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Surgical Management of Thoracolumbar Adjacent Segment Disease: Techniques and Outcomes in 107 Patients Undergoing Surgical Intervention

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ABSTRACT

Background: Adjacent segment disease (ASD) is a known sequela of thoracolumbar instrumented fusions. Various surgical options are available to address ASD in patients with intractable symptoms who have failed conservative measures. However, the optimal treatment strategy for symptomatic ASD has not been established. We examined several clinical outcomes utilizing different surgical interventions for symptomatic ASD.

Methods: A retrospective review was performed for a consecutive series of patients undergoing revision surgery for thoracolumbar ASD between October 2011 and February 2022. Patients were treated with endoscopic decompression (N = 17), microdiscectomy (N = 9), lateral lumbar interbody fusion (LLIF; N = 26), or open laminectomy and fusion (LF; N = 55). The primary outcomes compared between groups were re-operation rates and numeric pain scores for leg and back at 2 weeks, 10 weeks, 6 months, and 12 months postoperation. Secondary outcomes included time to re-operation, estimated blood loss, and length of stay.

Results: Of the 257 patients who underwent revision surgery for symptomatic ASD, 107 patients met inclusion criteria with a minimum of 1-year follow-up. The mean age of all patients was 67.90 ± 10.51 years. There was no statistically significant difference between groups in age, gender, preoperative American Society of Anesthesiologists scoring, number of previously fused levels, or preoperative numeric leg and back pain scores. The re-operation rates were significantly lower in LF (12.7%) and LLIF cohorts (19.2%) compared with microdiscectomy (33%) and endoscopic decompression (52.9%; P = 0.005). Only LF and LLIF cohorts experienced significantly decreased pain scores at all 4 follow-up visits (2 weeks, 10 weeks, 6 months, and 12 months; $P < 0.001$ and $P < 0.05$, respectively) relative to preoperative scores.

Conclusion: Symptomatic ASD often requires treatment with revision surgery. Fusion surgeries (either stand-alone lateral interbody or posterolateral with instrumentation) were most effective and durable with respect to alleviating pain and avoiding additional revisions within the first 12 months following revision surgery.

Clinical Relevance: This study emphasizes the importance of risk-stratifying patients to identify the least invasive approach that treats their symptoms and reduces the risk of future surgeries.

Level of Evidence: 3.

Complications

Keywords: adjacent segment disease, thoracolumbar, lateral lumbar interbody fusion, microdiscectomy, endoscopic, hemilaminotomy, kyphosis, revision surgery, Complications

INTRODUCTION

Adjacent segment disease (ASD) is an important long-term complication associated with thoracolumbar spinal fusion surgery, but the pathophysiology is often debated. Some studies theorize that ASD develops due to the increased stress that spinal fusion places on adjacent spinal segments.[1] However, the biological and environmental factors that predispose a patient to develop degenerative spinal pathology severe enough to necessitate fusion surgery are progressive in nature, resulting in degeneration at other levels over time.[1–4] Thus, the most likely explanation for the development of ASD is a combination of these theories.

Numerous studies have investigated factors that contribute to the development of ASD, including patient age, type of fusion, and length of fusion construct.[5–7] While not all cases of ASD require surgical treatment, posterior revision decompression surgery and extension of fusion has been the mainstay of treatment for patients who fail conservative management.[8–11] However, less invasive approaches confer the potential benefit of symptomatic relief without incurring the potential risks and complications of traditional open surgery such as increased blood loss and prolonged recovery.[12] Extending a prior fusion construct often requires removal, attachment onto, or replacement of instrumentation at previously treated spinal levels, further increasing the morbidity of the revision operation. Within this context, there may be a role for minimally disruptive mini-open decompression surgery or endoscopic surgery, without fusion, as a fusion-sparing alternative to the management of select patients with symptomatic ASD in the lumbar spine. In the current article, we present the results of a large retrospective 10-year study examining clinical outcomes for a range of surgical interventions for symptomatic ASD.

