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Relationship between facet joint opening on CT and facet joint effusion on MRI in patients with lumbar spinal stenosis: analysis of a less invasive decompression procedure

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OBJECTIVE Both facet joint opening (FJO) on CT and facet joint effusion (FJE) on MRI are reportedly indicators of segmental instability in the lumbar facet joints of patients with lumbar spinal stenosis (LSS). However, no study has investigated both parameters simultaneously. Therefore, the association between these findings and which parameter is better for predicting clinical outcomes after surgical treatment remains unclear. The purpose of this study was to investigate the relationship between FJO and FJE in patients who underwent less invasive decompression procedures for LSS and to investigate the impact of these findings on clinical outcomes.

METHODS This study included 1465 lumbar levels (L1–2 to L5–S1) in 293 patients who underwent less invasive surgery for LSS and had ≥ 5 years of follow-up. FJO was defined as joint space widening ≥ 2 mm on preoperative axial CT images. FJE was defined as fluid effusion in the facet joint on preoperative axial T2-weighted MR images. The characteristics and distributions of FJO and FJE were investigated with other preoperative radiological findings. The association between need for further surgery and FJO/FJE was analyzed according to intervertebral level.

RESULTS FJO was observed at 402 levels (27%), and FJE was found at 306 levels (21%). The correspondence rate between FJO and FJE was 70% (kappa 0.195, $p < 0.01$). One hundred thirty-seven levels (9%) had both FJO and FJE. Levels with both FJO and FJE more commonly had lateral olisthesis, lateral wedging, and axial intervertebral rotation than other levels ($p < 0.001$). Levels with both FJO and FJE were more likely than other levels to need further surgery (OR 2.42, $p = 0.027$).

CONCLUSIONS The correspondence rate between FJO and FJE was not high. However, multivariate analysis showed that levels with both FJO and FJE had a higher risk of requiring further surgery than those with other radiological findings, such as lateral olisthesis, lateral wedging, and axial intervertebral rotation. Patients with levels with both FJO and FJE need careful long-term follow-up after undergoing a less invasive decompression procedure.

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KEYWORDS facet joint opening; facet fluid effusion; lumbar spinal stenosis; reoperation; decompression surgery

Lumbar spinal stenosis (LSS) is the most frequent indication for spine surgery in patients older than 65 years.[1] The gold-standard surgical treatment for LSS is decompression surgery. Disruption of the posterior lumbar supporting structures may cause problematic instability after decompression, especially in patients with spondylolisthesis or scoliosis.[2] Therefore, additional fusion procedures are considered for patients with LSS and segmental instability. However, clear criteria for additional fusion have not been established. Segmental instability is generally assessed by using lateral standing dynamic flexion-extension radiography.[3,4] Several studies have focused

ABBREVIATIONS FJE = facet joint effusion; FJO = facet joint opening; LSS = lumbar spinal stenosis.

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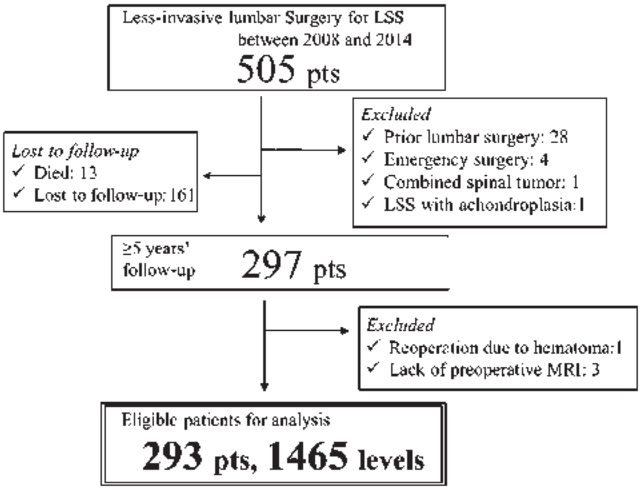

FIG. 1. Flow diagram of the study. This study included 293 of 505 patients screened for inclusion.

on the radiological findings of the facet joints to evaluate segmental instability, specifically facet joint opening (FJO) on CT and facet joint effusion (FJE) on MRI.

FJO on CT has been shown to indicate segmental instability in biomechanical studies.[5,6] Hasegawa et al.[6] used an original device to measure the neutral zone with intraoperative biomechanical examination and found that FJO was the strongest radiological predictor of instability. They used the same device to confirm these results in a comparative study of patients with and without spondylolisthesis.[7] However, there are no reports on the association between FJO and clinical outcomes.

