

Comparison of clinical outcomes following minimally invasive lateral interbody fusion stratified by preoperative diagnosis

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Abstract

Purpose Lumbar fusion has been shown to be effective in treating a variety of degenerative spinal conditions, though significant differences exist in the magnitude of clinical improvement across different surgical diagnoses. With modern, minimally disruptive approaches for fusion, diagnosis-specific differences in clinical improvement may be reduced. The purpose of this study is to report and compare interim clinical improvements in patients treated with XLIF for various degenerative lumbar conditions.

Methods 160 patients underwent XLIF for either degenerative spondylolisthesis ($n = 68$), degenerative disc disease ($n = 20$), adjacent segment disease ($n = 26$), or post-laminectomy syndrome ($n = 46$). Average age was 61 years and 66 % were female. Mean BMI was 28.9 kg/m². 37 % were smokers, 23 % had diabetes mellitus, 22 % had depression. Mean age was highest for ASD patients (66 years) and lowest for DDD patients (48 years) ($p < 0.001$). There were no other baseline demographic differences between groups. Patient-reported clinical outcomes measures were collected at baseline and prospectively at standard intervals. Interim results at an average of 19 months follow-up are reported here.

Results In total, 197 levels were treated with XLIF (mean 1.2 per patient). There were no cases of symptomatic pseudoarthrosis or implant/instrument failure. Overall, 1 patient (0.6 %) had a major complication and 12 % had a minor

complication. Approach-related anterolateral thigh/groin sensory changes were present in 14 % and hip flexion weakness in 9 %. At last follow-up, overall ODI decreased 47 % (44.1–23.5), VAS LBP decreased 59 % (6.9–2.8), VAS LP decreased 56 % (7.1–3.1), and SF-36 PCS improved 40 % (30.9–43.2) (all $p < 0.001$). Baseline ODI was significantly lower for DDD patients ($p = 0.052$). At last follow-up, mean percent improvements on all outcomes were highest for DSP group, though not all differences were significant. Improvements between diagnostic groups were statistically different for LBP ($p = 0.021$), but were similar for all other clinical outcomes. Percentage of patients reaching MCID and SCB thresholds ranged from 60 to 95 % in clinical outcomes. Patient satisfaction for the entire group was 93 % when asked whether satisfied with surgical outcome.

Conclusions XLIF has been demonstrated in the current series to lead to significant improvements in clinical outcomes and high rates of MCID and SCB and reduce the discrepancy in outcomes between well accepted and technically challenging indications compared to traditional open approaches for IBF. Complication rates were low, with only one patient in the series experiencing a major complication. Further investigation with larger cohorts and longer follow-up is warranted.

Keywords XLIF · DLIF · SCB · MCID · Glassman

Introduction

Lumbar interbody fusion can be an effective treatment for a variety of degenerative spinal conditions and pathologies [1–8]. However, significant discrepancies in the magnitude of postoperative clinical improvement can exist between different surgical diagnoses [4]. Historically, patients with degenerative spondylolisthesis (DSP) have been reported to

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have greater improvements in pain and disability after lumbar fusion compared to those with degenerative disc disease (DDD), failed-back or post-laminectomy syndrome (PLS), and degenerative changes adjacent to a prior fusion (adjacent segment disease, ASD) [4]. In addition, for “revision” indications such as ASD and PLS, subsequent surgeries may associate with greater technical challenges and higher risk of postoperative complications, likely due to the presence of scar tissue and muscle denervation associated with traditional, open posterior approaches [9].

Alternatively, modern, less invasive approaches for lumbar interbody fusion have gained in popularity, one such approach being the mini-open lateral transpoas approach (XLIF[®], NuVasive, Inc., San Diego, CA) [10]. Benefits of the lateral approach include the preservation of bony and ligamentous structures and also allows for the placement of a large intervertebral cage [11–16]. These advantages may translate to added clinical improvement for less well established and revision indications, thereby addressing the shortcomings of open, traditional approaches, particularly in treating patients with prior lumbar surgery. Direct comparisons of complications and clinical outcomes stratified by preoperative diagnosis specifically following in lateral fusion, however, are heretofore unreported. Thus, the purpose of this study was to investigate potential discrepancies in clinical improvements in patients treated with XLIF for DSP, DDD, ASD, and PLS. Results at an average of 18.5 months are reported here.

