Laminectomy alone versus fusion for grade 1 lumbar spondylolisthesis in 426 patients from the prospective Quality Outcomes Database

Andrew K. Chan, MD,¹ Erica F. Bisson, MD, MPH,² Mohamad Bydon, MD,³ Steven D. Glassman, MD,⁴ Kevin T. Foley, MD,⁵ Eric A. Potts, MD,⁶ Christopher I. Shaffrey, MD,⁷ Mark E. Shaffrey, MD,⁷ Domagoj Coric, MD,⁸ John J. Knightly, MD,⁹ Paul Park, MD,¹⁰ Michael Y. Wang, MD,¹¹ Kai-Ming Fu, MD, PhD,¹² Jonathan R. Slotkin, MD,¹³ Anthony L. Asher, MD,⁸ Michael S. Virk, MD, PhD,¹² Panagiotis Kerezoudis, MD, MS,³ Silky Chotai, MD,¹⁴ Anthony M. DiGiorgio, DO, MHA,¹ Regis W. Haid, MD,¹⁵ and Praveen V. Mummaneni, MD¹

¹Department of Neurological Surgery, University of California, San Francisco, California; ²Department of Neurological Surgery, University of Utah, Salt Lake City, Utah; ³Department of Neurological Surgery, Mayo Clinic, Rochester, Minnesota; ⁴Norton Leatherman Spine Center, Louisville, Kentucky; ⁵Department of Neurological Surgery, University of Tennessee, Semmes-Murphey Neurologic and Spine Institute, Memphis, Tennessee; ⁶Department of Neurological Surgery, Indiana University, Goodman Campbell Brain and Spine, Indianapolis, Indiana; ⁷Department of Neurological Surgery, University of Virginia, Charlottesville, Virginia; ⁸Neuroscience Institute, Carolinas Healthcare System and Carolina Neurosurgery & Spine Associates, Charlotte, North Carolina; ⁹Atlantic Neurosurgical Specialists, Morristown, New Jersey; ¹⁰Department of Neurological Surgery, University of Michigan, Ann Arbor, Michigan; ¹¹Department of Neurological Surgery, University of Miami, Florida; ¹²Department of Neurological Surgery, Weill Cornell Medical Center, New York, New York; ¹³Geisinger Health System, Danville, Pennsylvania; ¹⁴Department of Neurological Surgery, Vanderbilt University, Nashville, Tennessee; and ¹⁵Atlanta Brain and Spine Care, Atlanta, Georgia

OBJECTIVE The AANS launched the Quality Outcomes Database (QOD), a prospective longitudinal registry that includes demographic, clinical, and patient-reported outcome (PRO) data to measure the safety and quality of spine surgery. Registry data offer “real-world” insights into the utility of spinal fusion and decompression surgery for lumbar spondylolisthesis. Using the QOD, the authors compared the initial 12-month outcome data for patients undergoing fusion and those undergoing laminectomy alone for grade 1 degenerative lumbar spondylolisthesis.

METHODS Data from 12 top enrolling sites were analyzed and 426 patients undergoing elective single-level spine surgery for degenerative grade 1 lumbar spondylolisthesis were found. Baseline, 3-month, and 12-month follow-up data were collected and compared, including baseline clinical characteristics, readmission rates, reoperation rates, and PROs. The PROs included Oswestry Disability Index (ODI), back and leg pain numeric rating scale (NRS) scores, and EuroQol-5 Dimensions health survey (EQ-5D) results.

RESULTS A total of 342 (80.3%) patients underwent fusion, with the remaining 84 (19.7%) undergoing decompression alone. The fusion cohort was younger (60.7 vs 69.9 years, $p < 0.001$), had a higher mean body mass index (31.0 vs 28.4, $p < 0.001$), and had a greater proportion of patients with back pain as a major component of their initial presentation (88.0% vs 60.7%, $p < 0.001$). There were no differences in 12-month reoperation rate (4.4% vs 6.0%, $p = 0.93$) and 3-month readmission rates (3.5% vs 1.2%, $p = 0.45$). At 12 months, both cohorts improved significantly with regard to ODI, NRS back and leg pain, and EQ-5D ($p < 0.001$, all comparisons). In adjusted analysis, fusion procedures were associated with superior 12-month ODI ($\beta -4.79$, 95% CI -9.28 to -0.31 ; $p = 0.04$).

CONCLUSIONS Surgery for grade 1 lumbar spondylolisthesis—regardless of treatment strategy—was associated with significant improvements in disability, back and leg pain, and quality of life at 12 months. When adjusting for covariates, fusion surgery was associated with superior ODI at 12 months. Although fusion procedures were associated with a lower

ABBREVIATIONS BMI = body mass index; EQ-5D = EuroQol-5 Dimensions health survey; MCID = minimum clinically important difference; MIS = minimally invasive surgery; NRS = numeric rating scale; ODI = Oswestry Disability Index; PRO = patient-reported outcome; QOD = Quality Outcomes Database; SLIP = Spinal Laminectomy versus Instrumented Pedicle Screw; SPORT = Spine Patient Outcomes Research Trial.

SUBMITTED August 17, 2017. **ACCEPTED** August 2, 2018.

