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Open versus minimally invasive decompression for low-grade spondylolisthesis: analysis from the Quality Outcomes Database

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OBJECTIVE Lumbar decompression without arthrodesis remains a potential treatment option for cases of low-grade spondylolisthesis (i.e., Meyerding grade I). Minimally invasive surgery (MIS) techniques have recently been increasingly used because of their touted benefits including lower operating time, blood loss, and length of stay. Herein, the authors analyzed patients enrolled in a national surgical registry and compared the baseline characteristics and postoperative clinical and patient-reported outcomes (PROs) between patients undergoing open versus MIS lumbar decompression.

METHODS The authors queried the Quality Outcomes Database for patients with grade I lumbar degenerative spondylolisthesis undergoing a surgical intervention between July 2014 and June 2016. Among more than 200 participating sites, the 12 with the highest enrollment of patients into the lumbar spine module came together to initiate a focused project to assess the impact of fusion on PROs in patients undergoing surgery for grade I lumbar spondylolisthesis. For the current study, only patients in this cohort from the 12 highest-enrolling sites who underwent a decompression alone were evaluated and classified as open or MIS (tubular decompression). Outcomes of interest included PROs at 2 years; perioperative outcomes such as blood loss and complications; and postoperative outcomes such as length of stay, discharge disposition, and reoperations.

RESULTS A total of 140 patients undergoing decompression were selected, of whom 71 (50.7%) underwent MIS and 69 (49.3%) underwent an open decompression. On univariate analysis, the authors observed no significant differences between the 2 groups in terms of PROs at 2-year follow-up, including back pain, leg pain, Oswestry Disability Index score, EQ-5D score, and patient satisfaction. On multivariable analysis, compared to MIS, open decompression was associated with higher satisfaction (OR 7.5, 95% CI 2.41–23.2, p = 0.0005). Patients undergoing MIS decompression had a significantly shorter length of stay compared to the open group (0.68 days [SD 1.18] vs 1.83 days [SD 1.618], p < 0.001).

ABBREVIATIONS ASA = American Society of Anesthesiologists; BMI = body mass index; MIS = minimally invasive surgery; NASS = North American Spine Society; NRS = numeric rating scale; ODI = Oswestry Disability Index; OL = open laminectomy; PRO = patient-reported outcome; QOD = Quality Outcomes Database.

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CONCLUSIONS In this multiinstitutional prospective study, the authors found comparable PROs as well as clinical outcomes at 2 years between groups of patients undergoing open or MIS decompression for low-grade spondylolisthesis.

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KEYWORDS open surgery; MIS; minimally invasive surgery; decompression; spondylolisthesis; Quality Outcomes Database; QOD; spine surgery; lumbar; registry

Degenerative lumbar spondylolisthesis is one of the most common causes of low-back pain; the reported prevalence is 11.5% in the US according to one estimate.[1] For a select group of patients in whom conservative measures have failed, a surgical intervention may be considered.[2]

For patients with Meyerding grade I spondylolisthesis without significant instability on lateral radiographs, decompression alone has been shown to be associated with optimum clinical outcomes.[3–6] A conventional open laminectomy (OL) for spondylolisthesis involves stripping of deep paraspinal muscles away from the spinous processes and retraction to expose the lamina, and subsequently performing laminectomy with or without facetectomy to decompress the spinal canal and neural elements. However, there are some well-recognized drawbacks of this conventional technique, including tissue trauma (e.g., multifidus atrophy due to prolonged duration of retraction), disturbed arteriolar blood supply, postoperative chronic low-back pain due to altered biomechanics of the posterior column, and secondary instability.[7–13] To address these concerns, minimally invasive surgery (MIS) procedures have been increasingly used to address spinal pathologies. MIS allows the surgeon to minimize trauma to normal anatomical structures while achieving optimum decompression.

Among MIS techniques, unilateral decompression performed using muscle-splitting serial tube dilators and retractors is one of the most commonly used procedures. Tubular decompression allows for effective bilateral neural decompression while protecting muscle tissue and tendon attachments, potentially causing less biomechanical instability compared to OL.[6,14–20] Nevertheless, OL is still considered to be an effective procedure; it is widely performed and has been shown to have optimal long-term outcomes.