FJE on MRI was first described by Chaput et al.[8] and Rihn et al.[9] in 2007. FJE on MRI was positively correlated with spondylolisthesis[8] and degree of radiographic sagittal instability in patients with degenerative lumbar disease.[9] However, later studies have not reached a consensus regarding whether presence of FJE affects surgical choice or clinical outcomes. Lattig et al.[10] reported that surgical treatment (decompression alone or with additional fusion) does not depend on FJE, whereas Tamai et al.[11] reported that FJE was not associated with clinical outcomes at 2-year follow-up after less invasive microscopic decompression procedures.

Despite the results of basic studies, the clinical importance of FJO on CT and FJE on MRI has not been clarified, especially their effects on surgical treatment. Moreover, no study has simultaneously investigated both parameters in patients with LSS.

We have performed less invasive decompression procedures (microscopic or microendoscopic surgery) for LSS since the 1990s. We have determined the criteria for additional fusion procedures in patients with LSS according to findings on dynamic radiographs, without reference to FJO on CT or FJE on MRI. The aims of this study were 1) to investigate the relationship between FJO and FJE in patients who underwent less invasive decompression procedures for LSS and 2) to investigate the impact of these findings on clinical outcomes, especially need for revision surgery.

TABLE 1. Patient demographic and clinical characteristics

Characteristic	Value
No. of patients/levels	293/1465
Age, yrs	71 (63–76)
Sex	
Male	155
Female	138
Surgical technique	
Microscopy	111
Microendoscopy	182
Decompression level at index surgery (n = 424 levels)	
L1–2	4 (1.3)
L2–3	34 (11.6)
L3–4	121 (41.3)
L4–5	239 (81.6)
L5–S1	26 (8.9)
Follow-up period, yrs	5.9 (5.0–6.9)
Further lumbar surgery	
Patients	28
Levels	38
Revision level	
L1–2	0 (0.0)
L2–3	5 (1.7)
L3–4	9 (3.1)
L4–5	18 (6.1)
L5–S1	6 (2.0)

Values are shown as number, number (percent), or median (interquartile range).

Methods

Patients

This study was approved by the Institutional Review Board of Osaka City University. We recruited 505 consecutive patients aged ≥ 40 years who underwent less invasive decompression procedures for LSS from 2008 to 2014 at a single institution. We included patients who underwent preoperative plain CT or CT myelography and had follow-up for ≥ 5 years at our institution. We excluded patients with a history of spinal surgery, acute vertebral fracture, spinal tumor, spinal infection, and emergency surgery, as well as those who had not undergone preoperative MRI.

The flow diagram of the study is shown in Fig. 1. A total of 293 patients with a median follow-up period of 5.9 years were eligible for analysis. Table 1 shows patient demographic and clinical characteristics. Microscopic surgery was performed on 111 patients; 8 of these patients were intraoperatively converted from microendoscopic surgery. The remaining 182 patients underwent microendoscopic surgery. Revision surgery was defined as further lumbar surgery performed for progression of lumbar degeneration or postoperative instability, whether at the index decompression level or another lumbar level. Patients who required revision surgery because of insufficient decompression, postoperative hematoma, or infection were excluded.