INCLUDE WHEN CITING Published online November 30, 2018; DOI: 10.3171/2018.8.SPINE17913.

rate of reoperation, there was no statistically significant difference at 12 months. Further study must be undertaken to assess the durability of either surgical strategy in longer-term follow-up.

<https://thejns.org/doi/abs/10.3171/2018.8.SPINE17913>

KEYWORDS lumbar; spondylolisthesis; laminectomy; fusion; Quality Outcomes Database

DEGENERATIVE lumbar spondylolisthesis is a major cause of low-back pain with an estimated prevalence of 11.5% in the United States.⁸ For patients who are symptomatic and in whom conservative management strategies fail, surgical treatment is considered and may take the form of a decompressive laminectomy and spinal fusion alone or in combination.^{1,3,7,13,14} Recently, two randomized clinical trials sought to compare the two surgical techniques and arrived at conflicting conclusions. In the Spinal Laminectomy versus Instrumented Pedicle Screw (SLIP) trial by Ghogawala and colleagues, there was a significant improvement in overall health-related quality of life in patients who underwent fusion in addition to decompression versus decompression alone.⁵ However, in the study by Försth and colleagues, there was no added benefit in patients who underwent fusion compared to those who underwent decompression alone, using disability as the primary outcome measure.⁴ There are multiple reasons for the discrepant findings, including a comparison of heterogeneous patient populations, different primary outcome measures, and nonuniform surgical techniques. Indeed, results pulled from randomized clinical trials may be difficult to generalize due to the stringent inclusion criteria used in those studies. Where trials fall short in the ability to capture the variability of “real-world” spine surgery practice, prospective registry data fill in the knowledge gap of a wide range of practice patterns.

The AANS launched the Quality Outcomes Database (QOD), a prospective longitudinal registry that includes demographic, clinical, and patient-reported outcome (PRO) data to measure the safety and quality of spine surgery. The QOD was established with the aim of evaluating risk-adjusted expected morbidity and surgical outcomes in order to improve care for patients receiving spine surgery.¹⁰ This glimpse into actual practice patterns of high-volume neurosurgical and orthopedic spine centers, including collecting PROs directly from patients through the spine surgeon's office, adds unique evidence to the assessment of outcomes following surgery for lumbar spondylolisthesis.

To this end, we compared the initial 12-month outcome data for patients undergoing fusion with or without laminectomy and those undergoing laminectomy alone for grade 1 degenerative lumbar spondylolisthesis in 12 of the highest-enrolling sites in the QOD.

Methods

The database has been enrolling patients since 2012, and as of June 2017 there were more than 12,000 patients across 80 participating sites nationwide who have been enrolled in the Spine Surgery QOD. Twelve of the sites participate in a lumbar spondylolisthesis module organized by the AANS/CNS Joint Section on Disorders of the Spine and Peripheral Nerves in association with the NeuroPoint Alliance, as first reported by Mummaneni

and colleagues.¹² We queried this lumbar spondylolisthesis module for data collected from July 2014 through December 2015 for patients undergoing surgery for grade 1 lumbar spondylolisthesis.

Inclusion Criteria

Preoperative plain radiographs (standing or dynamic) were obtained and were evaluated by surgeons at the participating sites to confirm the diagnosis of grade 1 spondylolisthesis (Fig. 1A) as defined by Meyerding classification.¹¹ Patients were included who underwent posterior-only surgery at the index level of lumbar spondylolisthesis (decompression alone or fusion with or without decompression). Patients were included who underwent single-segment surgery (single-level disc decompression [e.g., L4 or L4–5 decompressive laminectomy]) (Fig. 1B) or a two-level vertebral fusion (e.g., L4–5 posterior spinal fusion) (Fig. 1C).

Exclusion Criteria

Patients were excluded who had 1) grade 2 or higher spondylolisthesis; 2) surgery that included an approach other than posterior alone; and 3) surgery that included more than one disc level.

Demographic, Clinical, and Surgical Variables

The QOD registry collects data on demographic variables (age, sex, body mass index [BMI], and smoking status); patient comorbidities (American Society of Anesthesiologists classification, diabetes mellitus, coronary artery disease, anxiety, depression, osteoporosis); clinical characteristics (dominant symptom, presence of a motor deficit at presentation, ambulation status, symptom duration); socioeconomic factors (use of private insurance, ethnicity, education level, employment status); baseline PRO scores (Oswestry Disability Index [ODI], EuroQol-5 Dimensions health survey [EQ-5D], numeric rating scale [NRS] leg pain, NRS back pain); and surgical variables (decompression alone or fusion with or without decompression, use of minimally invasive surgery [MIS]).

Study Outcomes

We assessed ODI, NRS back pain, NRS leg pain, and EQ-5D at 12 months by using validated questionnaires. We also assessed for readmission within 90 days and return to the operating room within 12 months. Readmissions and reoperations that were deemed related to the index surgery were recorded by study site coordinators. We conducted additional analysis for ODI to assess whether patients achieved a minimum clinically important difference (MCID). An MCID was defined as an improvement in ODI by 12.8, in accordance with previously published analyses.²

FIG. 1. Artist's illustrations. **A:** Degenerative L4–5 grade 1 spondylolisthesis. **B:** Decompression-only surgery involving L4 and L5 decompressive laminectomies. **C:** An L4–5 transforaminal lumbar interbody fusion (TLIF), a surgical option that includes a fusion procedure in addition to decompression. Artist: Kenneth Probst. Copyright Department of Neurological Surgery, University of California, San Francisco. Published with permission. Figure is available in color online only.

