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CERVICAL SPINE

Increased Segmental Range of Motion Is Correlated With Spondylolisthesis in the Cervical Spine After Laminoplasty

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Study Design. A retrospective study.

Objective. The aim of this study was to determine the incidence of increased segmental range of motion (ROM) after laminoplasty and to clarify whether increased ROM is associated with spondylolisthesis. Finally, we explored the effect of increased segmental ROM on clinical results.

Summary of Background Data. Cervical laminoplasty for cervical spondylotic myelopathy causes reduced ROM, possibly due to the unintended contracture of the facet joint or a bony union. Although it is rarely studied, ROM may also increase following laminoplasty. Thus far, there are no reports describing the correlation between increased segmental ROM and segmental spondylolisthesis after laminoplasty.

Methods. We evaluated 187 segments from 39 cervical spondylotic myelopathy patients who underwent bilateral open door laminoplasty from C2 to C7. The segmental ROM and spondylolisthesis were measured using dynamic radiographs that were obtained preoperatively and 2 years postoperatively. The Japanese Orthopedic Association (JOA) score was used for clinical evaluation. To compare the clinical results, we compared the cases with increased ROM in at least one segment with the remaining cases.

Results. Increased segmental ROM (*i.e.*, $\geq 5^{\circ}$ increase) was observed in 25 of 187 segments (13.4%) from 14 cases. There was a strong correlation between increased ROM and spondylolisthesis. A high preoperative disc height was associated with increased segmental ROM 2 years postoperation. Regardless of the correlation with spondylolisthesis, there was no statistically significant correlation between increased segmental ROM and JOA score.

Conclusion. The decrease in segmental ROM after laminoplasty was not uniform. Approximately 13.4% of all segments showed increased ROM. The preoperative disc height might influence the risk for increased segmental ROM. Furthermore, increased ROM was correlated with spondylolisthesis in the segment, though it was not correlated with clinical results.

Key words: C2-C7, cervical spine, cervical spondylotic myelopathy, clinical results, dynamic radiographs, Japanese Orthopedic Association score, laminoplasty, retrospective study, segmental range of motion, spondylolisthesis.

Level of Evidence: 4

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Cervical laminoplasty is a surgical procedure currently performed in Asian countries and the United States.[1] This procedure is commonly used to treat cervical spondylotic myelopathy (CSM) and ossification of the posterior longitudinal ligament (OPLL). Cervical laminoplasty is known to resolve static conditions such as developmental canal stenosis, by the creation of a larger cervical canal.[2] Furthermore, it can resolve dynamic conditions such as segmental instability and spondylolisthesis,[3] due to a decreased range of motion (ROM) and release of the pincer mechanism. Decreased ROM after laminoplasty occurs due to an unintended bony union at the facet joint or contracture of the facet joint capsule.[3]

Many researchers have reported a significant decrease in cervical ROM after laminoplasty. Whether the ROM is preserved or reduced after laminoplasty is controversial; however, Ratliff and Cooper[4] have reported that the mean loss of cervical ROM was 50% following a Hirabayashi-type laminoplasty. Although they reported a decrease in full cervical ROM, that is, from C2 to C6 or C7 after laminoplasty, it is unclear whether the segmental ROM decrease is uniform or if it is present only in certain segments.

We hypothesized that the decrease in segmental ROM does not occur uniformly and that ROM increases in some

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segments after laminoplasty. Furthermore, we hypothesized that increased segmental ROM induces segmental instability, leading to spondylolisthesis and poor clinical results.

The primary aim of this study was to investigate the changes in segmental ROM within the laminoplasty area. The secondary aim was to explore the relationship between enhanced segmental ROM and the occurrence of spondylolisthesis. The third aim was to elucidate the relationship between the increase in segmental ROM and clinical results.

MATERIALS AND METHODS

This was a retrospective study. This study was approved by the local institutional review board.

From 2005 to 2009, we performed laminoplasty without instrumentation on 49 CSM cases. Of these, we included 39 cases with CSM that were treated with laminoplasty in our department. All patients in this study underwent laminoplasty from C2 to C7 and were followed up for at least 2 years. The study excluded patients with OPLL, cerebral palsy, trauma, a history of anterior cervical fusion, or currently on dialysis. Furthermore, we excluded patients who did not have dynamic cervical radiographs obtained pre-operation or 2 years postoperation (n = 10).

