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Correlation between cervical spine sagittal alignment and clinical outcome after cervical laminoplasty for ossification of the posterior longitudinal ligament

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OBJECTIVE The goal of this study was to determine the relationship between cervical spine sagittal alignment and clinical outcomes after cervical laminoplasty in patients with ossification of the posterior longitudinal ligament (OPLL).

METHODS Fifty consecutive patients who underwent a cervical laminoplasty for OPLL between January 2012 and January 2013 and who were followed up for at least 1 year were analyzed in this study. Standing plain radiographs of the cervical spine, CT (midsagittal view), and MRI (T2-weighted sagittal view) were obtained (anteroposterior, lateral, flexion, and extension) pre- and postoperatively. Cervical spine alignment was assessed with the following 3 parameters: the C2–7 Cobb angle, C2–7 sagittal vertical axis (SVA), and T-1 slope minus C2–7 Cobb angle. The change in cervical sagittal alignment was defined as the difference between the post- and preoperative C2–7 Cobb angles, C2–7 SVAs, and T-1 slope minus C2–7 Cobb angles. Outcome assessments (visual analog scale [VAS], Oswestry Neck Disability Index [NDI], 36-Item Short-Form Health Survey [SF-36], and Japanese Orthopaedic Association [JOA] scores) were obtained in all patients pre- and postoperatively.

RESULTS The average patient age was 56.3 years (range 38–72 years). There were 34 male patients and 16 female patients. Cervical laminoplasty for OPLL helped alleviate radiculomyelopathy. Compared with the preoperative scores, improvement was seen in postoperative VAS and JOA scores. After laminoplasty, 35 patients had kyphotic changes, and 15 had lordotic changes. However, cervical sagittal alignment after laminoplasty was not significantly associated with clinical outcomes in terms of postoperative improvement of the JOA score (C2–7 Cobb angle: p = 0.633; C2–7 SVA: p = 0.817; T-1 slope minus C2–7 lordosis: p = 0.554), the SF-36 score (C2–7 Cobb angle: p = 0.554; C2–7 SVA: p = 0.793; T-1 slope minus C2–7 lordosis: p = 0.829), the VAS neck score (C2–7 Cobb angle: p = 0.263; C2–7 SVA: p = 0.716; T-1 slope minus C2–7 lordosis: p = 0.497), or the NDI score (C2–7 Cobb angle: p = 0.568; C2–7 SVA: p = 0.279; T-1 slope minus C2–7 lordosis: p = 0.966). Similarly, the change in cervical sagittal alignment was not related to the JOA (p = 0.604), SF-36 (p = 0.308), VAS neck (p = 0.832), or NDI (p = 0.608) scores.

CONCLUSIONS Cervical laminoplasty for OPLL improved radiculomyelopathy. Cervical laminoplasty increased the probability of cervical kyphotic alignment. However, cervical sagittal alignment and clinical outcomes were not clearly related.

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KEY WORDS cervical spine sagittal alignment; clinical outcome; cervical laminoplasty; cervical ossification of the posterior longitudinal ligament

Ossification of the posterior longitudinal ligament (OPLL) results from pathologic replacement of the PLL and can lead to spinal cord compression and neurological deterioration.[1] Nonsymptomatic patients can be treated nonsurgically, but patients with symptomatic OPLL require surgical treatment.[18] There are 2 surgical approaches to treat OPLL: anterior decompression via discectomy or corpectomy and posterior decompression via laminectomy or laminoplasty. Although an anterior approach can directly decompress the spinal cord,[8] an indirect posterior decompression technique is more often used to treat patients with OPLL.[18] The posterior approach

ABBREVIATIONS ACDF = anterior cervical discectomy and fusion; CSM = cervical spondylotic myelopathy; HRQOL = health-related quality of life; JOA = Japanese Orthopaedic Association; NDI = Neck Disability Index; OPLL = ossification of the posterior longitudinal ligament; SF-36 = 36-Item Short-Form Health Survey; SVA = sagittal vertical axis; VAS = visual analog scale.

