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Original Article

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Risk Factors for Poor Outcomes Following Minimally Invasive Discectomy: A *Post Hoc* Subgroup Analysis of 2-Year Follow-up Prospective Data

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Objective: A *post hoc* subgroup analysis of prospectively collected data from a randomized controlled trial was conducted to identify risk factors related to poor outcomes in patients who underwent minimally invasive discectomy.
Methods: Patients were divided into satisfied and dissatisfied subgroups based on Oswestry Disability Index (ODI), visual analogue scale (VAS) back pain score (VAS-back) and leg pain score (VAS-leg) at short-term and midterm follow-up according to the patient acceptable symptom state threshold. Demographic characteristics, radiographic parameters, and clinical outcomes between the satisfied and dissatisfied subgroups were compared using univariate and multivariate analysis.
Results: A total of 222 patients (92.1%) completed 2-year follow-up, and the postoperative ODI, VAS-back, and VAS-leg were significantly improved after surgery as compared to preoperatively. Multivariate analysis indicated older age ($p=0.026$), lateral recess stenosis ($p=0.046$), and lower baseline ODI ($p=0.027$) were related to poor short-term functional improvement. Higher baseline VAS-back ($p=0.048$) was associated with poor short-term relief of back pain, while absence of decreased sensation ($p=0.019$) and far-lateral disc herniation ($p=0.004$) were associated with poorer short-term relief of leg pain. Lumbar facet joint osteoarthritis was identified as a risk factor for poor functional improvement ($p=0.003$) and relief of back pain ($p=0.031$). Disc protrusion ($p=0.036$) predicted poorer relief of back pain at midterm follow-up.
Conclusion: In this study, several factors were identified to be predictive of poor surgical outcomes following minimally invasive discectomy. (ClinicalTrials.gov number: NCT01997086).

Keywords: Minimally invasive discectomy, Risk factors, Disability, Back pain, Leg pain

INTRODUCTION

Lumbar disc herniation (LDH) is characterized by low back pain and radiating leg pain, and is one of the most costly disorders for society in terms of disability and work absenteeism.[1,2] Several randomized controlled trials (RCTs) concluded that surgical treatment provides more effective and rapid pain relief for patients who are surgical candidates.[2,3] Currently, conventional microdiscectomy performed with the aid of a microscope is commonly used in Western countries to treat LDH, and is considered to be the gold standard surgical procedure for the condition.[4] Over the past 2 decades, minimally invasive spine surgery (MISS) has become increasingly more common, and is efficient and effective for the management of a wide range of spine disorders.[5] Percutaneous transforaminal endoscopic discectomy (PTED), also referred to as transforaminal endoscopic lumbar discectomy,[6] and microendoscopic discectomy (MED), are 2 of the most popular minimally invasive discectomy procedures.[5,7]

The PTED and MED procedures are considered to be as effective as microdiscectomy, with the advantages of less surgical trauma, shorter length of hospital stay, and the potential of faster return to work.[8,9] A recent meta-analysis including 18 comparative studies reported that both PTED and MED achieve satisfactory results with high excellent and good outcome rates (PTED, 92.17%; MED, 91.81%).[10] We previously conducted a RCT examining PTED and MED, and the results showed that both procedures achieve equivalent and satisfactory outcomes for the treatment of LDH.[11,12]

Although favorable surgical outcomes can be achieved in more than 90% of cases with the aforementioned procedures, there are factors that may play a role in inferior outcomes. A key to successful surgical outcomes is proper patient selection; hence risk factors that predict poor clinical outcomes are useful in choosing patients who will benefit optimally from minimally invasive discectomy. Numerous studies have investigated preoperative outcome predictors, including sociodemographic, clinical, radiological, and psychological variables, that are associated with postsurgical clinical outcomes in patients undergoing open discectomy.[13] To date, only limited retrospective studies have examined possible risk factors associated with poor outcomes after minimally invasive discectomy, and no clear consensus has been achieved.[14-18]

Thus, the purpose of this study was to analyze the 2-year follow-up data of our RCT in order to identify potential risk factors related to poor outcomes in patients who underwent minimally invasive discectomy. Identifying factors associated with poor outcomes will help spine surgeons identify patients most likely to benefit from the procedure.

MATERIALS AND METHODS

1. Study Design and Inclusion/Exclusion Criteria

We previously conducted a single-center, open-label, RCT to compare the efficacy and safety of PTED and MED in patients with LDH for whom surgery was indicated. The study was registered with the ClinicalTrials.gov database (http://clinicaltrials.gov), and its registration number is NCT01997086. The clinical research ethics committee of the Third Affiliated Hospital of Sun Yat-sen University approved the clinical trial, and all participants provided written informed consent.

Patients with radicular pain and signs of radiculopathy, and an imaging study (magnetic resonance imaging or computed tomography) showing LDH at the level and side corresponding to the radicular signs or symptoms were considered potential participants. The detailed inclusion and exclusion criteria have been published previously.[11,12] All patients included in this study underwent either PTED or MED.

2. Surgical Interventions

All of the surgeons in the trial were highly experienced, and all had >3 years of experience performing MISS and had performed a minimum of 200 procedures. They had also received formal training in PTED and MED, and strictly adhered to standard operating procedures. The details of PTED or MED procedures are described in our prior publications.[11,12]

3. Outcomes Assessments

Participants were assessed preoperatively, and at 1 week, 1 month, 3 months, 6 months, 1 year, and 2 years postoperatively. In the current study, we selected clinical outcomes at 3 months and 2 years postoperatively to represent short-term and midterm outcomes, respectively. A research assistant collected baseline and follow-up data by administering questionnaires via telephone, email, mail, or in person.