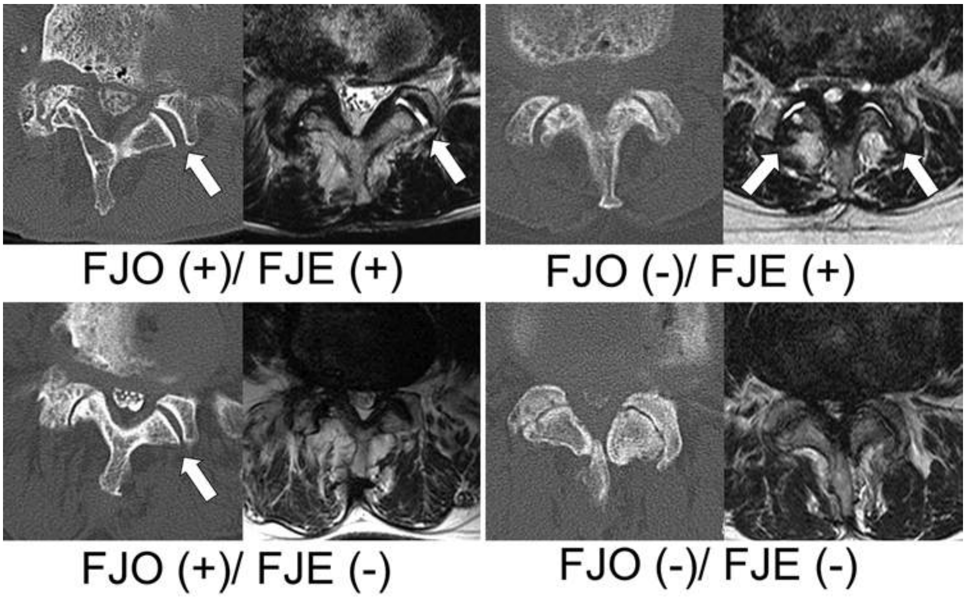

FIG. 2. Categorization of FJO and FJE. Four groups were defined according to the presence of FJO and FJE. White arrows indicate positive findings.

Surgical Indications and Procedures

The surgical indications for LSS were symptoms of neurogenic intermittent claudication, intolerable leg pain or numbness despite conservative treatment, severe muscle weakness, and bladder/bowel dysfunction. The criteria for additional fusion procedures were spondylolisthesis with > 3 mm of translation on dynamic flexion-extension radiography and/or a posterior opening disc angle > 5° on flexion radiography, lateral olisthesis > 3 mm on standing radiography, or a difference in lateral segmental wedging > 3° between standing and prone radiography. Patients desiring less invasive decompression surgery and patients with comorbidities such as old age or poor general condition underwent decompression alone at the attending surgeon's discretion, even if the criteria for additional fusion were met.

Both microscopic and microendoscopic surgical procedures included bilateral decompression via a unilateral approach, which was described in a previous report.[12] If preservation of the facet joint on the approach side was difficult because of facet angle sagittalization, the approach side was explored with spinous process splitting. One- or 2-level decompression was principally performed with a microendoscope. A microscope was used for multiple-level decompression and patients with facet angle sagittalization.

Evaluation of FJO on CT and FJE on MRI

FJO was evaluated on the middle images from L1–2 to L5–S1 in the axial plane on preoperative CT, as described in a previous report.[6] FJO was defined as either unilateral or bilateral facet joint widening > 2.0 mm.

FJE was assessed on preoperative axial T2-weighted MRI. The acquired images differed among individuals because MRI was performed at the referring hospitals. Therefore, FJE was defined as the presence of either unilateral or bilateral high-intensity signal within the facet joint that closely matched that of the cerebrospinal fluid on the middle images of the facet joint from L1–2 to L5–S1. This definition differs from that of Chaput et al.,[8] who measured effusion size under unified MRI acquisition conditions.

Each vertebral level in each patient was categorized into four groups according to the presence of FJO and/or FJE (Fig. 2). The evaluations were performed by two authors (K.Y. and H. Toyoda) who have ≥ 10 years of experience in spinal surgery and who were blinded to the patients' clinical information. Each parameter was measured with software assistance (Centricity K-Web, GE Healthcare). To determine intraobserver and interobserver variability of FJO and FJE, 20 randomly selected patients (100 lumbar levels) were assessed twice at 3-month intervals by an author (K.Y.) and an additional observer (H. Toyoda), both of whom were blinded to patient identity. Intraobserver agreement was achieved in 88 patients (88%) for FJO and in 94 patients (94%) for FJE. The kappa value was 0.666 ($p < 0.001$) for FJO and 0.813 ($p < 0.001$) for FJE. Interobserver agreement was achieved in 86 patients (86%) for FJO and in 93 patients (93%) for FJE. The kappa value was 0.580 ($p < 0.001$) for FJO and 0.777 ($p < 0.001$) for FJE.

Other Investigated Radiological Parameters

Plain radiographs were assessed for ≥ 3-mm spondylolisthesis, ≥ 3-mm lateral olisthesis was measured according to previously recommended methods,[13] and ≥ 3° lateral wedging at any lumbar level (L1–2 to L5–S1) was measured on standing lateral radiographs. Axial intervertebral rotation ≥ 3° was evaluated on preoperative CT images, in accordance with previously reported methods.[14] Pfirrmann grade (I–V)[15] and Modic change (types 1–3)[16] from L1–2 to L5–S1 were evaluated on MRI according to the original methods.