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can lead to complications such as persistent neuropathic arm pain, axial neck pain, or postoperative deterioration of cervical alignment due to progression of kyphosis.[18] Nonetheless, previous research suggests a reduced risk of complications compared with the anterior approach, especially CSF leakage; dislocation or pseudarthrosis of the bone graft; intraoperative neural, vascular, or esophageal injuries; and adjacent-segment disease; in addition, the operation itself has lower risk.[8,17,18]

Cervical laminectomy via the posterior approach in patients with OPLL can cause neurological deterioration due to kyphotic deformity. Although progressive cervical kyphosis after cervical laminectomy has been associated with myelopathy, postlaminectomy kyphotic deformity is not clearly related to the postoperative clinical outcome.[11] Moreover, patients with cervical kyphosis, as well as patients whose postoperative cervical alignment changes from lordotic to straight, often have poor surgical outcomes after laminoplasty.[7] Due to these concerns, a variety of laminoplasty techniques have been developed to decrease postoperative kyphotic deformity. However, some authors have reported kyphotic deformity even after laminoplasty. Patients who undergo laminoplasty tend to have a change in kyphotic alignment and increased axial neck pain, which can lead to poor surgical outcomes.

To our knowledge, no previous study has evaluated whether cervical sagittal alignment after laminoplasty for OPLL is related to health-related quality of life (HRQOL). The object of this study was to assess several different radiological parameters to determine whether cervical sagittal alignment after laminoplasty was related to clinical outcomes.

Methods

Patients and Operations

This retrospective study occurred at Yonsei University Medical Center. A total of 286 patients who underwent cervical laminoplasty for OPLL between January 2005 and January 2013 were reviewed. Of these patients, we used data from those who underwent laminoplasty between January 2012 and January 2013. Our institution's ethics committee approved the study. Patients with OPLL were excluded if their OPLL was associated with cervical spondylotic myelopathy from cervical stenosis or cervical deformity resulting from spinal injury, tumor, infection, congenital disorders, or inflammatory arthritis (including ankylosing spondylitis and rheumatoid arthritis). After all patients were reviewed, 82 were eligible for inclusion in the study. However, 32 patients could not be followed up due to their refusal to fill in the questionnaires or visit outpatient clinics. The remaining 50 patients had open-door laminoplasty and were followed up for more than 12 months.

Radiological and Clinical Assessments

Standing plain radiographs (anteroposterior, lateral, flexion, and extension), CT, and MRI of the cervical spine were obtained pre- and postoperatively (Table 1). Cervical spine alignment parameters included the C2–7 Cobb angle (Cobb angle from C-2 to C-7), C2–7 sagittal vertical axis (SVA), and T-1 slope minus C2–7 Cobb angle.

The C2–7 Cobb angle indicates the angle between 2 crossed perpendicular lines that are extended parallel to the inferior endplate of C-2 and C-7 on the standing lateral radiograph of the cervical spine.[21] Cervical spine alignment was measured through the cervical SVA, which was defined by using the distance between a plumb line dropped from the center of C-2 (or dens) and the posterosuperior aspect of C-7 (C2–7 SVA). The T-1 slope was measured as the angle between a horizontal plane and a line parallel to the superior T-1 endplate (Fig. 1 left). T2-weighted MR images were used to evaluate high signal intensity of the spinal cord. The occupying ratio of the spinal canal was measured on cervical CT in the sagittal view (Fig. 1 right).[19] We calculated the occupying ratio as a measure of spinal canal stenosis. An occupying ratio > 50% was defined as severe stenosis. Involvement of C-7 was checked during the operation.

Kyphosis was defined as an alignment of the C2–7 Cobb angle that was < 0°; straight was defined as an alignment between 0° and 10°, and lordosis was defined as an alignment that was > 10° (Fig. 2). We used an OPLL subtype classification by the Japanese Investigation Committee on the Ossification of the Spinal Ligaments that includes localized, segmental, continuous, and mixed types.[10]

Cervical sagittal alignment was defined as the T-1 slope minus the C2–7 Cobb angle (T-1 slope minus cervical lordosis), which is the cervical analog to the pelvic incidence minus lumbar lordosis (PI – LL) mismatch. Postoperative radiological parameters were used in a linear regression analysis to demonstrate that a C2–7 SVA of 30 mm corresponded to a T-1 slope minus C2–7 Cobb angle threshold of 22° (Fig. 3A). If patients had a T-1 slope minus C2–7 Cobb angle ≥ 22°, they were classified as having cervical sagittal malalignment. If they had a T-1 slope minus C2–7 Cobb angle < 22°, they were classified as having normal alignment.