Several patient-reported outcome measures (PROMs) were used to evaluate the effectiveness of the surgical procedures. The primary outcome measure was Oswestry Disability Index (ODI) score. Secondary outcomes included scores of the Medical Outcomes Study 36-item Short-Form Health Survey bodily pain (SF-36 BP) and physical function (SF-36 PF) scales, European quality of life-5 dimensions (EQ-5D) score, and visual analogue scale (VAS) scores for back pain (VAS-back) and leg pain (VAS-leg).

Patients were divided into satisfied and dissatisfied subgroups based on ODI score, VAS-back score, and VAS-leg score at short-term and midterm follow-up, according to the patient acceptable symptom state (PASS) threshold. PASS is a target score beyond which patients deem themselves to have attained an acceptable outcome.[19,20] The satisfied subgroup for functional improvement was defined as an ODI score less than or equal to the PASS threshold, ranging from 9.55 to 29.00 according to baseline scores.[20] The satisfied subgroup for relief of back pain or leg pain was defined as a VAS-back or VAS-leg score ≤ 2.[21]

The demographic characteristics, radiographic parameters, and clinical outcomes between the satisfied and dissatisfied subgroups were compared.

4. Radiographic Parameters

Preoperative anteroposterior and lateral plain radiographs, dynamic plain radiographs, computed tomography (CT) images, and magnetic resonance (MR) images were prospectively collected. The type and location of disc herniation, Modic change, Pfirrman disc classification, and adjacent segment degeneration (ASD) in the proximal and distal segments were determined based on MR images. The grade of lumbar facet joint osteoarthritis (LFJOA) and lateral recess stenosis was measured on either CT images or MR images.

Disc degeneration was classified into 5 grades by reviewing lumbar MR images according to the grading system of Pfirrmann et al.[22] In this study, we defined Pfirrmann grade ≥ 3 as disc degeneration. The grading system of Weishaupt et al.[23] is a feasible tool for grading the severity of LFJOA based on CT images or MR images. In this study, LFJOA was defined as Weishaupt grade ≥ 2, and no LFJOA was defined as grade 0 and 1. When there was a difference in the severity of facet joint osteoarthritis between right and left side, the side with the worst grade was used in the analysis. Lateral recess stenosis was defined as a lateral recess measurement of < 3 mm.[24]

5. Statistical Analysis

For continuous variables, differences between groups were compared using the Student t-test, whereas the chi-square test was used for categorical variables. Multiple logistic regression analysis was used to identify independent risk factors of poor outcomes. Variables with a value of $p < 0.1$ by univariate analysis were included in multiple logistic regression models. SPSS ver. 17.0 (SPSS Inc., Chicago, IL, USA) was used for all analyses. All p-values were 2-sided, and values < 0.05 were considered to indicate a statistically significant difference.

RESULTS

Of the 241 patients who were enrolled in our RCT, 119 received PTED and 122 received MED. A total of 222 patients (92.1%) completed the 2-year follow-up, and were included in the current analysis. The dropout rates were low, and were equivalent between treatment groups at each follow-up point. There was no evidence of differential dropout according to the assigned treatment.

The mean age of participants was 41.0 years old, and 40.7% were female. The most common type of disc herniation was paramedian, which accounted for 68% of cases, and L4–5 and L5–S1 were the most operated segments (> 95%). Functional ability and the degree of back pain and leg pain were significantly improved after surgery in both groups, and the magnitude of leg pain relief was greater than that of back pain relief. With respect to all clinical outcomes, there were no differences between the treatment groups at each postoperative follow-up point. Univariate analysis indicated that the surgical technique (PTED or MED) did not impact clinical outcomes at short-term and midterm follow-up.

1. Univariate Analysis of Short-term Outcomes

A total of 68 patients (30.1%) were defined as dissatisfied at 3-month follow-up according to the PASS threshold of ODI score. Although significant improvements in all of the clinical outcomes were seen in both the satisfied and dissatisfied subgroups, the magnitude of improvements was less in the dissatisfied subgroup (Table 1). Based on the results of univariate analysis, statistically significant predictors of inferior improvement in functional outcomes included lower baseline ODI score ($p < 0.001$), higher baseline SF-36 PF score ($p < 0.001$), higher baseline SF-36 BP score ($p = 0.002$), higher baseline EQ-5D score ($p < 0.001$), lower VAS-leg score ($p = 0.005$), older age ($p = 0.035$), negative nerve root tension test ($p = 0.012$), nonparamedian disc herniation ($p = 0.036$), nonextrusion ($p = 0.036$), and lateral recess stenosis ($p = 0.010$) (Tables 1, 2). Longer symptom duration ($p = 0.065$) and proximal ASD ($p = 0.077$), although not statistically significant, showed trends toward dissatisfied functional improvement and were included in multivariate logistic regression models.

According to the PASS threshold of VAS-back score, 24 patients (10.6%) were classified as dissatisfied at 3-month follow-up. Based on the results of univariate analysis, statistically significant predictors of inferior relief of back pain included higher baseline VAS-back score ($p < 0.001$) and longer symptom duration ($p = 0.036$) (Tables 1, 2). Predominant back pain symptoms ($p = 0.050$), absence of decreased sensation ($p = 0.066$), and absence of myotomal weakness ($p = 0.093$) showed trends toward dissatisfied relief of back pain (though not significant) and were included in multivariate logistic regression models.

