

Clinical Study

Preoperative severity of facet joint degeneration does not impact the 2-year clinical outcomes and cervical imbalance following laminoplasty

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Received 21 February 2018; revised 9 June 2018; accepted 13 June 2018

Abstract

BACKGROUND CONTEXT: The impact of preoperative facet degeneration (FD) on surgical outcomes following laminoplasty has not been established.

PURPOSE: To elucidate the influence of preoperative FD on pre and postoperative clinical symptoms and radiographic parameters.

STUDY DESIGN: Retrospective analysis of prospectively collected data.

PATIENT SAMPLE: A total of 135 consecutive patients who underwent laminoplasty for cervical spondylotic myelopathy with greater than 2 years follow-up.

OUTCOME MEASURES: The cervical Japanese Orthopedic Association score, visual analog scale, Short Form-36, Japanese Orthopedic Association Cervical Myelopathy Evaluation Questionnaire, and radiographic parameters (C7 slope, C2–C7 sagittal vertical axis, C2–C7 lordotic angle, and scoring of FD).

METHODS: FD severity of the bilateral facets of C2–3 to C7–T1 was graded using preoperative computer tomography images. Patients were divided into two quantiles according to the mean score of their FD grading: mild (n=69) and severe FD groups (n=66). The preoperative clinical score and radiographic parameters of the two groups were compared. Variables with $p < .05$ were included in the multinomial logistic regression model. The changes in clinical scores and radiographic parameters between both groups (from the preoperative to 2-year postoperative period) were compared using a mixed-effect model, after adjusting for age and sex.

RESULTS: Mean age and neck pain visual analog scale were independently associated with FD severity (age: $p = .004$, neck pain: $p = .004$). However, the other preoperative clinical scores and radiographic parameters were not significantly different. In terms of the change in clinical scores 2 years postlaminoplasty, no significant differences between the severe and mild FD groups were noted. While the mild FD group had a reduced C2–C7 lordotic angle, the severe FD group demonstrated an increased C2–C7 lordotic angle 2 years postlaminoplasty ($p = .044$). The change in C7 slope and C2–C7 sagittal vertical axis showed no significant differences.

CONCLUSIONS: Preoperative FD severity did not influence the 2-year surgical outcomes of laminoplasty, in terms of improvement in myelopathy, patient-oriented score of quality of life, physical and mental status, as well as neck pain. Furthermore, preoperative FD severity correlated with neither preoperative cervical imbalance nor balance deterioration after laminoplasty. These

FDA device/drug status: Not applicable

Author disclosures: **KT:** Nothing to disclose. **AS:** Nothing to disclose. **AY:** Nothing to disclose. **ST:** Nothing to disclose. **HT:** Nothing to disclose. **MH:** Nothing to disclose. **HT:** Nothing to disclose. **HN:** Nothing to disclose.

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results may encourage physicians to consider laminoplasty for patients with cervical spondylotic myelopathy, regardless of the severity of FD. © 2018 Elsevier Inc. All rights reserved.

Keywords: Cervical balance; Facet degeneration; Laminoplasty; Neck pain; Outcome; Quality of life.

Introduction

Laminoplasty, first described in 1981, has been widely used as a posterior decompression method for the treatment of patients with cervical spondylotic myelopathy (CSM), disc herniation, ossification of the posterior longitudinal ligament, and adjacent segment degeneration after anterior cervical decompression and fusion, with good clinical outcomes [1–5]. The current trend in the treatment of single and multilevel CSM in the United States indicated that laminoplasty is the third most common procedure, next to anterior cervical decompression and fusion and laminectomy and fusion [6].

While the cervical facet joints have key roles in guiding cervical motion and distributing the axial load, they are affected by degenerative changes that are characterized by space narrowing, erosion of the subchondral bone, and hypertrophy with osteophytes [7,8]. Facet degeneration (FD) is evidenced to have significant relationship with degenerative cervical spondylolisthesis [9] and chronic neck pain [10]. In our clinical setting, surgeons often encounter patients with severe FD during laminoplasty, especially elderly patients. Risk factors for poor outcome after laminoplasty include advancing age, cervical global or segmental kyphosis, and the presence of ossification of the posterior longitudinal ligament [11–13]. However, the impact of FD on clinical outcomes postlaminoplasty is not well established.