MATERIALS AND METHODS

Patient Population and Selection

Cases were retrospectively evaluated between September 2012 and February 2022 at a single academic institution under an institutional review board exemption. The cohort consisted of patients presenting with lumbar fusion, demonstrating clinical and radiographic evidence of progressive degeneration at spinal levels adjacent to their prior surgical construct, and presenting new back and/or leg symptoms refractory to conservative measures such as physical therapy, low-dose narcotics, nonsteroidal anti-inflammatory drugs, and epidural steroid injections. Presenting symptoms included neurogenic claudication, radiculopathy, or intractable back pain. Presenting pathology included disc herniation, degenerative disc disease, spinal stenosis, spondylolisthesis, or any combination thereof.

For inclusion, ASD was strictly defined as a new-onset pathology at levels immediately adjacent to the prior surgical construct. The revision techniques were classified into traditional open laminectomy and fusion (LF; with subclassifications noting whether patients received a posterior lumbar interbody fusion or transforaminal lumbar interbody fusion), lateral lumbar interbody fusion (LLIF; with mention of whether it was performed as stand-alone or with cage/plating and fixation), and endoscopic decompression (Endo) or microdiscectomy (MCD).

Patients were excluded if they underwent surgery for nondegenerative reasons such as infection or trauma. Additionally, this study primarily focused on degenerative compressive pathology. Therefore, patients having revision surgery specifically for spinal deformity, proximal junctional kyphosis, or spinal imbalance were excluded. Data were exclusively presented for those patients who had single-level decompression or fusion surgery at the ASD level, though it should be noted that certain procedures, such as open fusion, ranged from one to multiple levels.

Outcome Measures

Information on patient demographics, pre- and postoperative numeric pain scores for leg and back, surgical indications, surgical levels, number of levels, type of surgical intervention, operative time, blood loss, stage (1-, 2-, or 3-stage procedure), postoperative neurological symptoms, nonneurological surgical and postoperative medical complications, and long-term clinical follow-up was collected.

Clinical outcome measures included preoperative and postoperative numeric pain scale scores for back and leg pain performed at initial and postoperative clinic visits. Scoring was performed at routine postoperative clinic visits and determined using a 10-point scale, with 10 being the greatest pain and 0 being the absence of pain. Postoperative clinic visits were routinely scheduled at 2, 10, 24 and 52 weeks postoperation. Patients were most often excluded for lack of both pre- and postoperative leg and back numeric pain score documented in the patient electronic medical record.

Imaging analysis was performed using dynamic radiographs to assess for stability and fusion after surgery. Available computed tomography (CT) scans were reviewed to further assess bony fusion. Re-operation rates for lack or resurgence of symptoms were evaluated.

Statistical Analysis

Descriptive statistics are reported as the number or mean with SD. Normalcy testing was done, and nonparametric tests were used when indicated. Overall re-operation rates following initial revision surgery were reported. Patient demographics and characteristics associated with the initial re-operation were analyzed using the χ^2 test, *t* test, and analysis of variance test as indicated. Statistical analyses were performed using SPSS. All tests were 2 sided, and a *P* value of <0.05 was considered statistically significant.

Surgical Group Classifications

1. *Traditional LF*: Patients who underwent traditional LF, with 83.3% receiving posterior lumbar interbody fusion and 8.3% undergoing either transforaminal lumbar interbody fusion or anterior lumbar interbody fusion.
2. *LLIF:* Further classifications included the following:

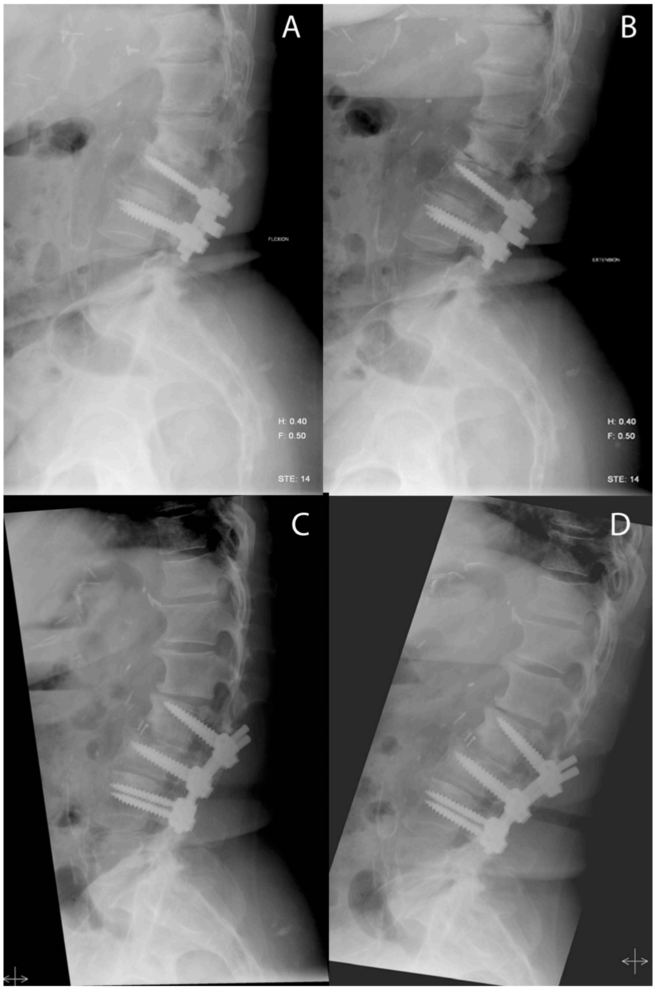

Figure 1. Perioperative images of a 67-year-old man with prior L3 to L4 posterolateral interbody fusion 5 years earlier undergoing open laminectomy and extension of fusion to L2. (A) Preoperative flexion radiograph. (B) Preoperative extension radiograph. (C) Postoperative flexion radiograph. (D) Postoperative extension radiograph.

- 11.1% who had an LLIF without cage/plating or fixation
- 74.1% with fixation
- 7.4% with cage and plating
- 7.4% with both cage/plating and fixation.

3. *MCD:* Patients who received a mini-open decompression with microscopic assistance.
4. *Endo*: Those who underwent an endoscopic-assisted decompression.

Representative cases are provided to illustrate typical presentations and subsequent treatments for each surgical group (Figures 1–4).

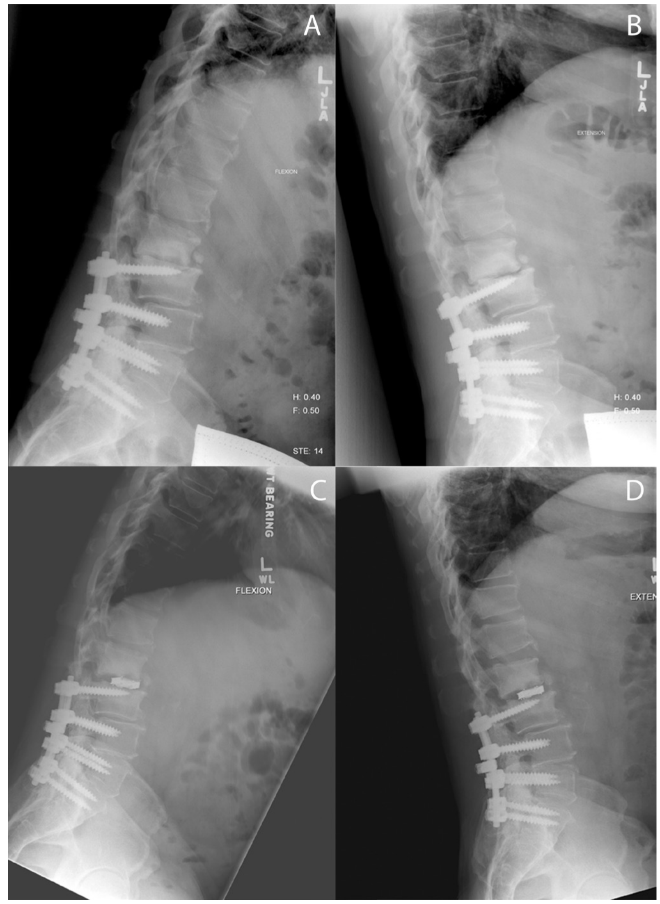

Figure 2. Perioperative images of a 60-year-old man with prior L3 to S1 instrumented fusion 3 years earlier undergoing right-sided lateral interbody fusion at L2 to L3. (A) Preoperative extension radiograph. (B) Preoperative flexion radiograph. (C) Postoperative flexion radiograph. (D) Postoperative extension radiograph 3.