As MIS techniques are increasingly adapted, it is important to investigate their outcomes in comparison to conventional open techniques. In the current study we used a prospective national registry to compare clinical and patient-reported outcomes (PROs) between open and minimally invasive decompression among patients with grade I spondylolisthesis.

Methods

Study Cohort

For the present study, the Quality Outcomes Database (QOD) was queried for patients undergoing surgery for Meyerding grade I degenerative lumbar spondylolisthesis between July 1, 2014, and June 30, 2016. The QOD is a prospective multiinstitutional registry established in 2012 with the objective to evaluate risk-adjusted expected morbidity, 30-day clinical outcomes of interest, and 12-month PROs. The overarching goal of this registry is to establish a data-driven mechanism of providing insights into improving quality of care for routinely performed spine surgeries in the US.[21–23] As of February 2019, more than 78,879 patients undergoing a lumbar surgery for degenerative disease across 105 participating sites in the nation have been enrolled in the lumbar spine surgery QOD module.[24] Among these sites, the 12 with the highest enrollment of patients into the lumbar spine module came together to initiate a focused project to assess the impact of fusion on PROs in patients undergoing surgery for grade I lumbar spondylolisthesis.[25–29] In order to determine the diagnosis of grade I spondylolisthesis,[30] surgeons at each of the participating sites evaluated preoperative standing or dynamic radiographs.[25–29] The primary outcome of interest for this study was the Oswestry Disability Index (ODI) score. Informed consent and institutional review board approval were obtained.

Predictor of Interest

For the current study, the cohort was divided into those undergoing OL and minimally invasive laminectomy. A case was considered MIS if there was use of tubular decompression.[15] All patients in both groups underwent a single-level decompression.

Outcomes of Interest

The primary outcome of interest was the ODI score[31] at 2-year follow-up. Secondary outcomes of interest included other PROs, such as the numeric rating scale (NRS) back pain, NRS leg pain,[32] EQ-5D questionnaire,[33] and North American Spine Society (NASS) satisfaction questionnaire.[34] The NASS satisfaction questionnaire assesses satisfaction by using a 4-point survey with scores 1 through 4, respectively: "surgery met my expectations," "I did not improve as much as I had hoped but I would undergo the same operation for the same results," "surgery helped but I would not undergo the same operation for the same results," and "I am the same or worse as compared to before surgery." We also analyzed perioperative and postoperative clinical outcomes including operating time, blood loss, complications, postoperative length of stay, discharge disposition, and reoperations.

Covariates

The following variables were included in the analyses for the current study:[25–29] 1) demographic characteristics including age, sex, body mass index (BMI), ethnicity, insurance status, education level, employment, and work-

ers' compensation; 2) comorbidities, including smoking, diabetes, osteoporosis, coronary artery disease, anxiety, history of major depressive disorder, and American Society of Anesthesiologists (ASA) classification; 3) clinical characteristics such as symptom duration, dominant symptom, ambulation, and presence of motor deficit; and 4) baseline PROs. Other surgical variables such as intraoperative blood loss and operating time were also documented. We also compared the rate of complications between the MIS and OL groups. These complications included deep vein thrombosis, new neurological deficit, myocardial infarction, urinary tract infection, surgical site infection, hematoma, cerebrovascular accident, durotomy, and pneumonia.

Statistical Analysis

Continuous variables were summarized using the mean (SD) and compared using the t-test. Categorical variables were summarized using frequencies with proportions and compared using chi-square or Fisher's exact test. We also performed a multivariable linear regression analysis to analyze the outcomes of interest, including change in ODI, change in NRS leg and back pain, and change in EQ-5D at the 2- or 3-year follow-up. We also performed multivariable logistic regression analysis for assessing NASS patient satisfaction at the 2- or 3-year follow-up. All analyses were performed with R version 3.3.1 (R Foundation for Statistical Computing), using the *rms* and *Arsenal* packages.[35] The p values were 2-tailed and were considered significant if they were less than 0.05.

Results

Of the 608 patients undergoing surgery for grade I spondylolisthesis across 12 sites, 140 patients (23.0%) underwent a decompression alone. Of these, 71 patients (50.7%) underwent an MIS decompression and 69 patients (49.3%) underwent an open decompression.