Surgical Technique

Laminoplasty was performed using the double-door (midsagittal spinous-splitting) technique. We used a bur to make bilateral gutters at the C3 to C7 laminae. After removing the spinous process, we split the center of the lamina with a diamond bur and opened the lamina symmetrically. A dome-like laminoplasty was performed for C2. We did not insert any bone grafts at the surgical site. After the operation, patients were required to wear a cervical collar for 4 weeks. Spinal instrumentation was not used for any surgery in this study.

Radiological Measurements

We used flexion/extension radiographs. Radiographs were taken at a 1.5 m film focus distance for each patient.

The segmental ROM was measured from C2 to 3, 3 to 4, 4 to 5, 5 to 6, and 6 to 7 using dynamic radiographs by two of the authors (H.S. and T.K.). H.S. measured the segmental ROM[5] (Figure 1) twice to determine the intra-observer error. The inter-observer error was also evaluated between the authors. To investigate the reliability of continuous measurements, the intraclass correlation coefficient (ICC) was used.

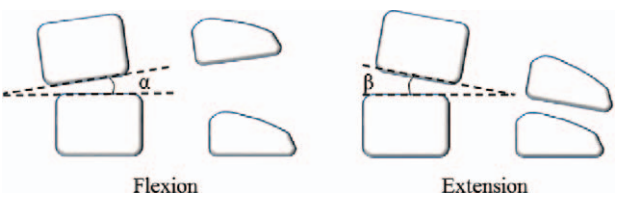

Figure 1. Measurement of the segmental range of motion based on dynamic radiographs.

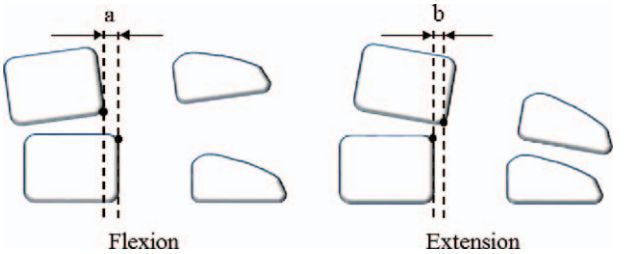

Figure 2. Measurement of the segmental spondylolisthesis (horizontal translation) based on dynamic radiographs.

We could not measure eight segments due to obstruction by the patient's shoulder. Ultimately, a total of 187 segments were evaluated in this study. We calculated the change in the segmental ROM based on the following formula: Change in the segmental ROM = segmental ROM 2 years postoperation – segmental ROM pre-operation.

The change in the segmental ROM was categorized into three types to avoid measurement error: an increase of $\geq 5^\circ$, a decrease of $\geq 5^\circ$, and a change between -5° and $+5^\circ$ compared with the pre-operative value were classified as Type 1 (increased), Type 2 (decreased), and Type 3 (no change), respectively.

To elucidate the effect of increased segmental ROM on clinical results, we compared cases with at least one segmental ROM that demonstrated an increase $\geq 5^\circ$ (Group A; increased ROM) with the remaining cases (Group B; ROM not increased).

Among Group A cases, we measured spondylolisthesis at each segment. Spondylolisthesis, which indicates horizontal translation, was measured using dynamic radiographs (Figure 2). Instability of segmental horizontal translation was defined as spondylolisthesis exceeding 3 mm.[6] We analyzed the correlation between segmental ROM and spondylolisthesis, as well as the change in spondylolisthesis prevalence measured pre- *versus* 2 years postsurgery among Group A.

We measured the height of cervical disc in the center at each level on the preoperative neutral lateral radiographs.[7] To determine factors that affect the postoperative increase in segmental ROM, the preoperative disc height was compared between Type 1 *versus* Type 2 and 3 cases.

Clinical Results

The clinical results were evaluated using the Japanese Orthopedic Association (JOA) scores,[2] and the recovery rate (%) was calculated according to the following formula: [(JOA score at 2 years postoperation – JOA score pre-operation) / (17-JOA score pre-operation) × 100].[8] Finally, the clinical results were compared between Groups A and B.

