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Clinical Studies

Preoperative factors affecting the two-year postoperative patient-reported outcome in single-level lumbar grade I degenerative spondylolisthesis

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ABSTRACT

Background: The choice of operative method for lumbar spinal stenosis with Meyerding grade I degenerative spondylolisthesis remains controversial. The purpose of this study was to identify the preoperative factors affecting the 2-year postoperative patient-reported outcome in Meyerding grade I degenerative spondylolisthesis.
Methods: Seventy-two consecutive patients who had minimally invasive decompression alone (D group; 28) or with fusion (DF group; 44) were enrolled. The parameters investigated were the Japanese Orthopaedic Association back pain evaluation questionnaire as patient-reported assessment, and L4 slippage (L4S), lumbar lordosis (LL), and lumbar axis sacral distance (LASD) as an index of sagittal alignment for radiological evaluation. Data collected prospectively at 2 years postoperatively were examined by statistical analysis.
Results: Sixty-two cases (D group; 25, DF group; 37) were finally evaluated. In multiple logistic regression analysis, preoperative L4S and LASD were extracted as significant preoperative factors affecting the 2-year postoperative outcome. Patients with preoperative L4S of 6 mm or more have a lower rate of improvement in lumbar spine dysfunction due to low back pain (risk ratio=0.188, p=.043). Patients with a preoperative LASD of 30 mm or more have a higher rate of improvement in lumbar dysfunction due to low back pain (risk ratio=11.48, p=.021). The results of multiple logistic analysis by operative method showed that there was a higher rate of improvement in lumbar spine dysfunction due to low back pain in patients with preoperative LASD of 30 mm or more in DF group (risk ratio=172.028, p=.01).
Conclusions: Preoperative L4S and LASD were extracted as significant preoperative factors affecting patient-reported outcomes at 2 years postoperatively. Multiple logistic analyses by the operative method suggested that DF may be advantageous in improving lumbar dysfunction due to low back pain in patients with preoperative LASD of 30 mm or more.

Introduction

The benefit of adding fusion to decompression in patients with lumbar degenerative spondylolisthesis is still controversial [1,2]. Recently, favorable outcomes have been reported for decompression preserving as much posterior supporting tissue as possible in cases of LSS [3–7]. Few RCTs found that the minimally invasive decompression alone (D) was noninferior to decompression with instrumented fusion in patients with lumbar stenosis and degenerative spondylolisthesis [8,9].

To the best of our knowledge, there has been no report of a prospective detailed study of preoperative factors affecting the 2-year postoperative outcomes using patient-reported assessment in patients who underwent single-level surgery for lumbar spinal stenosis (LSS) associated with single-level degenerative spondylolisthesis. The Japanese Orthopaedic Association back pain evaluation questionnaire (JOABPEQ) is a patient-based assessment to provides specific, yet multidimensional, outcome measures for patients with low back pain, including dysfunctions and disabilities caused by the disease, and psychosocial problems resulting from such dysfunctions and disabilities. The reliability and validity of the JOABPEQ have been verified by psychometric evaluations [10–12], and the reference values for JOABPEQ according to age and gender have been also established [13].

Currently, in our country, there is no clear standard for the choice of operative method for LSS with Meyerding grade I spondylolisthesis (without foraminal stenosis), and it is entrusted to the discretion of the institutions and the surgeons. Thus, it is difficult to conduct a randomized controlled trial (RCT), and we conducted the prospective, multicenter, patient-preference cohort study. In this study, we used the JOABPEQ, as a patient-reported assessment, and compared treatment outcomes of minimally invasive D or with fusion for single-level LSS patients caused by L4–L5 degenerative spondylolisthesis (without foraminal stenosis) and examined preoperative factors affecting the 2-year postoperative outcome.

Materials and methods

Study design

This prospective, multicenter, patient-preference cohort study was conducted in twelve university hospitals and their affiliated hospitals. Seventy-two consecutive patients who were operated from April 2012 to March 2014 were enrolled in this study. The subjects had Meyerding grade I (≥3 mm) spondylolisthesis according to plain radiography performed while in the standing lumbar neutral position [14]. They had LSS at the L4/5 level exhibiting intermittent neural claudication, had undergone conservative treatment for 3 months or longer without sufficient improvement, and subsequently had undergone surgery (D or with fusion) at the L4/5 vertebral level alone. We excluded patients with a history of cervical or lumbar surgery or concurrent conditions, such as other spinal disease (including foraminal stenosis at the L4/5 and degenerative scoliosis with a Cobb angle of ≥10°); osteoarthrosis that was being treated (hip, knee, ankle); tumor; rheumatoid arthritis; destructive spondyloarthropathy; mental disorder; neuropathy, such as Parkinson's disease; or peripheral nervous disease, such as diabetic neuropathy; and patients who did not provide consent.

Treatment strategies (selection of conservative or surgical treatment, and of operative method) were determined in accordance with the standards at the participating institutions. Patients were given sufficient oral and written explanations and selected D or decompression with fusion (DF), once they had given their written informed consent, the preoperative evaluation was conducted. QOL and each radiological parameter were evaluated preoperatively and at 2 years postoperatively.

The study was approved by the institutional review board of all author's hospital, and it adhered to the tenets of the Declaration of Helsinki. Written informed consent was obtained from all patients.

Patient groups and surgical details

Of 72 patients (females; 49, males; 23, mean age: 67 years) studied, 28 (females; 16, males; 12) and 44 (females; 33, males; 11) were classified into the D and DF groups, respectively.

Decompression involved endoscopic bilateral decompression via a unilateral approach in 18 patients, microscopic bilateral decompression via a unilateral approach in 2, and bilateral fenestration in 8. In all patients who underwent decompression, the midline structures (supraspinous-interspinous ligament complex) and facet joints were preserved as much as possible. The decompression and fixation technique used was posterior lumbar interbody fusion with a cage in 38 patients, transforaminal lumbar interbody fusion with a cage in 5, and posterolateral fusion in 1.

