Original Article

Corresponding Author
Kazunari Takeuchi
https://orcid.org/0000-0002-5480-3744

Department of Orthopaedic Surgery,
Odate Municipal General Hospital, 3-1 Yutaka-cho, Odate, Akita 017-0885, Japan
Tel: +81-186-42-5370
Fax: +81-186-42-2055
E-mail: t11161968@yahoo.co.jp

Received: August 23, 2018
Revised: October 25, 2018
Accepted: November 20, 2018

Comparison of Axial Symptoms and Limitations of Activities of Daily Living Accompanying Reduced Neck Mobility After Cervical Laminoplasty Preserving C2 Muscle Attachments With and Without C2 to T1 Instrumented Fusion

Kazunari Takeuchi, Toru Yokoyama
Department of Orthopaedic Surgery, Odate Municipal General Hospital, Akita, Japan

Objective: Muscles are usually detached from C2 to facilitate C2 pedicle screw insertion. The aim of this study was to compare 1-year postoperative axial symptoms and limitations in activities of daily living (ADLs) accompanying reduced neck mobility between 2 procedures in which all C2 muscle attachments are preserved: laminoplasty and C2 to T1 fusion (LPF group: n = 15) and laminoplasty alone (LP group: n = 26).

Methods: We examined axial symptoms and limitations in ADLs using the Japanese Orthopedic Association Cervical Myelopathy Evaluation Questionnaire. We also examined related factors, including the occiput (O)–C7 angle in extension and flexion, and the rotational and O–C2 ranges of motion (ROM).

Results: The postoperative decreases in the O–C7 angle in flexion (27.8° vs. 9.4°) and rotational ROM (40° vs. 15°), as well as the compensating postoperative increase in the O–C2 ROM (11.7° vs. 2.3°), were significantly greater in the LPF group. Most of the axial symptoms were similar between groups. The ability to perform ADLs tended to worsen more frequently in the LPF group, but the difference did not achieve significance.

Conclusion: Postoperative changes in axial symptoms and loss of ROM were not obstacles affecting patients’ ability to perform ADLs after laminoplasty with muscle-sparing C2 to T1 fusion.

Keywords: Laminoplasty, Surgical outcome, Axial symptom, Activities of daily living, Posterior fusion

INTRODUCTION

The severity of ossification of the posterior longitudinal ligament (OPLL) can be characterized by its assessment as K-line (+) or (-). The K-line is a straight line joining the midpoints of the spinal canal at C2 and C7 on a lateral radiograph. In K-line (+) OPLL, the ossified mass does not cross the K-line, whereas in K-line (-) OPLL, some portion of the OPLL mass crosses the K-line posteriorly. In large OPLL, the mass occupies >60% of the area anterior to the K-line. Cervical laminoplasty (LP) has been reported to result in poor outcomes in patients with K-line (-) or large OPLL. Therefore, posterior decompression with instrumented fusion has been used to treat cervical myelopathy with K-line (-) OPLL and has resulted in good neurologic im-
Axial Symptoms and ADL After Laminoplasty With and Without Instrumentation

Takeuchi K, et al.

Axial Symptoms and ADL After Laminoplasty With and Without Instrumentation

Takeuchi K, et al.

https://doi.org/10.14245/ns.1836184.092

www.e-neurospine.org

609

However, postoperative worsening of axial symptoms or limitation of activities of daily living (ADLs) accompanying reduced neck mobility are potential problems after posterior fusion; the added instrumentation in posterior fusion is thought to worsen these problems compared with LP alone.

Problems associated with LP are reduced by preserving the posterior muscles, especially the semispinalis cervicis (SSC) insertion onto the spinous process of C2. At our institution, instead of performing a conventional LP procedure—C3 to C7 LP, with reattachment of the SSC insertion onto C2—we perform C4 to C7 LP with C3 laminectomy, preserving the SSC insertion onto C2 (Fig. 1). Furthermore, in 2011, we changed the surgical procedure for cervical myelopathy with K-line (-) OPLL in neutral or flexed position from a modified LP preserving the SSC insertion onto C2, to LP with C2 to T1 instrumented fusion (LPF) (Fig. 2), completely preserving all muscle attachments to C2, including the rectus capitis posterior major (RCPM) and obliquus capitis inferior (OCI) origins and the SSC insertion (Fig. 3).