Statistical Analysis

Statistical differences between Groups A and B were determined using Chi-square tests and the Mann-Whitney *U* test. The normality of the data was first assessed using the Shapiro-Wilk test. Subsequently, the relationship between

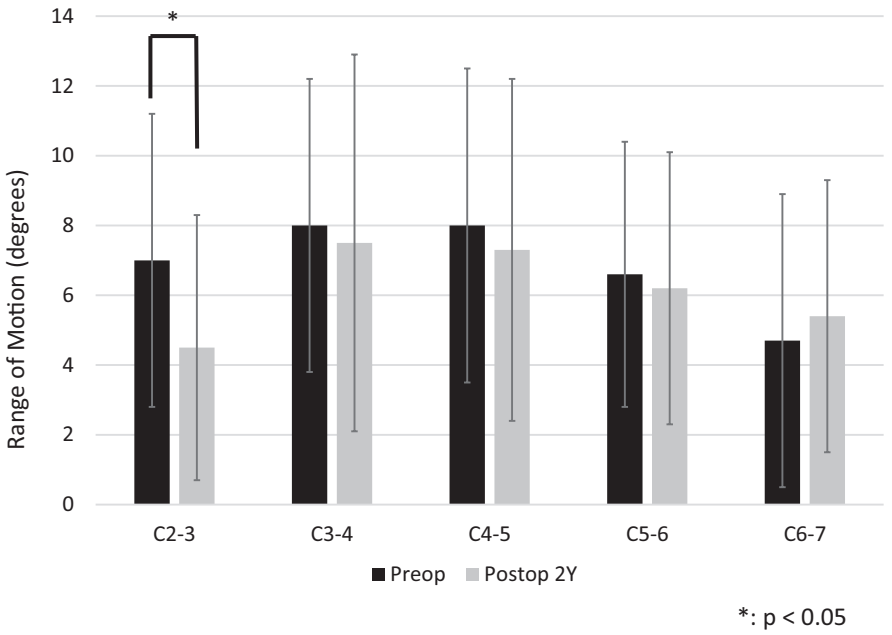

Figure 3. The segmental range of motion pre-operation and 2 years postoperation. A significant decrease was only observed at C2–3.

segmental ROM and spondylolisthesis was investigated using Pearson's correlation coefficient. Differences with a P value <0.05 were considered significant. Values are presented as the mean ± standard deviation. Receiver operating characteristic (ROC) analysis was used to assess the cut-off value of segmental ROM that predicts postoperative spondylolisthesis. All analyses were performed using SPSS software (version 17.0; IBM, Chicago, IL).

RESULTS

Demographic Data

The average age of the patients was 65.1 ± 11.6 years (range: 35–85 yrs) and the ratio of men to women was 31 : 8. The mean pre-operation segmental ROM values were as follows: C2 to C3: 7.0 ± 4.2; C3 to C4: 8.0 ± 4.2; C4 to C5: 8.0 ± 4.5; C5 to C6: 6.6 ± 3.8; and C6 to C7: 4.7 ± 4.2. The postoperation segmental ROM values at the 2-year follow-up were as follows: C2 to C3: 4.5 ± 3.8; C3 to C4: 7.5 ± 5.4; C4 to C5: 7.3 ± 4.9; C5 to C6: 6.2 ± 3.9; and C6 to C7: 5.4 ± 3.9 (Figure 3). There was a significant difference between the pre- and postoperation values at C2 to C3, but there were no significant differences at the other cervical segments. The pre- and postoperative JOA scores were 8.2 ± 3.5 (range: 1–14) and 12.4 ± 3.4 (range: 3–17), respectively. The recovery rate was 52.1 ± 26.2%.

Radiological Measurements

A total of 187 segments were evaluated in this study (Table 1). Types 2 and 3 were observed in 162 segments. Therefore, 86.6% of the segmental ROM values remained unchanged or decreased after laminoplasty. However, there were 25 Type 1 segments, which indicated that 13.4% of the segmental ROM values increased after laminoplasty. There were no statistically significant differences in the incidence of increased segmental ROM among each segment (Figure 4). Meanwhile, the average preoperative disc height of Type 1 segments was 6.4 ± 1.6 mm, while the average disc height of Type 2 and 3 segments was 5.6 ± 1.3 mm ($P < 0.01$).

TABLE 1. Characteristics of Evaluated Segments

Level	Type 1: Increase Change in ROM ≥5°	Type 2: Decrease −5° ≥Change in ROM	Type 3: No Change −5° <Change in ROM <5°	Total Segments
C2–3	3	13	23	39
C3–4	6	10	23	39
C4–5	5	5	29	39
C5–6	8	9	22	39
C6–7	3	2	26	31
Total	25	39	123	187

Change in ROM, ROM 2 years postoperation−ROM pre-operation.
Chi-squared test, P = 0.45.
ROM indicates range of motion.