Clinical and radiological outcome measures

The preoperative parameters for case data were age, gender, and operative method (D or with fusion). For the patient-reported

Table 1
The JOA Back Pain Evaluation Questionnaire (JOABPEQ).

With regard to your health condition during the last week, please circle the one item number of the answer for the following questions that best applies. If your condition varies depending on the day or the time, circle the item number of your condition at its worst.
Q1-1 To alleviate low back pain, you often change your posture. (1) Yes (2) No
Q1-2 Because of the low back pain, you lie down more often than usual. (1) Yes (2) No
Q1-3 Your lower back is almost always aching. (1) Yes (2) No
Q1-4 Because of the low back pain, you cannot sleep well. (If you take sleeping pills because of the pain, select “No.”) (1) No (2) Yes
Q2-1 Because of the low back pain, you sometimes ask someone to help you when you do something. (1) Yes (2) No
Q2-2 Because of the low back pain, you refrain from bending forward or kneeling down. (1) Yes (2) No
Q2-3 Because of the low back pain, you have difficulty in standing up from a chair. (1) Yes (2) No
Q2-4 Because of the low back pain, turning over in bed is difficult. (1) Yes (2) No
Q2-5 Because of the low back pain, you have difficulty putting on socks or stockings. (1) Yes (2) No
Q2-6 Do you have difficulty in any one of the following motions; bending forward, kneeling or stooping? (1) I have great difficulty (2) I have some difficulty (3) I have no difficulty
Q3-1 Because of the low back pain, you walk only short distances. (1) Yes (2) No
Q3-2 Because of the low back pain, you stay seated most of the day. (1) Yes (2) No
Q3-3 Because of the low back pain, you go up the stairs more slowly than usual. (1) Yes (2) No
Q3-4 Do you have difficulty in going up the stairs? (1) I have great difficulty (2) I have some difficulty (3) I have no difficulty
Q3-5 Do you have difficulty in walking more than 15 minutes? (1) I have great difficulty (2) I have some difficulty (3) I have no difficulty
Q4-1 Because of the low back pain, you do not do any routine housework these days. (1) No (2) Yes
Q4-2 Have you been unable to do your work or ordinary activities as well as you would like? (1) I have not been able to do them at all. (2) I have been unable to do them most of the time. (3) I have sometimes been unable to do them. (4) I have been able to do them most of the time. (5) I have always been able to do them.
Q4-3 Has your work routine been hindered because of the pain? (1) Greatly (2) Moderately (3) Slightly (somewhat) (4) Little (minimally) (5) Not at all Q5-1 Because of the low back pain, you get irritated or get angry at other persons more often than usual. (1) Yes (2) No
Q5-2 How is your present health condition? (1) Poor (2) Fair (3) Good (4) Very good (5) Excellent
Q5-3 Have you been discouraged and depressed? (1) Always (2) Frequently (3) Sometimes (4) Rarely (5) Never
Q5-4 Do you feel exhausted? (1) Always (2) Frequently (3) Sometimes (4) Rarely (5) Never
Q5-5 Have you felt happy? (1) Never (2) Rarely (3) Sometimes (4) Almost always (5) Always
Q5-6 Do you think you are in decent health? (1) Not at all (my health is very poor) (2) Barely (my health is poor) (3) Not very much (my health is average health) (4) Fairly (my health is better than average) (5) Yes (I am healthy)
Q5-7 Do you feel your health will get worse? (1) Very much so (2) A little bit at a time (3) Sometimes yes and sometimes no (4) Not very much (5) Not at all
VASs
Regarding 0 as “no pain (numbness) at all” and 10 as “the most intense pain (numbness) imaginable,” mark a point between0and 10 on the lines below to show the degree of your pain (numbness) when your symptom was at its worst during the last week.
0 10
VAS1 Degree of low back pain ———————————
VAS2 Degree of pains in buttocks and lower limb ———————————
VAS3 Degree of numbness in buttocks and lower limb ———————————
0: Comfortable condition without any pain at all 10: The most intense pain (numbness) imaginable

assessment, JOABPEQ and the visual analog scales (VASs) (Table 1) were used. JOABPEQ includes 25 questions that yield five domains: pain-related disorders, lumbar spine dysfunction, gait disturbance, social life dysfunction, and psychological disorders. VASs were used to evaluate the degree of low back pain (LBP) and pain or numbness in the buttocks and lower limbs with respect to the relevant domains in the JOABPEQ. The score of each domain was calculated according to the official guidelines and ranged from 0 to 100 points, which is proportional to the patient’s clinical condition [10–12]. When evaluating the JOABPEQ, an increase of ≥20 points within 2 years postoperatively or a 2-year score of ≥90 indicated effectiveness of the procedure [12]. When evaluating the VAS, an increase of ≥20 mm within 2 years postoperatively indicated effectiveness of the procedure [15].

For radiological assessment, we evaluated L4 slippage (mm), lumbar lordosis (L1−S1 sagittal plane Cobb angle in the neutral position), and lumbar axis sacral distance (LASD) [16] at preoperative and 2 years postoperatively. Lumbar axis sacral distance was used as an indicator of sagittal alignment, measuring the horizontal distance from the plumb line of the center of L1 to the back corner of S1 [16] (Fig. 1). Bone union and adjacent segment disease (ASD) were also evaluated at 2 years postoperatively. In this study, ASD was defined as a decrease in adjacent intervertebral height of at least 3 mm or 20%, and/or a sagittal translation greater than 3 mm and/or angle change greater than 10° between adjacent vertebral bodies.