TABLE 2. Differences between levels with and without FJO/FJE

Characteristic	FJO			FJE		
	Yes (n = 402)	No (n = 1063)	p Value	Yes (n = 306)	No (n = 1159)	p Value
Demographic & clinical						
Age, yrs	71 (63–75)	71 (63–76)	0.475	72 (63–76)	70 (63–76)	0.335
Male sex	238 (59)	537 (51)	**0.003**	137 (44)	553 (47)	0.359
BMI, kg/m^2	24.1 (21.9–26.2)	24.0 (21.9–26.1)	0.343	23.9 (21.8–25.6)	24.0 (21.9–26.2)	0.189
Level						
L1–2	38 (9)	255 (24)	**<0.001**	11 (4)	282 (24)	**<0.001**
L2–3	76 (19)	217 (20)		56 (18)	237 (20)	
L3–4	113 (28)	180 (17)		92 (30)	201 (17)	
L4–5	111 (28)	182 (17)		104 (33)	189 (16)	
L5–S1	64 (16)	229 (22)		43 (14)	250 (21)	
Decompression level at index surgery	153 (38)	271 (25)	**<0.001**	159 (52)	265 (23)	**<0.001**
Revision level	19 (5)	19 (2)	**0.002**	16 (10)	22 (2)	**<0.001**
Radiological findings						
Spondylolisthesis ≥3 mm	35 (9)	128 (12)	0.07	63 (21)	100 (9)	**<0.001**
Lateral olisthesis ≥3 mm	46 (11)	47 (4)	**<0.001**	39 (13)	54 (5)	**<0.001**
Lateral wedging ≥3°	104 (26)	244 (23)	0.242	96 (31)	252 (22)	**<0.001**
Axial intervertebral rotation ≥3°	77 (19)	133 (13)	**0.001**	65 (21)	145 (13)	**<0.001**
MRI findings						
Pfirrmann grade			**<0.001**			**<0.001**
II	3 (1)	15 (1)		1 (0)	17 (1)	
III	57 (14)	261 (25)		36 (12)	282 (24)	
IV	295 (73)	723 (68)		244 (80)	774 (67)	
V	47 (12)	64 (6)		25 (8)	86 (7)	
Modic change, type			**<0.001**			**0.0014**
None	329 (82)	937 (88)		250 (82)	1016 (88)	
1	12 (3)	18 (2)		8 (3)	22 (2)	
2	20 (5)	60 (6)		18 (6)	62 (5)	
3	41 (10)	48 (5)		30 (10)	59 (5)	

Values are shown as number (percent) or median (interquartile range) unless indicated otherwise. Boldface type indicates statistical significance ($p < 0.05$).

Statistical Analysis

First, the characteristics of FJO and FJE were investigated. Differences in categorical variables and continuous variables were examined with the chi-square test and the Mann-Whitney U-test, respectively. The combinations of FJE and FJO that were most likely to affect need for further surgical procedures were examined, and their characteristics were investigated. Multiple logistic regression analysis was performed on variables with $p < 0.1$ in univariate analysis to identify risk factors for revision surgery and to calculate the odds ratios with 95% confidence intervals. In this study, $p < 0.05$ was considered statistically significant. All statistical analyses were performed with IBM SPSS Statistics version 19.0 (IBM Corp.).

Results

Prevalence and Characteristics of FJO and FJE

The prevalence and characteristics of FJO and FJE are shown in Table 2. FJO was observed at a total of 402 levels (27%) in 181 patients (62%). Levels with FJO more frequently had lateral olisthesis (11% vs 4%, $p < 0.001$) and axial intervertebral rotation (19% vs 13%, $p = 0.001$) than levels without FJO.

FJE was observed at a total of 306 levels (21%) in 171 patients (58%). Levels with FJE more commonly had spondylolisthesis (21% vs 9%, $p < 0.001$), lateral olisthesis (13% vs 5%, $p < 0.001$), lateral wedging (31% vs 22%, $p < 0.001$), and axial intervertebral rotation (21% vs 13%, $p < 0.001$) than levels without FJE.

FJO and FJE were more commonly observed at L3–4 and L4–5 ($p < 0.001$) and at the decompression level ($p < 0.001$) at index surgery than levels without FJO or FJE. Pfirrmann grades and Modic changes differed significantly between levels with and without FJO and FJE, but the differences were very small.

