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腰部脊柱管狭窄症の手術成績に関する患者立脚型調査 －医師評価との乖離とその原因－

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Patient Standpoint Type Investigation about Surgical Outcome of Lumbar Canal Stenosis

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Maudsley Personal Inventory (モーズレイ性格テスト), short form36

はじめに

腰部脊柱管狭窄症に対する手術成績報告は過去22年間で307件，その中で患者立脚型調査にて評価した論文は４件で患者の満足度評価が中心であった。今回われわれは腰部脊柱管狭窄症に対して拡大開窓術を施行した患者の手術成績を患者立脚型調査により評価し，医師評価との乖離の有無とその原因を検討した。

対象および方法

対象は同一施設で同一術者により平成14年１月から平成15年12月の２年間に施行された腰部脊柱管狭窄症に対する拡大開窓術の全症例のうち患者立脚型調査の同意を得た患者25名，男性21名女性４名である。手術時年齢は57歳から78歳，平均70.2歳。手術前職業は重労働が８名，軽作業が９名，無職が８名。手術前復帰希望やスポーツ，趣味があった患者はゴルフが６名，つり２名，日本舞踊１名であった。除圧範囲は，単椎間が７例，２椎間が12例，３椎間が６例であった。

調査項目は医師による評価として間欠性跛行などの他覚所見の改善度とJOAスコア。患者による評価としてVAS評価，McGill疼痛評価，職業復帰，スポーツ復帰度，患者満足度，SF36，MPI心理テスト[1)2)3)]を調査し比較した。

結　果

医師による手術成績評価は他覚所見の改善は25例中23例92%。間欠性跛行消失は25例中19例76%。JOAスコア術前平均12.8が術後平均21.7と改善，そのうち満点例は５例20%に認めた。患

者による成績評価としてVAS評価は術前を10とすると術後4.1と改善。Mcgill疼痛質問表（最低45点，最高0点）では術前平均13.3が術後平均3.9と改善を認めた。職業復帰度は重労働は制限つき復帰2例，復帰できず5例。軽作業は完全復帰2例，制限つき復帰3例，復帰できず4例。スポーツ，趣味に関しては，ゴルフは制限つき復帰2例，復帰できず4例，つり，日本舞踊は復帰できなかった。Short form 36 (SF36) は身体的機能の改善が22例，88%と高かったが，社会活動の改善は9例，36%。全体的健康度の改善は8例，32%で社会的活動，全体的健康度は低かった。患者の満足度は大変満足5例，20%。まあまあ満足10例，40%で満足と答えた患者は6割程度で，医師による成績評価に比べ低かった。MPIで異常と判断された患者は6例で神経症型4例，うつ病型1例，精神不安定型1例で，6例とも手術の満足は得られなかった。

考　察

腰部脊柱管狭窄症に対する拡大開窓術の成績は良好とする報告が多いが，患者によっては手術が患者のQOLに貢献していない場合がある。我々は患者立脚型調査を行い，満足度は一様でなくしびれなどの自覚症状の残存に対する愁訴が多く，また心理テストに異常がある患者は満足度が低い結果を得た。本研究の限界としては1施設での研究で症例が少ないこと。第3者評価ではないこと。患者の多くが高齢者であること。評価方法自体の問題，長期成績評価ではないことで，これらを改善すればさらに正確な評価が期待できると思われる。患者によっては手術の過大な期待を持って手術を受ける場合があり，術前に手術の限界についてのインフォームドコンセントを適切に患者に行うことが重要であると考える。

結　語

今回の調査では患者立脚型調査と医師による成績評価には解離があった。手術に対する患者の要求度や心理的異常の有無を考慮して患者に手術のインフォームドコンセントを与える必要がある。

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Dural damage due to a loosened hydroxyapatite intraspinous spacer after spinous process–splitting laminoplasty

Report of two cases

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✓Excellent results from laminoplasty for cervical spinal myelopathy have been reported in many studies. Nevertheless, C-5 nerve root palsy or axial pain such as neck and shoulder pain after laminoplasty are known postoperative complications. To the authors' knowledge, dural damage from dislocation of the hydroxyapatite intraspinous spacer due to absorption of the tip of the spinous process has not been reported. Two cases of dural damage from dislocation of the hydroxyapatite intraspinous spacer after laminoplasty are described.

Radiographs, computed tomography myelography, and magnetic resonance (MR) imaging revealed the dislocation of the hydroxyapatite intraspinous spacer, the absorption of the tip of the spinous process, and dural sac compression due to the hydroxyapatite intraspinous spacer. In one patient, the MR imaging studies revealed liquorrhea around the hydroxyapatite intraspinous spacers. Both patients underwent removal of the hydroxyapatite intraspinous spacer and attained good neurological recovery.

In patients with dislocation of the hydroxyapatite intraspinous spacer associated with absorption of the tip of the spinous process after spinous process–splitting laminoplasty, each case should be evaluated for aggravating symptoms of myelopathy, dural damage, and liquorrhea around the spacer. *(DOI: 10.3171/SPI-07/08/230)*

KEY WORDS • **complication** • **dural defect** • **hydroxyapatite intraspinous spacer** • **laminoplasty** • **spinous process**

LAMINOPLASTY of the cervical spine was developed to decompress the spinal canal and reconstruct the posterior structure of the cervical canal to treat myelopathy resulting from spondylosis and ossification of the posterior longitudinal ligament. Many studies have reported excellent results from laminoplasty.[3,5,9,11–13]

At our institution, a hydroxyapatite intraspinous spacer was developed in 1987, and it has been used to maintain the enlargement instead of autogenous iliac bone.[11] Excellent results have been reported after spinous process–splitting laminoplasty in which the hydroxyapatite intraspinous spacer was used. Nevertheless, C-5 nerve root palsy[10,17–19] or axial pain such as neck and shoulder pain have been reported after laminoplasty.[7,8,15,20] New surgical methods have recently been developed to prevent these complications.[14,15]

Damage to the dura mater from dislocation of the hydroxyapatite intraspinous spacer due to absorption of the tip of the spinous process has not been reported. We describe two cases of dural damage from the implant, secondary to a loosened intraspinous spacer due to absorption of the tip of the C-4 spinous process.

Case Reports

Case 1

This 60-year-old man had presented with numbness and muscle weakness in the upper and lower extremities. Cervical spondylotic myelopathy was diagnosed, and he underwent spinous process–splitting laminoplasty in which hydroxyapatite intraspinous spacers were implanted from C-3 to C-7. After surgery, the patient had a good neurological recovery and returned to work. Five years postoperatively, he experienced progression of muscle weakness bilaterally in the upper and lower extremities. Radiographs showed that the hydroxyapatite intraspinous spacer of C-4 was dislocated. The CT myelography studies demonstrated absorption of the tip of the C-4 spinous process (Fig. 1),

Abbreviations used in this paper: CT = computed tomography; MR = magnetic resonance.

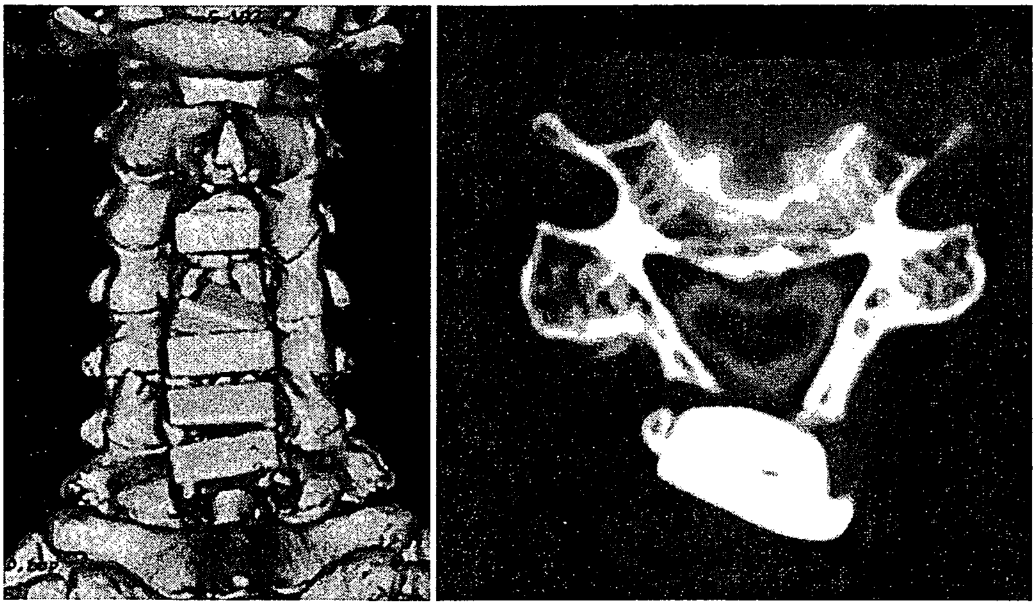

FIG. 1. Case 1. Follow-up CT myelography studies obtained 5 years postoperatively revealing dislocation of the hydroxyapatite intraspinous spacer associated with the absorption of the tip of the C-4 spinous process. *Left:* Three-dimensional CT scan. *Right:* Center level of the C-4 spacer.

and MR imaging studies demonstrated dural sac compression caused by the C-4 spacer (Fig. 2); the patient underwent removal of this spacer. Intraoperatively we could see that the C-4 spacer was loose, but that the other hydroxyapatite spacers had fused with the spinous process. The anterior side of the C-4 spacer was in contact with the dura mater and a pinhole-sized defect within the dura was found. There were no defects in the arachnoid layer and no liquorrhea. After the second surgery, the patient attained a good neurological recovery.