Materials and methods

Data were collected at a single institution as part of an institutional review board (IRB) approved prospective registry. Between 2008 and 2012, 187 patients were treated with XLIF between L1-4 at a single institution. Of those, 160 were included in the current study and were grouped by primary diagnosis into DDD ($n = 20$), DSP ($n = 68$), ASD ($n = 26$), and PLS ($n = 46$) cohorts. The remaining 27 patients had scoliosis, tumor, vertebral body fracture, discitis, or pseudoarthrosis and were excluded from this study. Patients treated outside of L1-5 levels were also excluded, and treatment for L5-6 was decided on a case-by-case basis.

Patients with a primary diagnosis of DSP had no history of prior lumbar surgery, included Grade 1 and II slips, and were exclusive of isthmic spondylolisthesis. Patients in the DDD group showed radiographic evidence of intervertebral disc desiccation, greater than 50 % disc space collapse, and/or modic endplate changes, without sagittal plane deformity. Of the 20 patients in this group, 18 (90 %) had preoperative leg pain in addition to back pain, of which 15 (75 %) had leg pain greater than or equal to back pain. ASD patients had

symptomatic instability, listhesis, and/or disc degeneration at the level adjacent to a previous fusion. PLS patients had either symptomatic recurrent disc herniation, instability or listhesis, and/or disc degeneration at the index level of a previous laminectomy or microdiscectomy.

Data pertaining to demographic, treatment, complication, and reoperation variables were collected through retrospective chart review. Clinical outcomes, which included the Oswestry Disability Index (ODI), numeric rating scale (NRS) for low back pain (LBP) and leg pain (LP), and short form-36 (SF-36) physical component (PCS) and mental component (MCS) were collected preoperatively and prospectively at intervals of 1, 3, 6, 12, and 24 months postoperative. Thresholds for determining minimal clinically important difference (MCID) and substantial clinical benefit (SCB) were previously defined by Copay et al. [17] and Glassman et al. [18], respectively (Table 1).

Complication data was collected perioperatively, and at regular follow-up intervals. Retrospective chart review was performed to confirm accuracy. Major and minor complications were classified according to previously proposed guidelines by Glassman et al. [19]. Postoperative approach-related thigh/groin sensory changes and/or hip flexion weakness, both known phenomena following XLIF [16, 20] were considered complications in presence of clear neurologic deficit or if hospital readmission or surgical intervention was required. Otherwise, cases of transient nerve-related pain or mechanical hip flexion weakness were classified as “side effects.”

Statistical analyses included frequency tests and Chi squared/Fishers’ Exact tests. One-way ANOVA and post hoc Tukey’s Range test for pairwise comparisons were also performed. Clinical improvements were analyzed as repeated measures using generalized linear mixed models with compound symmetric covariance structures. All statistical analyses were performed using JMP v11 (SAS Institute, Cary, NC) and significance was accepted at the 0.05 level.

Results

Average follow-up for the 160 patients was 18.5 months. Mean patient age was 60.6 years and 66 % were female. Mean body mass index (BMI) was 28.0 kg/m². Thirty-seven percent (37 %) of patients were smokers, 23 % had diabetes mellitus, and 22 % had depression (self-reported). Preoperative diagnosis was DSP for 68 patients, DDD for 20 patients, ASD for 26 patients, and PLS for the remaining 46. Mean age was highest for patients in the ASD group (66 years) and lowest for those in the DDD group (48 years) ($p < 0.001$). There were no other baseline demographic differences between groups (Table 2).

Table 1 Previously defined thresholds for substantial clinical benefit (SCB) and minimum clinically important difference (MCID)

Clinical outcome	SCB ^a			MCID ^b
	% Improvement	Final raw score	Net point improvement	Net point improvement
ODI	36.8	<31.3 points	18.8 points	12.8 points
NRS LBP	41.4	<3.5 points	2.5 points	1.2 points
NRS LP	38.8	<3.5 points	2.5 points	1.6 points
SF-36 PCS	19.4	≥35.1 points	6.2 points	4.9 points

SCB substantial clinical benefit, MCID minimum clinically important difference, ODI Oswestry Disability Index, NRS numeric rating scale, LBP low back pain, LP leg pain, SF-36 short form-36, PCS physical component score

^a Copay et al. [17]

^b Glassman et al. [18]

In total, 197 levels in 160 patients (mean 1.2, range 1–3) were treated with XLIF. The most common levels treated were L4-5 and L3-4, in 114 (71 %) and 49 patients (31 %), respectively. Direct posterior decompressions were performed in 65 (41 %) cases. Supplemental percutaneous posterior fixation was used in 140 (88 %) cases. There were significantly more patients in the DSP group (100 %) who underwent an additional posterior procedure (decompression, fixation, or both) compared to those in the DDD group (60 %).