Statistical Analysis

Descriptive statistics were reported as means and SDs and as frequencies and percentages where appropriate. Continuous variables were compared using an unpaired Student t-test and categorical variables were compared using Pearson's chi-square test and the Yates correction where appropriate via custom and built-in scripts (MATLAB; Mathworks). Multivariate linear regression models were fitted for ODI, NRS back pain, NRS leg pain, and EQ-5D after controlling for covariates of interest. Covariates included any baseline factor that reached $p < 0.20$ on univariate analysis. This analysis was conducted using R version 2.15.2 (R Foundation for Statistical Computing, <https://www.R-project.org>). Missing values in the data were imputed using the "missForest" R package, a nonparametric imputation method based on the random forest algorithm (<http://adsabs.harvard.edu/abs/2015ascl.soft05011S>). Probability values were 2-tailed and an alpha of 0.05 was considered statistically significant.

Results

Between July 1, 2014, and December 31, 2015, there were 426 patients who underwent surgery for grade 1 lumbar spondylolisthesis. This included 342 patients (80.3%) who underwent fusion with or without decompression and 84 patients (19.7%) who underwent decompression alone. Twelve-month follow-up was achieved by 77.5% of patients. Descriptive variables are presented in Table 1. Perioperative outcomes are summarized in Table 2.

Readmission Rates

Overall, 13 patients (3.1%) were readmitted within 90 days. In those who underwent decompression alone, there was 1 patient (1.2%) readmitted within 90 days. In those

who underwent fusion, 12 (3.5%) were readmitted within 90 days. The 90-day readmission rates did not differ significantly ($p = 0.45$). The readmission data are presented in Table 3.

Reoperation Rates

Overall, 20 patients (4.7%) returned to the operating room within 12 months. In those who underwent decompression alone, 5 (6.0%) returned to the operating room within 12 months. In those who underwent fusion, 15 (4.4%) returned within 12 months. The 12-month reoperation rates were not significantly different ($p = 0.93$). The reoperation data are presented in Table 3.

The reasons for return to the operating room for the decompression-alone group were revision laminectomies (3 patients) and conversion to transforaminal lumbar interbody fusion procedures (2 patients). All 5 of the reoperations occurred at the index level of the initial surgery. The reasons for return to the operating room in the fusion group were wound revisions and/or incision and drainage (7 patients), adjacent-segment disease (3 patients), screw reposition/hardware failures (3 patients), bony fracture within the fusion construct (1 patient), and evacuation of hematoma (1 patient). One of the patients requiring an incision and drainage also sustained a dural tear accompanied by a pseudomeningocele. Twelve of the 15 reoperations in the fusion group occurred at the index level of the initial surgical procedure. The remaining 3 occurred at adjacent segments.

Patient-Reported Outcomes

ODI

Overall, the mean ODI score improved significantly at 12 months for the entire study cohort (22.4 ± 19.8 , from

TABLE 1. Characteristics of patients undergoing surgery for grade 1 lumbar spondylolisthesis

Characteristic	All	Decompression Alone	Fusion	p Value
No. of patients	426	84	342	
Age (yrs)	62.5 ± 11.5	69.9 ± 10.5	60.7 ± 11.0	<0.001*
Female	252 (59.2%)	41 (48.8%)	211 (61.7%)	0.03*
BMI	30.5 ± 6.5	28.4 ± 5.2	31.0 ± 6.7	<0.001*
Smoker	46 (10.8%)	7 (8.3%)	39 (11.4%)	0.42
Comorbidities				
Diabetes mellitus	75 (17.6%)	22 (26.2%)	53 (15.5%)	0.02
Coronary artery disease	52 (12.2%)	16 (19.0%)	36 (10.5%)	0.11
Anxiety	67 (15.7%)	12 (14.3%)	55 (16.1%)	0.69
Depression	84 (19.7%)	12 (14.3%)	72 (21.1%)	0.16
Osteoporosis	25 (5.9%)	3 (3.6%)	22 (6.4%)	0.46
Dominant presenting symptom				<0.001*
Back pain dominant	165 (38.7%)	25 (29.8%)	140 (40.9%)	
Leg pain dominant	74 (17.4%)	33 (39.3%)	41 (12.0%)	
Back pain = leg pain	187 (43.9%)	26 (31.0%)	161 (47.1%)	
Motor deficit present at presentation	104 (24.4%)	32 (38.1%)	72 (21.1%)	0.001*
Independently ambulatory	380 (89.2%)	72 (85.7%)	308 (90.1%)	0.25
Symptom duration				0.01
<3 mos	11 (2.6%)	6 (7.1%)	5 (1.5%)	
≥3 mos	401 (94.1%)	75 (89.3%)	326 (95.3%)	
ASA grade				0.46
1 or 2	234 (54.9%)	49 (58.3%)	185 (54.1%)	
3 or 4	188 (44.1%)	34 (40.5%)	154 (45.0%)	
Ethnicity: Hispanic or Latino	23 (5.4%)	3 (3.6%)	20 (5.8%)	0.58
Education level: ≥4 yrs of college	158 (37.1%)	40 (47.6%)	118 (34.5%)	0.03*
Employment status: actively employed or employed & on leave	189 (44.4%)	28 (33.3%)	161 (47.1%)	0.02*
MIS techniques used	185 (43.4%)	48 (57.1%)	137 (40.1%)	0.005*
ODI, baseline	47.7 ± 16.9	40.9 ± 18.0	49.4 ± 16.2	<0.001*
NRS back pain, baseline	6.9 ± 2.6	5.8 ± 3.3	7.1 ± 2.4	0.002*
NRS leg pain, baseline	6.6 ± 2.8	6.1 ± 2.9	6.8 ± 2.7	0.06
EQ-5D, baseline	0.53 ± 0.22	0.59 ± 0.22	0.52 ± 0.23	0.01*