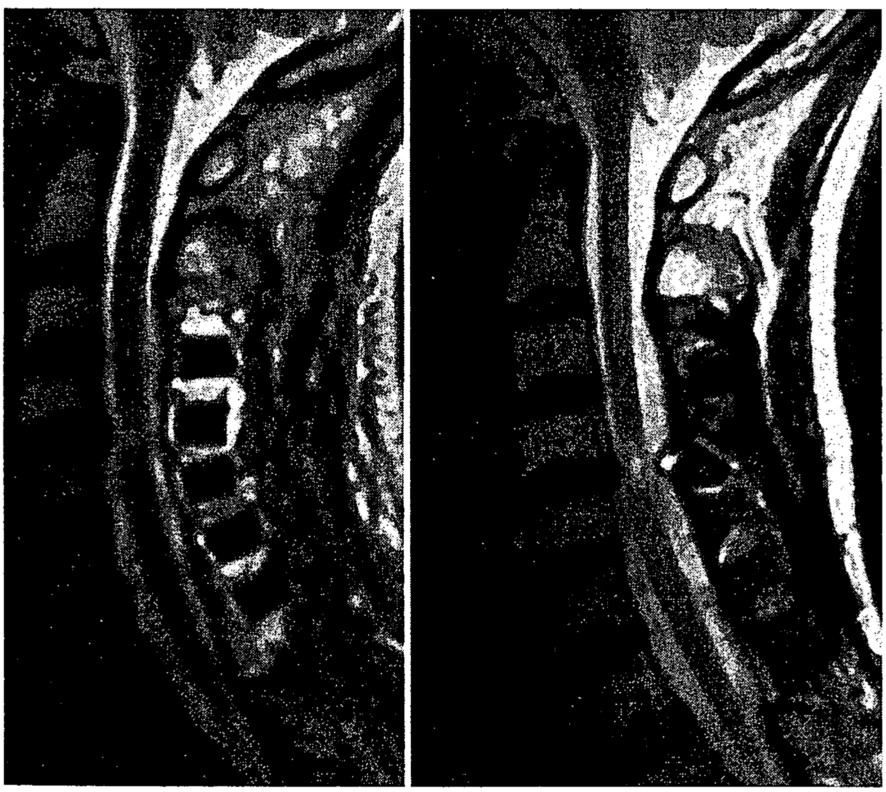

FIG. 2. Case 1. Sagittal MR imaging studies. An image obtained 6 months postoperatively *(left)* demonstrates no compression of the spinal cord. The 5-year postoperative image *(right)*, however, demonstrates dural sac compression caused by the hydroxyapatite intraspinous spacer at C-4.

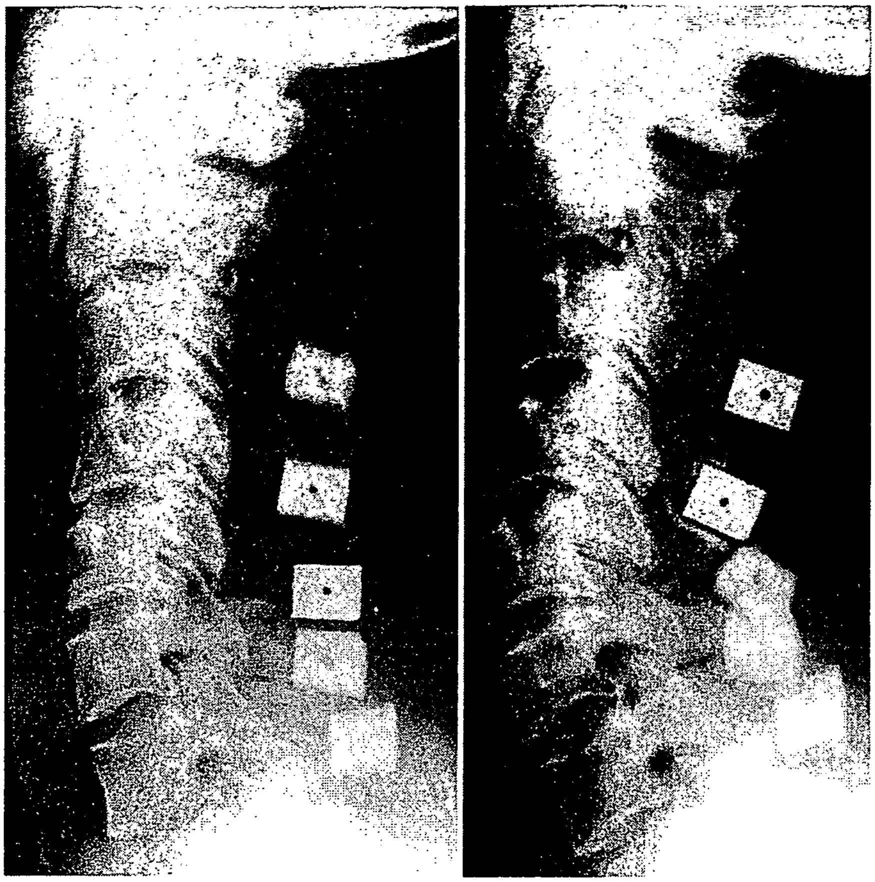

FIG. 3. Case 2. Radiographs obtained 1 year *(left)* and 4 years *(right)* after laminoplasty. This patient had undergone spinous process–splitting laminoplasty in which hydroxyapatite intraspinous spacers were implanted from C-3 to C-7. At 4 years postoperatively, radiographs showed that the spacer of C-4 and C-5 was dislocated.

Case 2

This 53-year-old man presented with numbness and muscle weakness bilaterally in the upper extremities. Cervical spondylotic myelopathy was diagnosed, and he underwent spinous process–splitting laminoplasty in which hydroxyapatite intraspinous spacers were implanted from C-3 to C-7. After surgery, the patient had a good neurological recovery and returned to work. Four years postoperatively he experienced headache, neck pain, and pain radiating to the upper and lower extremities and back during flexion of the neck. Radiographs showed that the hydroxyapatite intraspinous spacers of C-4 and C-5 were dislocated (Fig. 3). The CT myelography studies revealed absorption of the tip of the C-4 and C-5 spinous processes (Fig. 4), and MR imaging demonstrated liquorrhea around the hydroxyapatite intraspinous spacers of C-4 and C-5 (Fig. 5). The patient underwent removal of the spacers from C-3 to C-7. Intraoperatively we saw that although the C-4 and C-5 spacers were loose, other hydroxyapatite spacers were fused with the spinous process. The anterior side of the C-4 spacer was in contact with dura mater, and a 5-mm^2 defect was present in the dura mater and arachnoid layer (Fig. 6). Duraplasty was performed to relieve the liquorrhea. After the second surgery, the patient had no symptoms and was again able to return to work.

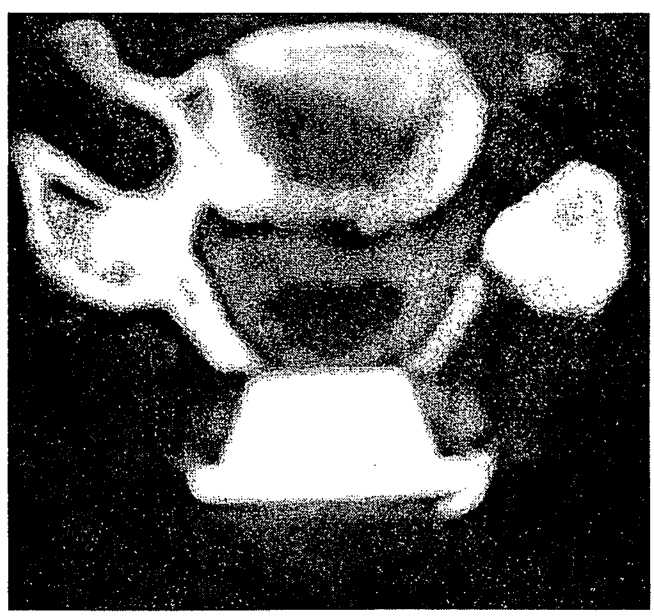

FIG. 4. Case 2. Follow-up CT myelography study obtained 4 years postoperatively, demonstrating dislocation of the hydroxyapatite intraspinous spacer associated with absorption of the tip of C-4 and C-5 spinous processes.