In addition, cervical sagittal imbalance is being recognized as one of the key factors in patients' low health-related quality of life or poor surgical outcomes [14]. Furthermore, cervical imbalance is demonstrated as a predictor of kyphotic deformity after laminoplasty [15]. As the cervical facet is one of the essential structures in the load distribution and spine stability [7,16], demonstrating the changes in the cervical balance of patients with severe FD postlaminoplasty, as well as determining the relationship between FD severity and cervical balance can aid physicians in deciding on the most appropriate treatment for patients with CSM.

The aim of the current study was to evaluate preoperative FD severity and elucidate its influence on pre and postoperative clinical symptoms and radiographic parameters. These results can help surgeons formulate more effective surgical strategies associated with high patient satisfaction and cost effectiveness.

Methods

This study was a retrospective analysis of prospectively collected data of patients who underwent laminoplasty for

CSM. All study participants provided informed consent, and the study protocol was approved by the Institutional Review Board of our institution (No. 3170). No funds were received in support of this work.

Patient population

We reviewed 141 patients who underwent C3–C6 laminoplasty for CSM at our institution between 2011 and 2013 and were followed up for more than 2 years postoperatively. Patients were excluded if they had past cervical surgery (n=4) and if they were less than 30 years old (n=2). A total of 135 patients were included in final analysis (81 women, 54 men; mean age at surgery 66.3±11.5 years).

Surgical procedure

In the period during which data were collected for this study, all patients with myelopathy due to multilevel cervical stenosis were treated with laminoplasty in our institution, regardless of the cervical alignment or facet degeneration. Ten patients underwent double door laminoplasty [4], while the remaining 125 patients underwent open door laminoplasty [17]. Surgical methods were decided on a case-by-case basis by the treating physicians. In all surgery, HA spacers were placed at each level to fix the opened lamina [18]. The day after surgery, all patients were allowed to sit up with a soft neck collar and, if possible, to stand and walk. Brace removal was allowed 1 week after surgery. All patients were then encouraged to start range of motion and isometric muscle strengthening exercises of the neck as early as possible.

Clinical evaluation

The Japanese Orthopaedic Association (JOA) score for cervical myelopathy, the scoring of the severity of myelopathy, was evaluated preoperatively and at 2 years postoperatively by the patient's corresponding surgeon [19]. Patient-oriented questionnaire scores were recorded preoperatively and at 2 years postoperatively. The scores included the visual analog scale (VAS) for neck pain, arm pain, and arm numbness; the 36-item Short-Form Health Survey (SF-36); and the JOA Cervical Myelopathy Evaluation Questionnaire (JOACMEQ). The SF-36 scores were summarized into the physical component summary (PCS) and mental component summary (MCS), according to a formula proposed by a previous report [20]. JOACMEQ has five functional scores for corresponding domains (cervical spine function, upper extremity function, lower extremity

function, bladder function, and QOL; a score of 0=worst, while a score of 100=best), calculated based on patients' answers to 24 questions [21].

Radiographic evaluation

Plain cervical X-ray in the neutral cervical position, with the patient sitting, were taken preoperatively and 2 years postoperatively. The parameters of cervical sagittal balance and cervical alignment were defined as follows. C2–C7 sagittal vertical axis (cSVA): the horizontal distance between the center of C2 and the posterosuperior corner of the C7 vertebral body [14]; C7 slope: the angle between a horizontal line and the C7 upper end plate [22]; C2–C7 lordotic angle: the lordotic angle between the tangent lines of the lower endplates of C2 and lower endplates of C7 vertebral body. Observers reviewed the images and measured the parameters using a computer software (Synapse; Fuji-film, Tokyo, Japan).

