



Technical notes & surgical techniques

Clinical and radiological outcomes of C3–C6 laminoplasty with C7 dome-like laminectomy[☆]



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ABSTRACT

Objective: The purpose of this study was to compare the surgical outcomes of C3–C6 laminoplasty and C3–C6 laminoplasty with C7 dome-like laminectomy for the treatment of patients with stenosis at the C6–7 level.

Methods: Forty-nine patients who underwent C3–C6 laminoplasty and 39 patients who underwent C7 dome-like laminectomy were selected based on strict criteria, including the presence of stenosis grade 2 at the C6–7 level preoperatively. The clinical and radiologic outcomes were compared at admission and at 1 and 2 years post-operatively.

Results: The baseline clinical characteristics did not differ significantly between the two groups. The Japanese Orthopedic Association score improved more significantly in the C7 dome-like laminectomy group ($p = 0.01$). There was no significant difference in neck pain between the two groups ($p = 0.15$). The spinal cord diameter at the C6–7 level was significantly increased in the dome-like laminectomy group ($p = 0.01$). There were no significant differences in the cross-sectional area of the paraspinal muscles, the cervical lordotic angle between C2–C7 and the cervical range of motion between the two groups ($p = 0.33, 0.46, \text{ and } 0.41$, respectively). Neurological deterioration was not observed in C7 dome-like laminectomy group while 4 patients developed neurological deterioration in C3–C6 laminoplasty group.

Conclusions: C7 dome-like laminectomy can be a surgical option for patients with stenosis grade 2 at the C6–7 level. It is possible to obtain adequate spinal cord decompression while obtaining good clinical and radiologic outcomes.

1. Introduction

Cervical laminoplasty is one of the standard treatments for cervical spondylotic myelopathy (CSM) or ossification of the posterior longitudinal ligaments (OPLL) and is reported to produce stable, long-term neurological improvements with benefits that last > 10 years [1–3].

C3–C6 laminoplasty is mainly chosen because the rate of post-operative axial symptoms is decreased compared with C3–C7 laminoplasty [4]. Major concerns regarding C3–C6 laminoplasty are whether myelopathic symptoms can be improved and maintained if patients have stenosis at the C6–7 level preoperatively. Inadequate opening of the lamina after laminoplasty is important an reason for needing

revision surgery [5].

We performed C3–C6 laminoplasty with C7 dome-like laminectomy (C7 dome laminoplasty) if stenosis was present at the caudal level. This modified cervical laminoplasty was designed to increase spinal cord decompression and preserve the integrity of the posterior supporting tissue. The present study was performed to compare the clinical and radiologic outcomes after C3–C6 laminoplasty group and C7 dome laminoplasty group for the treatment of patients with stenosis at the C6–7 level.