Combination of FJO and FJE

The distribution of levels with FJO and/or FJE is shown in Table 3. The correspondence rate between FJO and FJE

TABLE 3. Levels with FJO on CT and/or FJE on MRI

Characteristic	FJO	
	Yes	No
FJE		
Yes	137 (9)	169 (12)
No	265 (18)	894 (61)

Values are shown as number (percent).

was 70% (kappa 0.195, p < 0.01). The revision rates of the four groups were significantly different when categorized according to the presence of FJO and/or FJE (p < 0.001). The revision rate was 8% (11/137 levels) in the group with FJO and FJE, 3% (8/265 levels) in the group with FJO but without FJE, 3% (5/169 levels) in the group without FJO but with FJE, and 2% (14/894 levels) in the group without FJO and FJE.

Further analysis was performed to compare levels with both FJO and FJE with levels with other findings. Table 4 shows the differences between levels with FJO and FJE and levels with other findings. Levels with both FJO and FJE more frequently had lateral olisthesis (18% vs 5%, p < 0.001), lateral wedging (36% vs 22%, p = 0.001), and axial intervertebral rotation (26% vs 13%, p < 0.001) than other levels.

Factors Related to Revision Surgery

Lumbar revision surgery was performed at 38 levels in 28 patients (9.6% revision rate) during the follow-up period. Revision was performed at the same level as the index decompression at 18 levels; revision was performed at a different lumbar level at 20 levels.

Factors related to revision surgery are shown in Table 5. After adjustment for potential confounders, revision surgery was associated with presence of both FJO and FJE (OR 2.42, 95% CI 1.10–5.28) and L4–5 level (OR 5.93, 95% CI 2.13–16.49). Radiological findings on plain radiography (lateral olisthesis, lateral wedging, and axial intervertebral rotation) shifted toward unity and were no longer statistically significant in multivariate analysis.

Representative Case

A 64-year-old man with bilateral leg pain/numbness and intermittent claudication underwent microendoscopic posterior decompression at L4–5. Preoperative CT myelography and MRI showed both FJO and FJE at L4–5 (Fig. 3A), even though preoperative dynamic flexion-extension radiographs showed no findings of instability. The patient's leg symptoms and claudication resolved after surgery. However, severe low-back pain occurred 1 year postoperatively. Dynamic flexion-extension radiographs showed hypermobility at L4–5 between flexion and extension, as well as posterior opening at L4–5 during flexion. MRI showed a left-sided facet cyst at L4–5 (Fig. 3B). After conservative treatment failed, the patient underwent revision surgery at L4–5 with oblique lateral interbody fusion and posterior fixation at 1.5 years after the index surgery (Fig. 3C).

TABLE 4. Characteristics of levels with both FJO and FJE

Characteristic	FJO & FJE (n = 137)	Other Findings (n = 1328)	p Value
Demographic & clinical			
Age, yrs	72 (63–75)	70 (63–76)	0.812
Male sex	84 (61)	691 (52)	**0.038**
BMI, kg/m^2	24.1 (22.2–26.2)	24.0 (21.9–26.1)	0.45
Level			
L1–2	4 (3)	289 (22)	**<0.001**
L2–3	20 (15)	273 (21)	
L3–4	46 (34)	247 (19)	
L4–5	52 (38)	241 (18)	
L5–S1	15 (11)	278 (21)	
Decompression at index surgery	69 (50)	355 (27)	**<0.001**
Revision level	11 (8)	27 (2)	**<0.001**
Radiological findings			
Spondylolisthesis ≥3 mm	17 (12)	146 (11)	0.616
Lateral olisthesis ≥3 mm	25 (18)	68 (5)	**<0.001**
Lateral wedging ≥3°	49 (36)	299 (22)	**0.001**
Axial intervertebral rotation ≥3°	36 (26)	174 (13)	**<0.001**
MRI findings			
Pfirrmann grade			**<0.001**
II	1 (1)	17 (1)	
III	10 (7)	308 (23)	
IV	110 (80)	908 (68)	
V	16 (11)	95 (7)	
Modic change, type			**0.004**
None	109 (80)	1157 (87)	
1	3 (2)	27 (2)	
2	7 (5)	73 (5)	
3	18 (13)	71 (5)	

Values are shown as number (percent) or median (interquartile range) unless indicated otherwise. Boldface type indicates statistical significance (p < 0.05).