FD grading

FD was assessed using preoperative sagittal images of computer tomography (CT) taken for the aim of surgical planning. The images were reconstructed as sagittal slices after examining the 1.0-mm axial CT scans. The degree of FD was graded into 4 categories: grade 1, normal; grade 2, degenerative changes, including joint space narrowing, cyst formation, and small osteophytes without joint hypertrophy; grade 3, joint hypertrophy secondary to large osteophytes without fusion; and grade 4, bony fusion of the joint [8] (Fig. 1). Observers reviewed all sagittal slices and recorded the grade of six levels from C2–3 to C7–1 bilaterally. To assess the severity of each patient's FD, 12 FD scores were averaged for the current main analysis and the highest score among them was adopted as the patient's score in the validation analysis.

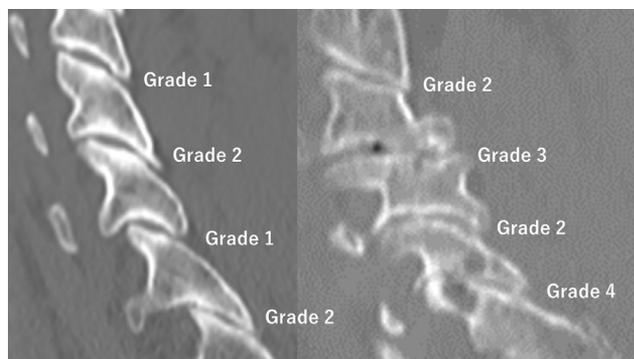


Fig. 1. Schematic drawing of the FD grading.

The degree of facet degeneration was graded into 4 categories: grade 1, normal facet without any degenerative changes; grade 2, degenerative changes including joint space narrowing, cyst formation, and small osteophytes without joint hypertrophy; grade 3, joint hypertrophy secondary to large osteophytes without fusion; grade 4, bony fusion of the joint. Grading was performed using sagittal slice of CT images.

Study design and statistical analysis

FD analysis was first performed. The numbers in each FD grades and mean score were compared at each level and between the right and left sides using the chi-squared test with residual analysis, one-way analysis of variance with post-hoc turkey test, and Mann-Whitney *U* test, as appropriate. The result of residual analysis was described as $p < .05$ when variables were $|r| > 1.96$, according to the Haberman method [23]. The relationship between the mean preoperative FD score and the maximum grade among C2–3 to C7–T1 in each patient was evaluated using Spearman's rank correlation coefficient.

Patients were then divided into two groups (mild and severe FD) according to their mean FD scores to identify the relationship between preoperative FD severity and preoperative clinical scores and radiographical parameters. The cutoff value between the two groups was decided as the average value of the mean FD score. The scores and parameters were compared between the mild and severe FD groups using the Mann-Whitney *U* test and chi-squared test. Subsequently, variables with a significance of $p < .05$ were included in the multinomial logistic regression model. In this calculation, the severe FD group was set as a dependent variable. Adjusted odds ratio and 95% confidence intervals of dependent variables were calculated.

Finally, the changes from preoperative to 2-year follow-up clinical scores and radiographic parameters between the two FD groups were analyzed using a mixed-effect model. Age and sex were included in the model as covariance to adjust for the differences between both groups. To validate the results, the change in the clinical scores and radiographical parameters were also compared between two groups based on the highest FD score rather than average score, the patients whose highest FD score was ≥ 3 and those whose highest FD score was ≤ 2 , using a mixed-effect model adjusted for age and sex. All analyses were performed using the SPSS computer software (version 23; SPSS, Chicago, Illinois). A *p* value of $< .05$ was considered statistically significant.

Results

FD analysis

In total, 510 (31.5%) grade 1, 657 (40.6%) grade 2, 332 (20.5%) grade 3, and, 121 (7.5%) grade 4 facets were examined, with a mean and standard deviation of 2.0 ± 0.9 (Table 1). The mean FD score significantly correlated with the maximum FD grade ($r = 0.765$, $p < .05$). Comparison at each level showed that the distribution of FD grade was significantly different between levels ($p = .020$). C5–6 had significantly higher number of grade 2 facets. There were significantly lower number of grade 3 facets at the C5–6 and C6–7 levels, compared to C7–T1. C7–T1 had a significantly higher occurrence of grade 3 but significantly lower occurrence of grade 2 facets ($p < .05$, respectively).