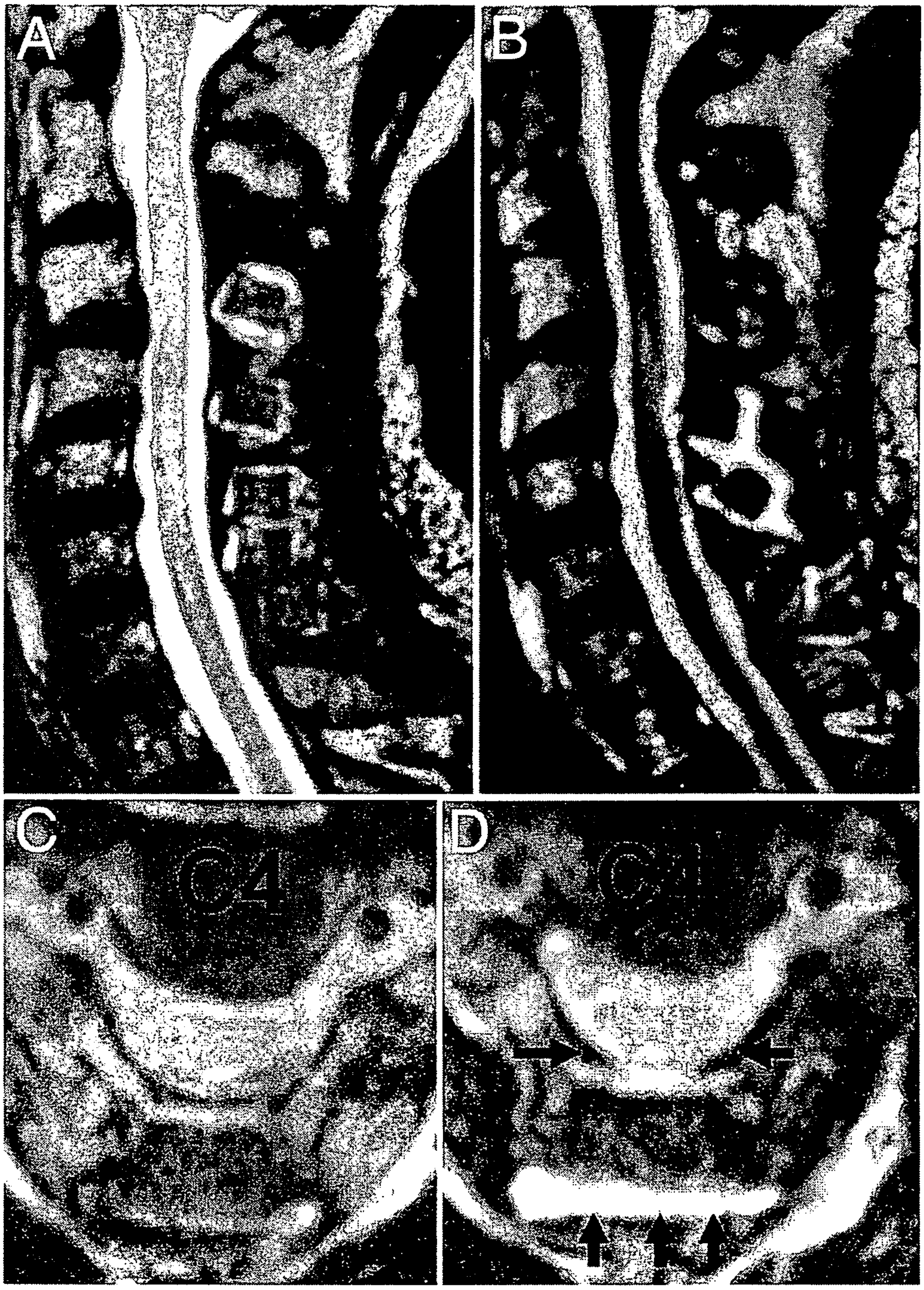

FIG. 5. Case 2. Sagittal (A) and axial (C) MR images obtained 1 year postoperatively demonstrating a good result. Sagittal (B) and axial (D) MR imaging studies obtained 4 years postoperatively demonstrating liquorrhea *(arrows)* around the hydroxyapatite intraspinous spacers of C-4 and C-5.

Discussion

Since 1987, C3–7 spinous process–splitting laminoplasty in which hydroxyapatite intraspinous process spacers are used has been performed for cervical myelopathy at our institution.[11] The intraspinous process spacer was specifically designed for this procedure. This implant has a trapezoid shape and a small hole, and is held in place with two nonabsorbable sutures passed through holes made in the expanded posterior elements. The porosity of a hydroxyapatite intraspinous process spacer is 40%. These devices come in 12-, 15-, and 20-mm widths. We select the optimal spacer size for the width of the split spinous process after the lamina has been expanded.

As an adequate size for hydroxyapatite spacers for the patient in Case 1, we selected the 15-mm spacer for C-3 and C-4 and the 20-mm spacer for C5–7. There was no displacement of the intraspinous process spacers at the 3-year

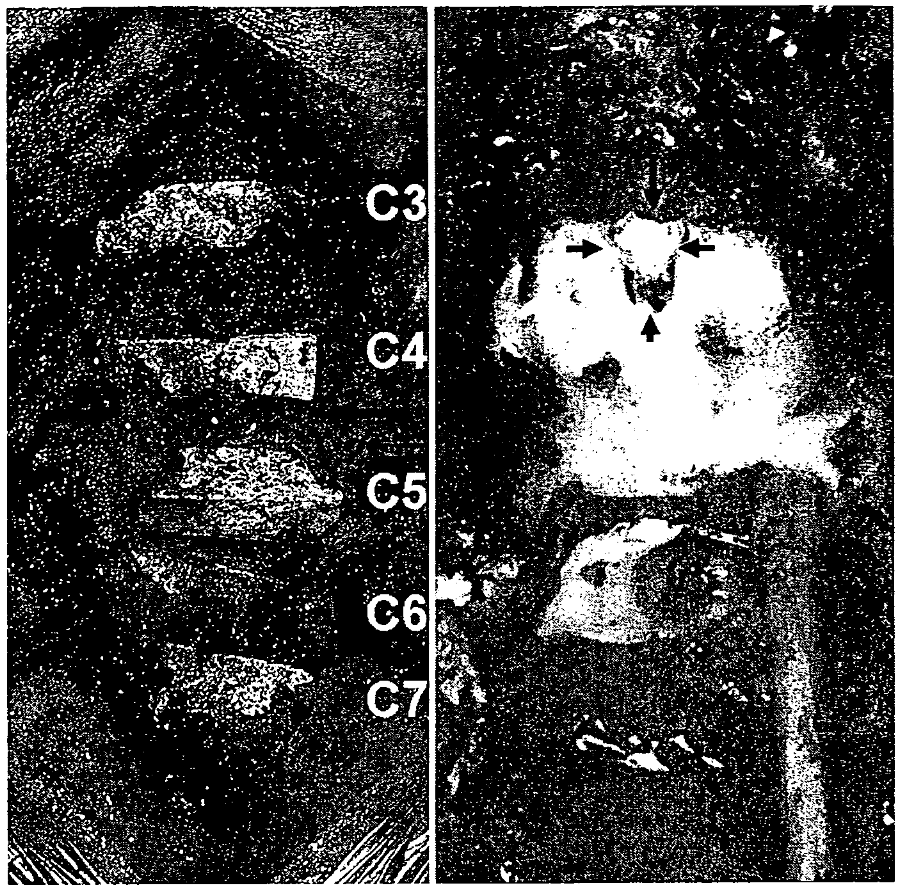

FIG. 6. Case 2. Intraoperative photographs. The anterior side of the C-4 spacer contacted with the dura mater, and a defect *(arrows)* was present in the dura mater and arachnoid layer measuring 5 mm^2. *Left:* Photograph taken before removal of the hydroxyapatite intraspinous spacer; liquorrhea was recognized between the C-4 and C-5 spacers. *Right:* Photograph taken after removal of the spacer. The defect in the dura mater and arachnoid layer can be seen on the anterior side of the C-4 spacer.

postoperative evaluation in this patient. At the 4-year follow-up, however, radiographs showed that the C-4 spacer was dislocated. An adequate size for hydroxyapatite spacers for the patient in Case 2 was the 20-mm spacer in C3–7. There was no displacement of the implants at the 2-year postoperative evaluation. At the 3-year follow-up, however, radiographs showed that the C-4 and C-5 spacers were dislocated.

Regarding complications related to the hydroxyapatite intraspinous spacer after spinous process–splitting laminoplasty, it has been reported that absorption of the tip of the spinous process occurred in laminoplasty, that the implant remained unfused with the spinous process in approximately 10% of cases, and that dislocation of the spacer occurred in approximately 3%.[2,4,6] The most common position for dislocation of the hydroxyapatite intraspinous spacer was at C-4, and the incidence of dislocation was higher in proportion to the amount of intervertebral motion before surgery.[2]

In our two patients, the aggravated symptoms of myelopathy, dural damage, and liquorrhea around the spacer were most likely due to contact of the anterior side of the C-4 spacer with the dura mater after absorption of the tip of the spinous process, and lack of fusion of the hydroxyapatite intraspinous spacer with the spinous process, which caused dislocation of the C-4 spacer toward the spinal cord and shifting of the cord dorsally.