We hypothesized that postoperative axial symptoms and limitations in ADLs accompanying reduced neck mobility would not increase after LPF compared with after LP alone despite the added instrumentation in posterior fusion. This retrospective study compared postoperative axial symptoms and limitations in ADLs accompanying postoperative reduced neck mobility after LPF with preservation of all muscle attachments to C2, with those of modified LP with preservation of the SSC insertion onto C2. Furthermore, the pre- and postoperative O–C7 angle, O–C2 ROM, and rotational ROM were measured after LP and LPF.

MATERIALS AND METHODS

1. Ethics Approval

This study was approved by the institutional ethics committee of Odate Municipal General Hospital according to the 1964 Helsinki declaration (approval number: 30-09), and informed consent was obtained from all participants.

Fig. 1. Cervical laminoplasty of C4 to C7 with C3 laminectomy with preserved semispinalis cervicis into C2 (white arrows) seen on 3-dimensional computed tomography (A) and intraoperative photograph (B).

Fig. 2. Cervical laminoplasty and C2 to T1 instrumented fusion seen on front radiograph (A) and lateral radiograph (B).

Fig. 3. Preservation of all muscle attachments (rectus capitis posterior major [black arrow], obliquus capitis inferior [white arrow], and semispinalis cervicis [black dotted arrow]) to C2 during cervical laminoplasty with C2 to T1 fusion.
Table 1. Anatomic distribution of neurologic symptoms in OPLL patients

| Group        | C3/4 | C4/5 | C5/6 | C6/7 |
|--------------|------|------|------|------|
| LPF (n=15)   | 7 (47)| 7 (47)| 7 (47)| 1 (7) |
| LP (n=26)    | 7 (27)| 11 (42)| 17 (65)| 3 (12) |

Values are presented as number of patients (%).

Table 2. Distributions of patients by OPLL classification

| Group        | Continuous | Segmental | Mixed | Circumscribed |
|--------------|------------|-----------|-------|---------------|
| LPF (n=15)   | 0 (0)      | 4 (27)    | 3 (20)| 8 (53)        |
| LP (n=26)    | 0 (0)      | 7 (27)    | 7 (27)| 12 (46)       |

Values are presented as number of patients (%). OPLL, ossification of the posterior longitudinal ligament; LPF, cervical laminoplasty plus C2 to T1 fusion; LP, cervical laminoplasty.

3. Operative Technique and Postoperative Management

Both groups underwent laminectomy at C3 with complete preservation of the SSC insertion at C2. The LP procedure used in both groups was a spinous process-splitting LP (double-door type) performed using a thread-wire saw, with the placement of hydroxyapatite spinous process spacers at C4 to C7. In the LPF group, pedicle screws were inserted bilaterally in the C2, C7, and T1 pedicles. Using retractors, bipolar cautery, and surgical scissors, the area of screw placement in the C2 pedicle were exposed in the space between the OCI and the SSC muscles, thus completely sparing the C2 muscle attachments. The rods were passed under the preserved SSC muscles into C2 bilaterally. Lateral mass screws at C4 to C6, or C5 pedicle screws, were used as mid-cervical anchors in the LPF group. Local bone graft was placed in the LPF group but not in the LP group. Postoperatively, no cervical collar was applied in either group. The postoperative exercise was started within 2 days in both groups, and patients were permitted to sit up or walk within 1 week after surgery.

4. Measurements of O–C7 Angle, O–C2 ROM, and Rotation ROM

Pre- and postoperative O–C7 angles in flexion and extension were measured using the McGregor line and the posterior tangents of the C7 vertebral body on flexion and extension lateral radiographs, respectively, of the cervical spine (Fig. 4). O–C2 ROM was also measured using the McGregor line and the Cobb...
Takeuchi K, et al.  

