Slope (SS)	Pre-op	0.846	0.101	0.005*
	Post-op	0.058	0.205	0.205		Post-op	0.633	0.008*	0.103
	Δ	0.435	0.692	0.408		Δ	0.921	0.257	0.270
ODI	Pre-op	0.365	0.434	0.654	Pelvic Incidence (PI)	Pre-op	0.825	0.101	0.016*
	Post-op	0.345	0.829	0.840		Post-op	0.911	0.169	0.153
	Δ	0.880	0.978	0.993		Δ	0.648	0.676	0.765
VAS Back	Pre-op	0.641	0.508	0.621	Lumbar Lordosis (LL)	Pre-op	0.019*	0.002*	0.006*
	Post-op	0.772	0.849	0.543		Post-op	0.003*	0.019*	0.072
	Δ	0.620	0.705	0.365		Δ	0.714	0.056	0.223
VAS Leg	Pre-op	0.966	0.060	0.564	Segmental Lordosis (SL)	Pre-op	0.430	0.767	0.967
	Post-op	0.171	0.188	0.949		Post-op	0.612	0.686	0.830
	Δ	0.277	0.025*	0.485		Δ	0.684	0.293	0.540
					PI−LL	Pre-op	0.012*	0.019*	0.542
						Post-op	0.006*	0.434	0.483
						Δ	0.654	0.136	0.368

* Indicates statistical significance (p<.05).

fusion and short-term patient outcomes as well as influence on spinopelvic parameters in patients with degenerative lumbar disease.

Comparing PROMs, the findings in this study show that patients undergoing ALIF had significantly lower preoperative VAS leg scores, however, these differences resolved postoperatively. Patients in each fusion group showed similar improvement as measured by the RR and the percentage of patients achieving MCID. Multivariate analysis showed that fusion technique did not affect any PROMs and did not affect odds of revision. The findings in this study are concordant with findings from multiple other retrospective cohort studies that have compared clinical outcomes between fusion techniques [6,7,24,8,9,16,19−23]. When comparing PLF with types of interbody fusion, two recent studies showed no significant difference in PROMs [13,24]. Similarly in two meta-analyses, McAnany et al. showed no difference in ODI, Short Form-12, VAS scores or overall complication rates and Campbell et al. showed no difference in VAS or ODI between patients undergoing PLF or TLIF [17,18]. When comparing an ALIF versus TLIF approach, several authors have also found no difference in VAS or ODI scores [7,16,22]. In one meta-analysis, Ajiboye et al. showed equivalent ODI and VAS scores between the two groups [6]. These findings are similar to the results seen in the present study where all PROMs, RR, and percentage of patients achieving MCID were similar between groups. However, one distinguishing factor of this is that the majority of patients in the aforementioned studies had a diagnosis of degenerative spondylolisthesis compared with a mixed population presented here.

In contrast to the findings presented here, a few studies have identified significant differences in PROMs between patients undergoing TLIF and PLF. Two studies showed that patients undergoing TLIF had significant improvements in VAS Leg and VAS Back scores [9,25]. As part of a cost-effectiveness analysis, Carreon et al. found improved 1-year ODI and Short Form 6-D scores also in favor of the TLIF group [26]. In a meta-analysis by Levin et al., the TLIF group had improved back pain and ODI scores [19]. These findings differ from the results presented here and may reflect the fact that all of the patients in the above mentioned studies underwent surgery for a diagnosis of spondylolisthesis. A TLIF may provide improved outcome scores, especially with VAS Leg after restoration of disc and foraminal height with an interbody device. With a mixed patient population in the current study, it is possible that these effects were lost and not generalizable to the entire degenerative population. Even when stratifying by diagnosis (Table 5), there were no significant differences in PROMs except for a higher degree of improvement in VAS Leg scores in patients with degenerative scoliosis compared with spondylolisthesis (p=.025).

When comparing spinopelvic parameters in this study, ALIF patients had a higher SL postoperatively as well as a higher magnitude of improvement compared with the PLF and TLIF groups. In addition, patients in the PLF and ALIF groups significantly improved with regards to SL, whereas patients in the TLIF group did not. Despite these slight differences in radiographic parameters, all groups had similar short-term PROMs. Several studies have analyzed radiographic parameters in degenerative disease, with the majority of studies involving single-level degenerative spondylolisthesis [6,9,11,20,27]. Overall, ALIF has been shown to lead to better restoration of radiographic parameters, especially with regards to SL and overall LL compared with TLIF or PLF [6,11,20,27]. In fact, in a study analyzing ALIF and TLIF patients, Hsieh et al. found that ALIF improved SL by 8.3° and overall LL by 6.2°, whereas TLIF actually decreased SL by 0.1° and decreased LL by 2.1° [28]. These findings are concordant with the results in this study, where patients in the ALIF group had significantly greater improvement in SL compared with PLF or TLIF groups. Like the findings in this study, the previously mentioned studies found no improvements in short-term PROMs. When stratifying the cohort by diagnosis, patients with degenerative scoliosis had lower LL and more PI−LL mismatch in the PLF and ALIF groups. This is unsurprising because patients with degenerative scoliosis may have advanced degenerative changes with loss of lordosis compared with spondylolisthesis patients.

This study includes several elements that differ from previous studies that have addressed fusion technique. It includes patients undergoing lumbar fusion for multiple types of degenerative pathology, not just spondylolisthesis. In addition, it analyzes PROMs as well as radiographic parameters. The cohort size reported here is also one of the largest that exists in current literature examining fusion techniques for degenerative lumbar disease. Despite these strengths, there are still some notable limitations to this study. This is a retrospective cohort study with baseline differences in age between the three groups. Due to the significant variability in the size of each group, propensity-matching could not be effectively applied in this cohort. Although multiple linear regression analysis was used to adjust for the baseline difference in age, it is possible that age or other confounding variables could account for differences in PROMs outside of surgical technique alone. The study also incorporates PROMs as the primary endpoints of the study and is thus subject to recall bias. Surgical techniques for posterior instrumentation after ALIF, as well as operative technique for TLIF and PLF may have varied slightly between each surgeon, contributing to a heterogeneous population within each group. This study also did not analyze fusion rates and is limited to only one year of follow-up data. It is certainly possible that with longer term follow-up, overall revision rates and subsequently PROMs may change.

In conclusion, this is one of the largest studies to incorporate PROMs and radiographic parameters for patients undergoing degenerative lumbar fusion surgery with three different fusion techniques. Despite some improvements in radiographic parameters postoperatively for patients undergoing ALIF, short-term outcomes were similar between all groups. Individual pathology varies and thus the approach should be tailored specifically to address each patient's pathology. Future retrospective studies incorporating a longer follow-up period or prospective randomized controlled trials are needed to further delineate this important topic.

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