A total of 27 patients (11.9%) were defined as dissatisfied based on the VAS-leg score at 3-month follow-up. Univariate analysis indicated statistically significant predictors of inferior relief of leg pain included predominant back pain symptoms ($p = 0.012$),

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Table 1. Comparison of clinical outcomes between satisfied and dissatisfied subgroups at short-term follow-up by univariate analysis

Variable	All patients (n = 226)	Functional improvement			Relief of back pain			Relief of leg pain		
		Satisfied (n = 158)	Dissatisfied (n = 68)	p-value	Satisfied (n = 202)	Dissatisfied (n = 24)	p-value	Satisfied (n = 199)	Dissatisfied (n = 27)	p-value
ODI score										
Baseline	45.3 ± 20.1	49.6 ± 21.0	35.6 ± 13.6	< 0.001**	45.6 ± 20.1	43.4 ± 20.5	0.615	46.1 ± 20.0	40.1 ± 20.6	0.148
At 3 months	12.3 ± 12.6	7.1 ± 6.7	24.2 ± 14.8	< 0.001**	10.3 ± 10.4	28.7 ± 17.1	< 0.001**	9.8 ± 9.6	30.6 ± 16.1	< 0.001**
SF-36 PF score										
Baseline	51.7 ± 23.8	47.8 ± 24.8	60.7 ± 18.5	< 0.001**	51.7 ± 23.6	51.5 ± 26.3	0.967	50.6 ± 23.4	59.3 ± 25.5	0.077*
At 3 months	90.3 ± 12.6	93.8 ± 6.4	82.1 ± 18.3	< 0.001**	92.2 ± 7.7	73.8 ± 26.5	0.002**	92.7 ± 6.7	72.6 ± 25.7	< 0.001**
SF-36 BP score										
Baseline	46.5 ± 19.3	43.9 ± 20.3	52.5 ± 15.3	0.002**	46.0 ± 19.6	50.5 ± 16.5	0.286	45.6 ± 19.5	53.1 ± 16.7	0.058*
At 3 months	87.1 ± 14.0	91.9 ± 8.7	75.9 ± 17.4	< 0.001**	89.8 ± 10.3	63.8 ± 19.0	< 0.001**	90.2 ± 9.2	64.2 ± 20.8	< 0.001**
EQ-5D score										
Baseline	0.52 ± 0.23	0.48 ± 0.25	0.62 ± 0.14	< 0.001**	0.52 ± 0.24	0.56 ± 0.15	0.365	0.51 ± 0.23	0.58 ± 0.19	0.137
At 3 months	0.90 ± 0.13	0.94 ± 0.09	0.82 ± 0.18	< 0.001**	0.93 ± 0.10	0.72 ± 0.22	< 0.001**	0.93 ± 0.09	0.71 ± 0.22	< 0.001**
VAS-back score										
Baseline	3.96 ± 2.47	3.99 ± 2.55	3.90 ± 2.31	0.815	3.80 ± 2.51	5.30 ± 1.60	< 0.001**	3.85 ± 2.49	4.82 ± 2.24	0.056*
At 3 months	0.95 ± 1.29	0.66 ± 0.92	1.63 ± 1.71	< 0.001**	0.60 ± 0.70	3.96 ± 1.20	< 0.001**	0.68 ± 0.84	2.96 ± 2.07	< 0.001**
VAS-leg score										
Baseline	5.43 ± 2.00	5.67 ± 2.03	4.86 ± 1.81	0.005**	5.42 ± 2.00	5.50 ± 2.04	0.856	5.46 ± 2.04	5.19 ± 1.69	0.500
At 3 months	0.96 ± 1.43	0.51 ± 0.83	2.02 ± 1.91	< 0.001**	0.68 ± 1.04	3.29 ± 2.07	< 0.001**	0.52 ± 0.70	4.19 ± 1.33	< 0.001**

Values are presented as mean ± standard deviation.
ODI, Oswestry Disability Index; SF-36 PF; 36-item Short Form Health Survey physical function; SF-36 BP, 36-item Short Form Health Survey bodily pain; EQ-5D, European quality of life-5 dimensions; VAS, visual analogue scale.
*p < 0.1. **p < 0.05.

absence of decreased sensation (p = 0.001), absence of myotomal weakness (p = 0.040), and far-lateral disc herniation (p < 0.001) (Tables 1, 2). Higher baseline SF-36 PF score (p = 0.077), higher baseline SF-36 BP score (p = 0.058), higher baseline VAS-back score (p = 0.056), higher body mass index (p = 0.064), and negative nerve root tension test (p = 0.056) showed trends toward dissatisfied relief of leg pain and were included in multivariate logistic regression models.

2. Univariate Analysis of Midterm Outcomes

According to the PASS threshold of ODI score, 16 patients (7.2%) were dissatisfied with functional improvement at 2-year follow-up. Comparison of clinical and radiological data between the satisfied and dissatisfied subgroups at midterm follow-up found significant differences between the 2 groups with respect to lower baseline ODI score (p = 0.030), higher baseline SF-36 PF score (p = 0.026), higher baseline SF-36 BP score (p = 0.017), female sex (p = 0.006), and the presence of LFJOA (p < 0.001) (Tables 3, 4). Higher baseline EQ-5D score (p = 0.063), though not significant, was associated with poorer improvement in functional outcomes and was included in multivariate logistic regression models.