Table 1
Analysis of preoperative facet degeneration

	Grade I	Grade II	Grade III	Grade IV	p value	Mean score	p value
Total	510 (31.5)	657 (40.6)	332 (20.5)	121 (7.5)		2.0±0.9	
C2–3	90 (33.3)	102 (37.8)	55 (20.4)	23 (8.5)	.020 [§]	2.0±0.9	.015 [§]
C3–4	86 (31.9)	110 (40.7)	59 (21.9)	15 (5.6)		2.0±0.9	
C4–5	78 (28.9)	106 (39.3)	64 (23.7)	22 (8.1)		2.1±0.9	
C5–6	86 (31.9)	126 (46.7)*	39 (14.4)*	19 (7.0)		2.0±0.9	
C6–7	93 (34.4)	119 (44.1)	42 (15.6)*	16 (5.9)		1.9±0.9	
C7–T1	77 (28.5)	94 (34.8)*	73 (27.0)*	26 (9.6)		2.2±1.0	
Right side	260 (32.1)	356 (44.0)*	142 (17.5)*	52 (6.4)	.003 [‡]	2.0±0.9	.011 [†]
Left side	250 (30.9)	301 (37.2)*	190 (23.5)*	69 (8.5)		2.1±0.9	

* p<.05, by residual analysis with Huberman adjustment after chi-squared test.

† Mann-Whitney U test.

‡ Chi-square test.

§ One-way analysis of variance.

|| p<.05, by post-hoc Turkey test.

The mean score showed significant difference among groups (p=.015), and between C6–7 and C7–T1 (1.9 vs 2.2, p=.021). Comparison between the right and left sides showed that the distribution of FD grades was significantly different (p=.003). The mean score was higher in the left than the right (2.1 vs 2.0, p=.011).

The impact of FD on clinical symptoms

We defined the cutoff value of the 2 preoperative FD groups based on the mean score: severe FD group (mean score >2.0, n=69) or mild FD group (≤2.0, n=66). The

mean age (70.3 vs 62.4 years, p<.001) and preoperative VAS of neck pain (30.3 vs 14.8 mm, p=.013) were significantly higher in the severe FD group than in the mild FD group (Table 2). However, the cJOA score, VAS of arm pain and arm numbness, MCS, PCS of SF-36, and all components of JOACMEQ showed no significant differences in the univariate analysis between both FD groups. Likewise, three radiographic parameters were not significantly different. Multinomial regression analysis demonstrated that age and preoperative neck pain were independently associated with preoperative FD severity (age: p=.004, neck pain: p=.004; Table 3).

Table 2
Patients demographics of two FD groups

	Mild FD group	Severe FD group	p value
Number	69	66	
Age (years old)	62.4±13.1	70.3±7.6	>.001*
Gender (female/male)	44/25	37/29	.384 [†]
Preoperative clinical score			
cJOA score (points)	10.1±3.0	9.7±3.3	.558*
VAS (mm)			
Neck pain	14.8±21.1	30.3±29.3	.013*
Arm pain	29.0±30.9	46.0±38.8	.078*
Arm numbness	50.1±31.8	61.1±31.9	.128*
SF-36			
PCS	28.5±17.2	22.7±12.1	.070*
MCS	40.8±14.7	41.4±13.8	.849*
JOACMEQ			
Cervical spine function	67.5±27.2	62.1±31.6	.414*
Upper extremity function	69.9±30.0	63.3±26.6	.310*
Lower extremity function	52.6±35.8	43.0±29.7	.189*
Bladder function	77.9±20.5	79.0±19.6	.803*
Quality of life	42.9±19.9	38.7±20.2	.347*
Preoperative radiographical parameters			
C2–C7 SVA (mm)	28.9±17.1	27.5±14.7	.632*
C7 slope (degree)	31.6±15.3	28.3±14.7	.236*
C2–C7 lordotic angle (degree)	9.4±15.3	9.6±17.1	.948*

* Mann-Whitney U test.