Axial Symptoms and ADL After Laminoplasty With and Without Instrumentation

Fig. 4. Measurements of O–C7 angle. Measurement lines obtained using McGregor line and the posterior tangents of the C7 vertebral body on flexion (A) and extension lateral (B) radiographs of the cervical spine. O, occiput.

Fig. 5. Measurements of O–C2 range of motion (ROM). Measurement lines obtained using the McGregor line and the Cobb line of the C2 vertebral body in lateral radiographs taken with the cervical spine in flexion (A) and extension (B). O–C2 ROM = β–α. O, occiput.

Fig. 6. Measurements of rotation range of motion (ROM). The lines for measurement were drawn horizontally through the eyeglass frames and through the bilateral acromion tips. (A) Left rotation angle. (B) Right rotation angle. Rotation ROM = left rotation angle + right rotation angle.

were measured using image processing software (Image J, US National Institutes of Health, Bethesda, MD, USA), which is accurate to 0.01°.

5. Evaluation of Axial Symptoms

Axial symptoms were evaluated in both groups using a 100-mm visual analogue scale (VAS). Patients were classified as having axial symptoms if they fulfilled 3 of the following 4 diagnostic criteria: (1) pain with minimal motion, (2) no tenderness with palpation, (3) pain improved with warming and worsened with cooling, and (4) pain improved by lying down, regarding pain or stiffness around the posterior neck or suprascapular area. Pre- and postoperative axial symptoms were compared...
6. Evaluation of ADLs Associated With Postoperative Reduced Neck Mobility

The frequencies of pre- and postoperative limitations of ADLs associated with each of the following neck movements in both groups were determined using Question 1 (cervical spine function) of the Japanese Orthopedic Association Cervical Myelopathy Evaluation Questionnaire (JOACMEQ) (Table 3). The severity of the limitation of each ADL was assessed pre- and postoperatively via a JOACMEQ completed by the patient.

7. Statistical Analysis

O–C7 angle, O–C2 ROM, and rotation ROM were analyzed using Student's t-test. Axial symptoms were analyzed using Student t-test, chi-square test, and Wilcoxon signed-rank test. Limitations in ADLs were analyzed using the chi-square test. Differences with p-values less than 0.05 were considered statistically significant.

RESULTS

1. Measurements of O–C7 Angle, O–C2 ROM, and Rotation ROM

Results of radiographic parameters and rotation ROM are shown in Table 4.

Mean O–C7 angle in flexion was similar between groups preoperatively, but was significantly larger in the LPF group postoperatively (101.6° vs. 83.6°, p < 0.0001). The mean postoperative increase in O–C7 angle in flexion was also significantly larger in the LPF group (27.8° vs. 9.4°, p < 0.0001). Objectively, therefore, it became hard to turn to the bottom 27.8° postoperatively in the patients in the LPF group. However, mean pre- and postoperative O–C7 angles in extension and mean postoperative decrease in O–C7 angle in extension were similar between groups.

Although mean preoperative O–C2 ROM was similar between groups, mean postoperative O–C2 ROM was significantly larger in the LPF group (34.9° vs. 25.1°, p = 0.0005). Mean postoperative increase in O–C2 ROM was also significantly larger in the LPF group (11.7° vs. 2.3°, p = 0.0005).

The mean preoperative rotation ROM was similar between groups, but mean postoperative rotation ROM was significantly smaller in the LPF group (40.0° vs. 15.0°, p < 0.0001).

2. Axial Symptoms

The mean preoperative and postoperative VAS scores for axial symptoms was similar between groups as shown in Table 5.
Table 5. Between-group comparison of axial symptoms before and after surgery

| Surgery               | LPF group | LP group | p-value<sup>a</sup> |
|-----------------------|-----------|----------|---------------------|
| Preoperative (mm)     | 18.0 ± 24.9 | 25.9 ± 29.3 | 0.384               |
| Postoperative (mm)    | 28.7 ± 20.9 | 29.9 ± 25.8 | 0.880               |

Values are presented as mean ± standard deviation.
LPF, cervical laminoplasty plus C2 to T1 fusion; LP, cervical laminoplasty.
<sup>a</sup>Student t-test.