RESULTS

Patient Demographics

Of the 257 patients who underwent revision surgery for ASD pathology, 107 patients (48.6% woman) met inclusion criteria and underwent either traditional open fusion ($n = 55$), LLIF ($n = 26$), mini-open decompression ($n = 9$), or Endo ($n = 17$). Leg pain and combined leg and back pain were the most common indications for surgery (Table 1). The mean continued patient follow-up for the study was 22 months and was not dissimilar between groups (P = 0.795). The mean age of all patients was 67.90 ± 10.51 years. There was no statistically significant difference between groups in age, gender, preoperative American Society of Anesthesiologists scoring, or number of previously fused levels (Table 2).

Postoperative Clinical Outcomes

Estimated blood loss was significantly elevated in LF (304 mL) when compared with LLIF (37.6 mL),

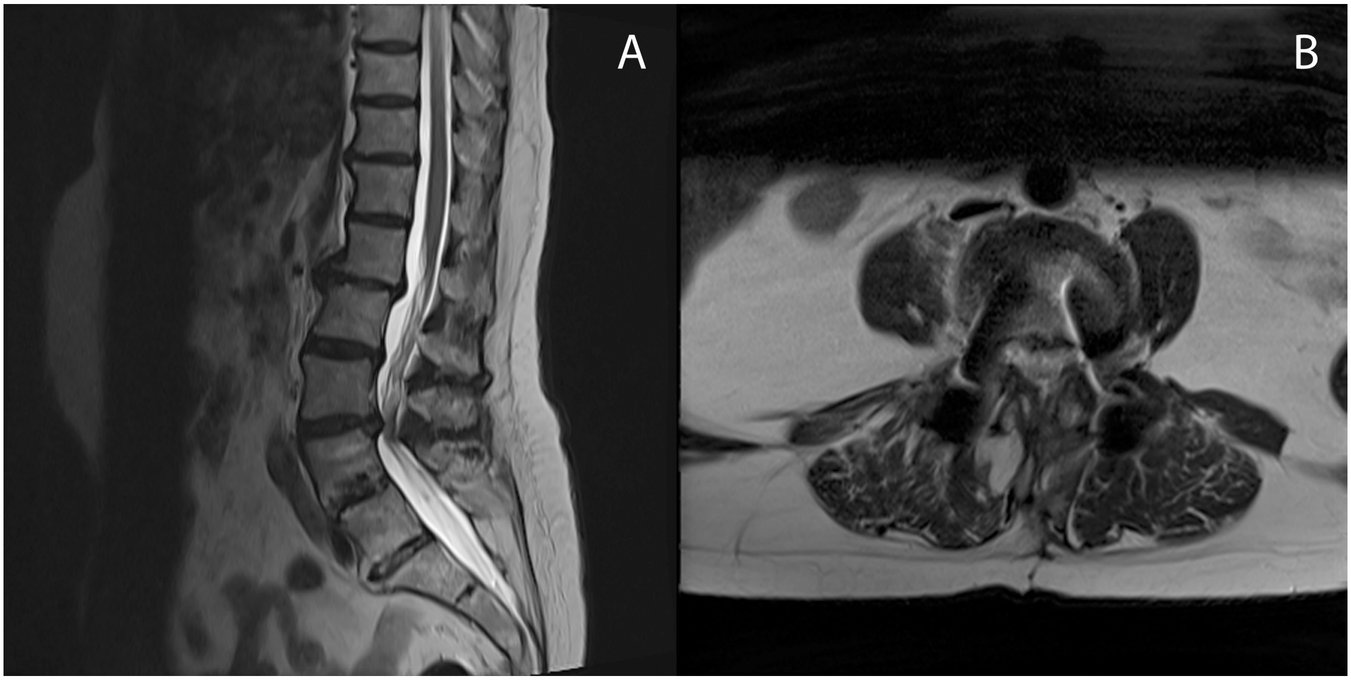

Figure 3. Perioperative images of a 72-year-old woman with prior L4 to S1 instrumented fusion 5 years earlier undergoing L3 to L4 microdiscectomy. (A) Preoperative sagittal T2 magnetic resonance imaging (MRI). (B) Postoperative axial T2 MRI.