Mean operative time (ORT) for all patients was 171 min, mean blood loss (EBL) was 73 mL, and postoperative length of stay (LOS) was 1.3 days. Complete treatment information stratified by diagnosis is presented in Table 3.

There were no cases of symptomatic pseudoarthrosis or hardware failure. For the entire study group, 1 patient (0.6 %) had a major complication and 19 patients (12 %) had a minor complication. Approach-related anterolateral thigh/groin sensory changes were present in 22 patients (14 %) and hip flexion weakness was present in 14 patients (9 %). Both these side effects were transient, resolving between 10 days and 6 months postoperative without additional intervention or sequelae. There were no incidences

of femoral neuropathy. Minor complication rate was highest for ASD (19 %) and PLS (17 %) patients. There were no statistically significant differences between incidences in complications or approach-related side effects between diagnosis groups (Table 4). Complications and approach-related side effects are listed in Table 5.

From preoperative to last follow-up, overall ODI decreased 47 % from 44.1 to 23.5. LBP decreased 59 % from 6.9 to 2.8 and LP decreased 56 % from 7.1 to 3.1. SF-36 PCS improved 40 % from 30.9 to 43.2 at last follow-up. All postoperative clinical improvements were statistically significant.

Subgroup comparisons by diagnosis revealed baseline ODI was significantly lower for DDD patients ($p = 0.052$), with no other differences in clinical scores between diagnoses at baseline. At last follow-up, mean percent improvements on all outcomes were highest for DSP group, though not all differences were significant. Improvements between diagnostic groups were statistically different for LBP ($p = 0.021$), but were similar for all other clinical outcomes (Table 6).

Using previously published definitions for MCID, percentage of patients reaching the threshold ranged from 60 to 95 % in clinical outcomes. While none of the percentage

Table 2 Demographic information stratified by preoperative diagnosis

	ASD ($n = 26$)	PLS ($n = 46$)	DDD ($n = 20$)	DSP ($n = 68$)	p value
Follow-up (months), mean \pm SD	15.9 \pm 1.9	18.6 \pm 1.4	18.0 \pm 2.2	19.6 \pm 1.2	0.427
Age (years), mean \pm SD	65.7 \pm 2.1	59.3 \pm 1.6	48.0 \pm 2.4	63.3 \pm 1.3	<0.001*
Female, n (%)	19 (73.1)	24 (52.2)	12 (60.0)	51 (75.0)	0.063
BMI (kg/m^2), mean \pm SD	27.7 \pm 1.0	28.1 \pm 0.8	27.7 \pm 1.1	28.2 \pm 0.6	0.955
Smoking, n (%)	7 (26.9)	17 (37.0)	9 (45.0)	26 (38.2)	0.631
Diabetes, n (%)	10 (38.5)	10 (21.7)	3 (15.0)	13 (19.1)	0.179
Depression, n (%)	8 (30.8)	12 (26.1)	3 (15.0)	12 (17.7)	0.400

* Statistically significant at $p < 0.05$

ASD adjacent segment disease, DDD degenerative disc disease, PLS post-laminectomy syndrome, DSP degenerative spondylolisthesis, n number of patients, SD standard deviation, BMI Body Mass Index

Table 3 Treatment information stratified by preoperative diagnosis

	ASD (<i>n</i> = 26)	PLS (<i>n</i> = 46)	DDD (<i>n</i> = 20)	DSP (<i>n</i> = 68)	<i>p</i> value
Levels treated, mean ± SD	1.4 ± 0.1	1.3 ± 0.1	1.2 ± 0.1	1.1 ± 0.1	0.137
Add'l post. procedure, <i>n</i> (%)	23 (88.5)	37 (80.4)	12 (60.0)	68 (100.0)	<0.001*
OR time (min), mean ± SD	212.8 ± 25.8	188.0 ± 16.8	150.8 ± 20.2	156.7 ± 14.3	0.139
EBL (mL), mean ± SD	87.5 ± 15.0	72.6 ± 10.7	49.4 ± 15.4	75.7 ± 8.9	0.343
LOS (days), mean ± SD	1.5 ± 0.2	1.2 ± 0.1	1.1 ± 0.2	1.4 ± 0.1	0.250

* Statistically significant at *p* < 0.05

ASD adjacent segment disease, DDD degenerative disc disease, PLS post-laminectomy syndrome, DSP degenerative spondylolisthesis, *n* number of patients, SD standard deviation, Add'l post. procedure additional posterior procedure, OR time operating time, min minutes, EBL estimated blood loss, LOS length of stay