Following a laminoplasty, we examined a kyphotic posture by using several measurements of cervical sagittal alignment, as well as clinical assessments, by calculating differences between pre- and postoperative outcomes. The measurement of changes in cervical sagittal alignment included C2–7 Cobb angle, C2–7 SVA, and T-1 slope minus C2–7 Cobb angle. The C2–7 SVA differences and T-1 slope minus C2–7 Cobb angle differences were calculated based on the C2–7 Cobb angle differences. These data were compared with the clinical outcomes that include visual analog scale (VAS), Oswestry Neck Disability Index (NDI), 36-Item Short-Form Health Survey (SF-36), and Japanese Orthopaedic Association (JOA) scores. By comparing results between pre- and postoperative cervical sagittal alignment, 0° for C2–7 Cobb angle differences, 0 mm for C2–7 SVA differences, and 5° for T-1 slope minus C2–7 Cobb angle differences were used to determine cervical kyphotic change (Fig. 3B and C). We classified the level of kyphotic changes into 3 subsets by evaluating the changes in C2–7 Cobb angle in patients with a laminoplasty: > 5°, 0°–5°, and < 0° (lordotic). The clinical outcome (VAS, NDI, SF-36, and JOA scores) was assessed in all patients pre- and postoperatively.

Statistical Analysis

All statistical analyses were performed with the Statis-

TABLE 1. Patient demographic data, radiological parameters, and clinical outcomes

Variable	Kyphosis	Straight	Lordosis	Total	p Value*
No. of patients	7	18	25	50	
Age, yrs	53.7 ± 10.0	54.3 ± 7.5	58.4 ± 9.1	56.3 ± 8.8	0.225
Sex (M/F)	5:2	11:7	18:7	34:16	
OPLL type, no. of patients (%)					
Segmental	4 (57)	6 (33)	1 (4)		
Continuous	0 (0)	5 (28)	7 (28)		
Mixed	3 (43)	7 (39)	17 (68)		
C2–7 Cobb angle, °	−5.4 ± 4.0	6.2 ± 2.6	16.9 ± 5.7	9.9 ± 9.2	0.001
C2–7 SVA, mm	24.0 ± 11.3	23.7 ± 15.4	16.8 ± 8.7	20.3 ± 12.1	0.125
T-1 slope, °	18.0 ± 6.9	25.8 ± 8.2	28.2 ± 7.3	25.9 ± 8.2	0.011
Occupying ratio, %	0.32 ± 0.07	0.45 ± 0.12	0.48 ± 0.11	0.45 ± 0.12	0.003
T2-weighted MR image cord signal change, no. of patients (%)	3 (43)	9 (50)	13 (52)		
C-7 involvement, no. of patients (%)	3 (43)	10 (56)	10 (40)		
VAS score, neck	4.0 ± 3.3	3.5 ± 3.0	3.0 ± 2.7	3.3 ± 2.8	0.682
VAS score, arm	3.9 ± 3.5	4.4 ± 3.1	3.3 ± 3.2	3.8 ± 3.2	0.556
JOA score	18.3 ± 1.5	18.5 ± 1.3	18.0 ± 1.5	18.2 ± 1.4	0.461

* One-way ANOVA.

tical Package for the Social Sciences version 18.0.0 (SPSS) with paired Student t-tests, paired t-tests, chi-square tests, linear regression analyses, and ANOVAs. The alpha level was set a priori at 0.05.

Results

All 50 patients were analyzed retrospectively. The study population consisted of 34 men and 16 women with an average age of 56.3 years (range 38–72 years). The mean clinical and radiological follow-up was 18.4 months (range 12–28 months). Sagittal alignment parameters included the C2–7 Cobb angle, C2–7 SVA, and T-1 slope minus C2–7 Cobb angle. The C2–7 Cobb angle was used to define the kyphosis (Cobb angle < 0°), straight (0°–10°), and lordosis (> 10°) groups. The C2–7 SVA was divided by 30 mm, and the T-1 slope minus C2–7 Cobb angle was divided by 22°.

Cervical laminoplasty for OPLL improved radiculomyelopathy, with postoperative clinical outcomes (VAS, NDI, SF-36, and JOA scores) better than preoperative values (Table 2). For the preoperative cervical curvature, 18 (72%) of the 25 patients had lordosis, and 7 (28%) had a straight curve. Thirty-nine patients (78%) maintained their original curvature or experienced improved curvature (e.g., from straight to lordosis or from kyphosis to lordosis). Four patients in the straight group changed to kyphosis, whereas 7 patients in the lordotic group changed to straight (Table 3). None of the cervical sagittal alignment parameters after laminoplasty were correlated with outcomes in terms of the JOA score (C2–7 Cobb angle: p = 0.633; C2–7 SVA: p = 0.817; T-1 slope – C2–7 lordosis: p = 0.554), the SF-36 score (C2–7 Cobb angle: p = 0.554; C2–7 SVA, p = 0.793; T-1 slope – C2–7 lordosis: p = 0.829), the VAS neck score (C2–7 Cobb angle: p = 0.263; C2–7 SVA: p = 0.716; T-1 slope – C2–7 lordosis: p = 0.497), or the NDI score (C2–7 Cobb angle: p = 0.568; C2–7 SVA: p = 0.279; T-1 slope – C2–7 lordosis: p = 0.966) (Table 4). In addition, the change in cervical alignment was unrelated to the clinical outcome.