MCD (5 mL), and Endo (5 mL). Length of stay was significantly longer in the LF cohort (4.0 days) compared with all other groups. Length of stay was significantly greater in the LLIF group (2.48 days) than in the Endo group (0.94 days) but not the MCD group (1.0 day). The number of re-operations was considered as patients who underwent a revision to the revision surgery within 6 months. The re-operation rates were significantly lower in the LF and LLIF cohorts (12.7% and 19.2%, respectively) compared with the MCD and Endo cohorts (33.3% and 52.9%, respectively).

Numeric pain scores for both the leg and back did not differ significantly between groups at preoperative presentation (P = 0.976 and 0.526, respectively). The LF cohort had the most significant decrease in both leg and back pain scores at 2-week follow-up. At 10 weeks, the decrease was maintained and matched by the LLIF and MCD cohorts. However, at 6 months postoperatively, the MCD group had a resurgence of pain score for both leg and back pain, while LF and LLIF remained constant. Throughout the 12-month follow-up period, the LF and LLIF cohort maintained a significant decrease in pain scores, both back and leg, when compared preoperatively (Figure 5 and Table 3).

DISCUSSION

Instrumented spinal fusion has become the mainstay of treatment for a variety of degenerative spine pathologies and conditions.[13] Nearly 45,000 spinal fusions are performed in the United States annually, and the number of fusions performed in the United States has increased by more than 600% from 1990 to 2011.[14] Therefore, as more patients undergo fusions, it is critical to understand the long-term complications associated with these procedures. ASD is characterized by the onset of new symptoms related to a neighboring lumbar segment following lumbar fusion.[15,16]

Furthermore, the incidence of ASD remains notably high.[17] It is estimated that up to 25% of individuals develop ASD within a decade of their initial surgery.[18] Approximately 3.9% of spinal fusions lead to symptomatic ASD each year, underscoring the necessity for effective treatment approaches.[19,20] For patients who exhibit symptoms and do not respond to conservative management, the standard treatment involves decompression and extension of the previous fusion construct.[21] However, many fewer invasive surgical options exist for treatment of ASD. Therefore, we sought to evaluate various surgical techniques for addressing ASD following thoracolumbar fusion to identify the most successful treatment strategies.

Our results demonstrated that traditional LF and LLIF were superior in terms of reducing leg and back pain and lowering re-operation rates compared with minimally invasive techniques, such as MCD and endoscopic-assisted MCD. These findings have several