Table 4 Adverse events stratified by preoperative diagnosis

	ASD (<i>n</i> = 26)	PLS (<i>n</i> = 46)	DDD (<i>n</i> = 20)	DSP (<i>n</i> = 68)	<i>p</i> value	Total (<i>n</i> = 160)
Major complications, <i>n</i> (%)	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.5)	0.715	1 (0.6)
Minor complications, <i>n</i> (%)	5 (19.2)	8 (17.4)	1 (5.0)	5 (7.4)	0.303	19 (11.9)
Approach-related side effects, <i>n</i> (%)						
Anterior thigh/groin pain	2 (7.7)	6 (13.0)	0 (0.0)	14 (20.6)	0.083	22 (13.8)
Hip flexion weakness	0 (0.0)	5 (10.9)	0 (0.0)	9 (13.2)	0.095	14 (8.8)

ASD adjacent segment disease, DDD degenerative disc disease, PLS post-laminectomy syndrome, DSP degenerative spondylolisthesis, *n* number of patients, SD standard deviation

Table 5 Complications and approach-related side effects

	<i>n</i> = 160
Major complications, <i>n</i> (%)	1 (0.6)
Myocardial infarction	1
Minor complications, <i>n</i> (%)	19 (11.9)
Dural tear	4
Transient dorsiflexion weakness	3
Urinary retention	3
Anemia requiring transfusion	3
Vertebral body fracture	2
Superficial wound dehiscence	3
Urinary incontinence	1
Side effects, <i>n</i> (%)	36 (22.6)
Approach-related thigh/groin pain	22
Hip flexion	14

of patients reaching MCID on each outcome statistically differed between groups, DSP patients had the highest rate on all measures, while ASD patients had the lowest rate on ODI, LBP, and LP. Percentage of patients reaching SCB were statistically different between groups on ODI (*p* = 0.029) and PCS (*p* = 0.022). For ODI, DSP patients had the highest rate of reaching SCB (78 %) while 60 % of ASD patients reached the threshold. Similarly for LBP,

93 % of DSP patients reached SCB, while 71 % of ASD patients reached the threshold. Complete MCID and SCB percentages stratified by diagnosis are presented in Table 7.

Patient satisfaction for the entire group was 93 % when asked whether satisfied with surgical outcome. Additionally, 93 % of patients also indicated they would do the surgery again, given their current outcome. Patient satisfaction was not statistically different between groups for either satisfaction with surgical outcome or willingness to undergo the same procedure. Eighty-eight percent (88 %) of ASD, 90 % of DDD patients, 91 % of PLS patients, and 97 % of DSP patients indicated satisfaction with surgical outcome (*p* = 0.139). Eighty-eight percent (88 %) of ASD patients, 95 % of DDD patients, 93 % of PLS patients, and 94 % of DSP patients indicated they would do the surgery again (*p* = 0.083).

Discussion

Degenerative spondylolisthesis (DSP) is one of the most responsive diagnoses to lumbar fusion. In addition to high rates of improvements on multiple clinical outcome measures, high rates of patients reaching meaningful clinical improvement thresholds such as MCID have also been reported [4]. This is likely due to the ability of interbody

Table 6 Self-reported clinical scores and improvements at last follow-up stratified by preoperative diagnosis

	ASD (<i>n</i> = 26)	PLS (<i>n</i> = 46)	DDD (<i>n</i> = 20)	DSP (<i>n</i> = 68)	<i>p</i> value
ODI, mean ± SD					
Baseline	49.1 ± 2.7	45.9 ± 2.3	38.1 ± 3.3	42.7 ± 1.7	0.052*
Last follow-up	31.7 ± 3.7	24.8 ± 3.1	22.3 ± 4.5	19.9 ± 2.4	0.066
Improvement (%)	36.2 ± 8.3	46.4 ± 6.9	46.5 ± 10.0	50.8 ± 5.2	0.532
NRS LBP, mean ± SD					
Baseline	7.3 ± 0.5	6.8 ± 3.8	6.4 ± 0.6	7.0 ± 0.3	0.705
Last follow-up	4.1 ± 0.5	2.7 ± 0.3	2.8 ± 0.5	2.4 ± 0.3	0.021*
Improvement (%)	42.0 ± 7.2	56.0 ± 5.3	59.1 ± 8.5	62.8 ± 4.3	0.110
NRS LP, mean ± SD					
Baseline	7.1 ± 0.5	7.3 ± 0.4	6.4 ± 0.6	7.1 ± 0.3	0.619
Last follow-up	3.8 ± 0.6	3.0 ± 0.5	2.7 ± 0.7	3.1 ± 0.4	0.659
Improvement (%)	43.3 ± 8.9	55.1 ± 6.9	58.4 ± 10.2	54.5 ± 5.3	0.651
SF-36 PCS, mean ± SD					
Baseline	29.6 ± 1.6	30.1 ± 1.3	33.4 ± 1.8	31.2 ± 1.0	0.422
Last follow-up	39.4 ± 2.1	41.7 ± 1.8	44.5 ± 2.4	45.2 ± 1.0	0.083
Improvement (%)	40.5 ± 10.2	44.9 ± 8.7	44.7 ± 11.9	51.9 ± 6.4	0.783