We assessed the postoperative change in cervical alignment, which was defined as the difference between the post- and preoperative C2–7 Cobb angles, C2–7 SVAs, and T-1 slope minus C2–7 Cobb angles. On the basis of the alignment change, we divided the patients into a kyphotic change group (< 0°) and a lordotic change group (> 0°), according to the C2–7 Cobb angles. Postoperatively, there were 35 patients in the kyphotic change group and 15 patients in the lordotic change group. Thus, although 70% of patients had kyphotic alignment change after laminoplasty, the change in cervical sagittal alignment was unrelated to the outcomes in terms of improvement in the JOA score (p = 0.604), SF-36 score (p = 0.308), VAS neck

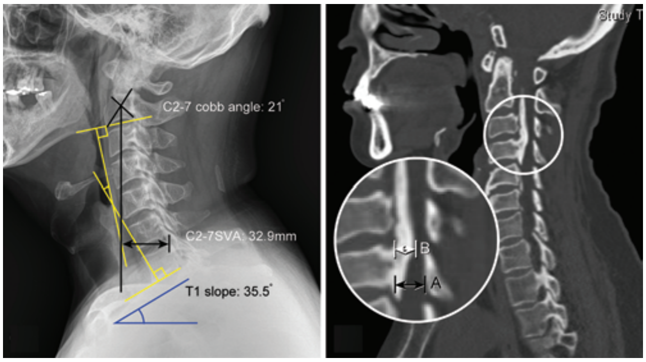


FIG. 1. Left: Cervical spine lateral radiograph demonstrating the C2–7 Cobb angle *(yellow)*, C2–7 SVA *(black arrow)*, and the angle of the T-1 slope. **Right:** Measurement of the occupying ratio on the CT sagittal view. The occupying ratio of the spinal canal = B *(white arrow)*/A *(black arrow)* × 100. A = anteroposterior diameter of the spinal canal; B = maximum anteroposterior thickness of the ossified ligament. Figure is available in color online only.

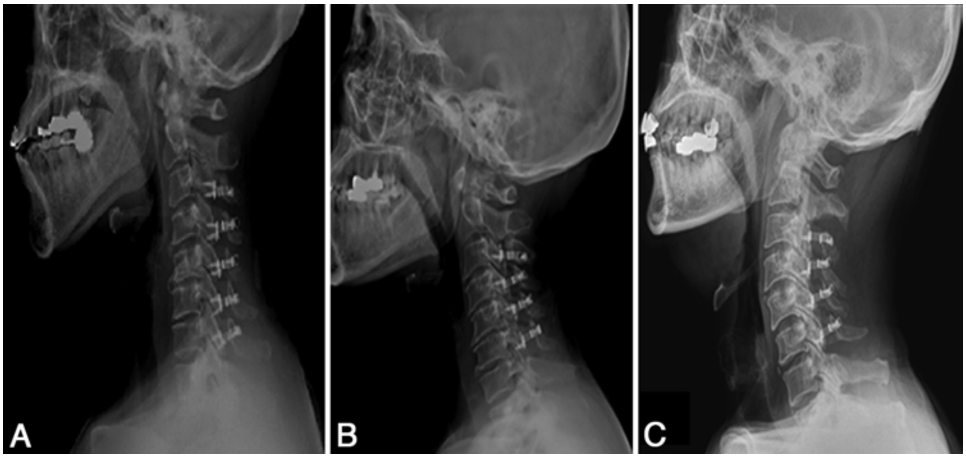
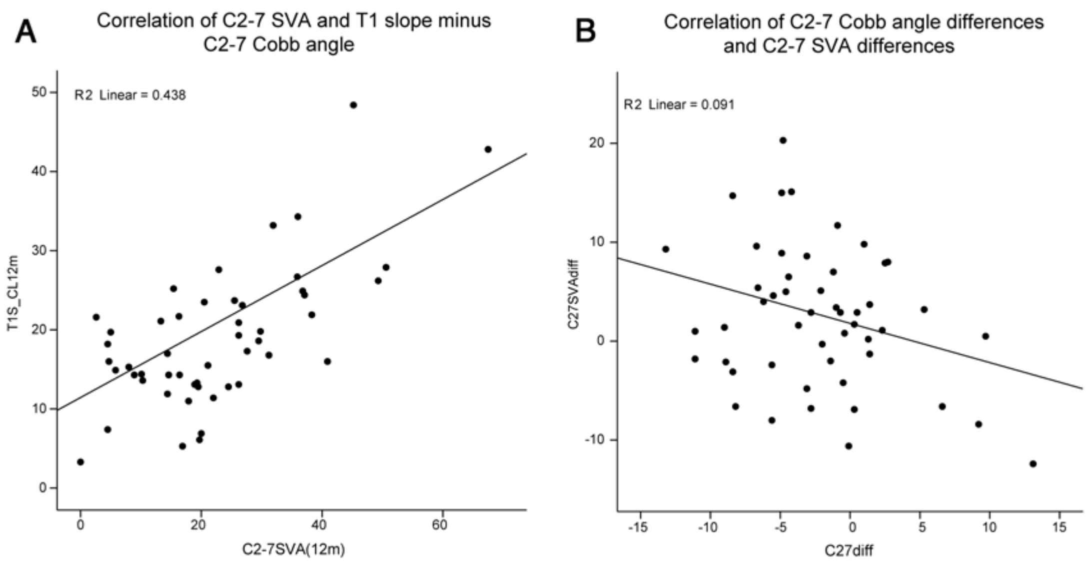