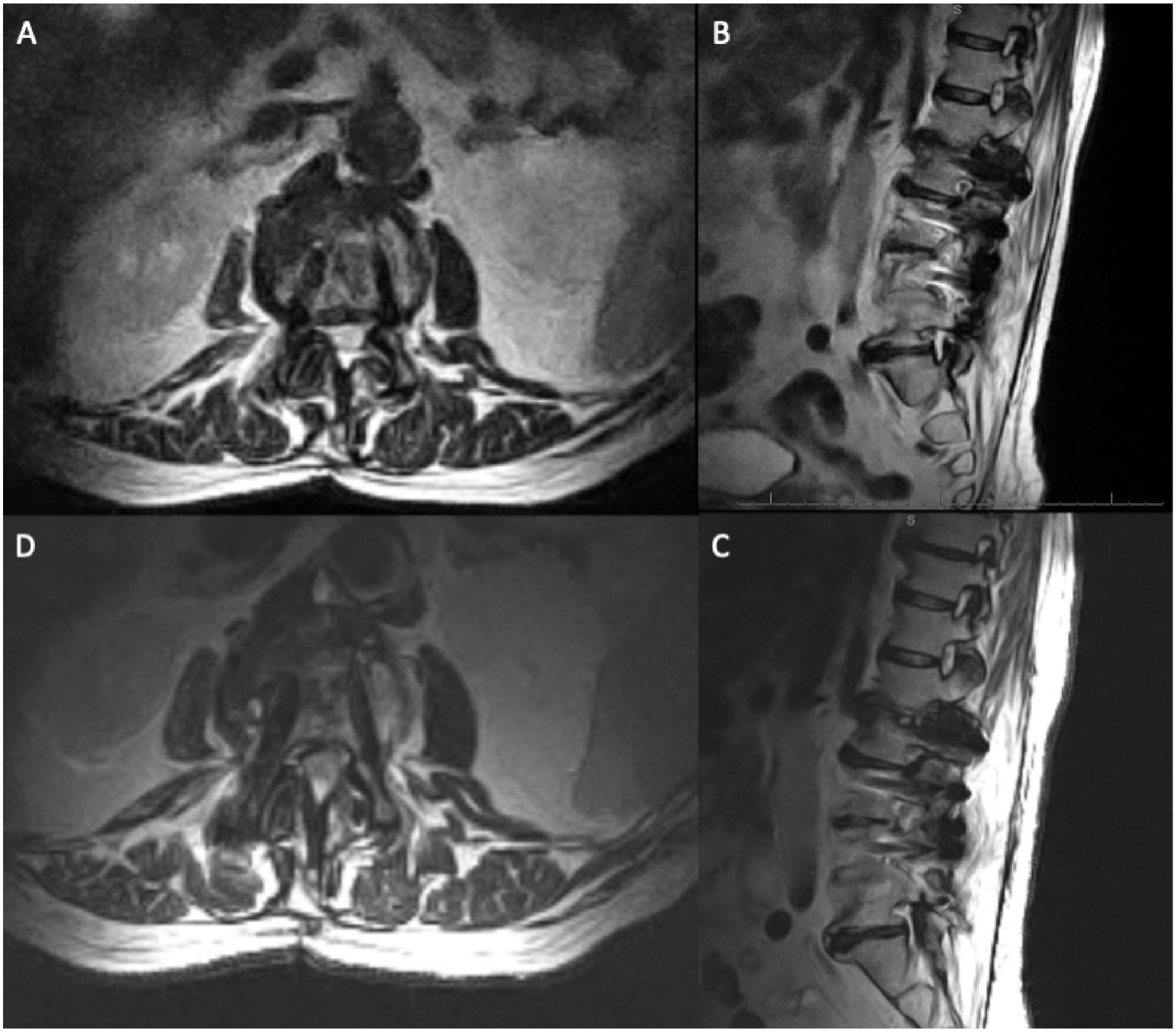

Figure 4. Perioperative images of an 80-year-old man with prior L2 to L4 instrumented fusion 6 years earlier undergoing right-sided L1 to L2 endoscopic-assisted foraminal decompression. (A) Preoperative axial magnetic resonance imaging (MRI). (B) Preoperative sagittal MRI. (C) Postoperative axial MRI. (D) Postoperative sagittal MRI.

important implications for both clinical decision-making and patient outcomes.

While minimally invasive techniques have shown potential in reducing morbidity and mortality,[22] our results indicate that these advantages may not outweigh the importance of pain relief and reduced re-operation rates when selecting the most appropriate treatment modality for ASD. Consequently, these factors should be prioritized when determining the optimal treatment options for patients with ASD.

Table 1. Indications for surgery by surgical cohort, % (*N* = 107).

Indication for Surgery	Open Laminectomy and Fusion (*n* = 55)	Lateral Lumbar Interbody Fusion (*n* = 26)	Microdiscectomy (*n* = 9)	Endoscopic Decompression (*n* = 17)
Back pain	6.1	7.7	0	5.9
Leg pain	14.3	19.2	55.6	64.7
Back and leg pain	67.4	65.4	0	29.4
Myelopathy	2.0	0	0	0
Neurogenic claudication	10.2	7.7	33.3	0
Other	0	0	11.1	0

Table 2. Mean demographic values by surgical cohort.