Discussion

In this analysis of long-term follow-up of 1465 lumbar levels in 293 patients who underwent less invasive decompression procedures for LSS, preoperative FJO was observed at 402 levels (27%) on CT and FJE was observed at 306 levels (21%) on MRI. Although the rate of correspondence between FJO and FJE was not high (70%), levels with both FJO and FJE were often scoliotic with signs such as lateral olisthesis, lateral wedging, or intervertebral rotation. These levels had a higher risk of requiring further lumbar surgery than other levels (OR 2.42). To the best of our knowledge, this is the first study to examine FJO and FJE simultaneously and to evaluate their relationships with clinical outcomes after decompression surgery for LSS.

TABLE 5. Factors related to further lumbar surgery

Characteristic	Reoperation (n = 38)	No Reoperation (n = 1427)	Univariate Analysis		Multivariate Analysis	
			Crude OR (95% CI)	p Value	Adjusted OR (95% CI)	p Value
Demographic & clinical						
Age, yrs	70.5 (63.8–76.3)	71 (63–76)	1.007 (0.973–1.043)	0.678		
Male sex	14 (37)	676 (47)	0.648 (0.333–1.263)	0.203		
BMI, kg/m2	25.7 (24.1–28.4)	26.1 (24–29.3)	0.955 (0.873–1.043)	0.32		
Level						
L1–2 or L2–3	5 (13)	581 (41)	Ref		Ref	
L3–4	9 (24)	284 (20)	3.682 (1.223–11.089)	**0.02**	2.815 (0.917–8.643)	0.071
L4–5	18 (47)	275 (19)	7.606 (2.795–20.698)	**<0.001**	5.93 (2.133–16.491)	**0.001**
L5–S1	6 (16)	287 (20)	2.429 (0.735–8.027)	0.146	2.757 (0.823–9.243)	0.1
Radiological findings						
Spondylolisthesis ≥3 mm	3 (8)	160 (11)	0.679 (0.206–2.232)	0.523		
Lateral olisthesis ≥3 mm	7 (18)	86 (6)	3.521 (1.507–8.227)	**0.004**	1.729 (0.630–4.747)	0.288
Lateral wedging ≥3°	14 (37)	334 (23)	1.909 (0.976–3.732)	0.059	1.365 (0.662–2.815)	0.399
Axial intervertebral rotation ≥3°	12 (32)	198 (14)	2.865 (1.422–5.771)	**0.003**	1.733 (0.764–3.930)	0.188
MRI findings						
Pfirrmann grade						
II or III	7 (18)	86 (6)	Ref			
IV	27 (71)	991 (69)	1.281 (0.552–2.968)	0.564		
V	4 (11)	107 (7)	1.757 (0.505–6.118)	0.376		
Modic change, type						
None	31 (82)	1235 (87)	Ref			
1	1 (3)	29 (2)	1.374 (0.181–10.409)	0.759		
2 or 3	6 (16)	163 (11)	1.466 (0.603–3.568)	0.399		
Findings on combination CT & MRI						
FJO & FJE	11 (29)	126 (9)	4.207 (2.038–8.681)	**<0.001**	2.415 (1.104–5.281)	**0.027**

Values are shown as number (percent) or median (interquartile range) unless indicated otherwise. Boldface type indicates statistical significance ($p < 0.05$).

There is no consensus about the threshold at which LSS can be treated with decompression surgery alone. Although some radiological factors have been reported that indicate poor prognosis after decompression procedures,[3,4,17] several randomized clinical trials have failed to confirm the effectiveness of fusion surgery in patients with spondylolisthesis.[18,19] Furthermore, less invasive decompression procedures that preserve posterior elements can improve clinical outcomes, even in patients with spondylolisthesis or scoliosis.[12,20] Therefore, it is urgent to establish the threshold for the use of decompression procedures alone for the surgical treatment of LSS. This study addressed this problem by evaluating radiological facet joint findings in patients without segmental instability on dynamic radiographs who underwent less invasive decompression procedures for LSS.

Fujiwara et al.[21] reported a biomechanical and imaging study of motion in cadaveric spinal segments. Axial rotational motion increased with cartilage degeneration of the facet joints followed by capsular ligament laxity, thereby allowing abnormal motion or hypermobility of the facet joint. However, segmental motion decreased in the end stages of degeneration of the disc or facet joint. These study results support the theory of three phases of degeneration proposed by Kirkaldy-Willis and Farfan.[22] The first phase is dysfunction of discoligamentous structures with minimal anatomical change. The second phase is relative instability. Decreased disc height, loosening of facet capsules and ligaments, and articular changes are seen in this phase. Continued degeneration leads to a third stabilization phase, in which increased stiffness and restabilization occur through the formation of osteophytes and fibrosis. Therefore, patients with LSS in the second phase of degeneration should be selected for additional fusion procedures.