To prevent dislocation of hydroxyapatite intraspinous spacers at our institution, the spinous processes have been split using a thread-wire saw.[1,16] The laminae were often so small or thin that reconstruction of the posterior arch was difficult, especially in the midcervical levels (C3–5). For spinous process–splitting procedures, in the past surgeons have used high-speed burs to divide the spinous processes. However, a large quantity of bone in the spinous process was sacrificed by the high-speed bur. By using the thread-wire saw, the cancellous bone of the split spinous process could be maintained, the fit between the hydroxyapatite intraspinous spacer and the split spinous process was better, and the absorption of the tip of the spinous process decreased. Nevertheless, in spinous process–splitting laminoplasty procedures, a lack of blood supply to the tip of the spinous process is expected due to splitting of the soft tissues and the creation of bilateral gutters. The absorption of the tip of the spinous process may not be completely preventable. In patients with dislocation of the hydroxyapatite intraspinous spacer associated with absorption of the tip of the spinous process after spinous process–splitting laminoplasty, each case should be evaluated for aggravating symptoms of myelopathy, dural damage, and liquorrhea around the spacer.

Conclusions

Two patients suffered dural damage from dislocation of the hydroxyapatite intraspinous spacer after laminoplasty. Radiographs, CT myelography, and MR imaging studies revealed the dislocation of the spacer and absorption of the tip of the spinous process. The patients underwent removal of the hydroxyapatite intraspinous spacer and attained good neurological recovery.

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ORTHOPAEDIC OUTCOME ASSESSMENT

Limitations of activities of daily living accompanying reduced neck mobility after cervical laminoplasty

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Abstract
Introduction After laminoplasty, difficulties with neck mobility often interfere with patients' activities of daily living (ADL). Although it has been reported that the flexion–extension range of motion significantly decreased after laminoplasty, in many studies using radiographs there were few patient-based outcomes. The purpose of this study was to reveal the frequency, severity and factors related to limitations of ADL accompanying neck mobility after laminoplasty.
Materials and methods A total of 58 patients were evaluated after laminoplasty to determine the frequency, severity and pre- and postoperative related factors of postoperative limitations of ADL accompanying each of three neck movements: (1) extension, (2) flexion and (3) rotation. The severity of limitations of each ADL was assessed using a questionnaire that was completed by the patient.
Results Difficulties in neck movement, such as rotation (41%), extension (34%) and flexion (17%), in that order ($P = 0.001$), caused limitations of ADL. The most relevant factor of limitations of ADL accompanying extension, flexion, and rotation were small postoperative O–C7 range of motion ($P = 0.0001$), small preoperative O–C7 range of motion ($P = 0.001$), and small postoperative rotation range of motion ($P = 0.0005$), respectively.
Conclusion There were more than a few patients with limitations of ADL accompanying reduced neck mobility after laminoplasty. This knowledge may be useful in the clinical outcomes of cervical laminoplasty.

Keywords Cervical laminoplasty · Activities of daily living (ADL) · Cervical myelopathy · Mobility · Range of motion

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Introduction

In recent years, long-term results of over 10 years for cervical myelopathy after cervical laminoplasty have been reported [10, 22, 29], and the neurological improvement following cervical laminoplasty has been as satisfactory as the outcome from anterior cervical fusion. However, difficulties in neck mobility including extension, flexion and rotation often interfere in patients′ activities of daily living (ADL) after laminoplasty, despite good postoperative neurological improvements. Regarding range of motion (ROM), it has been reported in many studies using radiographs that the flexion–extension ROM was significantly decreased after laminoplasty [1, 6, 13, 14, 21, 22, 28, 30]. However, these studies were performed with a "film" evaluation and were not patient-based outcomes that reflect the clinical symptoms accompanying postoperative difficulty of neck mobility. Therefore, the detailed particulars about the limitations of ADL accompanying reduced neck mobility after laminoplasty remain unclear.

This study examined retrospectively the frequency and severity of limitations of ADL accompanying neck mobility after laminoplasty and the related factors. This knowledge might be useful in the clinical outcomes of cervical laminoplasty.

Materials and methods

Patient group

Between 1988 and 2001, 85 patients with cervical myelopathy were treated with spinous process-splitting laminoplasty using hydroxyapatite spinous process spacers from C3 to C7 at Hirosaki University Hospital [17]. Of these 85 patients, 58 who were followed for more than 1 year were of an average age of 59 years (range 34–76 years) at the time of surgery. There were 43 men and 15 women. Cervical spondylotic myelopathy (CSM) was clinically evident in 30 cases and ossification of the posterior longitudinal ligament (OPLL) was present in 28 cases. Bone graft was not performed in all cases. Experienced spinal surgeons performed the operations in this series. The postoperative collar periods varied from 2 to 8 weeks. The patients wore a Philadelphia collar or a cervical collar. The average follow-up period was 4 years and 4 months (range 1 year to 12 years and 2 months), and the follow-up rate was 72%.

The frequencies of postoperative limitations of ADL accompanying each of the following neck movements were investigated: (1) extension, (2) flexion, and (3) rotation (Table 1). The severity of limitations of each ADL was assessed using a questionnaire that was completed by the patient (Table 2).

The flexion–extension ROM at O–C7 was measured using McGregor line and the posterior tangents of the C7 vertebral body on lateral flexion and extension radiographs of the cervical spine. The decrease in the rate of ROM was calculated using the following formula: Decrease rate (%) = (1 − postoperative ROM/preoperative ROM) × 100. The postoperative rotation ROM of patients with their spectacles on as measure lines was photographed in the cranial view using a digital camera (Fine Pix 4900 Zoom, Fuji Photo Film Co., Ltd., Tokyo, Japan) (Fig. 1). All the radiographs and digital photographs were scanned on a computer (Windows; VAIO Computer, Sony Corp., Tokyo, Japan) and measured using CANVAS 8, accurate to 0.1° (Deneba System, Inc., Arlington, USA). The measurements of ROM were done by two observers, and interobserver reliability was calculated. The second observer was blinded to the findings of the first observer. Reliability for the ROM was studied in terms of the intraclass correlation coefficient [2]. Interlaminar bone fusion of lamina was investigated from C2–C3 to C6–C7. Interlaminar bone fusion was evaluated by trabecular bone formation in a lateral radiograph [26].

Factors related to limitations of ADL were statistically analyzed in each movement. Preoperative factors, including gender, age, disease (CSM or OPLL), O–C7 ROM and Japanese Orthopedic Association (JOA) score were analyzed. Postoperative factors, including collar period, O–C7 ROM, decrease rate of O–C7 ROM, rotation ROM, number of interlaminar bone fusions and JOA score were analyzed. Student's t test, Welch's t test, Mann–Whitney's U test, χ^2 test and Fisher's exact probability test were used in the statistical analysis. All P values less than 0.05 were considered statistically significant.

Table 1 ADL index accompanying neck mobility

Movement	ADL
Extension	Gargling
Flexion	Watching one's step when climbing down the stairs or going down a slope
Rotation	Looking right and left when driving a car or crossing the street

ADL activities of daily living

Table 2 Questionnaire on the severity of the limitations of ADL

1. Easy (no limitation)
2. Difficult (mild limitation)
3. Impossible (severe limitation)

ADL activities of daily living

Results

The frequencies and severity of limitations of ADL are shown in Fig. 2. In a comparison of frequency between no limitations and mild/severe limitations, there was a significant difference among the three ADL ($P = 0.001$, χ^2 test). After cervical laminoplasty significantly more patients had limitations of ADL requiring rotation and significantly fewer patients had limitations of ADL requiring flexion.

Results of comparison between no limitations and mild/severe limitations of ADL accompanying extension are shown in Table 3. The average postoperative O–C7 ROM was smaller ($P = 0.0001$) in the presence of mild/severe limitations (36.2°) than of no limitations (48.2°). The average decrease in the rate of O–C7 ROM was larger ($P = 0.005$) in the presence of mild/severe limitations (33.9%) than of no limitations (11.5%).

Results of comparison between no limitations and mild/severe limitations of ADL accompanying flexion are shown in Table 4. Diseases were significantly different ($P = 0.038$) between no limitations and mild/severe limitations. Therefore, significantly more patients with OPLL had limitations of ADL requiring flexion. The average preoperative O–C7 ROM was smaller ($P = 0.001$) in the presence of mild/severe limitations (41.1°) than of no limitations (61.9°).