FIG. 2. Comparison of the Cobb angle on the cervical spine lateral radiograph. **A:** C2–7 Cobb angle < 0° (kyphosis group). **B:** C2–7 Cobb angle 0°–10° (straight group). **C:** C2–7 Cobb angle > 10° (lordosis group).



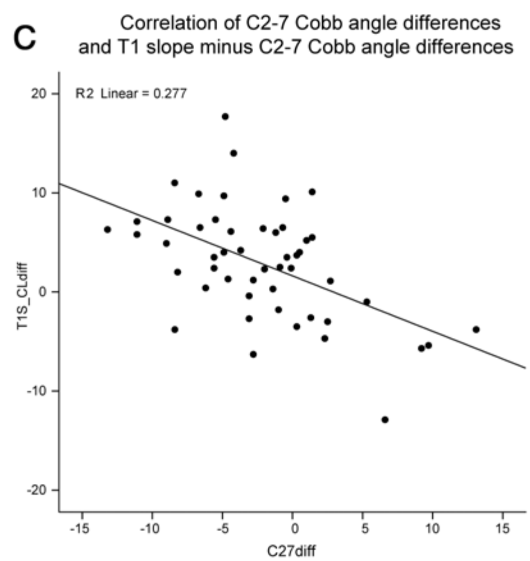


FIG. 3. Parameter correlations in linear regression analysis. **A:** Linear regression analysis showing that a C2–7 SVA value of 30 mm corresponded to a T-1 slope minus C2–7 Cobb angle value of 22°. **B:** C2–7 Cobb angle difference value of 0° corresponded to C2–7 SVA difference value of 0 mm. **C:** C2–7 Cobb angle difference value of 0° corresponded to T-1 slope minus C2–7 Cobb angle difference value of 5°.

TABLE 2. Comparison of the pre- and postoperative clinical outcome according to the cervical laminoplasty for OPLL

HRQOL Instrument	Preop Score (SD)	Postop Score (SD)	p Value*
VAS, neck	3.3 (2.8)	1.7 (1.7)	<0.01
VAS, arm	3.8 (3.2)	1.3 (1.8)	<0.01
NDI	12.5 (7.8)	7.7 (5.6)	0.002
SF-36	104.0 (8.6)	111.7 (5.3)	<0.01
JOA	18.2 (1.4)	19.2 (1.2)	<0.01

* Paired t-test.

TABLE 3. Postoperative changes in cervical curvature compared with preoperative cervical curvature according to the cervical laminoplasty for OPLL*

Postoperative Cervical Curvature	Preoperative Cervical Curvature			
	Lordosis	Straight	Kyphosis	Total
Lordosis	18	1	0	19
Straight	7	13	2	22
Kyphosis	0	4	5	9
Total	25	18	7	50

* Values reported are number of patients.

score ($p = 0.832$), and NDI score ($p = 0.608$). Likewise, the changes in cervical sagittal alignment were unrelated to the outcomes according to the C2–7 SVA differences and T-1 slope minus C2–7 Cobb angle differences (Table 5). In comparing the degree of kyphotic change after laminoplasty, 14 patients had > 5° kyphotic changes, 21 patients had 0°–5° kyphotic changes, and 15 patients had lordotic changes. The mean kyphotic changes were 2.2° ± 5.4° ($p < 0.001$). Clinical outcomes (VAS [neck] and NDI) were not significantly associated with the degree of kyphotic change (Table 6).