Demographic and Clinical Characteristics

Compared to patients undergoing an open decompression, patients undergoing an MIS decompression were older (72.26 [SD 9.66] years vs 66.91 [SD 12.57] years, p = 0.005); more likely to have Medicare or Medicaid (71.8%, n = 51 vs 47.8%, n = 33; p = 0.009); more likely to be unemployed (75.7%, n = 53 vs 54.4%, n = 37; p = 0.025); and more likely to have lower ASA scores (73.2%, n = 52 vs 55.2%, n = 37; p = 0.027). We did not find any difference between the 2 groups in terms of BMI, sex, education, smoking status, diabetes, coronary artery disease, anxiety, depression, osteoporosis, dominant symptom, motor deficit, ambulation status, and symptom duration. These characteristics are presented in Table 1.

Patient-Reported Outcomes

At baseline, patients undergoing MIS or open decompression did not differ in their severity of back pain (NRS [SD] 5.592 [3.267] for MIS vs 5.446 [3.336] for open, p = 0.798); leg pain (NRS [SD] 6.203 [3.003] for MIS vs 6.455 [2.840] for open, p = 0.618); ODI score (ODI [SD] 40.972 [18.947] for MIS vs 38.394 [17.053] for open, p = 0.405); and quality of life (EQ-5D [SD] 0.578 [0.224] for MIS vs 0.608 [0.201] for open, p = 0.413). Similarly, at 2 years, patients in both groups experienced significant improvement in their back pain (NRS [SD] 3.536 [2.885] for MIS vs 2.764 [2.808] for open, p = 0.156); leg pain (NRS [SD] 2.527 [3.096] for MIS vs 2.564 [3.131] for open, p = 0.951); ODI score (ODI [SD] 23.102 [18.503] for MIS vs 22.276 [19.270] for open, p = 0.813); and quality of life (EQ-5D [SD] 0.799 [0.150] for MIS vs 0.764 [0.193] for open, p = 0.283). Finally, we did not observe significant differences between the 2 groups in patient satisfaction (69.1% for MIS, n = 38 vs 87.7% for open, n = 50; p = 0.089). These results have been summarized in Table 2.

Clinical Outcomes

Patients undergoing MIS had an average operating time of 101.77 minutes (SD 48.47), compared to 114.21 minutes (SD 64.16) in those undergoing open decompression; the difference was not found to be significant (p = 0.249). Patients undergoing MIS decompression had a length of stay of 0.68 days (SD 1.18), which was significantly lower than the 1.83 days (SD 1.618) for open decompression (p < 0.001). Among patients undergoing MIS decompression, 93% (n = 66) were discharged to home, compared to 89.6% (n = 60) among patients undergoing open decompression (p = 0.478). Patients in the MIS group had a higher reoperation rate compared to those undergoing open decompression (14.1%, n = 10 vs 4.3%, n = 3); however, the difference was not statistically significant (p = 0.07). Among those undergoing reoperations (n = 13), 6 patients had a fusion, giving an overall secondary fusion rate of 4.3%; this rate was 5.6% (n = 4) for patients in the MIS group and 2.9% (n = 2) for patients in the OL group, and the difference was not found to be statistically significant (p = 0.68). Finally, the 2 groups did not differ in complication rate (MIS = 1.4%, n = 1 vs open = 7.2%, n = 5; p = 0.11). These results have been summarized in Table 3. Details regarding the patients who underwent a reoperation have been summarized in Tables 4 and 5. Durotomy was reported in 2 cases of OL; none of the MIS cases reported a durotomy.

Multivariable Analyses

On multivariable analyses, adjusted for an array of patient and clinical factors, open surgery compared to MIS was found to be associated with higher patient satisfaction at 2 years (OR 7.5, 95% CI 2.41–23.2; p = 0.0005). Type of surgery was not found to be associated with change in EQ-5D at 2 years, change in ODI at 2 years, change in NRS leg pain at 2 years, and change in NRS back pain at 2 years. These results have been summarized in Table 6.

Discussion

In the current study, we found that both OL and MIS decompression are associated with significant improvement among patients undergoing surgery for low-grade spondylolisthesis, as evidenced by the decrease in back and leg pain, decrease in disability, and improvement in quality of life at 2 years (Fig. 1).