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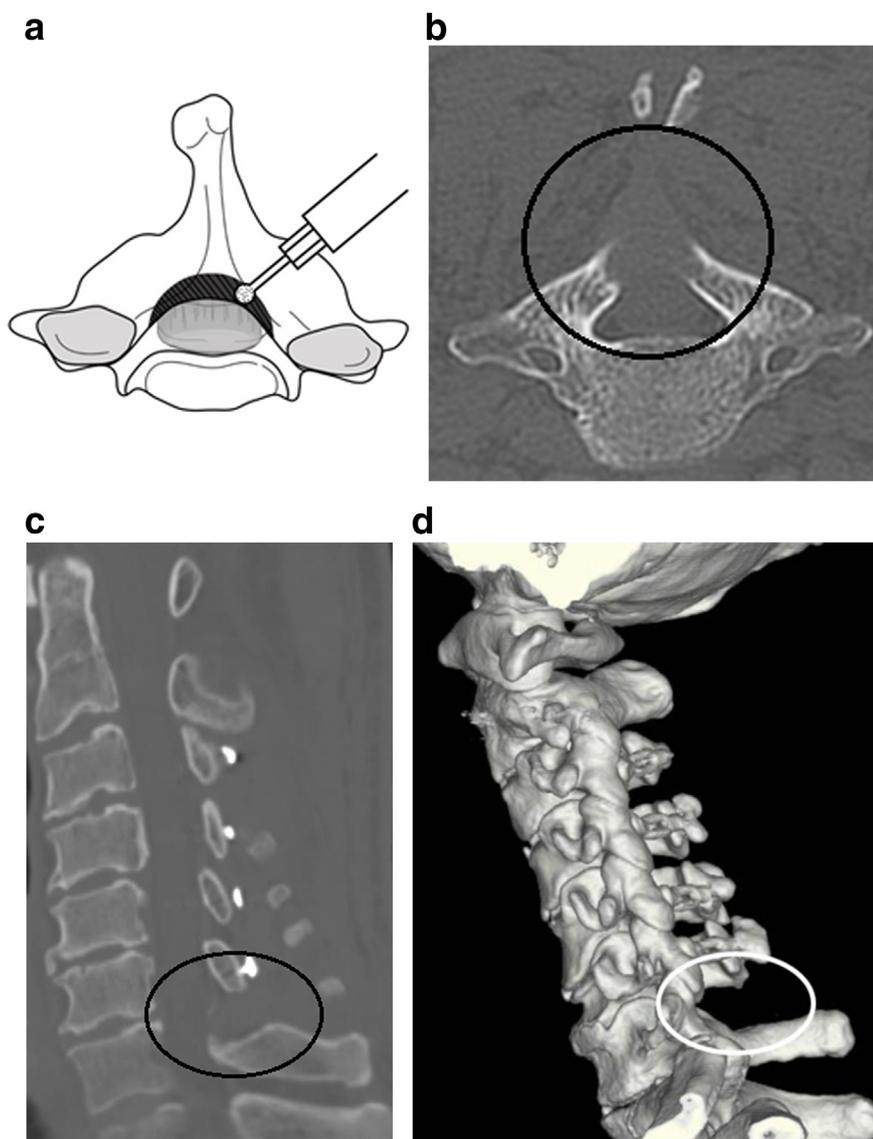


Fig. 1. C7 dome-like laminectomy. A: Dome-like grooves are drilled with a cutting burr at the C7 cephalad side. B, C: Postoperative computed tomography showing decompression of the central canal in the axial and sagittal views (black circle). D: Postoperative 3-D computed tomography.

2. Methods

Between February 2004 and November 2015, we treated 232 patients with CSM or OPLL with C3–C6 laminoplasty. The selection criterion for this study was the presence stenosis grade 2 at C6–7 level [6]. Until June 2013, C3–C6 laminoplasty was performed for patients with stenosis grade 2 at the caudal level. But, after July 2013, additional C7 dome laminoplasty was performed. Patients were excluded if they had undergone previous cervical spine surgery or had undergone surgery for trauma or other neurologic disease. One hundred eleven patients had stenosis grade 2 at the C6–7 level preoperatively. Of these patients, 4 patients with previous cervical spine surgery, 3 patients with acute trauma and 2 patient with other neurologic disease (1 brain tumor and 1 head trauma) were excluded. Among the remaining 102 patients, 88 patients with a follow-up period of at least 2 years were included in the present analysis, including 49 in the C3–C6 laminoplasty group and 39 in the C7 dome laminoplasty group. The present study was approved by the Institutional Review Board of the hospital (H-1609-097-793).

2.1. Operative technique

The surgical procedure (C3–C6 laminoplasty) was performed as previously described [7]. C7 dome laminoplasty was performed on the cephalad surface of the posterior arch. The dome laminoplasty carried out after detachment of only a part of posterior musculature. The burr was advanced approximately 1 cm toward the lower level, with drilling out in a semicircular fashion until the yellow ligaments appeared (Fig. 1).