We also compared the cervical sagittal alignment groups in terms of preoperative radiological parameters such as signal intensity on T2-weighted MR image, C-7 involvement during the operation, and an OPLL occupying ratio > 50%. Our results revealed no significant difference between groups, as assessed with the Cobb angle, in the presence of signal change ($p = 0.519$), C-7 involvement ($p = 0.875$), and the OPLL occupying ratio change ($p = 0.231$) (Table 7). When we compared these parameters with clinical outcomes, however, C-7 involvement during the operation was associated with a significantly lower JOA score ($p = 0.038$) (Fig. 4). In contrast, high-intensity cord signal change on the T2-weighted MR image ($p = 0.904$ on JOA score) and OPLL occupying ratio severity ($p = 0.77$ on JOA score) were unrelated to clinical outcomes.

Discussion

In the current study, cervical sagittal alignment after laminoplasty for OPLL was unrelated to clinical outcomes. Many reports have demonstrated that improper sagittal alignment is a major source of pain, disability, and poor health.[2,3,14] Proper global sagittal spinal alignment and balance are critical in maintaining an energy efficient, pain-free, and upright posture.[4] Cervical kyphosis or malalignment after anterior cervical discectomy and fusion (ACDF) has been associated with construct failure, decreased fusion rate, development of adjacent-segment disease, and poor clinical outcomes.[3,12,20,25]

In contrast, some authors have reported that cervical kyphosis is not related to neurological outcomes or postoperative pain. Iwasaki et al. observed deterioration of cervical alignment due to kyphosis, but there was no significant difference in surgery-related outcomes between patients with lordotic, straight, or kyphotic alignment.[7] Gum et al. stated that all HRQOL measures showed significant improvement from baseline to follow-up at 2 years after ACDF, with no relationship between improvement in patient-reported outcomes and cervical sagittal alignment.[5] Jagannathan et al. also found no significant relationship between the change in segmental kyphosis and postoperative functional status.[9] Villavicencio et al. conducted a prospective, double-blind, randomized study evaluating the relationship between lordotic alignment and clinical outcomes using normal and lordotically shaped allografts for ACDF.[24] They found that improved cervical Cobb angle alignment was not significantly correlated with clinical outcomes, but that maintaining or improving segmental sagittal alignment was associated with a greater improvement in outcome scores.

Several reports have suggested that an S-shaped deformity, such as a swan neck or reverse swan neck, as well as lordosis, straight, and kyphosis alignments, can influence the outcome of laminoplasty.[13] Shibuya et al. reported that patients with reverse swan-neck deformity of the cervical spine had lower preoperative JOA scores and recovery rates than those with other sagittal alignments of the cervical spine.[13,22] Kyphosis of the cervical spine did not influence clinical outcomes, including axial pain, JOA score, and recovery rates after expansive laminoplasty for patients with cervical spondylotic myelopathy (CSM).[13]

Given the results of previous studies, it is perhaps surprising that we found no relationship between cervical sagittal alignment after laminoplasty for OPLL and clinical outcomes. We considered axial pain from intraoperative injury or cervical sagittal imbalance after operation. Hosono et al. reported that the prevalence of preoperative axial neck pain in patients with CSM was 27%.[6] They noted that postoperative neck pain occurred in approximately 60% of patients who had undergone laminoplasty. Laminoplasty is a posterior method, and posterior structures, including the lamina, nuchal ligament, and posterior neck muscle, which help to prevent kyphotic alignment changes, are greatly damaged and atrophied after laminoplasty.[16] Posterior damage to the muscles, such as the semispinalis cervicis, trapezius, and rhomboid muscles, or contracture of the cervical spine, are possible causes of postoperative neck pain. Most experienced surgeons recommend preservation of the paraspinal muscles at C-2 or C-7 during cervical spine surgery because these muscles prevent postoperative instability and neck pain.[15]

In our study, it would be in the same context that C-7 involvement during the operation was associated with poor clinical outcomes. In addition, loss of lordosis or kyphotic alignment of the cervical spine and spinal cord may

TABLE 4. Relationship between clinical outcomes and cervical sagittal alignment after laminoplasty according to sagittal alignment parameters