TABLE 1. Comparison of demographic and clinical characteristics between MIS decompression and open decompression cohorts in patients with low-grade spondylolisthesis

Characteristic	Total, N = 140	MIS Decompression, n = 71	Open Decompression, n = 69	p Value
Age in yrs				**0.005**
Mean (SD)	69.627 (11.472)	72.264 (9.662)	66.913 (12.578)	
Range	26.070–95	51–95	26.070–87.690	
BMI				0.225
Mean (SD)	28.735 (5.380)	28.190 (4.688)	29.297 (5.993)	
Range	19.050–46.800	20.250–39.870	19.050–46.800	
Sex				0.061
Female	66 (47.1%)	39 (54.9%)	27 (39.1%)	
Male	74 (52.9%)	32 (45.1%)	42 (60.9%)	
Insurance				**0.009**
Medicare or Medicaid	84 (60%)	51 (71.8%)	33 (47.8%)	
Private	55 (39.3%)	19 (26.8%)	36 (52.2%)	
VA or government	1 (0.7%)	1 (1.4%)	0 (0.0%)	
Education				0.567
N-Miss	8	7	1	
<High school	4 (3.0%)	1 (1.6%)	3 (4.4%)	
High school	42 (31.8%)	20 (31.2%)	22 (32.4%)	
2 yrs of college	18 (13.6%)	7 (10.9%)	11 (16.2%)	
4 yrs of college	38 (28.8%)	22 (34.4%)	16 (23.5%)	
Postgrad college	30 (22.7%)	14 (21.9%)	16 (23.5%)	
Employment				**0.025**
N-Miss	2	1	1	
Employed & not working	1 (0.7%)	0 (0.0%)	1 (1.5%)	
Employed & working	47 (34.1%)	17 (24.3%)	30 (44.1%)	
Unemployed	90 (65.2%)	53 (75.7%)	37 (54.4%)	
Hx of major surgery	19 (13.6%)	8 (11.3%)	11 (15.9%)	0.419
Smoker	15 (10.7%)	8 (11.3%)	7 (10.1%)	0.817
Diabetes	32 (22.9%)	16 (22.5%)	16 (23.2%)	0.927
Coronary artery disease	22 (15.7%)	14 (19.7%)	8 (11.6%)	0.187
Anxiety	20 (14.3%)	11 (15.5%)	9 (13.0%)	0.681
Depression	18 (12.9%)	10 (14.1%)	8 (11.6%)	0.660
Osteoporosis	131 (93.6%)	64 (90.1%)	67 (97.1%)	0.093
Dominant symptom				0.164
Back dominant	36 (25.7%)	20 (28.2%)	16 (23.2%)	
Back equals leg	38 (27.1%)	15 (21.1%)	23 (33.3%)	
Leg dominant	66 (47.1%)	36 (50.7%)	30 (43.5%)	
Motor deficit	47 (33.6%)	26 (36.6%)	21 (30.4%)	0.442
Ambulation				0.448
Independent	117 (83.6%)	61 (85.9%)	56 (81.2%)	
Not independent	23 (16.4%)	10 (14.1%)	13 (18.8%)	
Symptom duration				0.214
<3 mos	9 (6.4%)	4 (5.6%)	5 (7.2%)	
3–12 mos	128 (91.4%)	64 (90.1%)	64 (92.8%)	
>12 mos	3 (2.1%)	3 (4.2%)	0 (0.0%)	
ASA				**0.027**
N-Miss	2	0	2	
1 or 2	89 (64.5%)	52 (73.2%)	37 (55.2%)	
3–5	49 (35.5%)	19 (26.8%)	30 (44.8%)	

Hx = history; N-Miss = number of patients for whom data are missing; VA = Veterans Affairs.
Boldface type indicates statistical significance.