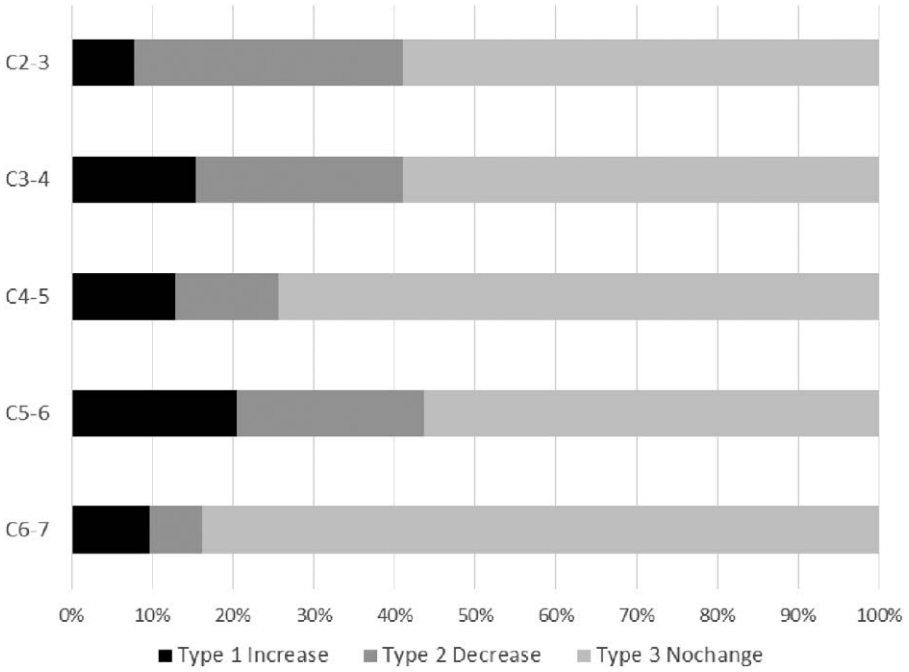

Figure 4. The prevalence of increased segmental range of motion (ROM) at each level (black).

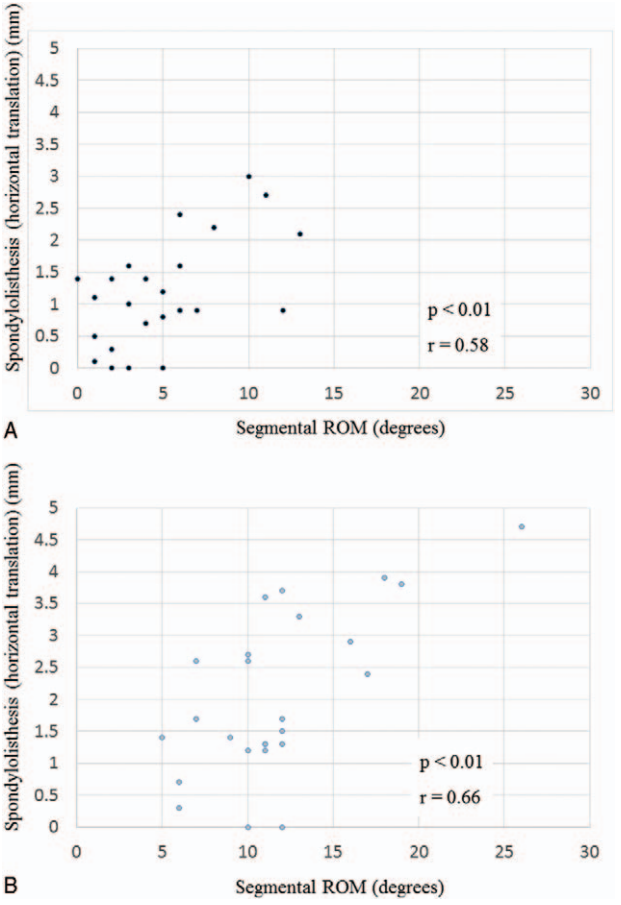

Figure 5. (**A**) The correlation between segmental range of motion (ROM) and spondylolisthesis among Type 1 (increased ROM) segments at the pre-operation time point. (**B**) The correlation between segmental ROM and spondylolisthesis among Type 1 segments 2 years postoperation.