Demographics	Open Laminectomy and Fusion (*n* = 55)	Lateral Lumbar Interbody Fusion (*n* = 26)	Microdiscectomy (*n* = 9)	Endoscopic Decompression (*n* = 17)	*P*
Follow-up, mo, mean	20.7	25.6	22.5	19.7	0.8
Age, y, mean	66.2	66.9	73.1	72.0	0.09
Body mass index, mean	28.4	27.8	28.9	26.0	0.229
Smoker, *n*	17	12	4	6	0.726
Gender, % woman	54.7	53.8	33.3	35.3	0.378
ASA score, mean	2.8	3	2.8	2.8	0.49
Previous levels fused					
1	21	3	2	3	
2+	21	20	6	12	
Levels operated, *n*					
T11–T12	2	1	0	0	
T12–L1	4	2	0	0	
L1–L2	13	5	1	1	
L2–L3	27	11	4	6	
L4–L5	35	0	1	3	
L5–S1	32	0	2	2	

Abbreviation: ASA, American Society of Anesthesiologists;

The traditional open fusion procedure offers direct access to the disc space for interbody fusion while minimizing the risk of thecal sac and nerve root damage.[23–25] However, this approach has several drawbacks, including extensive soft tissue dissection, longer recovery time, increased postoperative pain, and greater blood loss.[26–29] These challenges have prompted significant research into minimally invasive surgical techniques as potential alternatives. Numerous studies have underscored the benefits of minimally invasive surgical techniques for ASD treatment, with reported improvements in blood loss, hospital costs, operating time, short- and long-term pain outcomes, secondary medical complications, and transfusion need.[30–33]

Despite these reported benefits, our study found that the less invasive techniques of mini-open dorsal decompression and Endo did not provide the same level of pain relief and had higher re-operation rates compared with open fusion and LLIF. This may suggest that the mechanical advantages of LLIF, which allows for stabilization and height restoration as well as concurrent preservation of facet joints and minimal tissue dissection, contribute to a lower incidence of ASD.

In open posterior spinal procedures, the disruption of the posterior ligamento-muscular complex can increase reliance on bony fusion to maintain alignment and support.[34] This observation suggests that the less invasive nature of LLIF could lead to more favorable outcomes for patients with ASD. Screven et al drew similar conclusions in their series of 44 patients who underwent LLIF for ASD, with 91% of their patients experiencing significant improvement in their back, radicular, and claudication symptoms.[35]

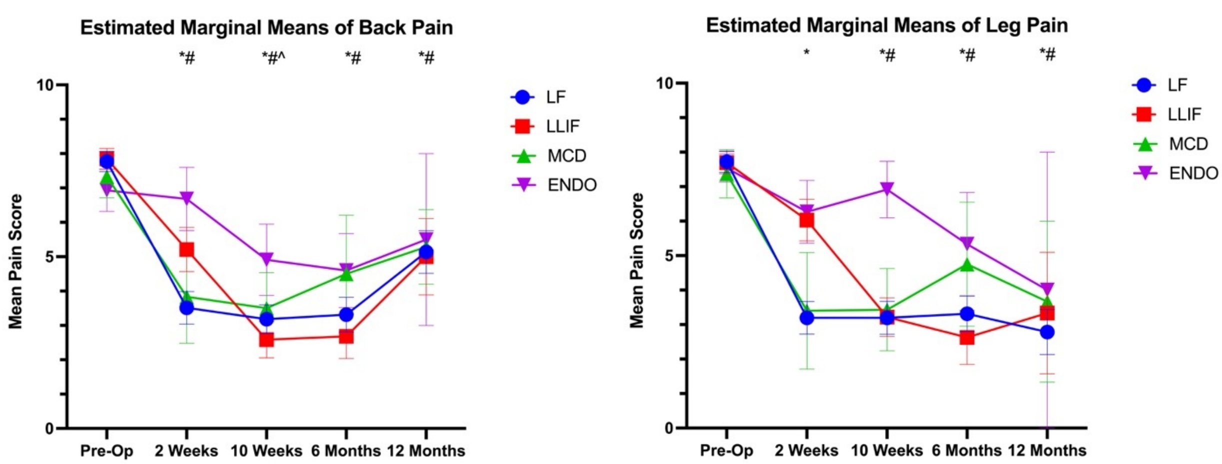

Figure 5. Numeric pain scale ratings for back (A) and leg (B) pain collected at 3 follow-up periods of 2 weeks, 10 weeks, and 6 months. *Significant change in pain for open laminectomy and fusion (LF) from preoperative time point ($P < 0.0001$). #Significant change in pain for lateral lumbar interbody fusion (LLIF) from preoperative time point ($P < 0.05$). ^Significant change in pain for microdiscectomy (MCD) from preoperative time point ($P < 0.0001$). Abbreviation: Endo, endoscopic decompression.