According to the PASS threshold of VAS-back score, 9 patients (4.1%) were dissatisfied with relief of back pain at 2-year follow-up. Univariate analysis indicated statistically significant predictors of poorer relief of back pain were higher baseline SF-36 BP score (p = 0.035), female sex (p = 0.019), far-lateral disc herniation (p = 0.017), disc protrusion (p = 0.090), and presence of LFJOA (p = 0.003) (Tables 3, 4). Higher baseline EQ-5D score (p = 0.070), though not significant, was associated with poorer relief of back pain and was included in multivariate logistic regression models.

Only 2 patients (0.9%) were dissatisfied at 2-year follow-up according to the PASS threshold of the VAS-leg score. Due to the small number of patients, it was not possible to conduct univariate analysis or multivariate analysis for relief of leg pain

Table 2. Comparison of clinical and radiological data between satisfied and dissatisfied groups at short-term follow-up by univariate analysis.

Variable	Functional improvement			Relief of back pain			Relief of leg pain		
	Satisfied (n = 158)	Dissatisfied (n = 68)	p-value	Satisfied (n = 202)	Dissatisfied (n = 24)	p-value	Satisfied (n = 199)	Dissatisfied (n = 27)	p-value
Surgery group, PTED:MED	84:74	29:39	0.147	100:102	13:11	0.666	97:102	16:11	0.305
Age (yr)	39.7 ± 11.5	43.2 ± 10.7	0.035**	40.4 ± 11.6	43.6 ± 19.6	0.194	40.3 ± 11.3	44.0 ± 11.3	0.116
Female sex	62 (39.2)	29 (42.6)	0.632	80 (39.6)	11 (45.8)	0.556	79 (39.7)	12 (44.4)	0.637
BMI (kg/m^2)	23.2 ± 3.4	23.2 ± 3.1	0.927	23.1 ± 3.1	24.2 ± 3.2	0.108	23.0 ± 3.4	24.3 ± 2.9	0.064*
Symptom duration ≥ 12 months	33 (20.9)	22 (32.4)	0.065*	45 (22.3)	10 (41.7)	0.036**	45 (22.6)	10 (37.0)	0.101
Dominant back pain	70 (44.3)	38 (55.9)	0.110	92 (45.5)	16 (66.7)	0.050*	89 (44.7)	19 (70.4)	0.012**
Heavy labor worker	28 (17.7)	18 (26.5)	0.134	42 (20.8)	4 (16.7)	0.635	39 (19.6)	7 (25.9)	0.443
Sedentary lifestyle	44 (27.8)	18 (26.5)	0.831	53 (26.2)	9 (37.5)	0.242	56 (28.1)	6 (22.2)	0.518
History of Smoking	34 (21.5)	13 (19.1)	0.683	44 (21.8)	3 (12.5)	0.426	41 (20.6)	6 (22.2)	0.846
History of hypertension	16 (10.1)	6 (8.8)	0.762	19 (9.4)	3 (12.5)	0.713	19 (9.5)	3 (11.1)	0.733
History of diabetes	6 (3.8)	3 (4.4)	0.829	8 (4.0)	1 (4.2)	0.961	8 (4.0)	1 (3.7)	0.937
Positive nerve root tension test	125 (79.1)	43 (63.2)	0.012**	151 (74.8)	17 (70.8)	0.678	152 (76.4)	16 (59.3)	0.056*
Decreased sensation	64 (40.5)	22 (32.4)	0.247	81 (40.1)	5 (20.8)	0.066*	83 (41.7)	3 (11.1)	0.001**
Myotomal weakness	46 (29.1)	19 (27.9)	0.858	62 (30.7)	3 (12.5)	0.093*	62 (31.2)	3 (11.1)	0.040**
Depressed reflex	49 (31.0)	21 (30.9)	0.984	61 (30.2)	9 (37.5)	0.984	63 (31.7)	7 (25.9)	0.546
Surgical segment			0.283			0.714			0.743
L3/4 or above	4 (2.5)	0 (0)		4 (2.0)	0 (0)		4 (2.0)	0 (0)	
L4/5	74 (46.8)	37 (54.4)		100 (49.5)	11 (45.8)		97 (48.7)	14 (51.9)	
L5/S1	80 (50.6)	31 (45.6)		98 (48.5)	13 (54.2)		98 (49.2)	13 (48.1)	
Location of disc herniation			0.036**			0.304			< 0.001**
Median	31 (19.6)	20 (29.4)		46 (22.8)	5 (20.8)		45 (22.6)	6 (22.2)	
Paramedian	117 (74.1)	39 (57.4)		141 (69.8)	15 (62.5)		143 (71.9)	13 (48.1)	
Far lateral	10 (6.3)	9 (13.2)		15 (7.4)	4 (16.7)		11 (5.5)	8 (29.6)	
Type of disc herniation			0.086*			0.909			0.496
Bulge	21 (13.5)	15 (22.7)		33 (16.6)	3 (13.0)		31 (15.8)	5 (19.2)	
Protrusion	77 (49.4)	35 (53.0)		100 (50.3)	12 (52.2)		97 (49.5)	15 (57.7)	
Extrusion	58 (37.2)	16 (24.2)		66 (33.2)	8 (34.8)		68 (34.7)	6 (23.1)	
Disc degeneration (Pfirrman grade ≥ 3)	115 (85.8)	45 (83.3)	0.665	146 (85.4)	14 (82.4)	0.665	146 (86.4)	14 (73.7)	0.140
Modic change	9 (6.7)	6 (11.1)	0.314	14 (8.2)	1 (5.9)	0.314	15 (8.9)	0 (0)	0.371
LFJOA	17 (10.9)	9 (13.6)	0.562	23 (11.6)	3 (13.0)	0.834	22 (11.2)	4 (15.4)	0.519
Proximal ASD	53 (39.6)	29 (53.7)	0.077*	73 (42.7)	9 (52.9)	0.416	72 (42.6)	10 (52.6)	0.403
Distal ASD	41 (56.9)	17 (53.1)	0.717	54 (55.7)	4 (57.1)	0.940	54 (56.8)	4 (44.4)	0.504
Lateral recess stenosis	1 (0.6)	5 (7.6)	0.010**	5 (2.5)	1 (4.3)	0.485	5 (2.6)	1 (3.8)	0.531
Residue of herniation	3 (1.9)	2 (2.9)	0.638	5 (2.5)	0 (0)	0.964	5 (2.5)	0 (0)	0.892
Recurrence of herniation	4 (2.5)	7 (7.4)	0.133	7 (3.5)	2 (8.3)	0.245	7 (3.5)	2 (7.4)	0.293
Reoperation	7 (4.4)	7 (10.3)	0.130	12 (5.9)	2 (8.3)	0.649	12 (6.0)	2 (7.4)	0.677