Correlation Between Change in the Segmental ROM and Spondylolisthesis

We measured the spondylolisthesis among 25 Type 1 segments, pre- and 2 years postoperation. Of these, one

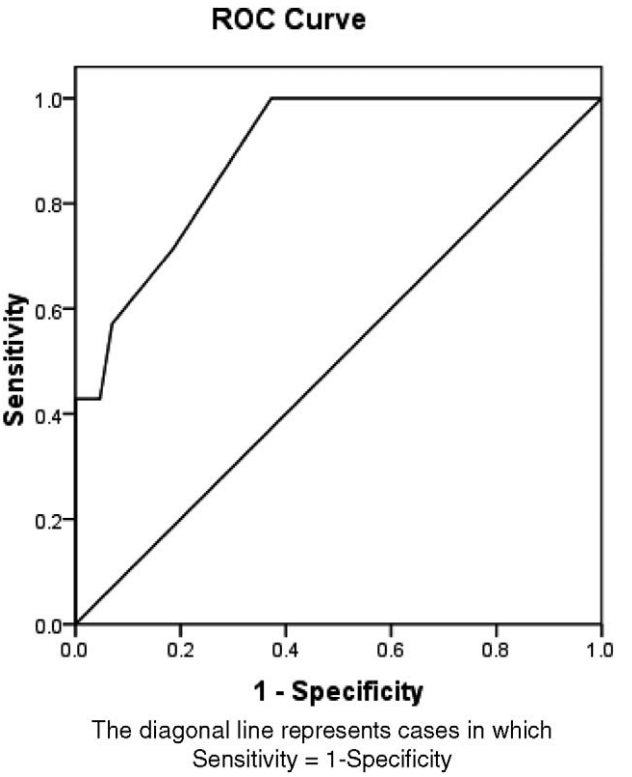

Figure 6. Receiver operating characteristic (ROC) curve analysis to determine the cut-off range of motion (ROM) increase that predicted spondylolisthesis. The cutoff was 10.5°. The area under the curve (AUC) was 0.89, sensitivity was 0.86, and specificity was 0.72.

TABLE 2. Comparison of Demographic Characteristics Between Groups

	Group		
Sex	Group A (n = 14)	Group B (n = 25)	*P*
Male	9	22	0.09
Female	5	3	
Age	65.9 ± 10.7	64.6 ± 12.3	0.97

Group A: Increased range of motion (ROM) 2 years postoperation, compared with pre-operation; Group B: Either decreased or unchanged ROM 2 years postoperation, compared with pre-operation.

segment (4%: 1/25) displayed spondylolisthesis >3 mm at pre-operation and six segments (24%: 6/25) exhibited spondylolisthesis >3 mm at 2 years postoperation. The prevalence of spondylolisthesis significantly increased (4–24%; $P < 0.05$). Conversely, the prevalence of spondylolisthesis >3 mm did not change between pre-operation and 2 years postoperation in Type 2 and 3 segments (6.6%: 10/162).

There was a positive correlation between segmental ROM and spondylolisthesis pre-operation ($r = 0.58$, $P < 0.01$) and 2 years postoperation ($r = 0.66$, $P < 0.01$) (Figure 5A,B) among Type 1 segments. The ROC curve analysis showed that the cut-off value of the segmental ROM that predicted the occurrence of spondylolisthesis greater than 3 mm was 10.5° among Type 1 segments [area under the curve (AUC): 0.894, 95% confidence interval (CI): 0.79–1.0, sensitivity: 0.86, specificity: 0.72, $P = 0.001$] (Figure 6).[9]

Correlation Between Clinical Results and Change in the Segmental ROM

We were able to obtain 14 cases with at least one Type 1 segment at 2 years postoperation (Group A). Of these, an increase in the segmental ROM was observed in one, two, three, and four segments from C2 to C3 to C6 to C7 in eight, three, one, and two cases, respectively. The remaining 25 cases (Group B) had only Type 2 or Type 3 segments. There were no statistically significant differences in sex or age between the two groups (Table 2). Furthermore, there were no significant differences in the clinical results (*i.e.*, JOA scores) between these two groups at pre- or 2 years postoperation (Table 3).