Results of comparison between no limitations and mild/severe limitations of ADL accompanying rotation are shown in

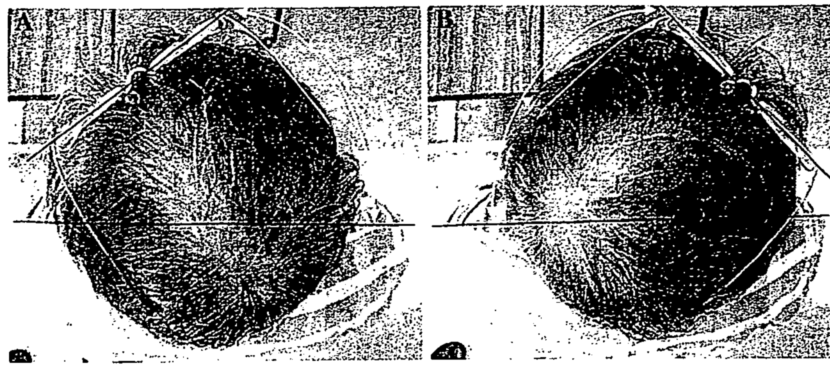

Fig. 1 Measurements of rotation ROM. The lines for measurements were obtained using glasses and the pattern of clothes. **a** Left rotation angle. **b** Right rotation angle. The total of the left and right rotation angles was calculated as rotation ROM

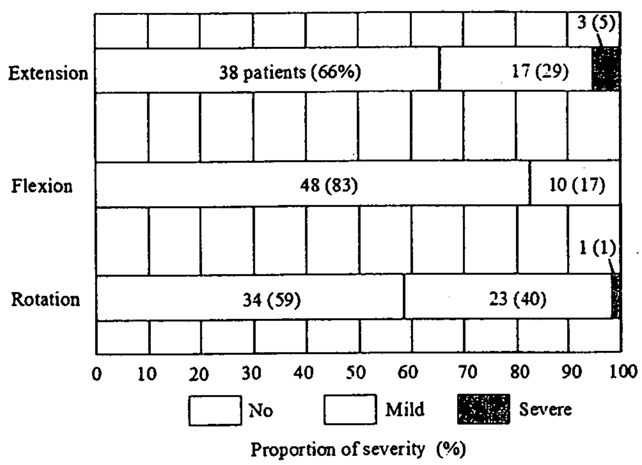

Fig. 2 Frequencies and severity of limitations of ADL accompanying each movement after cervical laminoplasty. Significantly more patients had limitations of ADL accompanying rotation

Table 5. The average postoperative rotation ROM was smaller ($P = 0.0005$) in the presence of mild/severe limitations (76.4°) than of no limitations (95.1°). Average number of interlaminar bone fusions was greater ($P = 0.006$) in the presence of mild/severe limitations (2.1 laminas) than of no limitations (1.1 laminas). Average postoperative JOA score was lower ($P = 0.027$) in the presence of mild/severe limitations (12.0 points) than of no limitations (13.6 points).

The intraclass correlation coefficient for O–C7 ROM and rotation ROM were 0.92 and 0.99, respectively. Good interobserver reliability was observed for the parameters.

Case study

A representative case (Fig. 3): a 73-year-old man with CSM underwent C3–C7 laminoplasty. He had mild limitations of ADL accompanying all movements of extension, flexion and rotation at 8 years and 6 months after surgery. Pre- and postoperative O–C7 ROM were 38° and 11.9°, respectively, and the decrease in the rate of O–C7 ROM was 69%. Postoperative rotation ROM was 41.8°. The number of interlaminar bone fusions was three. Pre- and postoperative JOA score were 1 point and 10.5 points, respectively.

Table 3 Comparison between no limitations and any limitations in extension

Parameter	No limitations	Mild/severe limitations	*P* value
Number of cases	38	20	–
Preoperative factors			
Gender (male:female)	26:12	17:3	ns[d]
Age (years)	60.3 ± 9.4	56.6 ± 12.3	ns
Disease (CSM:OPLL)	23:15	7:13	ns[c]
O–C7 ROM (degree)	59.3 ± 19.5	59.6 ± 19.9	ns
JOA score (points)	10.7 ± 3.2	10.2 ± 4.1	ns
Postoperative factors			
Collar periods (weeks)	2.3 ± 1.2	4.4 ± 2.4	ns[a]
O–C7 ROM (degree)	48.2 ± 10.3	36.2 ± 11.4	0.0001
Decrease rate of O–C7 ROM (%)	11.5 ± 28.8	33.9 ± 27.3	0.005
Number of interlaminar fusions	1.2 ± 0.9	2.1 ± 1.5	ns[b]
JOA score (points)	13.4 ± 2.6	12.2 ± 3.0	ns

Mean ± standard deviation

ns not significant, *CSM* cervical spondylotic myelopathy, *OPLL* ossification of the posterior longitudinal ligament, *ROM* range of motion

Student's *t* test, [a] Welch's *t* test, [b] Mann–Whitney *U* test, [c] Chi-squared test, [d] Fisher's exact probability test

Discussion

Cervical laminoplasty has become a standard technique for compressive myelopathy by CSM or OPLL, and the neurological outcomes over 10 years have been satisfactory [10, 22, 29]. However, several clinical problems after laminoplasty have been reported, including late deterioration of myelopathy symptoms [9, 14, 18, 22], C-5 palsies [4, 15, 16, 19, 29] and axial symptoms [7, 11, 12, 23, 27, 31]. Especially in recent years, a great deal of attention has been paid to axial symptoms as postoperative complications, which adversely affect patients' quality of life. On the other hand, radiological problems after laminoplasty, including

Table 4 Comparison between no limitations and any limitations in flexion

Parameter	No limitations	Mild/severe limitations	*P* value
Number of cases	48	10	–
Preoperative factors			
Gender (male:female)	34:14	9:1	ns[c]
Age (years)	58.9 ± 10.9	56.9 ± 8.9	ns
Disease (CSM: OPLL)	28:20	2:8	0.038[c]
O–C7 ROM (degree)	61.9 ± 18.4	41.1 ± 17.4	0.001
JOA score (points)	10.4 ± 3.3	11.3 ± 4.7	ns
Postoperative factors			
Collar periods (weeks)	2.9 ± 1.9	3.6 ± 2.2	ns
O–C7 ROM (degree)	45.5 ± 10.4	34.7 ± 19.9	ns
Decrease rate of O–C7 ROM (%)	20.0 ± 28.3	11.2 ± 44.0	ns[a]
Number of interlaminar fusions	1.4 ± 1.2	1.9 ± 1.1	ns[b]
JOA score (points)	13.1 ± 2.7	12.1 ± 2.8	ns

Mean ± standard deviation

ns not significant, *CSM* cervical spondylotic myelopathy, *OPLL* ossification of the posterior longitudinal ligament, *ROM* range of motion

Student's *t* test, [a] Welch's *t* test, [b] Mann–Whitney *U* test, [c] Fisher's exact probability test

Table 5 Comparison between no limitations and any limitations in rotation

Parameter	No limitations	Mild/severe limitations	*P* value
Number of cases	34	24	–
Preoperative factors			
Gender (male:female)	25:9	18:6	ns[b]
Age (years)	59.0 ± 10.5	59.2 ± 10.9	ns
Disease (CSM: OPLL)	20:14	10:14	ns[b]
JOA score (points)	10.7 ± 3.3	10.4 ± 3.8	ns
Postoperative factors			
Collar periods (weeks)	2.8 ± 2.0	3.4 ± 1.9	ns
Follow-up (months)	51.1 ± 32.5	57.6 ± 31.3	ns
Rotation ROM (degree)	95.1 ± 15.8	76.4 ± 22.9	0.0005
Number of fused laminas	1.1 ± 0.9	2.1 ± 1.4	0.006[a]
JOA score (points)	13.6 ± 2.8	12.0 ± 2.4	0.027

Mean ± standard deviation

ns not significant, *CSM* cervical spondylotic myelopathy, *OPLL* ossification of the posterior longitudinal ligament, *ROM* range of motion

Student's *t* test, [a] Mann–Whitney *U* test, [b] Chi-squared test

cervical malalignment [5, 8, 14, 20, 24, 25, 28–30] and loss of the flexion–extension ROM have also been reported [1, 6, 13, 14, 21, 22, 28, 30]. Although flexion–extension ROM was reported to be decreased to about half of the preoperative ROM after laminoplasty in many radiological studies, these studies were not patient-based outcomes that reflect the clinical symptoms accompanying difficulty in neck mobility. In the current retrospective study, the authors showed that the frequency, severity and factors related to limitations of ADL varied according to each of the three neck movements, namely, extension, flexion and rotation.

The current study had several limitations. The ADL indexes study might not have determined only ADL accompanying neck mobility after laminoplasty, because there is a possibility that compensation factors like hip and/or body mobility were involved. In addition, changes due to surgery in the severity of the limitations of ADL were unapparent, because preoperative ADL accompanying neck mobility was not examined. To reveal the influence of reduced neck mobility after laminoplasty, a comparative study, including pre- and postoperative ADL, with a group of similarly aged normal subjects may need to be done.