† Chi-squared test. FD, Facet degeneration; JOA, Japanese Orthopaedic Association; VAS, visual analog scale; SF, Short form; PCS, physical component summary; MCS, mental component summary; CMEQ, Cervical Myelopathy Evaluation Questionnaire; SVA, sagittal vertical axis.

Table 3
Multinomial regression analysis (dependent variable: preoperative severe FD)

	aOR	p value	95% CI
Age	1.08	.004	1.02–1.13
Preoperative Neck pain	1.03	.004	1.01–1.05

aOR, adjusted odds ratio; CI, confidence interval.

The impact of FD on clinical improvement

The 2-year postoperative JOA score, VAS of neck pain, arm pain and arm numbness, PCS and MCS of SF-36, cervical spine function, upper and lower extremity function, and QOL of JOACMEQ improved significantly compared with the preoperative values, in both mild and severe FD groups ($p < .05$, respectively). However, in terms of the change from preoperative to 2-year follow-up, there were no significant differences between the severe and mild FD groups in all clinical scores, after adjusting for age and sex (Fig. 2).

The impact of FD score on the change in balance parameters

The changes in cSVA and C7 slope were not significant between the two groups ($p = .095$ and $.475$ respectively; Fig. 3). However, the C2–C7 lordotic angle showed significant differences, with a decrease in lordotic angle in the

mild FD group, compared with an increase in the severe FD group ($p = .044$).

Validation analysis using the highest FD score

In the comparison between the patients whose highest FD score was ≥ 3 ($n = 102$) and those whose highest FD score was ≤ 2 ($n = 33$), there were no significant differences in the improvement of all clinical scores (JOA score: $p = .278$, neck pain: $p = .509$, arm pain: $p = .755$, arm numbness: $p = .912$, PCS: $p = .741$, MCS: $p = .279$, cervical function: $p = .486$, upper extremity function: $p = .859$, lower extremity function: $p = .505$, and bladder function: $p = .0146$, QOL: $p = .0788$). Similarly, there were no significant differences in the change in the three types of radiological parameters (C2–7 lordotic angle: $p = .0208$, cSVA: $p = .0538$, and C7 slope: $p = .0236$).

Discussion

The current study demonstrated that the preoperative severity of FD is significantly related to the preoperative patient’s neck pain, regardless to his and/or her age. However, preoperative FD severity did not significantly impact the 2-year surgical outcomes of laminoplasty, in terms of improvement in myelopathy, patient-oriented QOL score, physical and mental status, as well as neck pain. Furthermore, severe preoperative FD did not relate to preoperative cervical imbalance and deterioration of cervical balance after laminoplasty.