Fig. 7. Within-group comparisons demonstrated no significant aggravation of axial symptoms, as measured on a 100-mm visual analogue scale (y-axis), postoperatively in either group. Preop, preoperation; Postop, postoperation; LPF, laminoplasty with C2 to T1 fusion; LP, laminoplasty.

The frequency with which patients experienced postoperative worsening of axial symptoms was similar between groups (LPF group: 12 cases, LP group: 12 cases, p = 0.7513, chi-square test). The intragroup comparison demonstrated no significant aggravation of axial symptoms postoperatively in either group (LPF group: p = 0.17, LP group: p = 0.35, Wilcoxon signed-rank test) (Fig. 7). Furthermore, the proportion of patients experiencing new-onset axial symptoms after surgery was also similar between groups (LPF group: 7 cases, LP group: 9 cases, p = 0.5170, chi-square test).

3. Frequency and Severity of Limitations in ADLs Associated With Each Neck Movement

The numbers of patients in each group who found pre- and postoperative ADLs involving neck movements impossible, difficult, or easy are shown in Table 6. The frequency and severity of limitations in ADLs for both groups are shown in Fig. 8. There were no significant between-group differences in the number of patients with postoperative worsening of their ability to perform neck extension movements as assessed by JOACMEQ Question 1-1 (LPF group: 7 cases, LP group: 7 cases, p = 0.19, chi-square test), neck rotation as assessed by JOACMEQ Question 1-3 (LPF group: 7 cases, LP group: 6 cases; p = 0.11, chi-square test), or neck flexion as assessed by JOACMEQ Question 1-4 (LPF group: 7 cases, LP group: 6 cases; p = 0.11, chi-square test). In other words, the objective loss of motion did not affect the ability of the patients in either group to perform their ADLs.

DISCUSSION

A few reports have reported poor neurologic improvement in cervical myelopathy due to large OPLL or K-line (-) OPLL after cervical LP alone,<sup>1,2</sup> and that good postoperative neurologic improvement could be achieved by treating these OPLLs with posterior decompression and fusion.<sup>3</sup> However, there have been few reports on axial symptoms or limitations in ADLs associated with reduced neck mobility after posterior decompression and fusion.<sup>12</sup>

In the present study, postoperative VAS score measuring axial symptoms, and the proportion of patients whose symptoms worsened after surgery, were similar between groups. Takeuchi et al.<sup>7</sup> changed the LP procedure from conventional C3–7 LP, with reattachment of the SSC at C2, to C4–7 LP with C3 laminectomy, with preservation of the SSC at C2; their report demonstrated that modified LP with preservation of the SSC signif-

Table 6. Distributions of patient-reported level of difficulty in performing ADL-associated neck movements

| Variable                | LPF group (n = 15) | LP group (n = 26) |
|-------------------------|--------------------|-------------------|
| Extension (JOACMEQ Q1-1)|                    |                   |
| Preoperative, impossible:difficult:easy | 0:33:67            | 8:19:73           |
| Postoperative, impossible:difficult:easy | 13:67:20           | 4:42:54           |
| Extension (JOACMEQ Q1-2)|                    |                   |
| Preoperative, impossible:difficult:easy | 13:27:60           | 12:15:73          |
| Postoperative, impossible:difficult:easy | 13:60:27           | 15:31:54          |
| Rotation (JOACMEQ Q1-3) |                    |                   |
| Preoperative, impossible:difficult:easy | 33:47:20           | 19:23:58          |
| Postoperative, impossible:difficult:easy | 53:47:0            | 12:35:54          |
| Flexion (JOACMEQ Q1-4)  |                    |                   |
| Preoperative, impossible:difficult:easy | 13:13:73           | 8:19:73           |
| Postoperative, impossible:difficult:easy | 20:47:33           | 4:35:62           |

Values are presented as percentage.
ADL, activity of daily living; LPF, cervical laminoplasty plus C2 to T1 fusion; LP, cervical laminoplasty; JOACMEQ, Japanese Orthopedic Association Cervical Myelopathy Evaluation Questionnaire.
significantly reduced postoperative axial symptoms and maintained whole-cervical posterior muscle volume on magnetic resonance images compared with conventional LP with muscle reattachment. The SSC, most of which inserts on C2,19,20 acts as a dynamic stabilizer and extensor of the cervical spine.21-25 In the present study, there is a possibility that, in the LPF group, the preserved SSC insertion at C2 may act not as a dynamic extensor, but as a muscle that maintains the cervical spine in extension, and that preservation of C2 muscle attachments prevents atrophy of all posterior cervical muscles and, thus, postoperative axial symptoms.