ASA = American Society of Anesthesiologists.

Values are expressed as either the mean ± SD or the number of patients (%). Values do not add up to 100% where there are missing data.

* Denotes a statistically significant relationship, alpha level 0.05.

the baseline score of 47.7 ± 16.9 , $p < 0.001$). At baseline, those in the fusion cohort had greater disability (ODI 49.4 ± 16.2 vs 40.9 ± 18.0 , $p < 0.001$). ODI improved significantly at 12 months for both the fusion cohort (22.6 ± 20.4

from 49.4 ± 16.2 , $p < 0.001$) and the decompression-alone cohort (21.2 ± 17.0 from 40.9 ± 18.0 , $p < 0.001$) (Fig. 2A). There was no difference in 12-month ODI between the fusion cohort and the decompression-alone cohort ($p =$

TABLE 2. Perioperative outcomes for patients undergoing surgery for grade 1 lumbar spondylolisthesis

Periop Outcome	All	Decompression Alone	Fusion	p Value
No. of patients	426	84	342	
Estimated blood loss (ml)	193.5 ± 198.6	44.5 ± 59.0	230.1 ± 203.8	<0.001*
Operative time (mins)	172.2 ± 82.2	99.5 ± 49.4	187.1 ± 79.7	<0.001*
Length of hospitalization (days)	2.8 ± 1.8	1.0 ± 1.3	3.3 ± 1.7	<0.001*
Discharge disposition				0.92
Home or home healthcare	379 (89.0%)	75 (89.3%)	304 (88.9%)	
Other than home or home healthcare	47 (11.0%)	9 (10.7%)	38 (11.1%)	

* Denotes a statistically significant relationship, alpha level 0.05.

TABLE 3. Readmission and reoperation rates for patients undergoing surgery for grade 1 lumbar spondylolisthesis

Variable	All	Decompression Alone	Fusion	p Value
No. of patients	426	84	342	
Readmission w/in 90 days	13 (3.1%)	1 (1.2%)	12 (3.5%)	0.45
Reop w/in 12 mos	20 (4.7%)	5 (6.0%)	15 (4.4%)	0.93

0.50). There was similarly no difference in 12-month ODI change scores ($p = 0.59$) (Table 4). Of note, 250 (75.5%) of 331 patients with 12-month follow-up reached MCID regardless of surgical technique. A greater proportion of patients who reached 12-month follow-up in the fusion cohort (208 [77.3%]) achieved MCID compared to the decompression-alone cohort (42 [67.7%]), although this was not statistically significant ($p = 0.11$). Table 5 presents ODI MCID at 12 months by surgical technique.

In adjusted multivariate analysis (Table 6), the addition of fusion was independently associated with superior ODI at the 12-month follow-up period ($\beta -4.79$, 95% CI -9.28 to -0.31 ; $p = 0.04$). Additional factors significantly associated with 12-month ODI include BMI ($\beta 0.47$, 95% CI 0.21 to 0.73 ; $p = 0.001$), education status ($\beta -3.95$, 95% CI -7.38 to -0.52 ; $p = 0.02$), employment status ($\beta -6.10$, 95% CI -9.93 to -2.27 ; $p = 0.002$), and baseline ODI ($\beta 0.44$, 95% CI 0.30 to 0.57 ; $p < 0.001$).

NRS Back Pain, NRS Leg Pain, and EQ-5D

Overall, the mean NRS back pain scores improved significantly at 12 months for the entire study cohort (2.9 ± 2.7 from baseline 6.9 ± 2.6 , $p < 0.001$). At baseline, NRS back pain scores were worse for the fusion cohort compared to the decompression-alone cohort (7.1 ± 2.4 vs 5.8 ± 3.3 , $p = 0.002$). NRS back pain scores improved significantly at 12 months for both the fusion cohort (3.0 ± 2.8 from 7.1 ± 2.4 at baseline, $p < 0.001$) and the decompression-alone cohort (2.4 ± 2.5 from 5.8 ± 3.3 , $p < 0.001$) (Fig. 2B). There was no significant difference for 12-month follow-up NRS back pain ($p = 0.16$). There was similarly no difference in 12-month NRS back pain change scores ($p = 0.36$) (Table 4).