Table 3. Intra- and postoperative clinical outcome measures.

Clinical Outcome Measure	Open Laminectomy and Fusion	Lateral Lumbar Interbody Fusion	Microdiscectomy	Endoscopic Decompression	*P*
No. of levels fused, mean	1.82	1.27	0	0	<0.0001
No. of levels operated, mean	2.23	1.23	1.0	1.56	<0.0001
Estimated blood loss, mean	304.0	37.6	5.0	5.0	<0.0001
Length of stay, mean	4.0	2.48	1.0	0.94	<0.0001
Bone morphogenetic protein, mean	48	25	0	0	<0.0001
Complications, *n*	1	0	0	0	0.799
Interbodies per surgery, mean	0.65	1.2	0	0	<0.0001
% Requiring a third operation	12.7	19.2	33.3	52.9	0.005

The results of this study have important implications for the surgical management of ASD, highlighting the need to carefully consider the balance between the benefits of minimally invasive techniques and the potential for reduced pain relief and increased re-operation rates.

Despite the significant findings of this study, several limitations should be acknowledged. First, the single-surgeon analysis minimizes practice style and operative technique variability and may limit the generalizability to other institutions and surgeons. Second, the inclusion criteria of patients who underwent revision surgery may restrict the ability to characterize subclinical ASD or ASD not suitable for surgery. Long-term outcomes of ASD degeneration necessitate further research with extended follow-up periods.

Another limitation concerns the assessment of definitive fusion. However, imaging surrogates, such as 3-dimensional CT scans, dynamic radiographs, and nuclear medicine studies, can provide valuable insights. In this study, we used sagittal and coronal reconstructed fine-cut CT scans to identify bridging bone as the determinant of fusion, which is the best early indicator of successful arthrodesis. Longer follow-up periods may reveal osseous nonunion clinically or radiographically.

Third, the loss of follow-up throughout the study was of concern. However, follow-up in both the MCD and Endo cohorts persisted through re-operation, whereas follow-up was decreased in both the LF and LLIF groups, possibly due to the greater resolution of symptoms and less need for re-operation in this cohort. Similarly, the small sample sizes of the Endo and MCD cohorts remain a limitation. Future studies examining multicenter data with larger sample sizes may be useful in further elucidating these differences. However, our findings that fusion surgeries are superior in reducing re-operation rates compared with decompression alone align with broader surgical outcome trends. As highlighted by Telfeian et al., endoscopic minimally invasive treatment for radiculopathy that results from ASD is feasible but only transiently beneficial. ASD is a degenerative problem that is by definition progressive in nature. In concordance with our results, the authors reported a 33% failure rate within 2 years of transforaminal Endo.[18] Similar conclusions were drawn by Iwai et al, who described 13 patients with symptomatic ASD after lumbar fusion and underwent Endo, reporting a mean recovery rate of only 32.8%.[36] It is possible that the higher failure rate of this method could be related to the biomechanics associated with ASD, or the patients who have required a fusion in the past exhibit a specific phenotype that is less responsive to nonfusion approaches.

CONCLUSIONS

In our series, traditional LF and LLIF yielded lower re-operation for the management of ASD compared with minimally invasive decompression alone. LF and LLIF most durably improved numeric pain scores in both leg and back categories as well. While minimally invasive and endoscopic approaches offered some improvement in the short term, at 12 months, half of these patients required re-operation. Thus, the results of this study underscore the complexity of surgical decision-making for ASD, where the balance between minimally invasive techniques' short-term benefits and the long-term durability of more traditional fusion approaches must be carefully weighed.

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