2.2. Clinical evaluation

Neurological findings were evaluated using the Japanese Orthopedic Association (JOA, 17 points) myelopathy score. Neck pain was quantified using a visual analog scale (VAS). Assessments were made before surgery and at the 2-year follow-up.

2.3. Radiologic evaluation

All patients underwent preoperative plain dynamic cervical radiography, computed tomography (CT), and magnetic resonance imaging

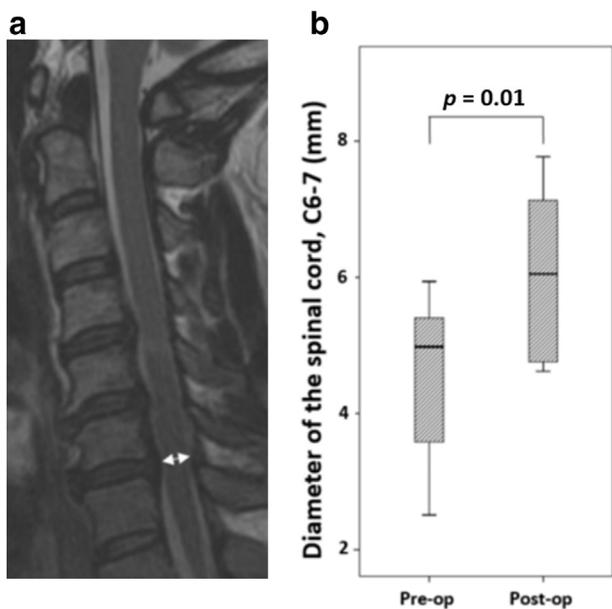


Fig. 2. A: Measurement of the spinal cord diameter on sagittal T2-weighted MRI (white double arrow). B: The spinal cord diameter at the C6–7 level was significantly increased after C7 dome-like laminectomy.

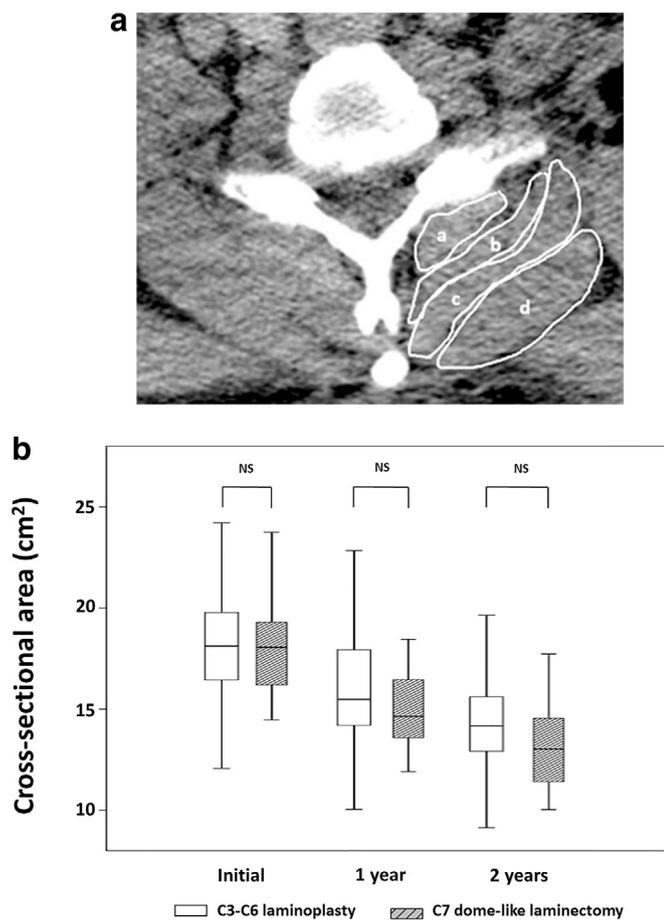


Fig. 3. A: The cross-sectional area of the paraspinal muscles at the C6–7 level, including the multifidus (a), semispinalis cervicis (b), semispinalis capitis (c) and splenius capitis (d), were measured via axial computed tomography. B: The change in the cross-sectional area of the paraspinal muscles at the C6–7 level. C7 laminoplasty indicates C3–C6 laminoplasty with C7 dome-like laminectomy.