* Statistically significant at $p < 0.05$

ASD adjacent segment disease, DDD degenerative disc disease, PLS post-laminectomy syndrome, DSP degenerative spondylolisthesis, *n* number of patients, SD standard deviation, ODI Oswestry Disability Index, NRS numeric rating scale, LBP low back pain, LP leg pain, SF-36 short form-36, PCS physical component score

Table 7 Percentage of patients reaching MCID and SCB at last follow-up stratified by preoperative diagnosis

	ASD (<i>n</i> = 26) (%)	DDD (<i>n</i> = 20) (%)	PLS (<i>n</i> = 46) (%)	DSP (<i>n</i> = 68) (%)	<i>p</i> value	Total (<i>n</i> = 160) (%)
ODI						
MCID	60.0	64.7	69.4	76.2	0.461	70.2
SCB	60.0	62.5	69.4	77.8	0.327	70.7
NRS LBP						
MCID	75.0	83.3	81.4	92.5	0.140	85.5
SCB	70.8	83.3	74.4	92.5	0.029*	82.9
NRS LP						
MCID	70.0	72.3	80.0	82.1	0.727	80.0
SCB	68.0	77.8	73.2	70.1	0.894	71.5
SF-36 PCS						
MCID	65.2	64.7	71.9	88.1	0.486	77.1
SCB	73.9	76.5	75.0	94.9	0.022*	84.0

* Statistically significant at $p < 0.05$

ASD adjacent segment disease, DDD degenerative disc disease, PLS post-laminectomy syndrome, DSP degenerative spondylolisthesis, *n* number of patients, MCID minimum clinically important difference, SCB substantial clinical benefit, ODI Oswestry Disability Index, NRS numeric rating scale, LBP low back pain, LP leg pain, SF-36 short form-36, PCS physical component score

fusion to correct the listhesis through realignment and stabilization. However, indications for fusion other than DSP have been shown to have relatively attenuated clinical improvements [7, 8, 21].

DDD with chronic low back pain, in particular, has been scrutinized due to its diagnostic complexity and outcome variability from within the published literature [21]. Clinical improvement ranging from moderate to high have been reported in several randomized clinical trials for a variety of fusion procedures in the treatment of DDD, with LBP improvement ranging from 22 to 77 % and ODI improvement ranging from 19 to 79 % [21].

Few studies have reported outcomes specifically for DDD patient cohorts following XLIF. Marchi et al. [22] reported in a series of 22 patients treated with XLIF a fusion rate of 93 % with a 70 % improvement in back pain and a 53 % improvement in ODI. Patients in their series also experience short operative times (average 72 min), low EBL (50 mL), and LOS (1 day), all comparable to the results of the current studies. Additionally, Berjano et al. [23] reported on the clinical results of a series of 97 patients, 80 % of which were classified as DDD. In their study, clinical improvement was reported as 61.3 %, leg pain improved 64 %, and ODI improved 55 %.

In the current series of DDD patients treated with XLIF, improvements on clinical outcomes at last follow-up ranged from 46 % on ODI, 65 % on LBP, 55 % on LP, and 45 % on PCS, all of which were statistically similar to those observed in DSP patients. Furthermore, there were no significant differences between the percentage of DDD patients and DSP patients reaching MCID on any clinical outcome measures. The authors hypothesize that this reduced discrepancy in clinical improvement between these two diagnoses may not be solely attributed to a minimally invasive surgical approach, but also to careful patient selection and preoperative evaluation of both radiographic and clinical symptoms. DDD patients selected for XLIF in the current series all exhibited significant disc space collapse, Modic endplate changes, as well as central, lateral recess, and/or foraminal stenosis. Clinically, 90 % of DDD patients in the current series had preoperative radicular pain in addition to back pain and all had failed previous conservative treatment.

Similarly, “revision” indications such as ASD and PLS treated through posterior approaches but can also be associated with significant morbidity due to scar tissue formation and injury to posterior bony structures and musculature [24]. In these cases, the lateral approach allows for the avoidance of scar tissue by allowing access to

the spine through a “virgin” anatomic plane and preventing further paraspinal muscle atrophy and fibrosis.