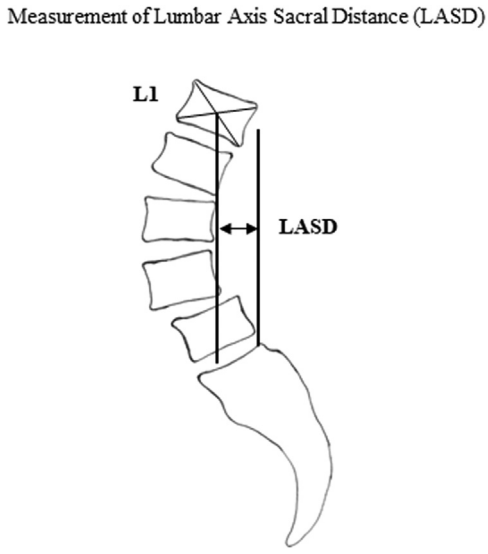

Fig. 1. Measurement of lumbar axis sacral distance (LASD). Lumbar axis sacral distance (LASD) was used as an indicator of sagittal alignment, measuring the horizontal distance from the plumb line of the center of L1 to the back corner of S1 (both arrows) [16].

Statistical analysis

Data were analyzed using commercially available software (Stata for Windows; Stata Corp.). The Wilcoxon rank-sum test or chi-square test was used to compare pairs of groups. In order to set the threshold values of the preoperative radiological measurement values and age, a univariate analysis for JOABPEQ and VASs was performed. After setting the threshold value by the univariation analysis, the multiple logistic regression analysis using the operative method, gender, age, preopera-

Table 2
Preoperative demographic data and clinical outcomes at 2 years postoperatively of two surgical groups.

Preoperative demographic data	Decompression alone (D) N=28	Decompression with fusion (DF) N=44	p-value
Preoperative age (years old)	69±7	65±10	.21
Gender			
Female	16	33	.11
Male	12	11	
Disease duration (Month)	49±68	34±32	.39
Radiological assessment	N=28	N=41	
L4 slippage (mm)	6.6±2.3	7.7±2.8	.054
Number of more than 8 mm (%)	9 (32)	19 (43)	.14
9 mm (%)	4 (14)	14 (32)	.065
10 mm (%)	2 (7)	11 (25)	.063
Lumbar lordosis (L1–S1) (degree)	37.8±15.7	42.0±12.2	.23
Lumbar axis sacral distance: LASD (mm)	23.6±15.3	21.9±16.8	.48
Clinical outcomes			
Postoperative complications	N=3	N=4	
Dura mater injuries	2	0	.82
Postoperative hematoma	1	0	
Deep vein thrombosis	0	1	
Deep infection	0	1	
Anginal attack	0	1	
Lumbar artery pseudoaneurysm	0	1	
Reoperation	0	1 (pseudoarthrosis)	.42
Adjacent segment disease	0	1 (L3/4)	.42
Drop out	N=3	N=7	
Data unavailability	3	5	
Reoperation	0	1	
Unknown death	0	1	

N, number.

tive L4 slippage, lumbar lordosis, and LASD as explanatory variables for JOABPEQ and VASs was used to examine preoperative factors affecting the efficacy rate of each domain of JOABPEQ and VASs at 2 years postoperatively. The multiple logistic regression analysis was also performed by the operative method, and a significant preoperative factor was examined in each operative method. A probability value of <.05 was considered statistically significant.

Results

Patient demographics and clinical outcomes

Table 2 shows the demographics for two surgical groups. No significant differences were noted between the groups regarding preoperative age, gender, degree of spondylolisthesis, lumbar lordosis angle, or LASD. Preoperative L4 slippage tended to be greater in the DF group (p=.054), and fixation was often chosen in cases with preoperative L4 slippage of 8 mm or more (Table 2).

Table 2 also shows clinical outcomes of two surgical groups. Postoperative complications occurred in three (two dura mater injuries, one postoperative hematoma) and four (one case each of deep vein thrombosis, deep infection, anginal attack, and lumbar artery pseudoaneurysm) patients, in the D and DF groups, respectively. In the DF group, L3/4 ASD and pseudarthrosis of L4/5 were noted in one patient, and the same patient required repeat surgery. No patient required repeat surgery in the D group. Three dropout cases (data unavailability) in the D group and seven dropout cases in the DF group (five data unavailability, one reoperation, one unknown death) were found at 2 years postoperatively. Fig. 2 shows the study enrollment and drop-off of patients, finally 62 cases (25 in the D group, 37 in the DF group) were evaluated for JOABPEQ and VAS at 2 years postoperatively.

Outcomes of radiological measurements and VASs

Table 3 shows the outcomes of pre- and postoperative radiological measurements and VASs, and it also shows a correlation between preoperative L4 slippage and LASD. There was no significant difference in preoperative L4 slippage between the D group and the DF group, but the L4 slippage at 2 years postoperatively was significantly reduced in the DF group (Table 3). That was indicating more significant correction was achieved in the DF group. On the other hand, in the comparison by gender, preoperative L4 slippage was significantly larger in females, and there was no significant difference in postoperative L4 slippage, but lumbar lordosis angle and LASD were significantly larger in females (Table 3). There was a significant positive correlation between preoperative L4 slippage and LASD, but after surgery, there was a significant correlation only in the D group (Table 3).

For VASs, in the comparison by operative method, there was no significant difference between the two surgical groups in all items of preoperative, postoperative comparison of VAS1-3 (Table 3). In the comparison by gender, there was a significant difference in preoperative VAS1 and postoperative VAS1-3 (Table 3). In Table 3, the number of each domain is different, since there was a domain that could not be calculated because of data defects.

Outcomes of multiple logistic analysis for JOABPEQ and VASs

For JOABPEQ and VASs, no significant differences between two surgical groups were noted in the efficacy rate for any domains at 2 years postoperatively (Table 4). In the comparison by gender, no significant differences between males and females were noted in the efficacy rate for any domain at 2 years postoperatively, but there was a tendency for the efficacy rate of “psychological disorder” in females to be lower (p=.066, Table 4).