(MRI) of the cervical spine. The spinal cord diameter at the C6–7 level was measured on sagittal T2-weighted MRI using picture archiving and communication system software (INFINITT PACS, INFINITT Healthcare, Seoul, Korea) (Fig. 2A). The cross-sectional area of the paraspinal muscle at the C6–7 level was measured by CT scanning (Fig. 3A). Cervical lordosis was measured as the C2–C7 angle, which was formed by two lines drawn parallel to the posterior margin of the C2 and C7 vertebral bodies on a radiograph in the neutral position (Fig. 4A). The range of motion (ROM) of the cervical spine was calculated by subtracting the maximal flexion angle from the maximal extension angle, which were obtained from the extension-flexion radiographs (Fig. 5A and B).

2.4. Statistical analyses

The statistical analyses were performed using the Student's *t*-test or Mann-Whitney *U* test for the continuous variables and the chi-square test for the categorical variables. The paired *t*-test and Wilcoxon signed-rank test were used to compare the JOA score and neck pain prior to surgery and at the 1- and 2-year follow-up. Repeated-measures analysis of variance was used to compare the cross-sectional area of the paraspinal muscles at the C6–7 level, the lordotic angle between C2–C7 and the cervical ROM prior to surgery and at the 1- and 2-year follow-up. A two-sided *p*-value of < 0.05 was considered significant. The SPSS statistical software package version 21.0 (IBM Corporation, New York, NY, USA) for Windows was used for the statistical analyses.

3. Results

The two groups did not differ significantly in baseline clinical characteristics, including mean age, sex, diagnosis and duration of symptoms (Table 1). In the C3–C6 laminoplasty group, the mean JOA scores were 9.7 ± 1.2 preoperatively and 13.0 ± 1.4 at the 2-year follow-up (Table 2). In the C7 dome laminoplasty group, the mean JOA scores were 9.7 ± 0.9 and 13.6 ± 1.0 at preoperatively and at the 2-year follow-up, respectively. There were significant overall changes in the JOA scores in both groups over time, but the changes were more significant in the C7 dome laminoplasty group ($p = 0.01$). Preoperatively, no significant intergroup differences were found in terms of preoperative neck pain (VAS, 3.0 ± 1.3 vs. 2.8 ± 0.8). After surgery, neck pain in both groups at the 2-year follow-up was slightly worse than that preoperatively (3.4 ± 1.2 vs. 3.8 ± 1.3). Neck pain was worse in the C7 dome laminoplasty group, although this result was not statistically significant ($p = 0.15$).

With regard to the radiologic outcomes, the spinal cord diameter at the C6–7 level was increased from 4.5 ± 1.3 mm to 6.0 ± 1.3 mm in the C7 dome-like laminectomy group ($p = 0.01$; Fig. 2B). The initial cross-sectional area of the paraspinal muscles at the C6–7 level was lower in the C7 dome laminoplasty group (17.9 ± 2.3 cm²) than in the C3–C6 laminoplasty group (18.5 ± 2.8 cm²; Fig. 3B). The difference between the two groups was not significant ($p = 0.35$). The cross-sectional area of the paraspinal muscles at the C6–7 level was lower at the 1-year follow-up in the C7 dome laminoplasty group (15.1 ± 2.4 cm²) than in the C3–C6 laminoplasty group (18.1 ± 2.9 cm²), with a similar finding at the 2-year follow-up (C7 dome laminoplasty group, 13.2 ± 2.1 cm² vs. the C3–C6 laminoplasty group, 14.3 ± 2.6 cm²). Overall, the cross-sectional area of the paraspinal muscles at the C6–7 level was decreased in both groups over time, but the difference between the two groups was not significant for either the 1- or 2-year follow-up measurements ($p = 0.14$ and 0.09 , respectively, for the between-group comparisons). The lordotic angle between C2–C7 declined from 13.1 ± 2.4 preoperatively to 11.6 ± 2.4 degrees at the 1-year follow-up and 9.6 ± 2.7 degrees at the 2-year follow-up in the C3–C6 laminoplasty group, whereas in the C7 dome laminoplasty group, it declined from 12.9 ± 2.8 preoperatively to 10.8 ± 3.1 degrees at the 1 year follow-up and 9.0 ± 2.5 degrees at the 2-year follow-up,