Both FJO on CT and FJE on MRI can be strong tools for discriminating segments with instability. However, this study revealed that the rate of correspondence between these findings was not high: 30% of levels had different findings on CT and MRI. This discrepancy may have arisen from the differences between CT and MRI because FJO on CT and FJE on MRI do not always represent segmental instability.

First, because only the facet joint space was evaluated when investigating FJO on CT, facet joints with thick, nondegenerated cartilage were sometimes classified with FJO. This explains why this study found a high prevalence of FJO of 27%, even though patients with apparent segmental instability on dynamic radiography had been excluded by our additional fusion criteria. Thus, FJO may indicate

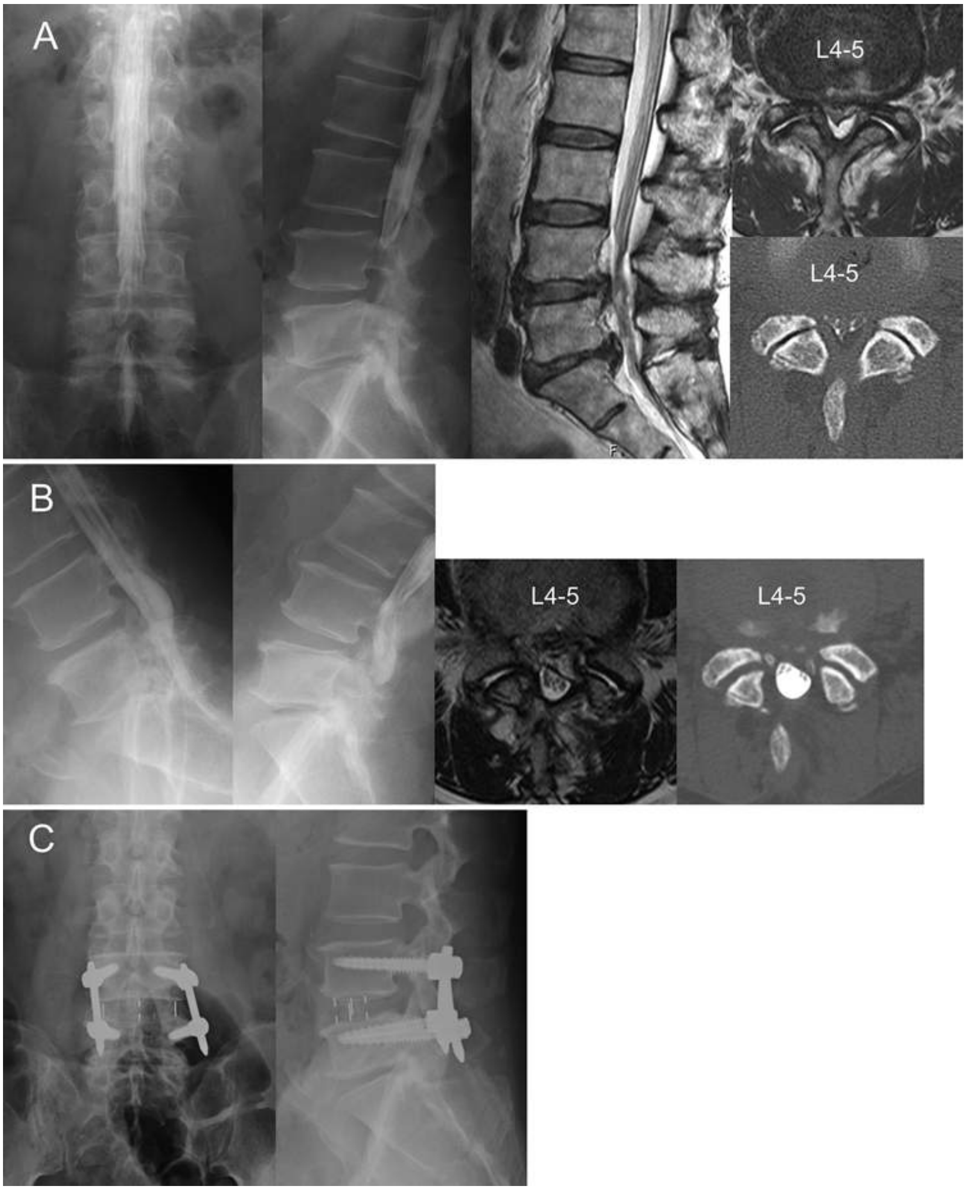

FIG. 3. Representative case of a 64-year-old man who underwent microendoscopic posterior decompression at L4–5. **A:** Preoperative plain radiographs (*left*) show no segmental instability, but both FJO on CT and FJE on MRI were present at L4–5 (*right*). **B:** Postoperative flexion-extension radiographs (*left*) show 12° of sagittal rotation at L4–5 and posterior opening at L4–5 on flexion, and the postoperative MR image shows a left-sided facet cyst and FJE at L4–5 and the CT image shows FJO at L4–5 (*right*). **C:** Radiographs showing that revision oblique lateral interbody fusion surgery was performed at L4–5 at 1.5 years after the index surgery.

either segmental instability or a nondegenerated facet. Second, FJE detected on MRI may be caused by multiple factors other than segmental instability. Facet joint osteoarthritis may result in effusion. Gellhorn et al.[23] suggested that facet fluid effusion is a characteristic feature of osteoarthritis because the facet joints are synovial joints and similar to knee and hip joints. Furthermore, inflammation of the facet joint, such as that seen in a pseudogout attack, also results in FJE on MRI.[24]

The most interesting finding of this study was that levels with both FJO and FJE were at risk for poor outcomes, after adjustment for other radiological parameters. This combination of findings on CT and MRI can eliminate causes other than segmental instability. Thus, the combination of both FJO and FJE suggests segmental instability. However, this issue requires further study. We do not recommend additional fusion procedures for all segments with both FJO and FJE because only 8% of these levels required further lumbar surgery within a mean follow-up period of 5.9 years. We suggest that surgeons should carefully consider the surgical strategy and perform close postoperative follow-up of patients with levels with both FJO and FJE. Additional fusion procedures should be adopted for segments with additional radiological or clinical evidence of segmental instability other than presence of both FJO and FJE. Meanwhile, the revision rates at the levels that did not have both FJO and FJE were significantly lower (range 2%–3%). This indicates that levels without both FJO and FJE could be treated with decompression procedures, regardless of other radiological findings such as spondylolisthesis or scoliosis.