In this study, factors related to the limitations of ADL accompanying extension were small postoperative O–C7 ROM and a large decrease rate of O–C7 ROM. As neither of these factors were relevant to limitations of ADL accompanying flexion, loss of flexion–extension ROM might be greater in extension than in flexion after laminoplasty. On the other hand, the relevant factors for limitations of ADL accompanying flexion were not postoperative ROM, but disease and preoperative ROM. As the average preoperative O–C7 ROM was smaller ($P = 0.0009$, Welch's *t* test) in OPLL (51°) than in CSM (67°) in this study, there is a possibility that the OPLL patients with small preoperative ROM had limitations of ADL accompanying flexion before surgery. On the other hand, one of the factors related to limitations of ADL accompanying rotation was small postoperative rotation ROM. Our present results, which demonstrated that the average postoperative rotation ROM was 76.4° in the group with mild/severe limitations and 95.1° in the group with no limitations, were not inconsistent with the study by Bennett et al. [3], which reported that active ROM utilized to cross the street was 86°, measured for normal subjects using a cervical range of motion device. The large number of interlaminar bone fusions was also one of the factors related to limitations of ADL accompanying rotation. There was a significant negative correlation between the number of interlaminar bone fusions and postoperative rotation ROM ($P = 0.008$, Spearman's correlation coefficient), and there was no significant correlation between the number of interlaminar bone fusions and postoperative O–C7 ROM in this study. Therefore, flexion–extension ROM at the upper cervical spine might increase in compensation for loss of ROM at the middle and lower cervical spine due to interlaminar bone fusions, although rotation ROM might not compensate for interlaminar bone fusions. Although another related factor was low postoperative JOA score, the authors cannot explain the relevance of

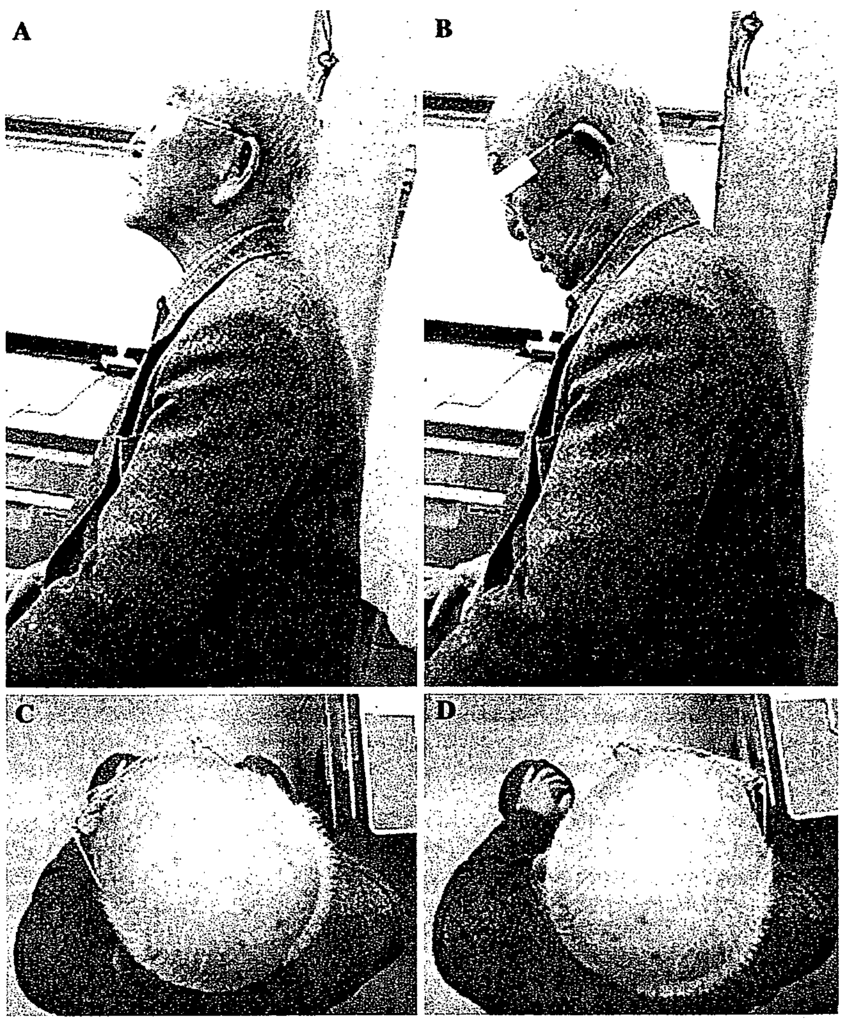

Fig. 3 A 73-year-old man with cervical spondylotic myelopathy underwent C3–C7 laminoplasty. **a** Extension. **b** Flexion. **c** Left rotation. **d** Right rotation

this factor to limitations of ADL accompanying rotation in this study. A detailed study of the spinal cord using such methods as magnetic resonance imaging will be helpful for defining the anatomical relationship between neurological improvement and neck mobility.

The current study focused on the limitation to ADL accompanying reduced mobility after cervical laminoplasty. After cervical laminoplasty, more than a few patients had limitations of ADL accompanying reduced mobility, and the related factors varied according to each of the three cervical movements of extension, flexion and rotation. For revealing the change in ADL after surgery, however, it will be necessary to analyze both pre- and postoperative ADL.

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ORIGINAL ARTICLE

Cervical Range of Motion and Alignment After Laminoplasty Preserving or Reattaching the Semispinalis Cervicis Inserted Into Axis

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Study Design: A radiographic study in 111 patients using radiographs was conducted.

Objective: To clarify whether the modified laminoplasty with C3 laminectomy preserving the semispinalis cervicis (SSC) inserted into C2 could maintain the postopertive range of motion (ROM) and sagittal alignment compared with conventional C3-C7 laminoplasty reattaching the muscle to C2.

Summary of Background Data: Intraoperative injury of the SSC is relevant to the significant loss of ROM and the malalignment after laminoplasty. To expose the C3 lamina, however, the SSC inserted into C2 could not be preserved in conventional C3-C7 laminoplasty.

Methods: The ROM and sagittal alignment of 70 patients (group A) (52 men, 18 women, mean age 59 y, mean follow-up period 1 y and 7 mo) with C4-C7 laminoplasty with C3 laminectomy were compared with those of 41 patients (group B) (28 men, 13 women, mean age 59 y, mean follow-up period 2 y and 6 mo) with C3-C7 laminoplasty using radiographs of the cervical spine.

Results: Regarding C2-C7 ROM, the postoperative ROM was larger ($P = 0.003$) and the decrease rate of ROM was smaller ($P = 0.0006$), and decreased ROM in extension was smaller ($P < 0.0001$) in group A. Regarding O-C2 ROM, the increased ROM was smaller ($P = 0.043$) and increased ROM in extension was smaller ($P = 0.001$) in group A. Regarding O-C7 ROM, the postoperative ROM was larger ($P = 0.029$) in group A. Regarding the cervical alignment, the increased lordotic angle at O-C2 was smaller ($P = 0.046$) in group A.

Conclusions: This modified laminoplasty preserving the SSC inserted into C2 is an effective procedure for maintaining postoperative ROM, especially in extension, and sagittal alignment of the upper cervical spine well.

Key Words: cervical laminoplasty, range of motion (ROM), alignment, cervical myelopathy, semispinalis cervicis muscle

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In recent years, the long-term results over 10 years for cervical spondylotic myelopathy (CSM) or ossification of the posterior longitudinal ligament (OPLL) after cervical laminoplasty have been reported, and the neurologic outcomes have been satisfactory.[1–3] As one of the problems after laminoplasty, however, many studies have reported that the flexion-extension range of motion (ROM) was significantly decreased after laminoplasty.[1,2,4–10] In our institutions, the flexion-extension ROM was decreased to about half of preoperative ROM after conventional C3-C7 laminoplasty reattaching the semispinalis cervicis (SSC) to C2. It has also been reported that the normal cervical alignment was often lost after laminoplasty,[11–15] and that postoperative nonrepair of the SSC inserted into C2 was correlated with significant loss of cervical lordosis.[13]

The SSC, most of which inserts into the C2 spinous process,[16] acts as a dynamic stabilizer[16,17] and as an extensor of the cervical spine.[18,19] Therefore, the SSC inserted into C2 might be closely related to ROM and alignment after cervical laminoplasty. In conventional C3-C7 laminoplasty, however, it is very difficult to preserve the SSC insertion into C2 while opening the C3 lamina. Therefore, the SSC insertion in C2 has been transiently detached from the C2 spinous process, and then repaired to the C2 spinous process at the time of wound closure.[13,20] From 2001, therefore, the authors changed the laminoplastic procedure from C3-C7 laminoplasty to C4-C7 laminoplasty with C3 laminectomy for complete preservation of the SSC inserted in C2.[21] The purpose of this study was to clarify whether this modified laminoplasty preserving the SSC insertion into C2 could maintain the postoperative ROM and cervical alignment compared with C3-C7 laminoplasty reattaching the SSC to C2.

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MATERIALS AND METHODS

Subjects (Group A)

The population consisted of 70 patients with cervical myelopathy who underwent C4-C7 laminoplasty with C3 laminectomy, between 2001 and 2003, with a minimum follow-up period of radiologic evaluation of 1 year. These 70 patients (group A) were the subjects of the study. Average age was 59.2 ± 11.5 years (range, 26 to 86 y) at the time of surgery. There were 52 men and 18 women. CSM was clinically evident in 48 cases and OPLL was present in 22 cases. Average Japanese Orthopedic Association (JOA) score was 11.7 ± 3.2 before surgery, and 13.8 ± 3.0 at the latest follow-up visit. The average follow-up period was 19.4 ± 6.0 months (range, 12 to 32 mo).