Variable	C2–7 Cobb Angle After Laminoplasty				C2–7 SVA After Laminoplasty			T-1 Slope − C2–7 Lordosis After Laminoplasty		
	<0°	0–10°	>10°	p Value*	<30 mm	≥30 mm	p Value†	<22°	≥22°	p Value†
No. of patients	9	22	19		38	12		36	14	
VAS score, neck	1.6 ± 1.7	2.1 ± 1.6	1.2 ± 1.8	0.263	1.7 ± 1.6	1.5 ± 2.0	0.716	1.6 ± 1.6	1.9 ± 2.1	0.497
VAS score, arm	1.2 ± 1.6	1.6 ± 2.0	1.0 ± 1.6	0.572	1.2 ± 1.7	1.5 ± 2.2	0.659	1.3 ± 1.7	1.3 ± 2.1	0.972
NDI score	5.7 ± 4.8	7.4 ± 5.2	8.1 ± 6.2	0.568	7.8 ± 5.3	5.8 ± 6.0	0.279	7.4 ± 5.2	7.3 ± 6.3	0.966
SF-36 score	109.7 ± 4.9	112.1 ± 5.7	111.2 ± 5.5	0.554	111.2 ± 5.7	111.7 ± 4.9	0.793	111.2 ± 5.9	111.6 ± 4.5	0.829
JOA score	18.9 ± 1.5	19.3 ± 1.5	19.4 ± 0.8	0.633	19.3 ± 1.3	19.2 ± 1.2	0.817	19.3 ± 1.3	19.1 ± 1.1	0.554

* One-way ANOVA.
† Independent t-test.

TABLE 5. Relationship between clinical outcomes and cervical sagittal alignment change after laminoplasty*

Variable	C2–7 Cobb Angle Diff			C2–7 SVA Diff			T-1 Slope − C2–7 Lordosis Diff		
	<0°	≥0°	p Value†	≤0 mm	>0 mm	p Value†	≤5°	>5°	p Value†
No. of patients	35	15		17	33		31	19	
VAS diff, neck	−1.7 ± 2.6	−1.5 ± 3.2	0.832	−1.2 ± 2.4	−1.9 ± 2.9	0.435	−1.7 ± 2.7	−1.6 ± 2.9	0.871
VAS diff, arm	−2.2 ± 3.1	−3.1 ± 3.0	0.379	−3.0 ± 3.0	−2.2 ± 3.1	0.393	−2.5 ± 3.4	−2.5 ± 2.5	0.991
NDI diff	−4.4 ± 8.9	−6.0 ± 6.8	0.608	−6.4 ± 7.9	−4.1 ± 8.5	0.468	−5.9 ± 8.9	−3.2 ± 7.1	0.352
SF-36 diff	6.9 ± 7.5	9.8 ± 7.5	0.308	7.3 ± 9.7	8.0 ± 6.5	0.808	8.9 ± 8.1	5.8 ± 6.3	0.255
JOA diff	1.1 ± 1.6	0.9 ± 1.2	0.604	1.2 ± 1.8	1.0 ± 1.4	0.654	1.2 ± 1.7	0.7 ± 1.1	0.275

* C2–7 Cobb angle diff = post-C2–7 Cobb angle − pre-C2–7 Cobb angle; C2–7 SVA diff = post-C2–7 SVA − pre-C2–7 SVA; diff = difference; JOA diff = post-JOA − pre-JOA; NDI diff = post-NDI − pre-NDI; SF-36 diff = post-SF-36 − pre-SF-36; T-1 slope − C2–7 lordosis diff = (post-T-1 slope − C2–7 lordosis) − (pre-T-1 slope − C2–7 lordosis); VAS diff = post-VAS − pre-VAS.
† Independent t-test.

TABLE 6. Relationship between clinical outcomes and kyphotic change after laminoplasty

Variable	Degree of Kyphotic Change After Laminoplasty			Total	p Value*
	>5	0–5	<0 (lordotic)		
No. of patients	14	21	15	50	
Mean kyphotic change, °	8.2 ± 2.4	2.6 ± 1.7	−3.8 ± 4.0	2.2 ± 5.4	<0.001
VAS (neck) diff	−2.4 ± 2.8	−1.2 ± 2.3	−1.5 ± 3.2		0.449
NDI diff	−7.4 ± 9.0	−2.5 ± 8.6	−6.0 ± 6.8		0.331

* One-way ANOVA.