This study had some limitations because it was a retrospective cohort study. The analyzed sample was not small, but it included a small number of patients who underwent revision. Moreover, this study lacked an evaluation of clinical outcomes other than further lumbar surgery because our analysis was performed according to intervertebral level, not according to patient. However, because revision surgery is the greatest problem among the surgical complications that may develop after less invasive decompression procedures for LSS, our study results are useful for spine surgeons. Lastly, this study did not include other detailed parameters that indicate segmental instability, such as intraoperative biomechanical measurement with the tool developed by Hasegawa et al.[5] or dynamic examination. We did not evaluate parameters determined with dynamic radiography because patients with segmental instability on dynamic radiography underwent fusion surgery. Therefore, the patients included in this study showed small translation or angular differences on dynamic radiography that may have been within the measurement error. Future studies should include dynamic radiographic findings with measurement of FJO/FJE to clarify the impact of FJO and FJE on dynamic radiological findings. Recent studies have reported the usefulness of weight-bearing or axial-loading MRI for patients with LSS.[25,26] Future studies should include these new evaluations in conjunction with FJO on CT and FJE on MRI to clarify the criteria for additional fusion procedures. However, the results of this study may be useful for determining the surgical strategy for patients with LSS who are unsure whether to choose only decompression or decompression with concurrent fusion surgery.

Conclusions

The correspondence rate between FJO and FJE in patients who underwent less invasive decompression procedures for LSS was not high. However, levels with both FJO and FJE were likely to have lateral olisthesis, lateral wedging, or axial intervertebral rotation. Presence of FJO and FJE was associated with a higher risk of further lumbar surgery than other radiological parameters on plain radiography. Therefore, attending surgeons must pay special attention during the follow-up of patients with levels with both FJO and FJE.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Yamada. Acquisition of data: all authors. Analysis and interpretation of data: Yamada, Toyoda. Drafting the article: Yamada. Critically revising the article: Toyoda. Reviewed submitted version of manuscript: Toyoda. Statistical analysis: Yamada, Takahashi. Administrative/technical/material support: Toyoda. Study supervision: Nakamura.

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