Controls (Group B)

Since 1987, C3-C7 double-door laminoplasty using hydroxyapatite spinous process spacers has been performed for cervical myelopathy in our institutions[22] with the postoperative collar period varying from 4 to 12 weeks. From 1997, the collar period was shortened to less than 2 weeks, which was nearly the same as the collar period in group A. The population consisted of 41 patients with cervical myelopathy who underwent C3-C7 laminoplasty with postoperative collar period less than 2 weeks, between 1997 and 2001, with a minimum follow-up period of radiologic evaluation of 1 year. These 41 patients (group B) were the controls of the study. The average age was 58.9 ± 11.0 years (range, 33 to 76 y) at the time of surgery. There were 28 men and 13 women. Patients demonstrated CSM in 29 cases and OPLL in 12 cases. There were no significant differences in age, sex distribution or the cause of myelopathy between these 2 groups. Average JOA score was 10.0 ± 3.8 before surgery, and 13.1 ± 2.9 at the latest follow-up visit. The average follow-up period was 29.9 ± 11.6 months (range, 12 to 67 mo); it was significantly longer ($P < 0.0001$) than that of group A.

Operative Technique and Postoperative Management

During the surgical procedure in group A, laminectomy was performed at C3 and the SSC insertion in C2 was preserved completely. Laminoplastic procedure was performed at C4-C7. In group B, the SSC insertion in C2 was transiently detached from the C2 spinous process, and then reattached to the C2 spinous process at the time of wound closure, and laminoplastic procedure was performed at C3-C7. In both groups, the laminoplastic procedure was adapted from the spinous process-splitting laminoplasty using hydroxyapatite spinous process spacers (double-door type) reported by Nakano et al,[22] and the spinous processes were split using a thread-wire saw.[9] The postoperative collar period was for 1 to 2 weeks in both groups. As postoperative management in both groups, the patients were permitted to sit up or walk within 1 week after operation and the postoperative exercise was started at 1 to 2 weeks after operation.

Radiologic Evaluation

The ROM at O-C2, C2-C7, and O-C7 was measured on lateral flexion and extension radiographs of the cervical spine. The O-C2 ROM was measured using McGregor line[23] and the posterior tangent of the odontoid process. The C2-C7 ROM was measured using the posterior tangents of the odontoid process and the C7 vertebral body. The ROM at O-C7 was measured using McGregor line and the posterior tangents of the C7 vertebral body. The decrease rate of each ROM was calculated using the following formula: decrease rate (%) = (1 − postoperative ROM/preoperative ROM) × 100. The decreased ROM at C2-C7 in each of the movements of flexion and extension at the final follow-up was calculated using the following formula: decreased ROM (degree) in flexion (or extension) = preoperative angle in flexion (or extension) − postoperative angle in flexion (or extension). The increased ROM at O-C2 in each of the movements of flexion and extension at the time of final follow-up was calculated using the following formula: increased ROM (degree) in flexion (or extension) = postoperative angle in flexion (or extension) − preoperative angle in flexion (or extension). Sagittal alignment at O-C2 and C2-C7 was also measured on lateral radiograph in neutral view. The O-C2 angle was measured as an angle between McGregor line and the line formed by the inferior border of the vertebral body of C2. Lordotic angle at C2-C7 was derived from the posterior tangents of the odontoid process and the C7 vertebral body. The increased angle of lordotic angle at O-C2 and C2-C7 at the final follow-up was calculated using the following formula: increased lordotic angle (degree) = postoperative angle − preoperative angle. All the radiographs were scanned on a computer (Windows; VAIO Computer, Sony Corp., Tokyo, Japan), and were measured using CANVAS 8 accurate to 0.1 degree (Deneba System, Inc, Arlington). The measurements of ROM and sagittal alignment were done by 2 observers and interobserver reliability was calculated. The second observer was blinded as to the findings of the first observer. Reliability was studied in terms of the intraclass correlation coefficient.[24]

The ROM and sagittal alignment were analyzed using t test. The relations between follow-up period and ROM and sagittal alignment measurement were also statistically analyzed using the Spearman rank correlation test. All P values less than 0.05 were considered statistically significant.

RESULTS

ROM

Results of measurements of C2-C7 ROM are shown in Table 1. Average postoperative C2-C7 ROM was larger ($P = 0.003$) in group A (27 degrees) than in group B (20 degrees), and the average decrease rate of C2-C7 ROM was smaller ($P = 0.0006$) in group A (19%) than in group B (47%). Decreased ROM in extension was smaller

TABLE 1. Comparison of ROM at C2-C7 Between Groups A and B

	Group A	Group B	P
Preoperative (degree)	38.9 ± 15.8	42.1 ± 15.2	n.s.
Postoperative (degree)	26.9 ± 12.6	20.0 ± 10.3	0.003
Decrease rate (%)	19.2 ± 54.6	47.4 ± 30.5	0.0006*
Decreased ROM			
Flexion (degree)	10.5 ± 10.3	11.9 ± 12.7	n.s.
Extension (degree)	1.4 ± 7.6	10.2 ± 10.7	< 0.0001

*Welch *t* test.
Mean ± standard deviation.
n.s. indicates not significant.
Student *t* test.

($P < 0.0001$) in group A (1 degree) than in group B (10 degrees). Results of measurements of O-C2 ROM are shown in Table 2. Average increase rate of O-C2 ROM was smaller ($P = 0.043$) in group A (31%) than in group B (67%). Increased ROM in extension was smaller ($P = 0.001$) in group A (1 degree) than in group B (6 degrees). Results of measurements of O-C7 ROM are shown in Table 3. Average postoperative O-C7 ROM was larger ($P = 0.029$) in group A (51 degrees) than in group B (46 degrees). On the other hand, there was no correlation between follow-up period and preoperative and postoperative ROM at C2-C7, O-C2, and O-C7. There was a statistical trend at longer follow-up periods toward larger decreased rate of C2-C7 ROM ($P = 0.051$), although the correlation was not statistically significant. There was no correlation between follow-up period and decreased rate of O-C7 ROM. The intraclass correlation coefficient for measurements of ROM at C2-C7, O-C2, and O-C7 were 0.97, 0.99, and 0.97, respectively. Good interobserver reliabilities were observed for the parameters.

Sagittal Alignment

Results of measurements of sagittal alignment at C2-C7 are shown in Table 4. Average preoperative and postoperative alignments, and the increased lordotic angle were similar in groups A and B. Results of measurements of sagittal alignment at O-C2 are shown in Table 5. Increased lordotic angle at O-C2 was smaller

TABLE 2. Comparison of ROM at O-C2 Between Groups A and B

	Group A	Group B	P
Preoperative (degree)	21.4 ± 7.5	19.0 ± 7.3	n.s.
Postoperative (degree)	24.4 ± 7.1	25.9 ± 7.5	n.s.
Increase rate (%)	30.7 ± 83.8	67.4 ± 102.6	0.043
Increased ROM			
Flexion (degree)	2.2 ± 4.6	1.2 ± 3.3	n.s.*
Extension (degree)	0.7 ± 6.1	5.7 ± 8.7	0.001*

*Welch *t* test.
Mean ± standard deviation.
n.s. indicates not significant.
Student *t* test.

TABLE 3. Comparison of ROM at O-C7 Between Groups A and B

	Group A	Group B	P
Preoperative (degree)	60.4 ± 17.4	61.2 ± 17.4	n.s.
Postoperative (degree)	51.4 ± 13.1	46.0 ± 10.9	0.029
Decrease rate (%)	9.2 ± 30.8	17.7 ± 31.8	n.s.

Mean ± standard deviation.
n.s. indicates not significant.
Student *t* test.

($P = 0.047$) in group A (0 degree) than in group B (2 degrees). On the other hand, there was no correlation between follow-up period and preoperative and postoperative cervical alignment at C2-C7 and O-C2. The intraclass correlation coefficient for measurements of C2-C7 alignment and O-C2 angle were 0.98 and 0.99, respectively. Good interobserver reliabilities were observed for the parameters.

Case Study

A Representative Case in Group A

A 68-year-old man with CSM underwent C4-C7 laminoplasty with C3 laminectomy and had postoperative evaluation at 18 months after surgery (Fig. 1). Preoperative and postoperative C2-C7 ROM was 42 and 36 degrees, respectively, and the decrease rate was 15%. Preoperative and postoperative O-C2 ROM was 19 and 18 degrees, respectively. Preoperative and postoperative O-C7 ROM was 61 and 54 degrees, respectively, and the decrease rate was 12%. Preoperative and postoperative alignment at C2-C7 was 22 and 35 degrees, respectively. Both the preoperative and postoperative O-C2 angle was 8 degrees. JOA score was 7 before surgery, and 14 after surgery.