Inter- and Intra-Observer Error

The inter- and intra-observer error in this study was 0.77 (95% CI: 0.65–0.85) and 0.80 (95% CI: 0.67–0.88), respectively.[10] The inter-observer error is considered good and intra-observer error is considered excellent.[9]

Illustrative Case

This case involved a 77-year-old woman. She experienced hand numbness and clumsiness before surgery. Two years after surgery, segmental ROM at C3 to C4 increased and exhibited spondylolisthesis (Figure 7).

DISCUSSION

In the current study, segmental ROM increased in 13.4% of segments after cervical laminoplasty. These enhancements correlated with spondylolisthesis but not the clinical outcome 2 years postoperation.

Current evidence suggests that the reduction in ROM of the cervical spine after laminoplasty is mainly due to the contracture of facet joint or bony union of the segments.[11] In a review, Duetzmann *et al.*[1] reported an overall 47.3% mean loss of ROM after laminoplasty. The goals of laminoplasty surgery appear to lie between solid fusion with limited facet joint movement and decompression alone with complete preservation of the normal cervical ROM.

The pathology of CSM includes two main aspects: the static factors (*i.e.*, developmental canal stenosis) and the dynamic factors (*i.e.*, segmental instability and spondylolisthesis). Some authors have emphasized the importance of limiting the

TABLE 3. Changes in Clinical Results Between Groups

	Pre-operation			Two yrs Postoperation		
	Group			Group		
JOA Score	Group A (n = 14)	Group B (n = 25)	*P*	Group A (n = 14)	Group B (n = 25)	*P*
Motor						
UEs	2.7 ± 0.8	2.4 ± 1.1	0.38	3.6 ± 0.7	3.2 ± 1.0	0.13
LEs	2.4 ± 1.1	1.9 ± 1.3	0.26	2.6 ± 1.0	2.4 ± 1.4	0.72
Sensory						
UEs	0.4 ± 0.6	0.5 ± 0.5	0.44	1.2 ± 0.8	1.0 ± 0.6	0.44
LEs	0.6 ± 0.8	0.6 ± 0.7	0.87	1.1 ± 0.7	1.4 ± 0.7	0.28
Trunk	1.0 ± 0.8	1.0 ± 0.8	0.92	1.9 ± 0.4	1.8 ± 0.4	0.94
Bladder function	1.7 ± 0.6	1.7 ± 1.0	0.97	2.6 ± 0.5	2.2 ± 0.8	0.32
Total	8.7 ± 3.1	8.0 ± 3.7	0.44	13.0 ± 2.7	12.1 ± 3.8	0.48
Recovery rate				51.5 ± 28.2	52.4 ± 25.7	0.81

Group A: Increased range of motion (ROM) 2 years postoperation, compared with pre-operation; Group B: Either decreased or unchanged ROM 2 years postoperation, compared with pre-operation. JOA indicates Japanese Orthopedic Association; LE, lower extremity; UE, upper extremity.