In multiple logistic regression analysis using operative method, gender, age, preoperative L4 slippage, lumbar lordosis, and LASD as explanatory variables for JOABPEQ at 2 years postoperatively, preoperative L4 slippage was extracted as a significant factor for “psychological disorder” (risk ratio of high slippage to low slippage=0.662; this means that efficacy rate of high slippage is about 1.5 times lower than low., p=.043) and “social life disturbance” (risk ratio of high slippage to low slippage=0.726; this means that efficacy rate of high slippage is about 1.4 times lower than low., p=.046), and there was a tendency for the ef-

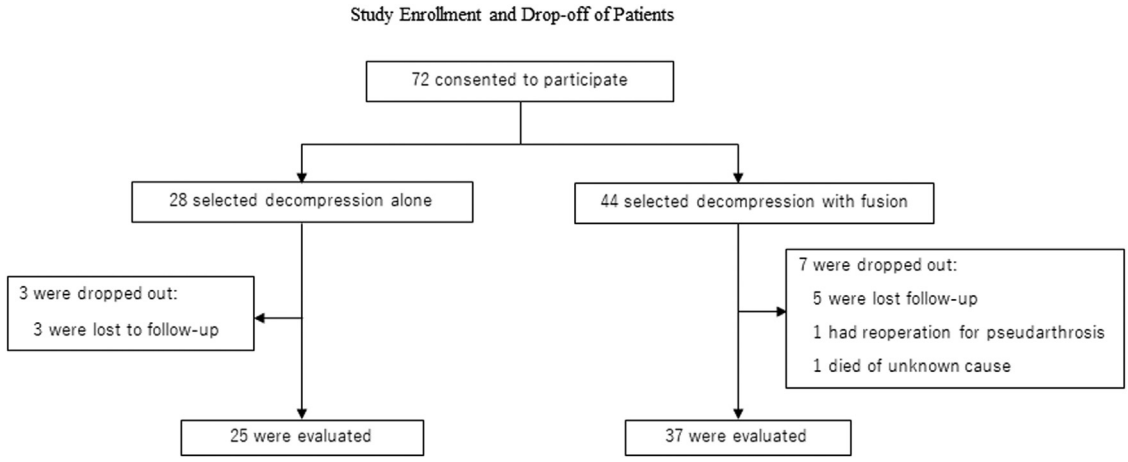

Fig. 2. Study enrollment and drop-off of patients. Seventy-two consecutive patients were enrolled in this study. Twenty-eight patients selected decompression alone (D) and 44 patients selected decompression with fusion (DF). Three patients were dropped out in the D group and 7 patients were dropped out in the DF group. Sixty-two patients (25 in the D group, 37 in the DF group) were the subject of the statistical evaluation.

Table 3
Radiological outcomes and pre- and postoperative visual analog scales (VASs) outcomes by operative method and gender.

Radiological outcomes and visual analog scales (VASs) outcomes						
Radiological outcome	Operative method			Gender		
	DF	D	p-value	F	M	p-value
Preoperative	N=41	N=28		N=46	N=23	
L4 slippage (mm)	7.7±2.8	6.6±2.3	.054	7.8±2.7	6.1±2.3	**.005***
lumbar lordosis (L1–S1)	42.0±12.2	37.8±15.7	.23	41.3±14.3	38.3±12.7	.24
Lumbar axis sacral distance(mm)	21.9±16.8	23.6±15.3	.48	24.4±14.9	18.7±18.0	.11
Postoperative	N=37	N=24		N=41	N=20	
L4 slippage (mm)	3.7±3.0	7.7±2.4	**<.0001***	5.2±3.5	5.6±3.2	.72
lumbar lordosis (L1–S1)	44.4±13.6	39.0±17.0	.26	44.4±16.4	37.9±11.2	**.03***
Lumbar axis sacral distance (mm)	22.8±16.0	22.8±20.0	.85	26.5±15.6	15.1±19	**.012***

Symptoms (VASs)	DF	D	p-value	F	M	p-value
Preoperative	N=43	N=27		N=48	N=22	
VAS1	56±26	55±28	.81	61±24	44±29	**.025***
VAS2	56±24	65±25	.06	63±22	52±30	.26
VAS3	54±30	62±30	.2	57±31	59±30	.77
Postoperative	N=36	N=23		N=38	N=22	
VAS1	23±27	20±22	.91	27±26	13±23	**.01***
VAS2	17±24	25±31	.52	24±27	14±27	**.038***
VAS3	19±25	25±30	.57	27±28	13±24	**.011***

Correlation between L4 slippage and lumbar axis sacral distance						
	DF+D	p-value	DF	p-value	D	p-value
Preoperative	N=69		N=41		N=28	
Correlation coefficient	0.39	**0.001***	0.47	**0.002***	0.39	**.001***
Postoperative	N=61		N=37		N=24	
Correlation coefficient	0.22	0.08	0.15	0.36	0.48	**.02***

DF, decompression and fusion; D, decompression; N, number; VAS1; low back pain; VAS2; buttock and lower limb pain; VAS3; buttock and lower limb numbness; F; female; M; male.
* Statistically significant; Significant p values are indicated in bold font.

ficacy rate of "lumbar spine dysfunction" and "psychological disorder" in females to be lower (Table 5). On the other hand, in multiple logistic regression analysis using surgery, gender, age, preoperative L4 slippage, lumbar lordosis, and LASD as explanatory variables for VASs at 2 years postoperatively, preoperative LASD was extracted as a significant factor for VAS1 (risk ratio of high LASD to low LASD=1.065; this means that efficacy rate of high LASD is about 1.1 times higher than low., p=.022) (Table 5). In Table 5, the number of each domain is different, since there was a domain that could not be calculated because of data defects.

In order to set the threshold values of the preoperative radiological measurement values and age, a univariate analysis was performed. Table 6 shows the univariate analysis outcome of efficacy rate of JOABPEQ and VASs by age and radiological measurement threshold. The results of univariate analysis showed significant differences and trends in age at 60 years, preoperative L4 slippage of 5 to 8 mm, preoperative LASD of 30 mm, and lumbar lordosis of 35 degrees. In Table 6, the number of each domain is different, since there was a domain that could not be calculated because of data defects.

Table 7 shows the results of multiple logistic regression analysis for JOABPEQ and VASs at 2 years postoperatively by radiological measurement threshold. The radiological measurement threshold was set to preoperative LASD to 30 mm, lumbar lordosis to 35 degrees, and preoperative L4 slippage was set from 5 to 8 mm, and multiple logistic regression analysis using the operative method, gender, age, preoperative L4 slip-

Table 4
Comparative study of the efficacy rate in JOABPEQ domains and visual analog scales (VASs) by operative method and gender.