DISCUSSION

Recently, the long-term results over 10 years for cervical myelopathy after laminoplasty have been reported[1–3] and the neurologic improvement has been as satisfactory as the outcome from anterior cervical fusion. However, some postoperative problems after laminoplasty have been reported, including significant loss of ROM[1,2,4–10] and cervical malalignment.[11–15] During

TABLE 4. Comparison of Sagittal Alignment at C2-C7 Between Groups A and B

	Group A	Group B	P
Preoperative (degree)	19.9 ± 14.4	19.1 ± 11.1	n.s.
Postoperative (degree)	22.8 ± 12.4	19.9 ± 11.6	n.s.
Increased lordotic angle (degree)	2.9 ± 9.9	0.7 ± 11.4	n.s.

Mean ± standard deviation.
n.s. indicates not significant.
Student *t* test.

TABLE 5. Comparison of Sagittal Alignment at O-C2 Between Groups A and B

	Group A	Group B	P
Preoperative (degree)	16.2 ± 8.8	12.9 ± 8.2	n.s.
Postoperative (degree)	15.9 ± 7.9	14.4 ± 8.1	n.s.
Increased lordotic angle (degree)	− 0.3 ± 4.9	1.5 ± 3.9	0.047

Mean ± standard deviation.
n.s. indicates not significant.
Student *t* test.

conventional C3-C7 laminoplasty, the SSC needs to be cut at its attachment point on the C2 spinous process to expose the C3 lamina completely. Conley et al,[18] in analyzing the cross-sectional areas and signal intensity of the cervical posterior muscles after neck motion using magnetic resonance imaging (MRI), reported that the SSC acts as an extensor of the cervical spine. Vasabada et al[19] reported in a 3-dimensional biomechanical study that most of the extension-moment-generating capacity comes from the SSC. On the other hand, Nolan and Sherk[16] reported that the SSC acts as a dynamic stabilizer, and that laminectomy involving the axis resulted in the loss of normal cervical alignment. Iizuka et al,[13] evaluating prospectively the morphology of the extensor musculature after laminoplasty using the coronal view of MRI, reported that morphologic repair of SSC had not been maintained in 18% of patients in whom the SSC insertion into C2 had been repaired, and that the degree of SSC repair affected postoperative cervical alignment. The current authors considered that the SSC insertion at C2 should be preserved during laminoplasty for preservation of postoperative ROM and cervical alignment.

Many authors have reported that preoperative ROM was significantly decreased after cervical laminoplasty, although there were few reports about the procedure for preservation of postoperative ROM. Iizuka et al[15] reported that the ROM after laminoplasty was better maintained, especially in extension, in patients who wore the cervical collar for 4 weeks rather than for 8 weeks. They speculated that early removal of the cervical collar prevents contracture of the facet joint and postoperative atrophy and dysfunction of the extensor musculature of the cervical spine. In the current study, the collar periods were less than 2 weeks and postoperative managements were the same between the 2 groups, therefore, preservation of the SSC inserted into C2 could prevent the loss of the extension in C2-C7 ROM after laminoplasty. Also, this modified laminoplasty could reduce the postoperative increased extension ROM at O-C2, which might occur as a compensatory change for loss of ROM at the middle and lower cervical spine. Yokoyama et al,[25] in analyzing 50 patients after laminoplasty using MRI, reported that the narrowing of dura diameter at C1 occurred after surgery, and was significantly correlated with small postoperative C2-C7 ROM. In cervical laminoplasty, in other words, it is important that postoperative C2-C7 ROM is maintained well. After this modified laminoplasty preserving the SSC insertion in C2, the whole cervical ROM at O-C7 was also maintained well without the compensatory change of O-C2 ROM. Therefore, this procedure was effective in maintaining postoperative C2-C7 and O-C7 ROM and preventing compensation of O-C2 ROM.

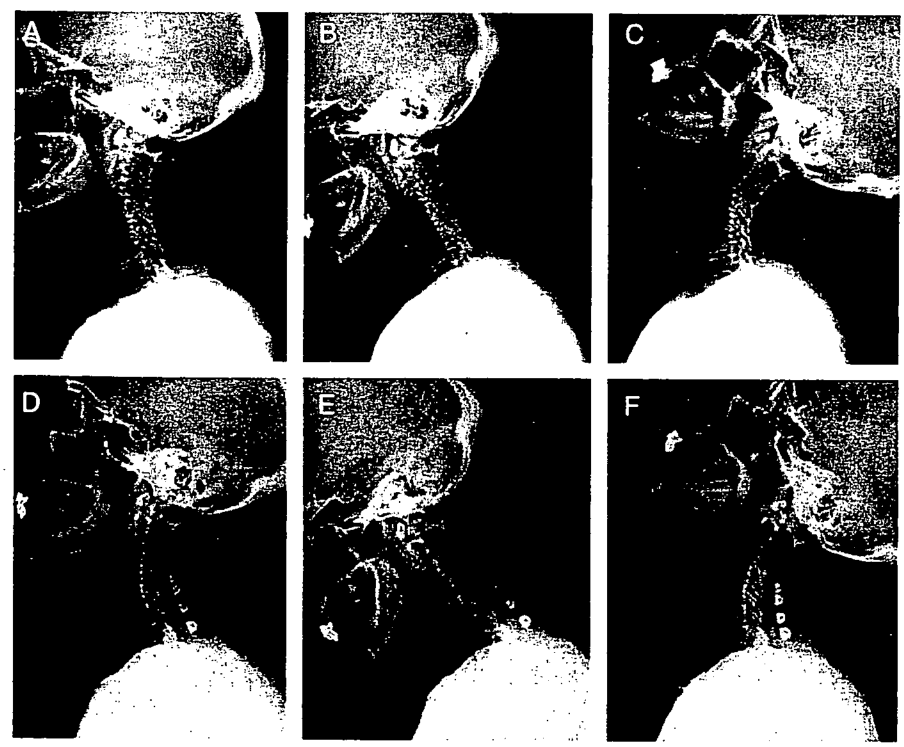

FIGURE 1. A 68-year-old man with CSM. Postoperative cervical alignment and ROM were maintained. A, Cervical alignment before surgery. B, Flexion before surgery. C, Extension before surgery. D, Cervical alignment 18 months after surgery. E, Flexion 18 months after surgery. F, Extension 18 months after surgery.

In the current study, although there was a statistical trend at longer follow-up periods toward larger decreased rate of C2-C7 ROM, the relation between follow-up period and decreased rate of C2-C7 was not statistically significant. Kimura et al,[8] evaluating the long-term results over 5 years of 29 patients after cervical laminoplasty, reported that the decreased rate of ROM was approximately 40% at the short-term follow-up (6 to 12 mo) and it remained unchanged at the long-term follow-up (5 to 14 y). Kawaguchi et al,[3] evaluating the long-term results over 10 years of 126 patients after laminoplasty, also reported that the ROM decreased rapidly 1 year after surgery and the subsequent ROM was almost unchangeably maintained. Therefore, significance might not have been reached in our study, because the minimum follow-up period was 1 year.

Loss of normal cervical alignment has been reported to occur often after laminoplasty. Some authors reported about the relationship between cervical malalignment and cervical posterior muscles, especially the deep muscles, after laminoplasty. Fujimura and Nishi,[11] evaluating 53 patients after expansive open-door laminoplasty using computed tomography images, reported that there was correlation between the deep muscles area and the curve index, and that a marked decrease in the curve index occurred in many cases in which the deep nuchal muscle area decreased to 60% or less of the preoperative size. Sasai et al,[12] analyzing 31 patients after laminoplasty, reported that lordotic alignment at C2-C3 and C6-C7 before surgery significantly decreased in 84% and 81% of patients, respectively, and that loss of lordotic alignment at C2-C3 was largely attributed to detachment of SSC on C2. Iizuka et al,[13] evaluating prospectively the morphology of the SSC of 22 patients after laminoplasty using coronal view of MRI, reported that postoperative nonrepair of the SSC inserting into C2 was relevant to significant loss of cervical lordosis. In the current study, preoperative and postoperative C2-C7 alignment, and postoperative increased lordotic angle at C2-C7 were similar between the 2 groups. Maeda et al,[26] evaluating the cervical ROM and alignment of 30 patients after expansive laminoplasty, reported that early removal of cervical orthosis and early postoperative rehabilitation was important for preservation of postoperative cervical lordosis. As the collar periods were less than 2 weeks and postoperative exercise was begun early in both groups in the current study, postoperative C2-C7 alignment could be maintained well in both groups. On the other hand, O-C2 angle underwent only minimal changes after this modified laminoplasty preserving the SSC, but was slightly increased after C3-C7 laminoplasty reattaching the SSC. Preservation of the SSC insertion into C2 might reduce the compensatory change of alignment at O-C2 after laminoplasty.

In conclusion, this modified laminoplasty preserving the SSC inserted into C2 maintained the postoperative ROM, especially in extension, and compared well with C3-C7 laminoplasty. The C2-C7 alignment was maintained well after laminoplasty both with and without preservation of the SSC, but compensation of O-C2 angle was smaller after this modified laminoplasty than after C3-C7 laminoplasty.

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