Although the objective data showed that the postoperative loss of O–C7 angle in flexion and the rotation ROM in the LPF group were significantly larger than in the LP group, the objec-

---

**Fig. 8.** Severity and distribution of limitations in activity of daily livings associated with reduced neck mobility in both groups. LPF, laminoplasty with C2 to T1 fusion; LP, laminoplasty; postop, postoperative; preop, preoperative; JOACMEQ, Japanese Orthopedic Association Cervical Myelopathy Evaluation Questionnaire; Impossible, I cannot do it; Difficulty, I can do it intermittently; Easy, I can do it without inconvenience.
Axial Symptoms and ADL After Laminoplasty With and Without Instrumentation

Takeuchi K, et al.

The postoperative losses of O–C7 angle in flexion and rotation ROM and the postoperative increase in O–C2 ROM in the LPF group were greater than those in the LP group. The pre- to postoperative changes in axial symptoms were almost the same in both groups. Although the frequency of patients with postoperative worsening of limitations in ADLs accompanying reduced neck mobility was greater for all neck movements in the LPF group than in the LP group, the differences were not statistically significant. With regard to axial pain and limitations of ADLs associated with reduced neck mobility after surgery, LP and C2 to T1 fusion with preservation of all C2 muscle attachments and muscle-sparing LP are equally recommended.

CONFLICT OF INTEREST

The authors have nothing to disclose.

REFERENCES

1. Fujiyoshi T, Yamazaki M, Kawabe J, et al. A new concept for making decisions regarding the surgical approach for cervical ossification of the posterior longitudinal ligament: the K-line. Spine (Phila Pa 1976) 2006;31:E990-3.
2. Fujimori T, Iwasaki M, Okuda S, et al. Long-term results of cervical myelopathy due to ossification of the posterior longitudinal ligament with an occupying ratio of 60% or more. Spine (Phila Pa 1976) 2014;39:58-67.
3. Koda M, Mochizuki M, Konishi H, et al. Comparison of clinical outcomes between laminoplasty, posterior decompression with instrumented fusion, and anterior decompression with fusion for K-line (-) cervical ossification of the posterior longitudinal ligament. Eur Spine J 2016;25:2294-301.
4. Kawaguchi Y, Matsu H, Ishihara H, et al. Axial symptoms after en bloc cervical laminoplasty. J Spinal Disord 1999;12:392-5.
5. Yoshida M, Tamaki T, Kawakami M, et al. Does reconstruction of posterior ligamentous complex with extensor muscle-culture decrease axial symptoms after cervical laminoplasty? Spine (Phila Pa 1976) 2002;27:1414-8.
6. Shiraiishi T, Fukuda K, Yato Y, et al. Results of skip laminectomy-minimum 2-year follow-up study compared with open-door laminoplasty. Spine (Phila Pa 1976) 2003;28:2667-72.
7. Takeuchi K, Yokoyama T, Aburakawa S, et al. Axial symptoms after cervical laminoplasty with C3 laminectomy compared with conventional C3-C7 laminoplasty: a modified laminoplasty preserving the semispinalis cervicis inserted
Takeuchi K, et al. Axial Symptoms and ADL After Laminoplasty With and Without Instrumentation