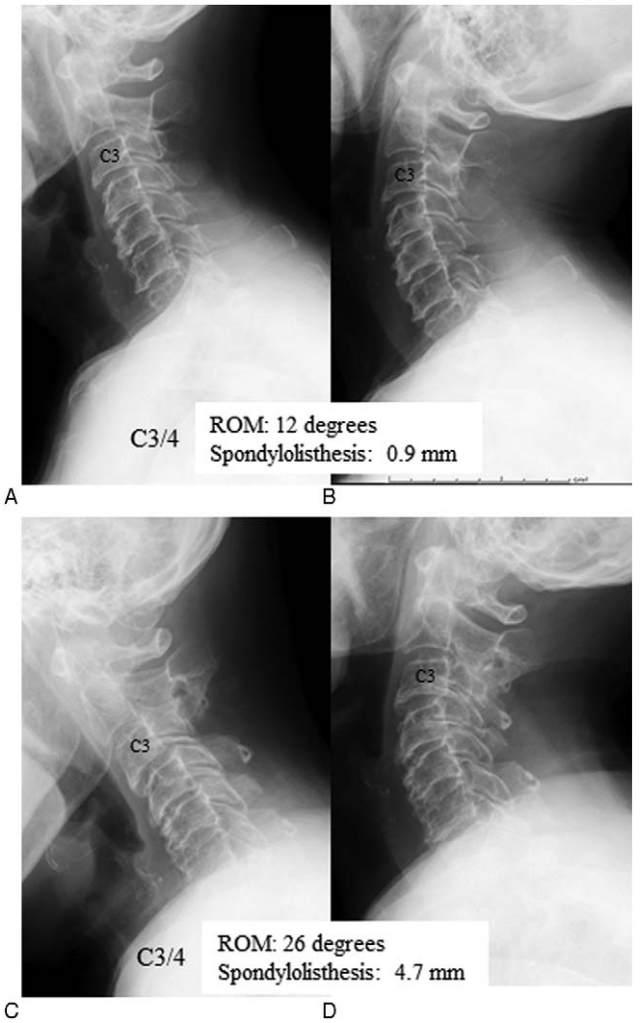

Figure 7. Radiographic images of a 77-year-old woman, before (**A**, **B**) and after (**C**, **D**) cervical laminoplasty. The segmental range of motion (ROM) at C3–4 increased from 12° to 26°. Spondylolisthesis at C3–4 increased from 0.9 to 4.7 mm. (**A**, **C**) Flexion; (**B**, **D**) Extension.

cervical ROM after posterior decompression to reduce the effects of dynamic factors.[12,13] We believe that laminoplasty is a beneficial surgical technique for managing both of these pathological aspects of CSM.

To the best of our knowledge, there are only two studies examining the segmental ROM after laminoplasty. Baba *et al.*[14] reported a significant decrease in segmental ROM at all levels except C2–3 and C7–T1. Similarly, Nagamoto *et al.*[15] reported a statistically significant decrease at C2–3 using computed tomography scans. We also observed a significant decrease in segmental ROM at C2–3. In addition, several researchers have reported that C2–3 is the most frequently fused level after laminoplasty.[11,16] However, the focus of these previous reports was on a decrease rather than an increase in the segmental ROM. Clinically, we should pay attention to segmental instability after laminoplasty as well.

Although most of the segmental ROMs decreased after laminoplasty, we found that ROM increased in 13.4% of segments in this study. This phenomenon seemed to occur much more frequently at C3 to C4 and C5 to C6 than at other levels, though there was no statistically significant difference in the incidence among all segments. However, statistically significant differences in preoperative disc height were observed between Type 1 *versus* Type 2 and 3 segments. The disc height of Type 1 segments was higher than that of Type 2 and 3 segments. Therefore, a high preoperative disc height might predict segmental instability at 2 years postoperation.

Furthermore, a segmental ROM greater than 10.5° strongly correlated with the incidence of spondylolisthesis after laminoplasty. Clinically, we should pay attention to increased segmental ROM, particularly ROM greater than 10.5° and the consequent segmental instability including spondylolisthesis.

In Type 1 segments, we showed a positive correlation between segmental ROM and spondylolisthesis. However, the increased segmental ROM did not lead to poor clinical results in the short term (2 years).

Our study has several limitations. First, our study was retrospective. Second, we used JOA scores for the clinical evaluation due to the retrospective study design, and differences between groups may have been observed if other tools for clinical evaluation were used, such as the Nurick disability index,[17] visual analog scale,[18] or short form 36.[19] Third, we did not find a statistically significant correlation between the increased segmental ROM and clinical results 2 years postoperation, though it might be too early to conclude that increased segmental ROM does not lead to poor clinical results. Fourth, our study did not include magnetic resonance imaging (MRI). Preoperative disc degeneration, as observed with MRI, might also affect the segmental instability. Fifth, we used the double door technique for all laminoplasty surgeries. Thus, our results may not be universally applied to single door laminoplasty. Further studies on long-term clinical results are warranted in the future.

CONCLUSION

In this study, 13.4% of segments exhibited an increase in segmental ROM after laminoplasty. Increased segmental ROM correlated with spondylolisthesis, especially with a ROM greater than 10.5°. A high preoperative disc height might affect the segmental instability at 2 years postoperation. However, we did not find a correlation between increased segmental ROM and clinical results based on JOA scores in the short term.

➢ Key Points

- ❑ Segmental range of motion (ROM) increased in 13.4% of all segments after laminoplasty.
- ❑ A higher preoperative disc height might be associated with an increased segmental ROM following laminoplasty.

- Increased segmental ROM did not influence clinical results in the short term (2 years postoperation).

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