In addition to anatomic and biomechanical advantages of the lateral approach for “revision” indications, clinical outcomes also compare favorably against those reported for open or posterior approaches. Djurasovic et al. [25] previously reported results of clinical improvement in following traditional anterior, posterior, or combined approaches for lumbar fusion in a series of 91 post-decompression patients and 42 ASD patients. For ASD patients at 1-year postoperative, LBP improved 26 % (8.0–5.9), LP improved 19 % (7.3–5.9), ODI improved 19 % (55.1–44.4), and PCS improved 7 % (27.2–29.2). For post-decompression patients at 1-year postoperative, LBP improved 31 % (7.4–5.1), LP improved 32 % (7.5–5.1), ODI improved 28 % (54.9–39.5), and PCS improved 21 % (26.1–31.7). In comparison, improvements on these four clinical outcomes in the current series of ASD and PLS patients ranged between 36–43 % and 45–56 %, respectively.

Further comparisons of percentage reaching MCID thresholds were also favorable for patients in the current series treated with XLIF. At 1-year postoperative, Djurasovic et al. [25] reported 42 and 52 % of ASD and post-decompression patients, respectively, reaching MCID

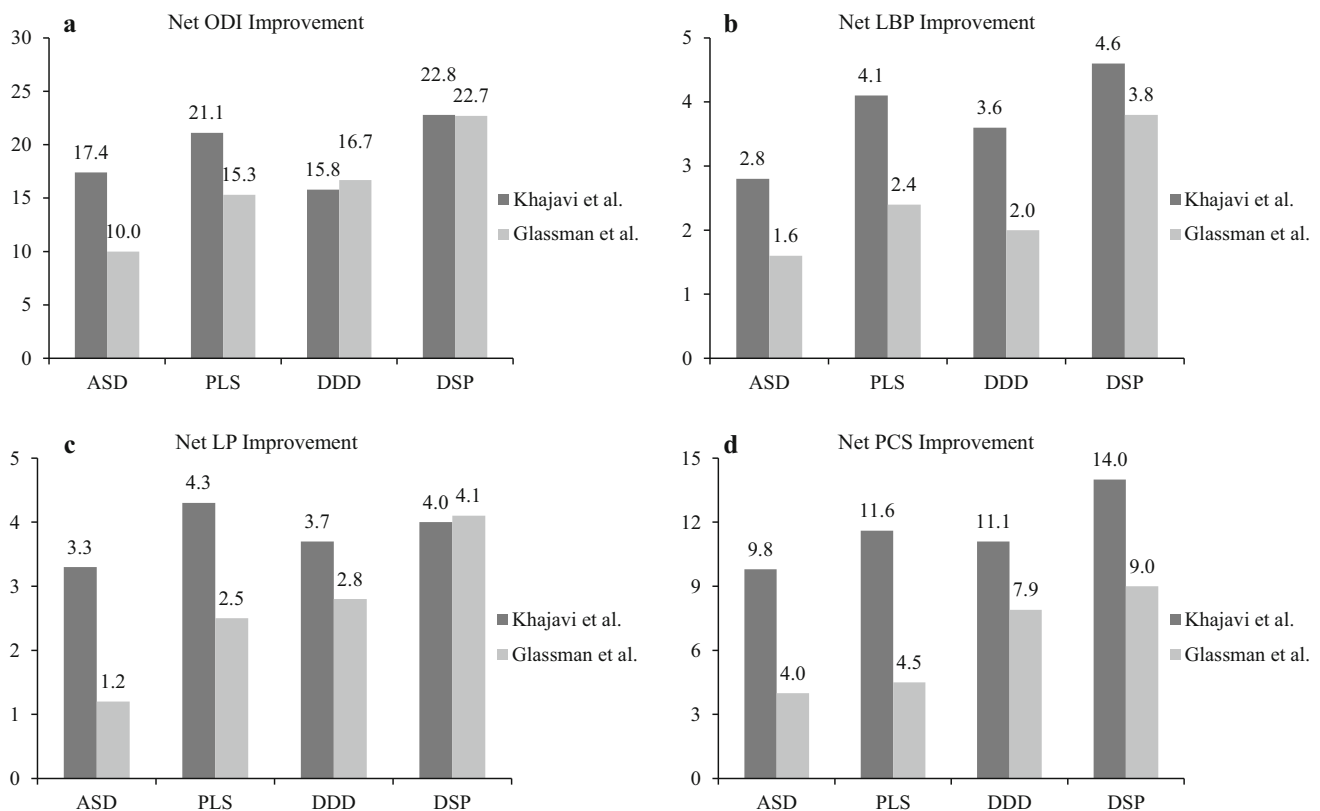


Fig. 1 a–d Comparison of mean change from baseline between patients in Glassman et al.’s [4] series and patients in the current series. ASD adjacent segment disease, DDD degenerative disc

disease, PLS post-laminectomy syndrome, DSP degenerative spondylolisthesis, ODI Oswestry Disability Index, LBP low back pain, LP leg pain, PCS physical component score

on ODI, compared to 60 and 69 % of ASD and PLS patients, respectively, in the current series. Similarly for PCS, 37 % of ASD and 38 % of post-decompression patients reached MCID in Djurasovic's series compared to 65 % of ASD and 72 % of PLS patients in the current series.