Overall, the mean NRS leg pain scores improved significantly at 12 months for the entire study cohort (2.4 ± 3.1 from baseline 6.6 ± 2.8 , $p < 0.001$). At baseline, NRS leg pain scores were greater for the fusion cohort (6.8 ± 2.7 vs 6.1 ± 2.9), but this did not reach statistical significance ($p = 0.06$). NRS leg pain scores improved significantly at 12 months for both the fusion cohort (2.5 ± 3.2 from 6.8 ± 2.7 at baseline, $p < 0.001$) and the decompression-alone cohort (2.1 ± 2.7 from 6.1 ± 2.9 , $p < 0.001$) (Fig. 2C). There was no significant difference for 12-month follow-up NRS leg pain ($p = 0.62$) or NRS leg pain change scores ($p = 0.93$) (Table 4).

Overall, the mean EQ-5D improved significantly at 12 months for the entire study cohort (0.78 ± 0.19 from baseline 0.53 ± 0.22 , $p < 0.001$). At baseline, EQ-5D was higher for the decompression-alone cohort (0.59 ± 0.22 vs

FIG. 2. Baseline, 3-month, and 12-month PROs following surgery for grade 1 lumbar spondylolisthesis. **A:** Average ODI at baseline, 3 months, and 12 months following surgery, by cohort. **B:** Average NRS back pain scores at baseline, 3 months, and 12 months following surgery, by cohort. **C:** Average NRS leg pain scores at baseline, 3 months, and 12 months following surgery, by cohort. **D:** Average EQ-5D at baseline, 3 months, and 12 months following surgery, by cohort. The error bars represent 1 SD. For both cohorts there were statistically significant improvements at 3- and 12-month follow-up, relative to baseline, for NRS back and leg pain, ODI, and EQ-5D ($p < 0.001$, all comparisons). At baseline, the fusion cohort had significantly worse ODI ($p < 0.001$), NRS back pain ($p = 0.002$), and EQ-5D ($p = 0.01$) without significant differences in NRS leg pain. Aside from 3-month EQ-5D ($p = 0.002$), there were no significant between-group differences with regard to each PRO at 3 months and 12 months.

0.52 ± 0.23 , $p = 0.01$). EQ-5D significantly improved at 12 months for both the fusion cohort (0.77 ± 0.20 from 0.52 ± 0.23 , $p < 0.001$) and the decompression-alone cohort (0.81 ± 0.16 from 0.59 ± 0.22 , $p < 0.001$) (Fig. 2D). There was no significant difference between the two cohorts for 12-month follow-up EQ-5D ($p = 0.81$) or 12-month change scores ($p = 0.20$) (Table 4).

Supplemental Tables 1–3 reveal factors associated with

TABLE 4. Mean 12-month change scores by surgical technique

Scoring System	All	Decompression Alone	Fusion	p Value
No. of patients	426	84	342	
ODI, 12-mo change	-25.0 ± 18.7	-20.1 ± 21.6	-26.1 ± 17.9	0.59
NRS back pain, 12-mo change	-3.9 ± 3.2	-3.1 ± 3.6	-4.1 ± 3.0	0.36
NRS leg pain, 12-mo change	-4.2 ± 3.6	-3.9 ± 3.7	-4.2 ± 3.6	0.93
EQ-5D, 12-mo change	0.24 ± 0.24	0.20 ± 0.25	0.25 ± 0.23	0.20

TABLE 5. ODI MCID at 12 months by surgical technique

MCID	All	Decompression Alone	Fusion	p Value
No	81 (24.5%)	20 (32.3%)	61 (22.7%)	0.11
Yes	250 (75.5%)	42 (67.7%)	208 (77.3%)	

12-month NRS back pain, NRS leg pain, and EQ-5D, respectively. Of note, fusion procedures were not associated with 12-month NRS back pain, NRS leg pain, or EQ-5D at 12 months ($p > 0.05$ for all).

Discussion

In the initial 12-month follow-up of 426 patients undergoing surgery for grade 1 degenerative lumbar spondylolisthesis, the overall cohort—regardless of surgical strategy—demonstrated significant improvements in ODI, NRS back and leg pain, and EQ-5D. There were no significant differences in readmission rates and reoperation rates. In multivariate adjusted analysis, the addition of fusion was associated with superior ODI at 12 months.

The improvement in all PROs, regardless of treatment modality, suggests that fusion or decompression alone both are efficacious treatment strategies for well-selected patients. Still, superior ODI at 12 months was associated with a fusion procedure. Additionally, there was a greater proportion of patients who achieved MCID in the fusion cohort, although this result was not statistically significant. This greater improvement in ODI seen in the fusion cohort was also seen in the SLIP trial, where at 4-year follow-up there was a 9-point difference in ODI, achieving a p value of 0.05.⁵ Defining MCID as a 10-point improvement in ODI, the SLIP trial did reveal a significantly greater proportion of patients (85% vs 61%) who achieved MCID in the fusion cohort. On the other hand, Försth et al. found no significant difference in ODI at 2 years in their subgroup analysis of patients with degenerative spondylolisthesis.⁴ Discrepant results are possibly due to these studies being underpowered to detect such differences.⁶ Additionally, the surgical techniques and inclusion criteria varied. The extent to which disability changes over time remains to be seen in long-term follow-up of this cohort.