TABLE 2. Analysis of baseline, 2-year follow-up, and change in PROs between MIS decompression and open decompression cohorts

Variable	Total, N = 140	MIS Decompression, n = 71	Open Decompression, n = 69	p Value
PROs at baseline				
NRS BP				0.798
N-Miss	4	0	4	
Mean (SD)	5.522 (3.289)	5.592 (3.267)	5.446 (3.336)	
Range	0 to 10	0 to 10	0 to 10	
NRS LP				0.618
N-Miss	5	2	3	
Mean (SD)	6.326 (2.916)	6.203 (3.003)	6.455 (2.840)	
Range	0 to 10	0 to 10	0 to 10	
ODI				0.405
N-Miss	3	0	3	
Mean (SD)	39.730 (18.039)	40.972 (18.947)	38.394 (17.053)	
Range	0 to 90	0 to 90	0 to 76	
EQ-5D				0.413
N-Miss	5	1	4	
Mean (SD)	0.592 (0.213)	0.578 (0.224)	0.608 (0.201)	
Range	0.049 to 1	0.049 to 1	0.216 to 1	
PROs at 2 yrs of follow-up				
NRS BP				0.156
N-Miss	29	15	14	
Mean (SD)	3.153 (2.861)	3.536 (2.885)	2.764 (2.808)	
Range	0 to 10	0 to 10	0 to 10	
NRS LP				0.951
N-Miss	30	16	14	
Mean (SD)	2.545 (3.100)	2.527 (3.096)	2.564 (3.131)	
Range	0 to 10	0 to 10	0 to 10	
ODI				0.813
N-Miss	23	12	11	
Mean (SD)	22.692 (18.810)	23.102 (18.503)	22.276 (19.270)	
Range	0 to 78	0 to 78	0 to 64	
EQ-5D				0.283
N-Miss	27	11	16	
Mean (SD)	0.783 (0.172)	0.799 (0.150)	0.764 (0.193)	
Range	0.008 to 1	0.378 to 1	0.008 to 1	
Change in PROs at 2 yrs of follow-up				
Change in BP				0.183
N-Miss	32	15	17	
Mean (SD)	1.917 (3.941)	1.429 (4.272)	2.442 (3.517)	
Range	–10 to 10	–10 to 10	–4 to 10	
Change in LP				0.935
N-Miss	34	18	16	
Mean (SD)	3.632 (3.533)	3.604 (3.543)	3.660 (3.557)	
Range	–6 to 10	–6 to 10	–5 to 10	
Change in ODI				0.987
N-Miss	25	12	13	
Mean (SD)	15.470 (19.743)	15.441 (20.771)	15.500 (18.787)	
Range	–29 to 76	–29 to 76	–27 to 58	

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TABLE 2. Analysis of baseline, 2-year follow-up, and change in PROs between MIS decompression and open decompression cohorts

Variable	Total, N = 140	MIS Decompression, n = 71	Open Decompression, n = 69	p Value
Change in PROs at 2 yrs of follow-up (*continued*)				
Change in EQ-5D				0.753
N-Miss	29	12	17	
Mean (SD)	−0.177 (0.252)	−0.184 (0.255)	−0.169 (0.250)	
Range	−0.737 to 0.700	−0.737 to 0.403	−0.669 to 0.700	
Patient satisfaction at 2–3 yrs*				0.089
N-Miss	28	16	12	
1	63 (56.2%)	26 (47.3%)	37 (64.9%)	
2	25 (22.3%)	12 (21.8%)	13 (22.8%)	
3	11 (9.8%)	7 (12.7%)	4 (7.0%)	
4	13 (11.6%)	10 (18.2%)	3 (5.3%)	

BP = back pain; LP = leg pain.
* Measured using the NASS scoring system.

Lumbar decompression without fusion remains a potential option for cases of low-grade spondylolisthesis.[28] The procedure may be preferred over fusion because of some undesirable consequences of the latter, including hardware malpositioning and failure.[36] Moreover, the increasing shift toward outpatient surgery to alleviate the financial burden associated with care for patients with degenerative disease has seen a parallel increase in adoption of MIS techniques.[37] The touted benefits of such techniques include less soft-tissue trauma, lower blood loss, and a shorter postoperative monitoring period.[38] Innovations in MIS techniques such as the unilateral laminectomy for bilateral decompression allow effective bilateral decompression of the spine, comparable to OL.[38] In the current study, we observed some of the aforementioned benefits of lumbar decompression, i.e., significantly shorter length of stay. These results are in agreement with previously published analyses, including a meta-analysis by Phan and Mobbs that showed a significantly shorter length of stay for patients undergoing an MIS decompression.[9]