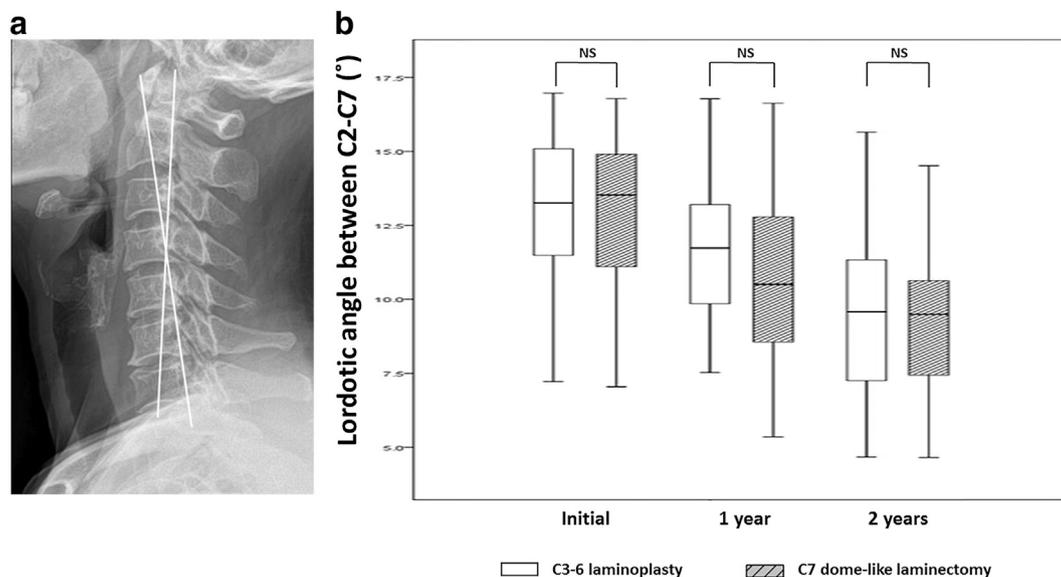


Fig. 4. A: The lordotic angle between C2–C7. B: The change in the lordotic angle between C2–C7. C7 laminoplasty indicates C3–C6 laminoplasty with C7 dome-like laminectomy.

although these differences were not statistically significant ($p = 0.74, 0.17,$ and $0.34,$ respectively, for the between-group comparisons; Fig. 4B). Cervical ROM in the C3–C6 laminoplasty group declined from 28.0 ± 2.8 preoperatively to 25.3 ± 2.2 degrees at the 1-year follow-up and 22.3 ± 2.3 degrees at the 2-year follow-up, whereas in the C7 dome laminoplasty group, it declined from 28.9 ± 4.0 preoperatively to 24.9 ± 3.5 degrees at the 1-year follow-up and $22.6 \pm 2.4^\circ$ at the 2-year follow-up; however, these results were not statistically significant ($p = 0.26, 0.65,$ and $0.68,$ respectively, for the between-group comparisons; Fig. 5C).

Four patients developed late neurological deterioration of myelopathic symptoms due to caudal segment pathology after C3–C6 laminoplasty. However, late neurological deterioration of myelopathic symptoms was not observed in any of the patients after C7 dome laminoplasty.