We found no differences with regard to the magnitudes of improvement of both leg and back pain from baseline. Selection bias is a potential issue for our comparisons, because the two cohorts were composed of different proportions of patients reporting dominant symptoms of back or leg pain at baseline. This is consistent with previous findings revealing no significant differences in the percentages of patients reporting a decrease in back and leg pain from baseline when comparing those who underwent fusion and those who underwent decompression for degenerative spondylolisthesis.⁴ It is important to note that it is unlikely that both procedures treat back and leg pain similarly; the lack of difference probably reflects a bias in surgical decision making based on the patient's primary presenting symptom.

At 12 months, we saw similar improvements in EQ-5D between both cohorts. This is similar to the 1-year outcomes of the SLIP trial⁵ and 2-year outcomes of the study

TABLE 6. Multivariate analysis assessing predictors of 12-month ODI following surgery for grade 1 lumbar spondylolisthesis

Variable	Adjusted β Coefficient (95% CI)	p Value
Addition of fusion to procedure	-4.79 (-9.28 to -0.31)	0.04*
Age (yrs)	-0.16 (-0.33 to 0.02)	0.09
Female	-3.18 (-6.47 to 0.11)	0.06
Private insurance	-0.38 (-4.20 to 3.44)	0.85
Diabetes mellitus	0.59 (-3.76 to 4.93)	0.79
Coronary artery disease	-0.13 (-5.06 to 4.80)	0.96
Depression	0.63 (-3.54 to 4.79)	0.77
Dominant presenting symptom		
Back pain dominant	-0.44 (-3.93 to 3.04)	0.80
Leg pain dominant	-1.83 (-6.62 to 2.95)	0.45
Back pain = leg pain	Reference	
Motor deficit at presentation	2.47 (-1.33 to 6.27)	0.20
Symptom duration ≥ 3 mos	7.87 (-2.35 to 18.09)	0.13
BMI	0.47 (0.21 to 0.73)	0.001*
Education ≥ 4 yrs of college	-3.95 (-7.38 to -0.52)	0.02*
Actively employed or employed & on leave	-6.10 (-9.93 to -2.27)	0.002*
MIS	-2.52 (-5.78 to 0.75)	0.13
ODI, baseline	0.44 (0.30 to 0.57)	<0.001*
NRS back pain, baseline	0.46 (-0.31 to 1.22)	0.24
NRS leg pain, baseline	-0.30 (-0.98 to 0.38)	0.38
EQ-5D, baseline	-1.92 (-11.54 to 7.70)	0.70

* Denotes a statistically significant relationship, alpha level 0.05.

by Försth et al.,⁴ in which similar improvements in quality of life were found. However, a significantly greater improvement was ultimately achieved at 2 years of follow-up in the SLIP fusion cohort—a result that held true in 3- and 4-year follow-up findings. It remains to be seen if this result is replicated in the QOD cohort with longer follow-up.

At 12 months, there was no difference in the rate of reoperation in the cohort undergoing decompression alone as opposed to fusion. This is somewhat inconsistent with the SLIP study, which found a significantly higher rate of reoperation in the decompression-alone group,⁵ although follow-up was longer in the SLIP study. Importantly, when reoperations occurred they addressed the same level as the index surgery—suggesting that for these patients, decompression alone may have been an insufficient initial treatment strategy. These findings suggest that lumbar laminectomy sufficiently destabilizes the spine in a proportion of patients requiring a subsequent fusion. Indeed, at 1 year, 40% of reoperations in the QOD laminectomy-alone cohort involved subsequent fusion procedures. The extent to which the reoperation rate in our prospective registry decompression-alone cohort approximates that found in prior administrative studies and randomized clinical trials (22%–34%)^{4,5,9} at extended follow-up remains to be seen. At 12 months, the reoperation rate for the present fusion cohort (4.4%) is higher than that of the studies conducted by Ghogawala et al.⁵ and Försth et al.,⁴ but is similar to the approximately 6.5% reoperation rate reported in the

Spine Patient Outcomes Research Trial (SPORT) surgical cohort.¹⁵ It is important to note that this stated reoperation rate is for the total SPORT study population. Although a majority of the cohort received a fusion procedure, 5.4% of the SPORT patients received decompression only.

In the SLIP study, all reoperations in the fusion cohort occurred at the adjacent level (disc herniation, clinical instability). The QOD registry demonstrates that there are a greater variety of reasons for return to the operating room besides adjacent-segment disease: wound revisions/wash-outs, bony fractures within the construct, and need for revision decompression. Additionally, fusion surgery, which requires instrumentation, has risks of hardware malposition and failure, which require reoperation as well. Further follow-up will demonstrate the extent to which either surgery affects local spinal alignment, stability, and reoperation profile.