Values are presented as mean ± standard deviation or number (%).
PTED, percutaneous transforaminal endoscopic discectomy; MED, microendoscopic discectomy; BMI, body mass index; LFJOA, lumbar facet joint osteoarthritis; ASD, adjacent segment degeneration.
*$p < 0.1$. **$p < 0.05$.

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Table 3. Comparison of clinical outcomes between satisfied and dissatisfied subgroups at midterm follow-up by univariate analysis

Variable	All patients (n = 222)	Functional improvement			Relief of back pain		
		Satisfied (n = 206)	Dissatisfied (n = 16)	p-value	Satisfied (n = 213)	Dissatisfied (n = 9)	p-value
ODI score							
Baseline	44.8 ± 19.9	45.6 ± 19.8	34.4 ± 18.8	0.030**	45.1 ± 19.8	34.4 ± 22.5	0.329
At 2 years	3.2 ± 7.4	1.5 ± 3.2	24.8 ± 11.5	< 0.001**	2.2 ± 5.0	26.4 ± 14.5	0.005**
SF-36 PF score							
Baseline	52.1 ± 23.5	51.2 ± 23.1	64.7 ± 25.1	0.026**	51.7 ± 23.4	62.2 ± 24.5	0.189
At 2 years	97.5 ± 5.1	98.5 ± 2.7	84.4 ± 9.6	< 0.001**	98.1 ± 3.7	82.8 ± 10.9	0.003**
SF-36 BP score							
Baseline	46.5 ± 19.0	45.7 ± 19.1	57.4 ± 14.7	0.017**	46.0 ± 19.1	59.6 ± 13.1	0.035**
At 2 years	96.0 ± 9.3	98.0 ± 5.0	70.1 ± 12.7	< 0.001**	97.2 ± 7.1	68.0 ± 11.8	< 0.001**
EQ-5D score							
Baseline	0.53 ± 0.22	0.52 ± 0.23	0.63 ± 0.15	0.063*	0.52 ± 0.22	0.66 ± 0.13	0.070*
At 2 years	0.97 ± 0.07	0.99 ± 0.04	0.80 ± 0.12	< 0.001**	0.98 ± 0.05	0.77 ± 0.12	< 0.001**
VAS-back score							
Baseline	3.94 ± 2.42	3.96 ± 2.42	3.69 ± 2.50	0.668	3.94 ± 2.42	3.89 ± 2.47	0.950
At 2 years	0.37 ± 0.86	0.20 ± 0.50	2.56 ± 1.41	< 0.001**	0.23 ± 0.51	3.67 ± 0.87	< 0.001**
VAS-leg score							
Baseline	5.40 ± 1.92	5.40 ± 1.96	5.38 ± 1.41	0.963	5.42 ± 1.92	4.78 ± 2.12	0.326
At 2 years	0.19 ± 0.56	0.09 ± 0.31	1.44 ± 1.21	< 0.001**	0.15 ± 0.49	1.11 ± 1.17	0.038**

Values are presented as mean ± standard deviation.
ODI, Oswestry Disability Index; SF-36 PF; 36-item Short Form Health Survey physical function; SF-36 BP, 36-item Short Form Health Survey bodily pain; EQ-5D, European quality of life-5 dimensions; VAS, visual analogue scale.
*p < 0.1. **p < 0.05.

at midterm follow-up.

3. Multivariate Analysis of Short-term Outcomes

Multivariate logistic regression modeling for risk factors of poor short-term outcomes in terms of functional improvement, relief of back pain, and relief of leg pain are presented in Table 5. Older age (odds ratio [OR], 1.05; 95% confidence interval [CI], 1.01–1.09; p = 0.026), lateral recess stenosis (OR, 15.54; 95% CI, 1.05–333.33; p = 0.046), and lower baseline ODI score (OR, 0.96; 95% CI, 0.93–0.99; p = 0.027) were found to be statistically significant risk factors for poorer short-term functional improvement. Higher baseline VAS-back score (OR, 1.25; 95% CI, 1.00–1.57; p = 0.048) was the only risk factor associated with poorer short-term relief of back pain. Absence of decreased sensation (OR, 5.13; 95% CI, 1.31–20.1; p = 0.019) and far-lateral disc herniation (OR, 6.06; 95% CI, 1.78–20.6; p = 0.004) were risk factors for poorer short-term relief of leg pain.