Operative method																
	Pain-related disorder		Lumbar spine dysfunction		Gait disturbance		Social life disturbance		Psychological disorder		VAS1		VAS2		VAS3	
	DF	D	DF	D	DF	D	DF	D	DF	D	DF	D	DF	D	DF	D
Total (N)	31	23	30	23	35	24	36	25	37	25	36	23	36	23	36	24
efficacy rate	0.774	0.913	0.567	0.565	0.886	0.75	0.667	0.6	0.216	0.24	0.667	0.522	0.833	0.783	0.694	0.75
p-value	.273		1		.289		.601		1		.288		.736		.773	

Gender																
	Pain-related disorder		Lumbar spine dysfunction		Gait disturbance		Social life disturbance		Psychological disorder		VAS1		VAS2		VAS3	
	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M
Total (N)	39	15	37	16	40	19	40	21	40	22	38	21	38	21	39	21
efficacy rate	0.821	0.867	0.514	0.688	0.8	0.895	0.575	0.762	0.15	0.364	0.605	0.619	0.737	0.619	0.692	0.667
p-value	1		.366		.476		0.173		**.066***		1		.387		1	

JOABPEQ, the Japanese Orthopaedic Association back pain evaluation questionnaire; DF, decompression and fusion; D, decompression; N, number; VAS1, low back pain; VAS2, buttock and lower limb pain; VAS3, buttock and lower limb numbness; F, female; M, male.
* p<.08; Trending p value is indicated in bold font.

Table 5
Multiple logistic regression analysis using operative method, gender, age, and preoperative radiological findings as explanatory variables for JOABPEQ and VASs at 2 years postoperatively.

Multiple logistic regression analysis for JOABPEQ and VASs						
	Social life disturbance		Psychological disorder		VAS1	
	N=58(DF:33, D:25)		N=59(DF:34, D:25)		N=56(DF:33, D:23)	
Variable	Exp(B)	p-value	Exp(B)	p-value	Exp(B)	p-value
Operative method (D/DF)	1.835	.352	1.806	0.456	3.091	.101
Gender(M/F)	0.293	.102	0.265	0.08	0.377	.173
Age	0.949	.197	1.003	0.947	0.94	.141
Preop. slippage (mm)	**0.726**	**.046***	**0.662**	**0.043***	0.901	.474
Preop. lordosis (degree)	1.027	.266	1.007	0.821	0.976	.321
Preop. LASD (mm)	1.015	.502	1.034	0.191	**1.065**	**.022***
Constant	249.447	.083	1.829	0.86	153.917	.126

JOABPEQ, the Japanese Orthopaedic Association back pain evaluation questionnaire; DF, decompression and fusion; D, decompression; N, number; VAS1; low back pain; VAS2; buttock and lower limb pain; VAS3; buttock and lower limb numbness; Exp(B), risk ratio; D/DF, risk ratio of DF to D; M/F, risk ratio of F to M; Preop., preoperative; LASD, lumbar axis sacral distance.
* Statistically significant; Significant p values and risk ratios are indicated in bold font.

page, lumbar lordosis, and LASD as explanatory variables for JOABPEQ was performed. In the results of multiple logistic regression analysis, gender, preoperative L4 slippage, LASD, and lumbar lordosis were extracted as significant preoperative factors affecting the 2-year postoperative outcome. Women had a lower rate of improvement in lumbar spine dysfunction due to LBP (risk ratio of women to men=0.17, p=.034) and psychological disorder (risk ratio=0.222, p=.045) compared to men. Patients with preoperative L4 slippage greater than 5 to 6 mm have a lower rate of improvement in LBP (risk ratio of high slippage to low slippage=0.159, p=.049) and lumbar spine dysfunction due to LBP (risk ratio=0.188, p=.043). Preoperative lumbar lordosis angle of less than 35 degrees was associated with a lower rate of improvement in gait disturbance due to LBP (risk ratio of high lordosis to low lordosis=11.638, p=.017). Patients with a preoperative LASD greater than 30 mm have a higher rate of improvement in postoperative LBP (risk ratio of high LASD to low LASD=20.905, p=.008) and lumbar spine dysfunction due to LBP (risk ratio=11.48, p=.021). In Table 7, the number of each domain is different, since there was a domain that could not be calculated because of data defects.

Table 8 shows the outcome of comparative study between operative methods by the degree of preoperative radiological measurements in multiple logistic regression analysis for JOSBPEQ at 2 years postoperatively. The radiological measurement threshold was set to preoperative LASD to 30 mm, lumbar lordosis to 35 degrees, and preoperative L4 slippage was set from 5 to 8 mm, and multiple logistic regression analysis using gender, age, preoperative L4 slippage, lumbar lordosis, and LASD as explanatory variables for JOABPEQ was performed by operative method. The results of multiple logistic analysis by operative method showed that there was a higher rate of improvement in lumbar spine dysfunction due to LBP in patients with preoperative LASD greater than 30 mm in DF group (risk ratio of high LASD to low LASD=172.028, p=.01). The improvement rate of lumbar spine dysfunction due to LBP was lower in patients with preoperative L4 slippage of more than 6 mm in DF group (risk ratio of high slippage to low slippage=0.049, p=.042). The improvement rate of psychological disorder was lower in patients with preoperative L4 slippage of more than 5 mm in DF group (risk ratio=0.086, p=.048). On the other hand, in the D group, there was a significant difference in gender, and women showed a lower rate of improvement in psychological disorder than men (risk ratio of women to men=0.006, p=.031). In Table 8, the number of each domain is different, since there was a domain that could not be calculated because of data defects.

Table 6
Univariate analysis outcome of efficacy rate of JOABPEQ and VASs by age and radiological measurement threshold.