4. Discussion

4.1. Summary of results

The purpose of the present study was to compare the surgical outcomes of C3–C6 laminoplasty and C3–C6 laminoplasty with C7 dome-like laminectomy (C7 dome laminoplasty) for the treatment of patients with stenosis at the C6–7 level. C7 dome laminoplasty can be a surgical option for patients with stenosis grade 2 at the C6–7 level. The overall clinical outcome after C7 dome laminoplasty was excellent with good radiologic outcomes, including preservation of the preoperative cross-sectional area of the paraspinal muscles, cervical lordosis and maintenance of cervical ROM.

4.2. C3–C6 laminoplasty and C3–C7 laminoplasty

In laminoplasty for cervical myelopathy, C3–C6 laminoplasty is performed more frequently than C3–C7 laminoplasty for several reasons. First, an extensive amount of time is required to make gutters at C7, which has the largest lamina in the subaxial cervical spine. The lamina index (height \times thickness) is 3 times larger at C7 than at C5 [8]. Second, although the difference was not statistically significant, the frequency of axial symptoms was lower after C3–C6 laminoplasty than after C3–C7 laminoplasty. An anatomical study investigating the cervical connective tissue of human nuchal ligaments in cadavers using

microscopy showed that the preservation of the C7 spinous process could reduce pain [4]. Third, it is well known that preserving the C2 and C7 posterior anatomic integrity of the muscle and ligamentous structure is the key factor for maintaining stability in posterior cervical spine surgery [9–12]. Thus, preserving the C2 and C7 structure is important to prevent the development of axial pain and kyphotic deformity. The long-term (8 to 10 years) neurologic outcomes of C3–C6 laminoplasty preserving muscles attached to the C2 and C7 spinous processes are satisfactory, with reduced frequencies of postoperative axial neck pain and kyphotic deformity [13].

There are two main concerns about C3–C6 laminoplasty: Is the ventral compression of the spinal cord fully released, allowing maximum neurological recovery? Is the operative gain maintained throughout the remaining life of the patient? The reasons for the recurrence of symptoms after laminoplasty fall into three categories: technique-related, inadequate treatment, and disease progression [14]. Technique-related issues, including C5 motor paresis, hematoma, dislocation of grafted bone, lamina closure and hinge fracture, are beyond the scope of this study. Coexistent foraminal stenosis and marked ventral compression due to osteophytes, disc abnormalities, and cervical kyphosis may contribute to inadequate treatment [14,15]. Few previous reports have described adjacent canal stenosis after laminoplasty [16–18]. The authors suggest that adjacent canal stenosis is caused by biomechanical changes that can be attributed to elevation of the lamina. Considering these points, we performed C7 dome laminoplasty if stenosis was present at the caudal level.

4.3. C3–C6 laminoplasty with C7 dome-like laminectomy (C7 dome laminoplasty)

Additional C7 dome laminoplasty implies more decompression, which may lead to more improvement of the JOA score. Concern was that neck pain would be worse because of muscle dissection for C7 dome laminoplasty. However, there was no statistically significant difference when compared with the C3–C6 laminoplasty group ($p = 0.15$). This was probably due to the fact that muscles and connective tissue of nuchal ligaments were preserved, as shown in Fig. 3.

The lordotic angle and cervical ROM of the C7 dome laminoplasty group were well maintained without statistically significant differences when compared to the C3–C6 laminoplasty group, as shown in Figs. 4 and 5. Preservation the C7 structure would have made it possible to