In the SLIP trial, although half of the patients with decompression alone who ultimately required reoperation at 4 years received their reoperation within the first 2 years of follow-up, the first reoperation in the fusion group did not occur until almost 3 years after the index surgery.⁵ Likewise, in the study by Försth et al., at 1 year, approximately 5% of the decompression-alone cohort required reoperation, whereas zero fusion patients required reoperation at the same time interval.⁴ Although the risk of reoperation was initially lower for the fusion cohort, the line graphs of risk intersect at the 5-year follow-up, with the fusion cohort ultimately having a greater proportion of reoperations thereafter.⁴ The extent to which the incidence of reoperation changes over time remains to be seen in longer follow-up of this QOD cohort.

This study has several limitations. First, as a nonrandomized evaluation of a breadth of practice patterns, there is no attempt to standardize surgical decision-making or surgical technique. Our findings are susceptible to selection bias and group heterogeneity. In this study, the fusion cohort was significantly younger, with a higher mean BMI, and had a greater proportion of patients who presented with a component of back pain. Observations should be made with these differences as context. Second, findings herein are reported from patients with only 1-level spondylolisthesis and may not be generalizable to patients with multilevel disease. Additionally, the spondylolisthesis study group uses only a subset of QOD registry sites. It is possible that the subgroup findings may differ from those of the overall registry. However, we believe that this practical design—which permits the allocation of dedicated study coordinators and staff—allows ongoing auditing of our prospective database and ensures data accuracy.

The QOD registry was designed to collect several outcomes: reoperation rates, readmission rates, and PROs. An important outcome in the comparison of fusion versus decompression alone is fusion status, as assessed by follow-up radiographs. Identifying patients who actually achieve radiographic fusion and abstracting their associated PROs will help to define the role of fusion in achieving satisfactory outcomes following surgery for grade 1 degenerative lumbar spondylolisthesis. Likewise, baseline radiographs may help to identify factors that may also affect outcomes

(e.g., slip angle, slip degree), but were not available for the present study.

When comparing treatment strategies, durability and the avoidance of additional surgical intervention are primary concerns. Longer-term follow-up from the QOD lumbar spondylolisthesis module will be reported in future studies and will shed light on the durability of each procedure. Additionally, when comparing treatment strategies, value must be considered. This study did not aim to evaluate value, and future studies should be undertaken to evaluate health-resource utilization data in the context of these two treatment strategies.

Nonetheless, the present study provides initial benchmarking data for the real-world experience of multiple spine centers in the surgical treatment of grade 1 lumbar spondylolisthesis. Such data will prove invaluable as scrutiny increases in the United States regarding the value and costs of spine surgery.

Conclusions

This study assessed outcomes following grade 1 lumbar spondylolisthesis surgery in a real-world setting that includes a wide range of practice environments. Both decompression-alone and fusion approaches were associated with significant improvements in disability, back and leg pain, and EQ-5D at 12 months. The addition of fusion was associated with superior ODI at 12 months. Although fusion procedures had a lower rate of reoperation at 12 months, this result did not reach statistical significance. Longer-term study—specifically an assessment of 2-year follow-up—must be undertaken to assess the durability of either surgical strategy.

Acknowledgments

We thank all of the site research coordinators for their help with data extraction and validation. We also thank the Neurosurgery Research and Education Foundation (NREF) for its financial support of this work.

References

- Cheng JS, Park P, Le H, Reisner L, Chou D, Mummaneni PV: Short-term and long-term outcomes of minimally invasive and open transforaminal lumbar interbody fusions: is there a difference? *Neurosurg Focus* 35(2):E6, 2013
- Copay AG, Glassman SD, Subach BR, Berven S, Schuler TC, Carreon LY: Minimum clinically important difference in lumbar spine surgery patients: a choice of methods using the Oswestry Disability Index, Medical Outcomes Study questionnaire Short Form 36, and pain scales. *Spine J* 8:968–974, 2008
- Dhall SS, Wang MY, Mummaneni PV: Clinical and radiographic comparison of mini-open transforaminal lumbar interbody fusion with open transforaminal lumbar interbody fusion in 42 patients with long-term follow-up. *J Neurosurg Spine* 9:560–565, 2008
- Försth P, Ólafsson G, Carlsson T, Frost A, Borgström F, Fritzell P, et al: A randomized, controlled trial of fusion surgery for lumbar spinal stenosis. *N Engl J Med* 374:1413–1423, 2016
- Ghogawala Z, Dziura J, Butler WE, Dai F, Terrin N, Magge SN, et al: Laminectomy plus fusion versus laminectomy alone for lumbar spondylolisthesis. *N Engl J Med* 374:1424–1434, 2016