4. Multivariate Analysis of Midterm Outcomes

Multivariate logistic regression modeling for risk factors of poorer midterm outcomes in terms of functional improvement and relief of back pain are presented in Table 6. The presence of LFJOA (OR, 8.13; 95% CI, 2.05–32.26; p = 0.003) was the only risk factor for poorer midterm functional improvement. Statistically significant risk factors associated with poorer midterm relief of back pain included the presence of LFJOA (OR, 7.87; 95% CI, 1.21–52.63; p = 0.031) and disc protrusion (OR, 12.7; 95% CI, 1.19–136.3; p = 0.036).

DISCUSSION

Endoscopic spine surgery has become a well-accepted technique, and is the most frequently used method to treat LDH.[9,25] A recent meta-analysis established the superiority of endoscopic discectomy over microdiscectomy, and concluded that endoscopic discectomy has the potential to take the place of microd-

Table 4. Comparison of clinical and radiological data between satisfied and dissatisfied subgroups at midterm follow-up by univariate analysis

Variable	Functional improvement			Relief of back pain		
	Satisfied (n = 206)	Dissatisfied (n = 16)	p-value	Satisfied (n = 213)	Dissatisfied (n = 9)	p-value
Surgery group, PTED:MED	105:101	6:10	0.299	107:106	4:5	0.734
Age (yr)	40.4 ± 11.5	44.3 ± 9.7	0.191	40.6 ± 11.4	41.0 ± 12.5	0.926
Female sex	77 (37.4)	12 (75.0)	0.006**	82 (38.5)	7 (77.8)	0.019**
BMI (kg/m^2)	23.2 ± 3.3	23.6 ± 2.9	0.927	23.1 ± 3.3	25.0 ± 3.7	0.106
Symptom duration ≥ 12 months	48 (23.3)	5 (31.3)	0.472	49 (23.0)	4 (44.4)	0.139
Dominant back pain	97 (47.1)	9 (56.3)	0.480	100 (46.9)	6 (66.7)	0.246
Heavy labor worker	35 (17.0)	5 (31.3)	0.153	38 (17.8)	2 (22.2)	0.666
Sedentary lifestyle	57 (27.7)	3 (18.8)	0.567	58 (27.2)	2 (22.2)	0.740
History of smoking	47 (22.8)	1 (6.3)	0.204	47 (22.1)	1 (11.1)	0.688
History of hypertension	18 (8.7)	1 (6.3)	0.732	18 (8.5)	1 (11.1)	0.560
History of diabetes	8 (3.9)	1 (6.3)	0.496	9 (4.2)	0 (0)	0.529
Positive nerve root tension test	154 (74.8)	10 (62.5)	0.282	158 (74.2)	6 (66.7)	0.700
Decreased sensation	79 (38.3)	5 (31.3)	0.573	82 (38.5)	2 (22.2)	0.324
Myotomal weakness	61 (29.6)	5 (31.3)	0.890	64 (30.0)	2 (22.2)	0.615
Depressed reflex	66 (32.0)	4 (25.0)	0.761	69 (32.4)	1 (11.1)	0.279
Surgical segment			0.513			0.555
L3/4 or above segment	4 (1.9)	0 (0)		4 (1.9)	0 (0)	
L4/5	100 (48.5)	10 (62.5)		104 (48.8)	6 (66.7)	
L5/S1	102 (19.5)	6 (37.5)		105 (49.3)	3 (33.3)	
Location of disc herniation			0.772			0.017**
Median	48 (23.3)	4 (25.0)		51 (23.9)	1 (11.1)	
Paramedian	142 (68.9)	10 (62.5)		147 (69.0)	5 (55.6)	
Far lateral	16 (8.1)	2 (12.5)		15 (7.0)	3 (33.3)	
Type of disc herniation			0.756			0.091*
Bulge	33 (16.3)	3 (18.8)		36 (17.1)	0 (0)	
Protrusion	100 (49.5)	9 (56.3)		102 (48.6)	7 (87.5)	
Extrusion	69 (34.2)	4 (25.0)		72 (34.3)	1 (12.5)	
Disc degeneration (Pfirrman grade ≥ 3)	145 (84.8)	13 (92.9)	0.697	153 (85.5)	5 (83.3)	0.884
Modic change	13 (7.6)	2 (14.3)	0.316	14 (7.8)	1 (16.7)	0.402
LFJOA	17 (8.4)	7 (43.8)	< 0.001**	20 (9.5)	4 (50.0)	0.003**
Proximal ASD	73 (42.7)	7 (50.0)	0.596	75 (41.9)	5 (83.3)	0.110
Distal ASD	54 (58.1)	5 (55.6)	0.884	57 (58.8)	2 (40.0)	0.407
Lateral recess stenosis	7 (3.5)	0 (0)	0.984	7 (3.3)	0 (0)	1.000
Residue of herniation	6 (2.9)	0 (0)	1.000	6 (2.8)	0 (0)	1.000
Recurrence of herniation	8 (3.9)	1 (6.3)	0.496	9 (4.2)	0 (0)	1.000
Reoperation	14 (6.8)	1 (6.3)	1.000	15 (7.0)	0 (0)	0.883

Values are presented as mean ± standard deviation or number (%).
PTED, percutaneous transforaminal endoscopic discectomy; MED, microendoscopic discectomy; BMI, body mass index; LFJOA, lumbar facet joint osteoarthritis; ASD, adjacent segment degeneration.
*$p < 0.1$. **$p < 0.05$.