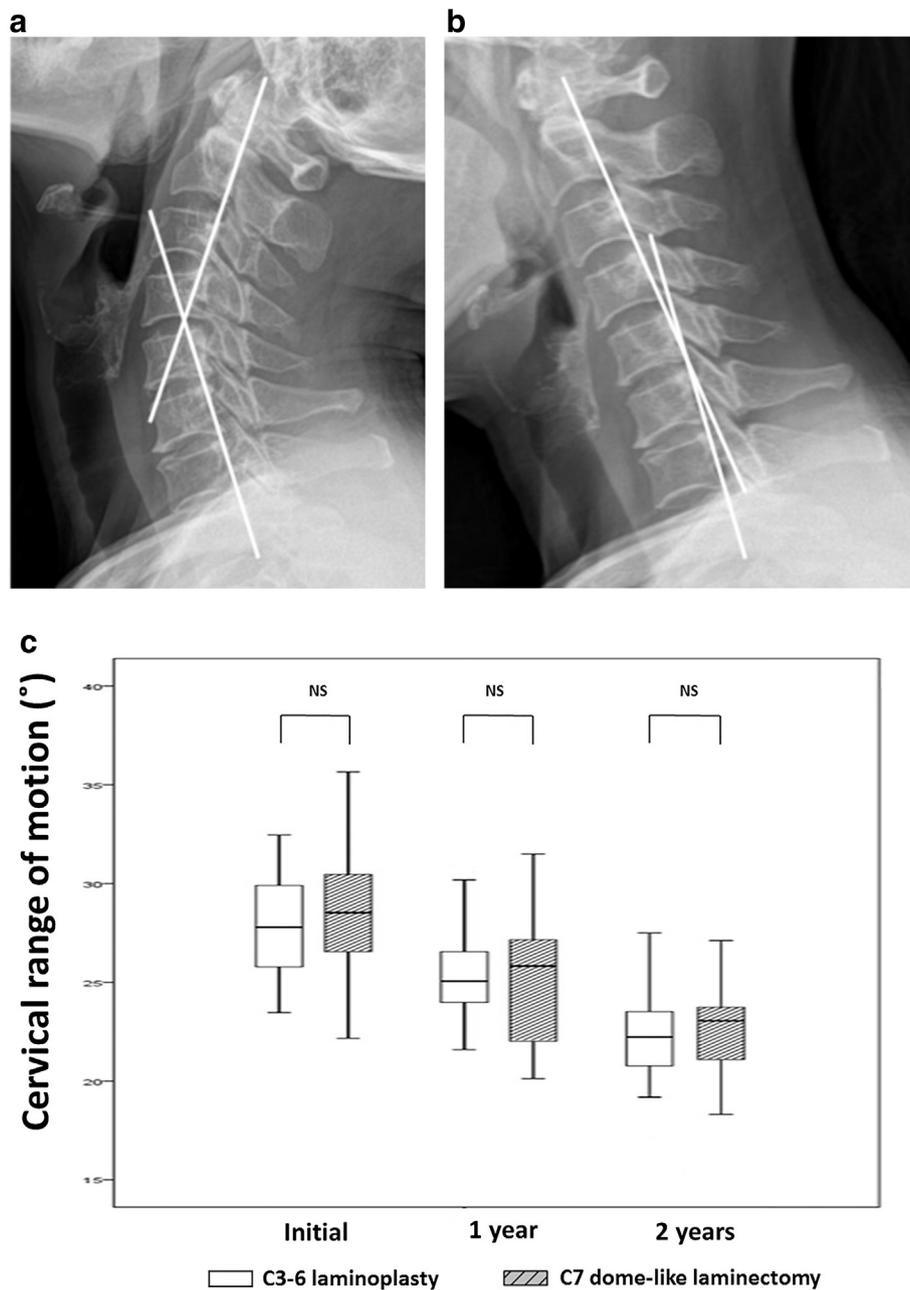


Fig. 5. A, B: Cervical range of motion was determined as A-B in the dynamic series. C: The change in cervical range of motion. C7 laminoplasty indicates C3–C6 laminoplasty with C7 dome-like laminectomy.

Table 1
Baseline clinical characteristics of the two groups.