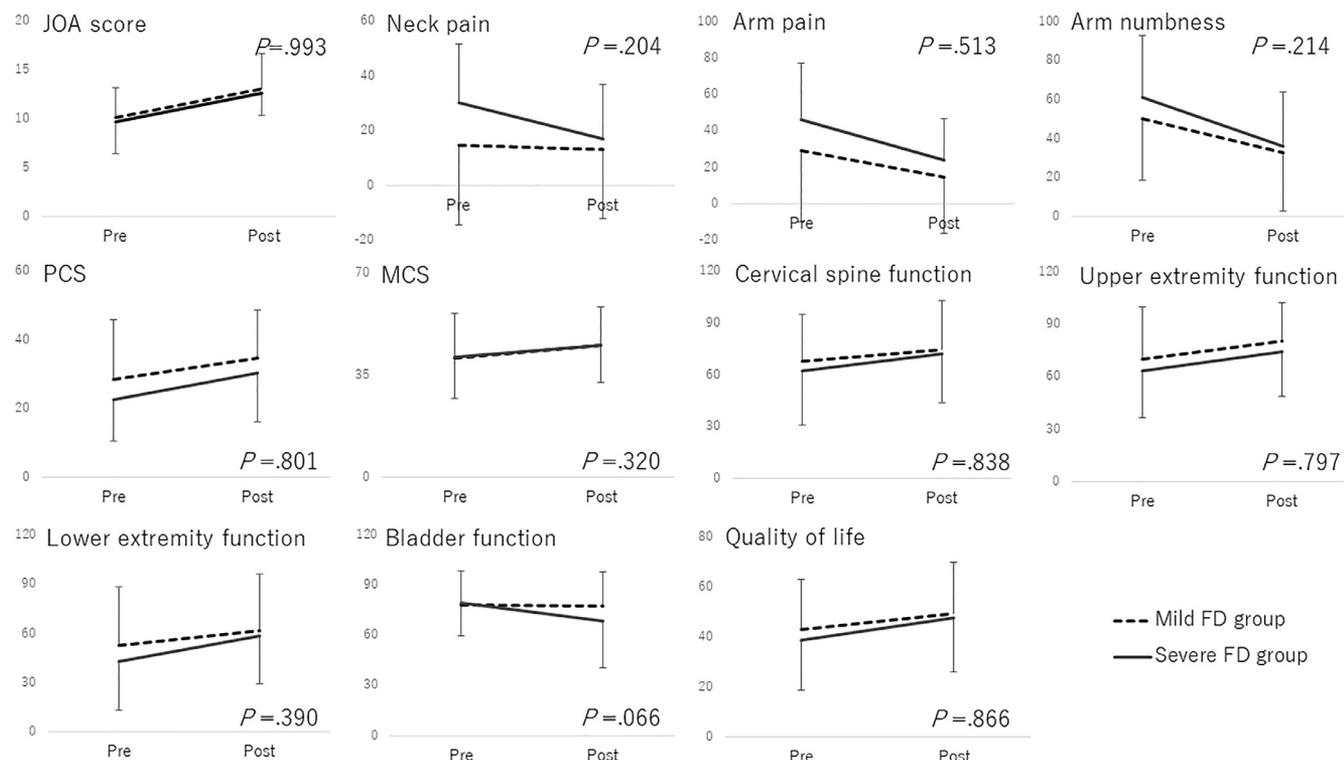


Fig. 2. The change in the clinical score. p value was calculated using a mixed-effect model, after adjusting for age and sex.

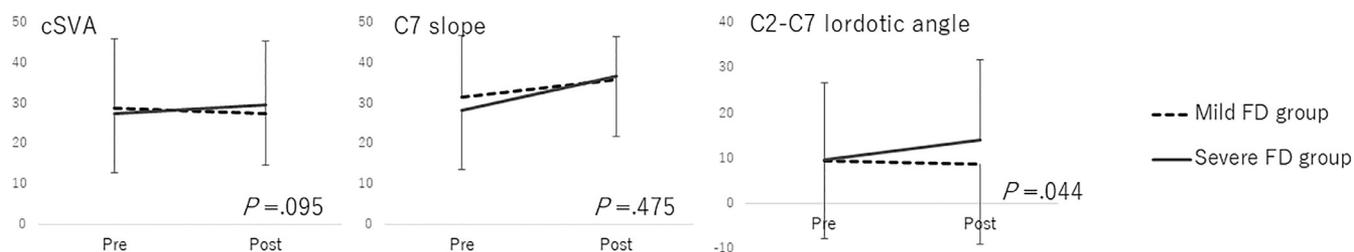


Fig. 3. The change in the balance parameters. p value was calculated using a mixed-effect model, after adjusting for age and sex.

In the current study, FD was analyzed using CT images with a 4-grade scoring system, as reported by Park et al. in 2014 [8]. Although CT is associated with radiation exposure, the images can provide us clearer information regarding the joint space, osteophyte, and bony fusion compared to plain radiography and magnetic resonance imaging. In terms of the evaluation of FD severity, the mean FD score from bilateral C2–3 to C7–T1 were used for analysis in the current study. It is a common procedure to decide the global severity of factors to compare the clinical outcome between the patients with multiple factors such as disc or facet [24]. Also, we performed an additional validation using the highest FD score instead of the mean score, and the results showed a close resemblance with the results for the analysis using the mean score.