In contextualizing our stratified results against those reported for fusion via traditional posterior approaches, we directly compared our study against Glassman et al.'s [4] stratification study for clinical outcomes following open, traditional approach for posterolateral fusion (PLF) in a series of 327 patients. To our knowledge, this study is among the highest quality literature that reports direct comparisons between diagnoses groups. The study included four diagnostic groups similar to those in the current study: DDD, ASD, PLS, and SP. Descriptions noted in the methodology section of Glassman's paper described DDD, ASD, and PLS groups to have similar classification guidelines as the current study. However, for Glassman's SP group, both degenerative and isthmic spondylolisthesis

were included, while the current study only examined the degenerative type.

At last follow-up, net score changes were higher for patients in the current series compared to their corresponding groups in Glassman's series, with the exception of ODI for the DDD groups (Fig. 1). SP patients in both studies experienced the highest improvements on all outcome measures. Particularly of note is the discrepancy in improvement in the "revision" groups, ASD and PLS. Patients in these groups who underwent XLIF had consistently higher improvements on all clinical outcomes compared to those in Glassman's study who underwent a PLF. In the ASD group, net score improvement on ODI (19.7 vs. 10.0), LBP (2.9 vs. 1.6), and PCS (10.0 vs. 4.0) for patients in the current series were almost double that of net score improvements in Glassman's group, while LP (3.6 vs. 1.2) improvement for patients in the current series was three times that of Glassman's group. In addition, the disparity in percentage of patients reaching MCID across diagnostic