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Table 5. Risk factors associated with dissatisfied outcomes at short-term follow-up by multivariate logistic regression analysis

Factor	OR	95% CI	p-value
Multivariate modeling for dissatisfied functional improvement			
Age	1.05	1.01–1.09	0.026**
Symptom duration ≥ 12 months	1.42	0.60–3.39	0.425
Absence of positive nerve root tension test	1.11	0.46–2.68	0.822
Location of disc herniation (paramedian vs. median & far-lateral)	1.20	0.54–2.70	0.652
Type of disc herniation (extrusion vs. bulge & protrusion)	1.11	0.50–2.49	0.802
Proximal ASD	1.57	0.72–3.46	0.259
Lateral recess stenosis	15.54	1.05–333.33	0.046**
Preoperative ODI score	0.96	0.93–0.99	0.027**
Preoperative SF-36 PF score	1.00	0.97–1.03	0.925
Preoperative SF-36 BP score	1.00	0.98–1.03	0.775
Preoperative EQ-5D score	10.00	0.68–142.85	0.093
Preoperative VAS-leg score	0.97	0.76–1.24	0.814
Multivariate modeling for dissatisfied relief of back pain			
Symptom duration ≥ 12 months	2.08	0.83–5.21	0.117
Dominant back pain	1.09	0.37–3.24	0.878
Absence of decreased sensation	1.97	0.67–5.77	0.217
Absence of myotomal weakness	2.57	0.71–9.34	0.150
Preoperative VAS-back score	1.25	1.00–1.57	0.048**
Multivariate modeling for dissatisfied relief of leg pain			
BMI	1.06	0.92–1.22	0.393
Dominant back pain	1.36	0.43–4.29	0.600
Absence of positive nerve root tension test	2.04	0.74–5.63	0.168
Absence of decreased sensation	5.13	1.31–20.1	0.019**
Absence of myotomal weakness	2.35	0.59–9.27	0.224
Location of disc herniation (far-lateral vs. median & paramedian)	6.06	1.78–20.6	0.004**
Preoperative SF-36 PF score	1.01	0.98–1.03	0.635
Preoperative SF-36 BP score	1.02	0.99–1.05	0.213
Preoperative VAS-back score	1.21	0.93–1.58	0.156

OR, odds ratio; CI, confidence interval; ASD, adjacent segment degeneration; ODI, Oswestry Disability Index; SF-36 PF; 36-item Short Form Health Survey physical function; SF-36 BP, 36-item Short Form Health Survey bodily pain; EQ-5D, European quality of life-5 dimensions; VAS, visual analogue scale; BMI, body mass index.
**$p < 0.05$.

iscectomy as the gold standard for the treatment of lumbar disc diseases.[26] Numerous studies have investigated correlations between clinical outcomes after discectomy and demographic, clinical, and radiographic variables; however, no clear consensus with respect to risk factors for poorer outcomes has been reached. A recent systematic review that included 40 high-quality studies examined preoperative predictors associated with postoperative outcomes in patients who underwent open lumbar discectomy.[13] The authors concluded that more severe leg pain, better mental health status, shorter symptom duration, and younger age were associated with positive postoperative outcomes, while intact annulus fibrous, longer duration of sick leave, receiving worker's compensation, and greater severity of baseline symptoms were associated with negative postoperative outcomes. However, only a small number of retrospective studies and studies with a small sample size have examined risk factors for poorer surgical outcomes after minimally invasive discectomy.

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Table 6. Risk factors associated with dissatisfied outcomes at midterm follow-up by multivariate logistic regression analysis

Factor	OR	95% CI	p-value
Multivariate modeling for dissatisfied functional improvement			
Female sex	3.41	0.97–12.05	0.057
LFJOA	8.13	2.05–32.26	0.003**
Preoperative ODI score	0.98	0.93–1.03	0.394
Preoperative SF-36 PF score	1.01	0.97–1.06	0.625
Preoperative SF-36 BP score	1.03	0.99–1.06	0.171
Preoperative EQ-5D score	6.06	0.08–500.0	0.421
Multivariate modeling for dissatisfied relief of back pain			
Female sex	9.35	0.97–90.91	0.053
Location of disc herniation (far-lateral vs. median & paramedian)	3.07	0.34–27.58	0.316
Type of disc herniation (protrusion vs. bulge & extrusion)	12.7	1.19–136.3	0.036**
LFJOA	7.87	1.21–52.63	0.031**
Preoperative SF-36 BP score	1.02	0.96–1.07	0.567
Preoperative EQ-5D score	35.7	0.06–1000	0.269

OR, odds ratio; CI, confidence interval; LFJOA, lumbar facet joint osteoarthritis; ODI, Oswestry Disability Index; SF-36 PF; 36-item Short Form Health Survey physical function; SF-36 BP, 36-item Short Form Health Survey bodily pain; EQ-5D, European quality of life-5 dimensions.
**$p < 0.05$.