	Gait disturbance		Social life disturbance		Psychological disorder		VAS1	
	N=56(DF:n=32, D:n=24)		N=58(DF:n=33, D:n=25)		N=59(DF:n=34, D:n=25)		N=56(DF:n=33, D:n=23)	
Variable	ER(L/H)	p-value	ER(L/H)	p-value	ER(L/H)	p-value	ER(L/H)	p-value
Age:Low≦60y<High	1.000/0.787	.182	**0.909/0.563**	**.041***	0.273/0.204	.69	**0.889/0.542**	**.069†**
Age:Low≦65y<High	**0.952/0.750**	**.074†**	0.762/0.553	.161	0.182/0.237	.751	0.750/0.514	.098
Age:Low≦70y<High	0.813/0.840	1	0.688/0.556	.418	0.152/0.296	.217	0.613/0.577	.794
Age:Low≦75y<High	0.809/0.900	.672	0.592/0.800	.294	0.180/0.400	.201	0.596/0.600	.709
L4 slippage:Low≦4mm<High	1.000/0.811	1	0.750/0.618	1	0.500/0.196	.202	0.750/0.585	.641
L4 slippage:Low≦5mm<High	0.889/0.795	.478	**0.833/0.537**	**.041***	**0.389/0.143**	**.046***	0.684/0.553	.401
L4 slippage:Low≦6mm<High	0.889/0.767	.304	0.759/0.500	.06†	0.310/0.129	.121	0.621/0.571	.79
L4 slippage:Low≦7mm<High	0.848/0.792	.727	0.722/0.478	.097	0.278/0.125	.21	0.611/0.571	.787
L4 slippage:Low≦8mm<High	0.865/0.750	.298	**0.725/0.421**	**.042***	0.275/0.100	.186	0.605/0.579	1
L4 slippage:Low≦9mm<High	0.833/0.778	.65	0.667/0.375	.135	0.255/0.000	.184	0.551/0.875	.125
L4 slippage:Low≦10mm<High	0.843/0.667	.281	0.648/0.400	.351	0.241/0.000	.324	0.577/0.800	.638
LASD:Low≦10mm<High	0.833/0.818	1	0.692/0.622	.751	0.385/0.174	.135	0.462/0.651	.332
LASD:Low≦20mm<High	0.852/0.793	.731	0.724/0.552	.274	0.233/0.207	1	0.517/0.704	.18
LASD:Low≦30mm<High	0.829/0.800	1	0.674/0.533	.363	0.227/0.200	1	**0.524/0.857**	**.032***
LASD:Low≦40mm<High	0.840/0.667	.289	0.654/0.500	.657	0.208/0.333	.605	0.580/0.833	.386
Lumbar lordosis:Low≦25°<High	0.700/0.851	.357	0.700/0.612	.729	0.200/0.220	1	0.727/0.565	.497
Lumbar lordosis:Low≦35°<High	**0.667/0.897**	**.058†**	0.684/0.600	.578	0.263/0.195	.737	0.600/0.595	1
Lumbar lordosis:Low≦45°<High	0.788/0.875	.494	0.559/0.720	.278	0.229/0.200	1	0.611/0.571	.787
Lumbar lordosis:Low≦55°<High	0.824/0.833	1	0.596/0.857	.24	0.226/0.143	1	0.604/0.500	1

JOABPEQ: the Japanese Orthopaedic Association back pain evaluation questionnaire; DF: decompression and fusion; D: decompression; N: number; LASD: lumbar axis sacral distance; ER: efficacy rate; L/H: low/high.

* Statistically significant; p<.05.

† p<.08. Significant or trending p-values are shown in bold.

Table 7
Multiple logistic regression analysis for JOABPEQ and VASs at 2 years postoperatively by radiological measurement threshold.

Grouping by the degree of preoperative radiological measurements	Preoperative explanatory variables	Lumbar spine dysfunction		Gait disturbance		Psychological disorder		VAS1	
		N=50(DF:n=27, D:n=23)		N=56(DF:n=32, D:n=24)		N=59(DF:n=34, D:n=25)		N=56(DF:n=33, D:n=23)	
		Exp(B)	p-value	Exp(B)	p-value	Exp(B)	p-value	Exp(B)	p-value
High: Age>60yrs, L4 slippage>5mm, lumbar lordosis>35°, LASD>30mm	Operative method(D/DF)	0.98	.978	1.761	.525	1.609	.556	4.898	.079
	Gender(M/F)	**0.191**	**.047***	0.188	.121	0.239	.063	0.45	.265
	Age (Low/High)	0.177	.083	0	.999	0.472	.392	0.15	.124
	L4 slippage (Low/High)	0.568	.485	0.572	.62	0.243	.086	**0.159**	**.049***
	Lordosis (Low/High)	1.045	.951	**7.049**	**.029***	0.9	.887	0.769	.71
	LASD (Low/High)	**5.248**	**.047***	1.114	.912	1.906	.473	**18.411**	**.007***
High: Age>60y, L4 slippage>6mm, lumbar lordosis>35°, LASD>30mm	Operative method(D/DF)	1.178	.821	1.642	.56	1.287	.738	2.743	.164
	Gender(M/F)	0.198	.061	0.173	.094	0.241	.058	0.39	.181
	Age (Low/High)	0.198	.125	0	.999	0.631	.609	0.159	.132
	L4 slippage (Low/High)	**0.188**	**.043***	0.619	.62	0.294	.146	0.305	.123
	Lordosis (Low/High)	0.903	.895	**7.098**	**.028***	0.809	.774	0.754	.689
	LASD (Low/High)	**10.57**	**.016***	1.172	.876	2.021	.451	**16.078**	**.008***
High: Age>60y, L4 slippage>7mm, lumbar lordosis>35°, LASD>30mm	Operative method(D/DF)	1.003	.996	1.677	.538	1.175	.829	2.585	.176
	Gender(M/F)	**0.167**	**.031***	0.162	.083	**0.231**	**.049***	0.363	.155
	Age (Low/High)	0.2	.112	0	.999	0.551	.495	0.191	.177
	L4 slippage (Low/High)	0.322	.198	0.457	.448	0.388	.292	0.241	.106
	Lordosis (Low/High)	1.263	.747	**9.644**	**.022***	1.09	.904	1.129	.859
	LASD (Low/High)	**9.033**	**.031***	1.394	.756	1.798	.53	**20.905**	**.008***
High: Age>60y, L4 slippage>8mm, lumbar lordosis>35°, LASD>30mm	Operative method(D/DF)	1.073	.921	1.874	.467	1.219	.789	2.156	.254
	Gender(M/F)	**0.17**	**.034***	0.174	.1	**0.222**	**.045***	0.389	.175
	Age (Low/High)	0.188	.102	0	.999	0.507	.432	0.169	.145
	L4 slippage (Low/High)	0.193	.079	0.226	.16	0.281	.19	0.346	.217
	Lordosis (Low/High)	1.293	.724	**11.638**	**.017***	1.121	.874	1.162	.826
	LASD (Low/High)	**11.48**	**.021***	1.786	.593	1.874	.484	**14.922**	**.013***