6. Ghogawala Z, Resnick DK, Glassman SD, Dziura J, Shaffrey CI, Mummaneni PV: Randomized controlled trials for degenerative lumbar spondylolisthesis: which patients benefit from lumbar fusion? **J Neurosurg Spine** **26**:260–266, 2017
7. Ghogawala Z, Shaffrey CI, Asher AL, Heary RF, Logvinenko T, Malhotra NR, et al: The efficacy of lumbar discectomy and single-level fusion for spondylolisthesis: results from the NeuroPoint-SD registry: clinical article. **J Neurosurg Spine** **19**:555–563, 2013
8. Kalichman L, Kim DH, Li L, Guermazi A, Berkin V, Hunter DJ: Spondylolysis and spondylolisthesis: prevalence and association with low back pain in the adult community-based population. **Spine (Phila Pa 1976)** **34**:199–205, 2009
9. Martin BI, Mirza SK, Comstock BA, Gray DT, Kreuter W, Deyo RA: Reoperation rates following lumbar spine surgery and the influence of spinal fusion procedures. **Spine (Phila Pa 1976)** **32**:382–387, 2007
10. McGirt MJ, Spero T, Dittus RS, Harrell FE Jr, Asher AL: The National Neurosurgery Quality and Outcomes Database (N²QOD): general overview and pilot-year project description. **Neurosurg Focus** **34**(1):E6, 2013
11. Meyerding HW: Diagnosis and roentgenologic evidence of spondylolisthesis. **Radiology** **20**:108–120, 1933
12. Mummaneni PV, Bisson EF, Kerezoudis P, Glassman S, Foley K, Slotkin JR, et al: Minimally invasive versus open fusion for Grade I degenerative lumbar spondylolisthesis: analysis of the Quality Outcomes Database. **Neurosurg Focus** **43**(2):E11, 2017
13. Rosenberg WS, Mummaneni PV: Transforaminal lumbar interbody fusion: technique, complications, and early results. **Neurosurgery** **48**:569–575, 2001
14. Wang JC, Mummaneni PV, Haid RW: Current treatment strategies for the painful lumbar motion segment: posterolateral fusion versus interbody fusion. **Spine (Phila Pa 1976)** **30** (16 Suppl):S33–S43, 2005
15. Weinstein JN, Lurie JD, Tosteson TD, Hanscom B, Tosteson AN, Blood EA, et al: Surgical versus nonsurgical treatment for lumbar degenerative spondylolisthesis. **N Engl J Med** **356**:2257–2270, 2007

Disclosures

Dr. Bisson is a consultant for nView. Dr. Foley is a consultant for Medtronic; has direct stock ownership in Discgenics, Medtronic, NuVasive, SpineWave, and TrueVision; and is a patent holder with Medtronic and NuVasive. He also receives royalties for patents from Medtronic. He is on the board of directors for Discgenics and TrueVision. Dr. Fu is a consultant for SI-BONE. Dr. Glassman is an employee of Norton Healthcare. He is a patent holder with, a consultant for, and receives royalties from Medtronic. He is the past president of the Scoliosis Research Society. Dr.

Haid has direct stock ownership in NuVasive, SpineWave, and Globus. He is a consultant for NuVasive and receives royalties from that company. He also receives royalties from Medtronic and Globus. He is a patent holder with Medtronic. He is chair of the NREF. Dr. Knightly is on the board of directors for the NPA (NeuroPoint Alliance). Dr. Mummaneni is a consultant for DePuy Spine, Globus, and Stryker, and he has direct stock ownership in Spinicity/ISD. He receives clinical or research support for the study described (includes equipment or material) from the NREF. He receives royalties from DePuy Spine, Thieme Publishing, and Springer Publishing, and honoraria from AOSpine and Spineart. Dr. Park is a consultant for Globus, Medtronic, NuVasive, and Zimmer-Biomet. He receives royalties from Globus. Dr. Potts is a consultant for Medtronic. Dr. Chris Shaffrey is a consultant for Medtronic, NuVasive, and Zimmer-Biomet. He has direct stock ownership in NuVasive, and he is a patent holder with Medtronic, NuVasive, and Zimmer-Biomet. Dr. Slotkin is a consultant for Stryker and Medtronic. Dr. Wang is a patent holder with DePuy-Synthes Spine and Spineology. He is a consultant for DePuy-Synthes Spine, Stryker, K2M, and Globus Medical. He has direct stock ownership in Globus Medical.

Author Contributions

Conception and design: Mummaneni, Bisson, Bydon, Glassman, Asher. Acquisition of data: Chan, Bisson, Bydon, Wang, Virk, Kerezoudis, Chotai, DiGiorgio. Analysis and interpretation of data: Mummaneni, Chan, Bisson, Glassman, Foley, Potts, CI Shaffrey, Coric, Knightly, Park, Fu, Slotkin, Asher, Virk, Kerezoudis, Chotai, DiGiorgio. Drafting the article: Mummaneni, Chan, Bisson, Bydon, Glassman, Foley, Potts, CI Shaffrey, Coric, Knightly, Park, Wang, Fu, Slotkin, Asher, Virk, Chotai, DiGiorgio. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Statistical analysis: Chan, Bisson, Virk. Administrative/technical/material support: Mummaneni, Bisson, Bydon, ME Shaffrey, Asher, Haid. Study supervision: Mummaneni, Bisson, Bydon, Asher, Haid.

Supplemental Information

Online-Only Content

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

Supplemental Tables 1–3. <https://thejns.org/doi/suppl/10.3171/2018.8.SPINE17913>.

Correspondence

Praveen V. Mummaneni: University of California, San Francisco, CA. praveen.mummaneni@ucsf.edu.