Whereas previous studies have also shown more favorable results for MIS in terms of operating time and blood loss following the procedure,[9] we found comparable results for these outcomes in our cohort. Previous studies have also shown greater improvement in PROs for patients undergoing MIS laminectomy compared to OL.[9] However, we did not observe any difference in long-term ODI and EQ-5D scores between the 2 procedures. We found that patients undergoing MIS laminectomy were less likely to have long-term satisfaction with the procedure. One reason behind this finding could be that patients in the MIS group were older, and hence may have had other comorbidities and frailty, both of which have been shown to impact long-term outcomes.[39] Another reason might be that

TABLE 3. Analysis of clinical outcomes between MIS decompression and open decompression cohort

Variable	Total, N = 140	MIS Decompression, n = 71	Open Decompression, n = 69	p Value
Length of surgery				0.249
N-Miss	23	19	4	
Mean (SD)	108.68 (57.8)	101.77 (48.47)	114.21 (64.16)	
Length of stay				**<0.001**
Mean (SD)	1.243 (1.521)	0.676 (1.180)	1.826 (1.618)	
Discharge disposition				0.478
N-Miss	2	0	2	
Home	126 (91.3%)	66 (93.0%)	60 (89.6%)	
Not home	12 (8.7%)	5 (7.0%)	7 (10.4%)	
Related return to operating room w/in 3 yrs	13 (9.3%)	10 (14.1%)	3 (4.3%)	0.07
Secondary fusion rate	6 (4.3%)	4 (5.6%)	2 (2.9%)	0.68
Complication rate	6 (4.3%)	1 (1.4%)	5 (7.2%)	0.11

Boldface type indicates statistical significance.

TABLE 4. Reoperation details

Group	Index Procedure	Index Procedure Laterality	Reason for Reop	Reop Procedure	Revision Fusion	Duration Btwn Index & Revision Surgery
MIS						
MIS_1	L4–5 decompressive partial rt hemilaminectomy, nerve root decompression, through midline incision	Unilat	New lt-sided (contralat to index) LP	MIS L4–5 midline incision, lt hemilaminectomy	No	18 mos
MIS_2	L4–5 lt hemilaminectomy	Unilat	Re-emergence of symptoms	L3–5 OL & microdiscectomy	No	9 mos
MIS_3	L3–4 rt laminectomy	Unilat	Recurrence of rt-sided pain, MRI revealed L2–5 stenosis	L2–5 OL & foraminotomy	No	7 mos
MIS_4	L4–5 partial rt hemilaminectomy, along w/ a microscopic nerve root decompression	Unilat	Persistent LP, MRI revealed persistent foraminal stenosis at L4–5	Details unknown	Yes	2 yrs
MIS_5	Rt L5–S1 decompression w/ iO-Flex device	Unilat	Persistent symptoms, MRI showed swelling of rt L5 nerve root	MIS L5–S1 decompression & TLIF	Yes	3 mos
MIS_6	L4–5 bilat hemilaminectomy, medial facetectomies, foraminotomies	Bilat	Recurrent bilat hip pain, imaging revealed L4–5 synovial cyst	Open L4–5 bilat partial laminectomies, medial facetectomies, foraminotomies	No	1 yr
MIS_7	L4/5 microdiscectomy w/ a Taylor retractor	Bilat	Persistent foot drop	L4/5 & L5/S1 MIS TLIF	Yes	1 yr
MIS_8	L5/S1 foraminotomy w/ a Taylor retractor	Unilat	Unrelated to index procedure; new disc herniation	L3/4 & L4/5 endoscopic discectomy	No	2 yrs
MIS_9.1	L4–5 bilat partial hemilaminotomy, exploration, decompression & foraminotomy, rt microdiscectomy	Bilat	Recurrent herniation L4–5, re-emergence of symptoms 4 wks postop	L4–5 rt microsurgical re-exploration, lysis of adhesions, discectomy	No	2 mos
MIS_9.2			Persistently symptomatic after 1st reop	L4–5 transfacet lumbar interbody fusion	Yes	3 mos after reop, 5 mos after index op
MIS_10	L5–S1 MIS bilat decompression via unilat lt tubular approach	Bilat	Re-emergence of symptoms, new lt LP & weakness, L5–S1 disc collapse, spondylolisthesis	L5–S1 lt hemilaminotomy, medial facetectomy, foraminotomy w/ microdiscectomy	No	2 mos
Open						
Open_1	L4–5 lt laminotomies, mesial facetectomy	Unilat	Contralat pain (rt side) at follow-up. MRI: L4–5 w/ grade I anterior listhesis of L4 on L5, worse in flexion. Bilat synovial cyst at L4–5, L5–S1 degenerative facet arthropathy	L4–5 & L5–S1 PLIF	Yes	7 mos
Open_2	L1–2 OL	Bilat	Recurrent herniation, synovial cyst leading to central stenosis; sudden onset of hip pain & LP	L1–2 OL, same side	No	3 mos
Open_3	L3–4 OL, bilat	Bilat	Symptoms resolved for approx 2 mos, then patient developed new radicular symptoms at L5 & S1	Lt L3 hemilaminectomy & L3/4 foraminotomy, L4–5 TLIF	Yes	8 mos