JOABPEQ, the Japanese Orthopaedic Association back pain evaluation questionnaire; DF, decompression and fusion; D, decompression; N, number; Exp(B), risk ratio; LASD, lumbar axis sacral distance; D/DF, risk ratio of DF to D; M/F, risk ratio of F to M; Low/High, risk ratio of "High" to "Low".

* Statistically significant; Significant p values and risk ratios are indicated in bold font.

Discussion

Herkowitz and Kurz et al. [17] reported that performing decompression with rather than without (laminectomy and medial facetectomy) fusion inhibited the progression of spondylolisthesis, resulting in superior clinical outcomes. Kornblum et al. [18] reported that, although performing posterior fusion after use of instrumentation resulted in a more elevated bone healing rate, the clinical outcomes might not necessarily have improved. Meanwhile, a large number of reports also have indicated that decompression and fusion cause greater surgical invasion and more severe complications than D, with some investigators proposing that caution is required for elderly patients in particular [19–22]. In this study, there was no significant difference in postoperative complication or reoperation rates between the two surgical groups (Table 2).

Table 8
Comparative study between operative methods of multiple logistic regression analysis for JOABPEQ and VASs at 2 years postoperatively by radiological measurement threshold.

Grouping by the degree of preoperative radiological measurements	Preoperative explanatory variables	Lumbar spine dysfunction				Psychological disorder			
		DF(n=27)		D(n=23)		DF(n=34)		D(n=25)	
		Exp(B)	p-value	Exp(B)	p-value	Exp(B)	p-value	Exp(B)	p-value
High: Age>60y, L4 slippage>5mm, lumbar lordosis>35°, LASD>30mm	Gender(M/F)	0.172	.159	0.102	.104	0.343	.344	**0.006**	**.037***
	Age (Low/High)	0.161	.149	0	1	0.438	.488	>1000	.999
	L4 slippage (Low/High)	0.309	.348	1.704	.694	**0.086**	**.048***	8.453	.264
	Lordosis (Low/High)	0.41	.455	1.578	.653	0.335	.34	17.118	.099
	LASD (Low/High)	**29.263**	**.022***	1.232	.856	3.412	.351	0.205	.324
High: Age>60y, L4 slippage>6mm, lumbar lordosis>35°, LASD>30mm	Gender(M/F)	0.094	.123	0.175	.159	0.267	.224	**0.006**	**.031***
	Age (Low/High)	0.097	.163	0	1	0.567	.637	>1000	.999
	L4 slippage (Low/High)	**0.049**	**.042***	0.627	.703	0.083	.063	10.411	.21
	Lordosis (Low/High)	0.201	.29	1.456	.714	0.323	.319	19.125	.088
	LASD (Low/High)	**172.028**	**.01***	1.75	.65	4.918	.308	0.177	.28
High: Age>60y, L4 slippage>7mm, lumbar lordosis>35°, LASD>30mm	Gender(M/F)	0.101	.111	0.182	.175	0.258	.202	0	.999
	Age (Low/High)	0.155	.152	0	1	0.393	.39	>1000	.999
	L4 slippage (Low/High)	0.224	.258	0.53	.677	0.205	.215	>1000	.999
	Lordosis (Low/High)	0.506	.549	1.654	.625	0.615	.623	7.759	.168
	LASD (Low/High)	**64.58**	**.026***	2.048	.617	3.714	.372	0.298	.414
High: Age>60y, L4 slippage>8mm, lumbar lordosis>35°, LASD>30mm	Gender(M/F)	0.167	.151	0.305	.326	0.295	.253	0.065	.079
	Age (Low/High)	0.162	.138	0	1	0.318	.275	>1000	.999
	L4 slippage (Low/High)	0.524	.562	0	.999	0.392	.415	0	.999
	Lordosis (Low/High)	0.57	.615	1.336	.789	0.628	.638	7.542	.156
	LASD (Low/High)	**27.932**	**.031***	>1000	.999	2.196	.534	0.514	.679

JOABPEQ, the Japanese Orthopaedic Association back pain evaluation questionnaire; DF, decompression and fusion; D, decompression; N, number; Exp(B), risk ratio; LASD, lumbar axis sacral distance; D/DF, risk ratio of DF to D; M/F, risk ratio of F to M; Low/High, risk ratio of "High" to "Low."

* Statistically significant; Significant p values and risk ratios are indicated in bold font.

In terms of issues associated with performing D for LSS with degenerative spondylolisthesis, the most concerning risk is restenosis with postoperative progression of spondylolisthesis. However, Matsunaga et al. reported no clear relationship between segmental instability and clinical symptoms [23]. Recent reports on the treatment outcomes of endoscopic or microscopic decompression, with conservation of the intervertebral facet joints and posterior support of tissue as much as possible for patients with degenerative spondylolisthesis, have noted that little exacerbation of spondylolisthesis occurs [3–6]. Matsudaira et al. reported that the technique for decompressing the spinal canal with preservation of the posterior elements of its roof can be useful for the treatment of patients with Meyerding grade I degenerative spondylolisthesis [7]. However, because these studies were retrospective in nature, the investigators indicated that a multicenter, prospective study was required.