TABLE 7. Relationship between preoperative radiological parameters and cervical sagittal alignment after laminoplasty

Variable	Kyphosis, Cobb Angle < 0°	Straight, Cobb Angle 0°–10°	Lordosis, Cobb Angle > 10°	p Value*
No. of patients	9	22	19	
Patients (%) w/ T2-weighted MR image signal change	4 (44.4)	13 (59.1)	8 (42.1)	0.519
Patients (%) w/ C-7 involvement	4 (44.4)	11 (50.0)	8 (42.1)	0.875
Patients (%) w/ OPLL occupying ratio > 50%	1 (11.1)	6 (27.3)	8 (42.1)	0.231

* Chi-square test.

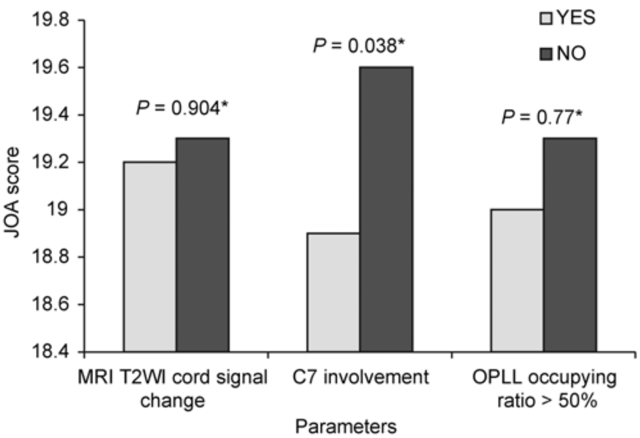


FIG. 4. Comparison of the JOA score according to 3 preoperative radiological parameters. Asterisk = independent t-test.

contribute to the development of myelopathy. In patients with cervical kyphotic deformity, the spinal cord could be compressed by tethering over the apical vertebra or intervertebral disc or by OPLL.[23] In addition to neurological dysfunction, patients may experience severe mechanical neck pain secondary to facet joint disruption.

Nevertheless, in the current study, the postoperative change in cervical alignment (kyphotic and lordotic groups) was unrelated to clinical outcomes. When we compared the results of cervical spine alignment after laminoplasty, kyphotic alignment change was found in 70% of patients, whereas postoperative kyphosis was present in 18% of patients. Although there are a number of possible explanations for the maintenance of cervical curvature, above all else we suggest that OPLL itself can prevent postoperative kyphosis because it provides support to the spinal column. That is, kyphotic changes do not always occur after cervical laminoplasty, and the lordotic changes are not always associated with good clinical outcomes.

We also considered whether variables such as preoperative duration of symptoms or disease severity could affect clinical outcome. The importance of these variables may have been overlooked in previous studies.

This study had several limitations. First, data are limited to the upper level of the spine. Pain, disability, and poor health status caused by whole-spine sagittal alignment and balance were excluded. Ideally, evaluation of whole-spine sagittal alignment by using full-length standing radiographs would have been done. The relatively short-term follow-up and small sample size are additional limitations. A long-term follow-up would be necessary for patients with OPLL, as the progression of OPLL or kyphotic change after laminoplasty could influence clinical outcomes. In addition, there were no preoperative "lordosis" patients who progressed to "kyphosis," and only 4 "straight" patients progressed to "kyphosis." It may be possible for a large number of patients that true kyphotic change or cervical alignment could influence clinical outcomes. Future studies with longer-term follow-up and larger numbers of patients are needed.

Conclusions

As a surgical approach, posterior cervical laminoplasty is a well-known and successful operation for OPLL to alleviate symptoms. After cervical laminoplasty, cervical sagittal alignment often tends to kyphotic change. However, relationships between cervical sagittal alignment and clinical outcomes have remained unclear. In the present study, neither cervical sagittal alignment after laminoplasty nor the alignment change after OPLL was correlated with clinical outcomes. No sagittal parameters were related to clinical outcomes. Only C-7 involvement during the operation was related to clinical outcomes. When considering cervical laminoplasty as a treatment for OPLL, the spine surgeon should consider cervical sagittal alignment as a treatment strategy, but its effect on clinical outcome is not clear.

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Disclosure

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: Ha, Lee. Acquisition of data: Lee. Analysis and interpretation of data: Lee. Drafting the article: Lee. Critically revising the article: Ha, Lee. Reviewed submitted version of manuscript: Ha, DA Shin, Yi, Kim, HC Shin, Yoon. Statistical analysis: Lee. Administrative/technical/material support: Kim. Study supervision: Ha.

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