Approx = approximately; PLIF = posterior lumbar interbody fusion; TLIF = transforaminal lumbar interbody fusion.

TABLE 5. PROs for patients undergoing a reoperation

Group	Follow-Up Time	ODI	EQ-5D	NRS	Patient Satisfaction
MIS					
MIS_1	2 yrs after reop	0	0.827	Back: 3, leg: 0	1
MIS_2	1 yr after reop	25	0.778	Back: 7, leg: 7	1
MIS_3	3 yrs after reop	18	0.778	Back: 5, leg: 3	1
MIS_4	1 yr after reop (performed elsewhere)	0	1	Back: 0, leg: 0	4
MIS_5	3 yrs after reop	53	0.708	Back: 5, leg: 0	2
MIS_6	2 yrs after reop	3	0.810	Back: 2, leg: 4	2
MIS_7	NA	NA	NA	NA	NA
MIS_8	NA	NA	NA	NA	NA
MIS_9	1 yr after last reop	62	0.689	Back: 8, leg: 0	4
MIS_10	2 yrs after reop	31	0.312	Back: 0, leg: 0	1
Open					
Open_1	2 yrs after reop	7	1	Back: 1, leg: 0	1
Open_2	2 yrs after reop	29	0.308	Back: 8, leg: 0	1
Open_3	1 yr after reop	20	0.761	Back: 4, leg: 4	2

NA = not applicable.

TABLE 6. Significant predictors in multivariable analyses for outcomes of interest

Variable	Adjusted β Coefficient	95% CI	p Value
Change in EQ-5D			
Baseline EQ-5D	0.38	0.30 to 0.47	**<0.001**
Change in ODI			
Diabetes	–8.5	–16.82 to –0.30802	**0.04**
Baseline NRS BP	0.69	–11.72 to –0.55	**0.03**
Baseline ODI	19.31	13.77 to 24.84	**<0.001**
Change in NRS LP			
Baseline NRS LP	2.16	1.24 to 3.09	**<0.001**
Change in NRS BP			
Unemployed vs employed	2.06	0.54 to 3.6	**0.0085**
Baseline NRS BP			**<0.001**
Variable	**Adjusted OR**	**95% CI**	**p Value**
Patient satisfaction			
Employment: employed & not working vs unemployed	0.003	0.00002 to 0.004	**0.001**
Dominant symptom: BP = LP vs leg dominant	0.12	0.03 to 0.4	**0.003**
OL vs MIS laminectomy	7.5	2.41 to 23.2	**0.0005**

All models adjusted for age, BMI, sex, insurance status, employment status at baseline, smoking status, diabetes, depression, predominant symptom, presence of motor deficit, ambulation status at presentation, symptom duration, ASA grade, NRS back pain at baseline, NRS leg pain at baseline, ODI at baseline, and EQ-5D at baseline.

patients in the MIS group were more likely to be receiving Medicare and Medicaid compared to patients in the OL group, who were more likely to have private insurance; insurance status has been shown to have an impact on patient-reported metrics. Nevertheless, one possible reason behind a lower satisfaction rate in the MIS may be attributed to inadequate decompression achieved, particularly in cases in which there was bilateral compression. The higher reoperation rate observed in our results may also be attributed to inadequate decompression. Previous studies have also shown a lower secondary fusion rate following MIS decompression.[6] However, in our cohort the secondary fusion rate was found to be comparable between the 2 groups (5.6% vs 2.9%, p = 0.68).