Ghogawala et al. [2] reported that among patients with degenerative grade I spondylolisthesis, the addition of lumbar spinal fusion to laminectomy was associated with slightly greater but clinically meaningful improvement in overall physical health–related quality of life than laminectomy alone. On the other hand, Austevoll et al. [8,9] reported that microdecompression alone preserving the midline structure (supraspinous-interspinous ligament complex) was noninferior to decompression with instrumented fusion over a period of 2 years. Our comparison of clinical outcomes using a patient-reported outcome measures at 2 years postoperatively indicated no significant difference between the two operative groups, and the selection of operative method did not affect the 2-year surgical outcome in Meyerding grade I degenerative spondylolisthesis (Tables 4, 5, 6). Minimally invasive decompression surgery with as much posterior supportive tissue (midline structure and facet joint) preserved as possible may yield clinical results comparable to those of fusion surgery, but longer-term prospective studies are needed in the future.

In radiological evaluation, L4 slippage was significantly reduced in DF group than in D group and there was a significant positive correlation between L4 slip and LASD preoperatively, but only in group D postoperatively (Table 3). Although DF group may have an advantage over D group in terms of sagittal alignment improvement, D group also maintained postoperative LASD comparable to DF group (Table 3). In this study, we found that patients with preoperative L4 slippage of 8 mm or more tended to undergo fusion surgery, and the extent to which D can be applied to cases with large L4 slippage needs to be examined in the future.

In the results of multiple logistic regression analysis, gender, preoperative L4 slippage, LASD, and lumbar lordosis were extracted as significant preoperative factors affecting the 2-year postoperative outcome (Tables 5, 7). Patients with preoperative L4 slippage of 5 to 6 mm or less, lumbar lordosis of 35 degrees or more, and LASD of 30 mm or less show good improvement in LBP and functional disability related to LBP after surgery, regardless of the operative method, and good improvement could be expected with minimally invasive decompression surgery (Table 7). Ogura et al. [24] reported that sagittal imbalance more consistently affected clinical outcomes, particularly LBP and this is probably because decompression usually partly improves preoperative spinopelvic sagittal malalignment in LSS treated with decompression surgery alone. In this study, LASD also improved postoperatively in the decompression group, which may be related to improvement in LBP. Furthermore, in the decompression group, L4 slippage and LASD correlated before and after surgery, and future studies are needed to determine the extent to which L4 slippage and LASD can be managed by D.

On the other hand, patients with large slippage (>8–9 mm) tend to undergo fusion surgery (Table 2), but even with fusion surgery, the improvement rate of functional disability due to LBP is low in patients with L4 slippage >6 mm (Table 8). In a previous report, it was reported that in patients with preoperative LASD of 35 mm or more, postoperative functional improvement was better in the group with reduced slippage compared with the group without reduced slippage [16]. In the present study, postoperative L4 slippage was significantly reduced by the fusion surgery, which may have improved functional disability due to LBP even

in patients with preoperative LASD of 30 mm or more. Therefore, reduction of postoperative slippage as much as possible in fusion surgery may lead to improvement of functional disability due to LBP.

For the reason gender affected the postoperative result (Tables 7 and 8), it was suggested that significantly greater preoperative L4 slippage in females (Table 3) and significantly higher preoperative LBP VAS in females (Table 3) could have affected postoperative results. In the comparison by gender, preoperative L4 slippage was significantly larger in females, and there was no significant difference in postoperative L4 slippage, but lumbar lordosis and LASD were significantly larger in females. With regard to LASD, despite the fact that there is no significant difference between males and females (Table 3) and between two surgical groups at preoperative (Table 3), it is significantly larger in females at postoperative (Table 3), and there is a possibility that factors specific to females are involved. Females generally have weaker trunk muscle strength than males [25], and it has been reported in the past that trunk muscle strength affects lumbar alignment and LBP-related QOL [26,27]. Furthermore, there have been reports of females being risk factors in lumbar spine surgery [28,29], and gender was also considered to be a key factor in the surgery of degenerative spondylolisthesis from this study.

Limitations of this study included a small sample size, the short follow-up period of only 2 years, the multicenter investigation design, and the possibility of subject selection bias. Going forward, a larger-scale RCT must be conducted.

Conclusions

In multiple logistic regression analysis, preoperative L4 slippage and LASD were extracted as significant preoperative factors affecting the 2-year postoperative outcome.

Patients with preoperative L4 slippage of 6 mm or less, lumbar lordosis of 35 degrees or more, and LASD of 30 mm or less show good improvement in LBP and functional disability related to LBP after surgery, regardless of the operative method, and good improvement could be expected with minimally invasive decompression surgery.

Postoperative L4 slippage was significantly reduced by the fusion surgery, which may have improved functional disability due to LBP even in patients with preoperative LASD of 30 mm or more. Therefore, correction of local alignment of the slipped vertebrae to the extent possible in fusion surgery may lead to improvement of functional disability due to LBP.

Author Contribution

Tsukasa Kanchiku designed the study and wrote the manuscript. Tsukasa Kanchiku, Miho Sekiguchi, Naofumi Toda, Noboru Hosono, Morio Matsumoto, Nobuhiro Tanaka, Koji Akeda, Hiroshi Hashizume, Masahiro Kanayama, Sumihisa Orita, Daisaku Takeuchi, Mamoru Kawakami, Masahiko Kanamori and Eiji Wada collected and provided the data. Mitsuru Fukui statistically analyzed the data. All authors read and corrected the manuscript.

Ethical approval

This study was approved by the institutional review board (IRB) of Yamaguchi University (Approval code: H23-169).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Short summary

Preoperative L4 slippage and LASD were extracted as significant preoperative factors affecting the two-year postoperative outcome. Fusion surgery may be advantageous in improving lumbar dysfunction due to low back pain in patients with preoperative LASD of 30 mm or more.

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