The purpose of the present study was to identify preoperative factors that predict clinical outcomes after minimally invasive discectomy for the treatment of LDH. There are several advantages of the present study over previous studies. The major advantage is that the data were from a prospective study with relatively large numbers of patients who underwent 2 of the most common minimally invasive discectomy procedures, PTED and MED. Other advantages include the analysis of risk factors based on the presence of functional improvement, back pain relief, and leg pain relief, and analysis of risk factors for poorer outcomes at short-term and midterm follow-up. Notably, patients were divided into satisfied and dissatisfied subgroups in terms of ODI score, VAS-back score, and VAS-leg score according to the PASS threshold. Using the PASS may be more appropriate for defining surgical satisfaction in terms of different PROMs on the individual level, as it is based on the absolute postoperative score rather than the preoperative to postoperative change in score.[20] Hence, the use of high-quality prospective data and the detailed analysis provides useful information for determining which patients are most likely to benefit from the procedures examined.

We found older age, lateral recess stenosis, and lower baseline ODI score were associated with poorer short-term functional improvement following minimally invasive discectomy. Although most studies have found older age to be associated with poorer postoperative outcomes, there have been conflicting results.[13,27] A prospective study by Wu et al.[28] that included 80 patients who underwent PTED found that older age was associated with inferior outcomes. The results showed that patients older than 40 years tended to have inferior outcomes as compared to younger patients (unfavorable rate 32.7% vs. 10.7%, respectively). A retrospective study by Ahn et al.[29] also reported that patients older than 40 years, and patients with concurrent lateral recess stenosis tended to have worse outcomes following PTED for recurrent LDH. The authors postulated that it is difficult to decompress concurrent lateral recess bony stenosis by PTED, especially of the medial part of the pedicle, because this portion is thicker and harder than the tip of the superior facet.

It is unclear if higher or lower baseline ODI and VAS scores predict poorer postoperative outcomes. Hong et al.[14] and Cook et al.[30] suggested that lower baseline ODI scores and higher baseline VAS-back scores are associated with superior outcomes. However, our data indicated that a lower baseline ODI score was a risk factor for poorer short-term functional improvement and a higher baseline VAS-back score was a risk factor for poorer short-term relief of back pain. These findings are consistent with the results of the Spine Patient Outcomes Research Trial (SPORT), which showed that patients with a lower preoperative ODI score and predominant back pain had a poorer surgical treatment effect.[31,32] Another prospective study evaluating the outcomes of microdiscectomy also found that patients with predominant back pain had a lower success rate and inferior

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clinical outcomes.[33]

The results of the present study indicated that the absence of decreased sensation and far-lateral disc herniation were associated with poorer short-term relief of leg pain; findings that have not been previously reported. Shen et al.[17] reported that patients who presented with numbness were more likely to have excellent outcomes following PTED, because the presence of numbness may assist in an early and accurate diagnosis of LDH. Direct compression and irritation of the dorsal root ganglion from far-lateral herniation may be the major reason for poorer neural recovery and reduction of leg pain.[34]

In the current study, the results of univariate and multivariate analysis for the first time identified LFJOA as a risk factor for poorer functional improvement and relief of back pain at 2-year follow-up. Manchikanti et al.[35] reported that the prevalence of lumbar facet joint pain was 16% (95% CI, 9%–23%) in patients with recurrent pain after various spinal surgical interventions. Bokov et al.[36] analyzed the reasons for persistent pain syndromes following surgical interventions for LDH, and found that facet joint pain was responsible for 23.1% of cases that underwent microdiscectomy. Although facet joint pain is estimated to be responsible for low back pain in 15%–45% patients, LFJOA has received far less study than other causes of back pain, such as disc degeneration.[37,38] Fortunately, interest in LFJOA and its effects on low back pain, disability and function has increased in recent years.[39] Protrusion was another predictor of poorer midterm relief of back pain in this study. The 1-year follow-up results of SPORT also indicated that extrusion and sequestration were more likely to be associated with relief of back pain after surgery than the protrusion.[40] A prospective study conducted by Dewing et al.[33] showed that younger patients with contained disc herniation had significantly worse outcomes than those with sequestered or extruded herniation. Chen et al.[16] retrospectively reviewed the records of 521 patients who underwent full endoscopic lumbar discectomy, and reported that protrusion was a predictor of poorer outcomes.

The major limitation of the present study is the absence of long-term follow-up results (more than 4 years); hence we could not identify risk factors associated with poorer long-term outcomes. Another limitation is the potential bias raised by asymmetric facet joint osteoarthritis when defining LFJOA based on radiographic assessment. However, asymmetric LFJOA was uncommon in our patients; only 6 cases were identified and defined as LFJOA.

CONCLUSION

Patients with LDH who undergo PTED or MED achieved satisfactory short-term and midterm outcomes in terms of functional improvement and relief of back and leg pain. Older age, lateral recess stenosis, and lower baseline ODI score were associated with poorer short-term functional improvement following minimally invasive discectomy. Higher baseline VAS-back score was associated with poorer short-term relief of back pain, while the absence of decreased sensation and far-lateral disc herniation were associated with poorer short-term relief of leg pain. LFJOA was identified, for the first time, as a risk factor for poor functional improvement and relief of back pain at midterm follow-up. The protrusion was also a predictor of poorer midterm relief of back pain.

NOTES

Conflict of Interest: The authors have nothing to disclose.

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