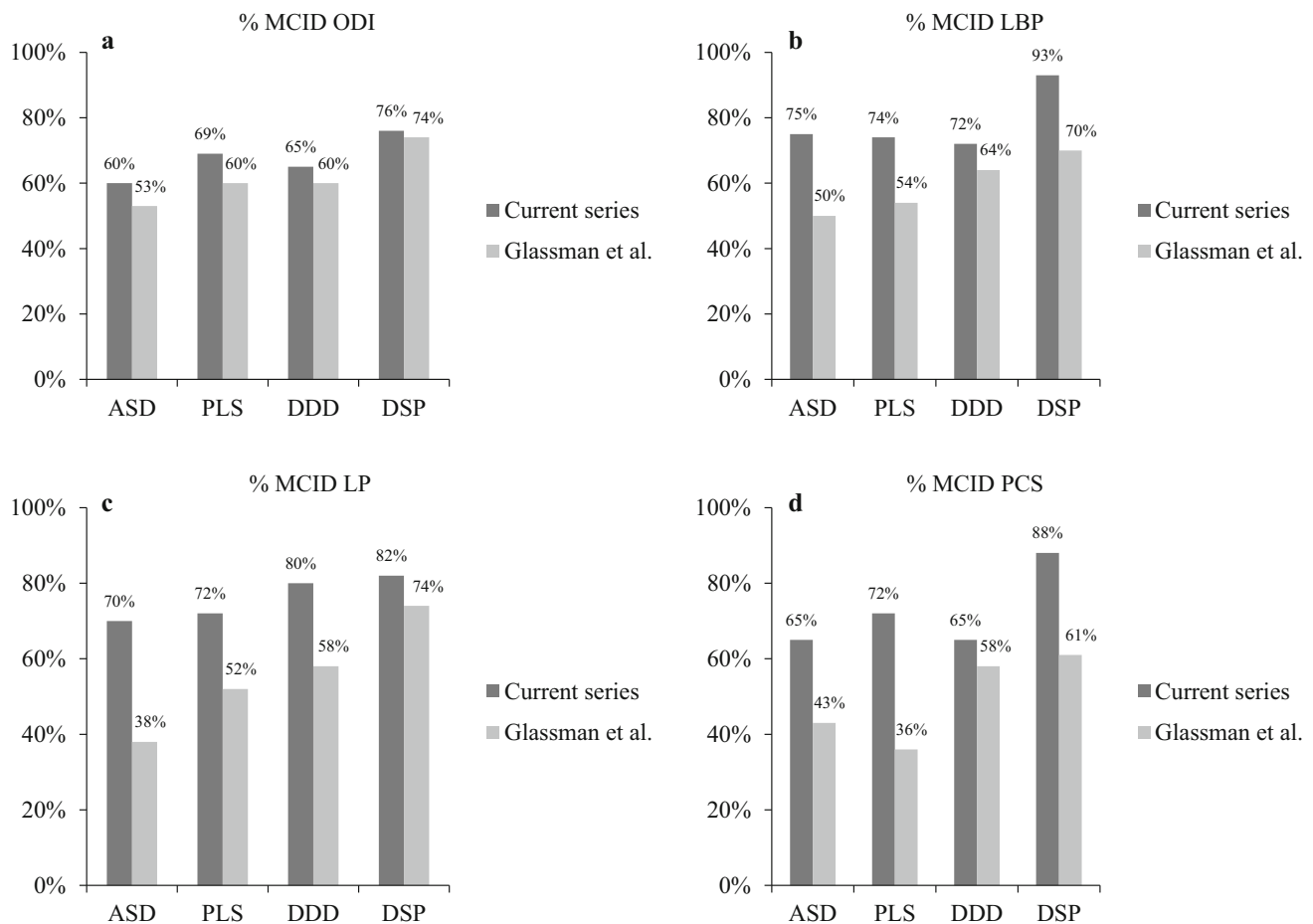


Fig. 2 a–d Comparison of minimum clinically important difference (MCID) differences between Glassman et al.'s [4] series and patients in the current series. *ASD* adjacent segment disease, *DDD* degenerative disc disease, *PLS* post-laminectomy syndrome, *DSP*

degenerative spondylolisthesis, *MCID* minimum clinically important difference, *ODI* Oswestry Disability Index, *LBP* low back pain, *LP* leg pain, *PCS* physical component score

indications was reduced for those in the current series (Fig. 2). In the current series of patients treated with XLIF, percentage of ASD, DDD, and PLS patients reaching MCID in LP ranged between 70 and 80 %, compared to 82 % of DSP patients. In contrast, Glassman et al. reported between 38 and 58 % of ASD, DDD, and PLS patients reached MCID, compared with 74 % of SP patients.

Excluding patients with transient, approach-related side effects, percentage of patients with any complication in this series was 12 %, with <1 % classified as a major. In comparison, Glassman reported a 35 % complication rate, including a 45 % rate in the SP group, a 40 % rate in the PLS group, a 40 % rate in the ASD group, and a 9 % rate in the DP group. In addition, the major complication rates in these groups ranged from 3 to 15 %, with the highest rate observed in SP patients. Revision surgery was also required for 21 (10 %) patients in these four diagnostic groups, including surgery for nonunion and implant removals, whereas there were no patients in the current study who required a return to operating room.

To our knowledge, the current study represents one of the first comparisons of SCB and MCID between diagnostic groups. These two measures provide great value for contextualizing clinical improvements by describing both the percentage of patients reaching a minimum improvement and patients who can be considered a clinical success.

Regarding the weaknesses of the current study, while the overall study cohort is fairly large, individual group sizes were still relatively small. In addition, classification of the indication groups were straightforward in cases such as spondylolisthesis or isolated one-level disc degeneration in patients with no prior lumbar surgery, but guidelines were less clear for ASD and PLS groups. In instances where there was ambiguity regarding the most appropriate classification, best judgment was taken to assign according to primary indication for surgery. Finally, as this is an interim report of clinical outcomes, long-term conclusions on efficacy and maintenance of improvement are yet to be determined.

Conclusion

While lumbar IBF is generally well accepted for indications such as spondylolisthesis, consensus regarding its utility for more controversial indications such as DDD, or for more technically challenging indications such as PLS, and ASD are more variable. XLIF has been demonstrated in the current series to lead to significant improvements in clinical outcomes and reduces the discrepancy in outcomes between well accepted, controversial, and technically challenging indications compared to traditional open approaches for IBF. Additionally, high rates of patients from

all diagnosis groups reached MCID and SCB thresholds. Complication rates were low, with only one patient in the series experiencing a major complication. Further investigation with larger cohorts and longer follow-up is warranted.

Conflict of interest Dr. Khajavi is a consultant for and has received research funds from NuVasive, Inc, though none related to the current work. Alessandria Shen, following her position at Georgia Spine and Neurosurgery and INSPIRE became employed directly by NuVasive, Inc. for a short time. She currently has no conflicts to report. No other authors have any conflicts.

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