	C3–C6 laminoplasty group (n = 49)	C7 dome laminoplasty group (n = 39)	p-Value
Mean age (y)	62.0 ± 11.3	61.5 ± 11.7	0.82
Sex (Male:Female)	36:13	30:9	0.71
Diagnosis			0.40
CSM	22	21	
OPLL	37	18	
Duration of symptoms (months)	17.0 ± 5.5	16.4 ± 7.3	0.73

Abbreviations: CSM, cervical spondylotic myelopathy; OPLL, ossified posterior longitudinal ligament.

The values represent the means ± the standard deviations.

prevent the development of kyphotic deformity.

In our study, 4 patients developed late neurological deterioration of myelopathic symptoms due to caudal segment pathology after C3–C6 laminoplasty. In these four patients, 1 patient underwent revision surgery (anterior cervical discectomy and fusion, C6–7), and their myelopathic symptoms improved after the additional surgery. Given the results of previous studies, which have shown that the incidence of neurological deterioration ranges from 0 to 5.7%, we consider the incidence of late neurological deterioration after C3–C6 laminoplasty in this study (8.2%) to be high [1–3,19]. This result may be because only high-risk patients with grade 2 stenosis at the caudal level were included in this study.

A drawback of C7 dome laminoplasty is the risk of spinal cord injury. Although an experienced spine surgeon can adapt to this technique with ease, this procedure requires careful attention to avoid this complication. Fortunately, we have not observed spinal cord injury or

Table 2
Clinical outcomes of the two groups.

	C3–C6 laminoplasty group (n = 49)	C7 dome laminoplasty group (n = 39)	p-value
JOA score			
Prior to surgery	9.7 ± 1.2	9.7 ± 0.9	0.75
2-year f/u	13.0 ± 1.4	13.6 ± 1.0	0.07
Changes in JOA score	3.2 ± 1.4	3.9 ± 0.7	0.01
p-Value	< 0.01	< 0.01	
Neck pain (VAS)			
Prior to surgery	3.0 ± 1.3	2.8 ± 0.8	0.61
2-year f/u	3.4 ± 1.2	3.8 ± 1.3	0.21
Change in neck pain	0.5 ± 1.5	1.0 ± 1.2	0.15
p-Value	0.49	0.12	

Abbreviations: JOA, Japanese Orthopedic Association; VAS, visual analog scale. The values represent the means ± the standard deviations. Boldface type indicates statistical significance.

cerebrospinal fluid leakage to date.

4.4. Limitations

There are several limitations of this study. First, this study involved a relatively small number of patients and a short follow-up period. This was also a retrospective study, and patients who did not follow-up were not included. As patients with recurrence of symptoms may have presented to other doctors, it is possible that we were unaware of some cases of late neurological deterioration. Additional prospective follow-up studies with a much larger patient population than this study are needed to determine the usefulness of C7 dome laminoplasty. Second, we recruited patients with 2 diseases: CSM and OPLL. Further studies involving a sufficiently large number of patients with a homogenous disease entity are needed. Third, we used postoperative follow-up CT images in a sectional area analysis because MRI is not a routine examination in the postoperative follow-up after laminoplasty. The muscle density obtained via unenhanced CT has been demonstrated in other studies to be a good indicator of muscle strength and function [20,21]. However, unenhanced CT may not be sufficiently clear to visualize the borders of the posterior extensor muscles of the cervical spine. A large longitudinal study with a detailed assessment of the muscle using MRI is required to further establish the contributions of paraspinal muscle injury to the development of cervical spine degenerative changes.

5. Conclusions

The C3–C6 laminoplasty and C7 dome laminoplasty groups had similar clinical and radiologic outcomes, but the improvement in the JOA score was greater in the latter group. Furthermore, late neurological deterioration of myelopathic symptoms was not observed in any of the patients after C7 dome laminoplasty. C7 dome laminoplasty is one surgical option if stenosis grade 2 is present at the caudal level.

Conflict of interest and source of funding

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

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