Park et al. demonstrated that the facets of the upper cervical levels are more likely to degenerate and have more advanced degrees of degeneration than the lower cervical levels [8]. In addition, they showed that a facet arthrosis > grade 3 was significantly more common on the left side than the right. These findings were in keeping with our results; we demonstrated that the occurrence of grade 3 severity at C5–6 and C6–7 were significantly lower compared with the higher levels. Grade 3 facets were higher in the left side than the right, and mean score was also significantly higher in the right. Although the exact mechanism has yet to be determined, facet asymmetry may potentially impact the differences of FD severity between the right and left sides. The inclination of sagittal plane at C4–5 and C5–6 levels were reported to be significantly different between the right and left sides; asymmetry may result in the differences of FD severity [25].

In terms of the relationship between neck pain and FD, Manchikanti et al. concluded that the prevalence rate of facet joint pain in chronic neck pain approximately 60%, using diagnostic facet blocks with 1% lidocaine [26]. Analyzing the preoperative patient, the current study also revealed that FD severity is significantly related to neck pain, independent of a patient's age. On the other hand, there was no significant relationship between FD severity and a patient's preoperative QOL, physical function, or mental status. This could be because the degree of neurological symptoms may have a higher effect on the scoring of patients with CSM.

To the best of our knowledge, the current study is the first to evaluate the influence of FD severity on the surgical outcomes of laminoplasty. We demonstrated that preoperative

FD severity did not have a significant impact on the improvement of myelopathy, patient-oriented score of QOL, and physical and mental status 2 years postlaminoplasty. Interestingly, neck pain significantly improved regardless of the severity of preoperative FD; in addition, no significant difference in improvement was seen between the mild and severe FD groups. We postulate three possible reasons for this. First, some neck pain in patients with CSM is due to radiculopathy and myelopathy, and not FD [27]. Second, postoperative neck pain in both groups also included pain from paravertebral neck muscles and fascia due to contracture and/or atrophy following surgical invasion. The influence of pain from FD may be relatively diminished after posterior surgery because of these other factors. Third, previous reports demonstrated significant loss of cervical range of motion after laminoplasty, potentially due to spontaneous laminar and facet fusion [28]. This acceleration of facet fusion following laminoplasty may also contribute to the improvement of neck pain in both groups.

The current results showed that there was no correlation between preoperative radiographic parameters, including cervical balance parameters, and FD severity. In terms of radiographic parameters, the change in the C2–7 lordotic angle, the alternative parameter of cervical alignment, demonstrated significant difference. Patients with severe preoperative FD tend to be more lordotic after laminoplasty, while those with mild FD tend to be straight. Although the C2–C7 lordotic angle was known as slightly decrease after laminoplasty [29], it should be verified with considering the patients FD severity. The cSVA, which is considered the key indicator of cervical balance [30], did not show significant differences between the two groups, indicating that preoperative FD severity is related to neither preoperative cervical imbalance nor postoperative balance deterioration. Based on these results, we believe that laminoplasty can be considered as a treatment for patients with CSM, regardless of their preoperative FD severity.

There are several limitations in the present study. First, its retrospective nature makes it difficult to exclude bias, in terms of the referral for a certain type of surgery, or the particular surgical techniques applied. In addition, a longer observation period is required to determine the impact of FD severity on surgical outcomes and radiographic parameters. The change in FD score after laminoplasty should also be considered. Finally, our dataset includes two types of laminoplasty, open door and double door,

and this difference in technique might influence the result. Therefore, to identify the exact effect of FD on surgical outcomes after laminoplasty, a prospective study with a longer follow-up period (eg, more than 10 years) with postoperative CT images is required. Nevertheless, this study was conducted using several clinical score and radiographic parameters collected prospectively; the number of subjects were also sufficient for analysis. Therefore, in spite of these limitations, we believe that the current study findings can provide guidance in the development of an effective strategy to treat patients with CSM.

Conclusion

We demonstrated that preoperative severity of FD did not significantly impact the 2-year surgical outcomes of laminoplasty, in terms of improvement in myelopathy, patient-oriented QOL score, physical and mental status, as well as neck pain. Furthermore, preoperative FD severity does not relate to preoperative cervical imbalance or postoperative balance deterioration. These results may encourage physicians to consider laminoplasty as a treatment for CSM patients, regardless of their preoperative FD severity.

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