Limitations of the Study

The present study may have some limitations. First, this study was a nonrandomized evaluation of several practices without standardization of surgical decision-making. Hence, there may be heterogeneity in the patient selection process, rendering the study susceptible to selection bias. Second, the current study was not powered to detect differences in the outcomes observed here. Third, analyses to evaluate cost-effectiveness were not performed, which have previously been shown to favor the MIS procedure.[40] Moreover, information regarding the specific approach (i.e., unilateral vs bilateral decompression) was not documented. Finally, postoperative radiographic outcomes including sagittal motion and difference in slip percentage at follow-up were not reported, which may have further strengthened our results.

Conclusions

These results indicate that lumbar decompression without fusion remains an effective procedure to address low-grade spondylolisthesis. We found comparable results

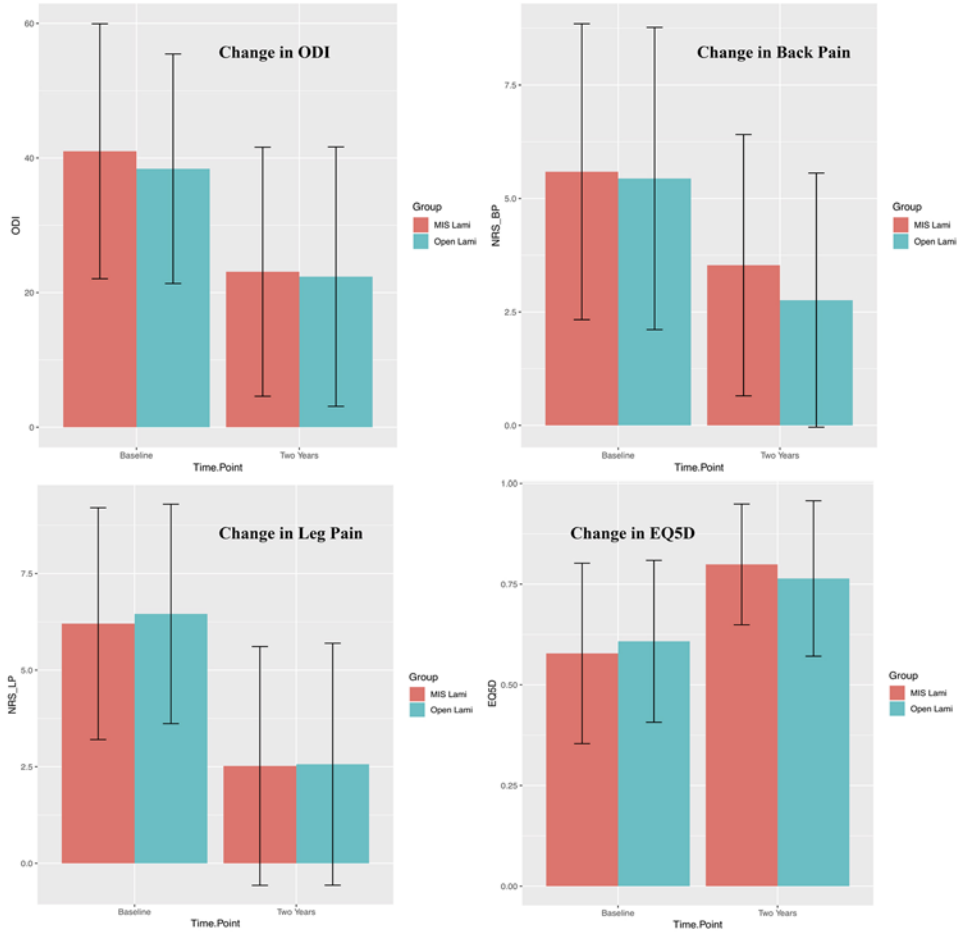

FIG. 1. Bar graphs showing PROs at baseline and at 2 years for MIS and open decompression. *Whiskers* represent the IQR. BP = back pain; Lami = laminectomy; LP = leg pain. Figure is available in color online only.

between OL and MIS techniques. Ultimately, decision-making for open versus MIS decompression may depend on surgeon preference.

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Disclosures

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