into axis. Spine (Phila Pa 1976) 2005;30:2544-9.
8. Ono A, Tonosaki Y, Numasawa T, et al. The relationship between the anatomy of the nuchal ligament and postoperative axial pain after cervical laminoplasty: cadaver and clinical study. Spine (Phila Pa 1976) 2012;37:E1607-13.
9. Takeuchi K, Yokoyama T, Ono A, et al. Limitations of activities of daily living accompanying reduced neck mobility after cervical laminoplasty. Arch Orthop Trauma Surg 2007;127:475-80.
10. Takeuchi K, Yokoyama T, Ono A, et al. Limitation of activities of daily living accompanying reduced neck mobility after laminoplasty preserving or reattaching the semispinalis cervicis into axis. Eur Spine J 2008;17:415-20.
11. Takeuchi K, Yokoyama T, Numasawa T, et al. K-line (-) in the neck-flexed position in patients with ossification of the posterior longitudinal ligament is a risk factor for poor clinical outcome after cervical laminoplasty. Spine (Phila Pa 1976) 2016;41:1891-5.
12. Takeuchi K, Yokoyama T, Numasawa T, et al. A novel posterior approach preserving three muscles inserted at C2 in multilevel cervical posterior decompression and fusion using C2 pedicle screws. Eur Spine J 2018;27:1349-57.
13. Tani T, Ushida T, Taniguchi S, et al. Functional neuroscie: evoked potentials and related techniques. Selected presentations from the 8th International Evoked Potentials Symposium (Fukuoka, Japan). Supplements to Clinical Neurophysiology, Vol. 59. Amsterdam (the Netherlands): ELSEVIER; 2006. Chapter 35, Partial conduction block in cervical compression myelopathies: waveform changes of ascending spinal evoked potentials; p. 265-74.
14. Investigation Committee on OPLL of the Japanese Ministry of Public Health and Welfare. The ossification of the posterior longitudinal ligaments after cervical laminoplasty for patients with ossification of the posterior longitudinal ligament-a multi-institutional study. Spine (Phila Pa 1976) 2006;31:2998-3005.
15. Yonenobu K, Nakamura K, Toyama Y. OPLL: ossification of the posterior longitudinal ligament. Japan: Springer; 2006.
16. Tomita K, Kawahara N, Toribatake Y, et al. Expansive midline T-saw laminoplasty (modified spinous process-splitting) for the management of cervical myelopathy. Spine (Phila Pa 1976) 1998;23:32-7.
17. Nakano K, Harata S, Suetsuna F, et al. Spinous process-splitting laminoplasty using hydroxyapatite spinous process spacer. Spine (Phila Pa 1976) 1992;17(3 Suppl):S41-3.
18. Fukui M, Chiba K, Kawakami M, et al. JOA Back Pain Evaluation Questionnaire (JOABPEQ)/JOA Cervical Myelopathy Evaluation Questionnaire (JOACMEQ). The report on the development of revised versions. April 16, 2007. The Subcommittee of the Clinical Outcome Committee of the Japanese Orthopaedic Association on Low Back Pain and Cervical Myelopathy Evaluation. J Orthop Sci 2009;14:348-65.
19. Sherk HH. Stability of the lower cervical spine. In: Kehr P, Weidner A, editors. Cervical spine I. New York: Springer Verlag Wien; 1987. p. 59-64.
20. Takeuchi K, Yokoyama T, Aburakawa S, et al. Anatomic study of the semispinalis cervicis for reattachment during laminoplasty. Clin Orthop Relat Res 2005;(436):126-31.
21. Conley MS, Stone MH, Nimmons M, et al. Specificity of resistance training responses in neck muscle size and strength. Eur J Appl Physiol Occup Physiol 1997;75:443-8.
22. Nolan JP Jr, Sherk HH. Biomechanical evaluation of the extensor musculature of the cervical spine. Spine (Phila 1976) 1998;13:9-11.
23. Conley MS, Meyer RA, Bloomberg JJ, et al. Noninvasive analysis of human neck muscle function. Spine (Phila 1976) 1995;20:2505-12.
24. Vasavada AN, Li S, Delp SL, et al. Influence of muscle morphology and moment arms on the moment-generating capacity of human neck muscles. Spine (Phila Pa 1976) 1998;23:412-22.
25. Heller JG, Pedlow FX Jr, Gill SS. Anatomy of the cervical spine. In: Clark CR, editor. The cervical spine. 4th ed. Philadelphia (PA): Lippincott Williams & Wilkins; 2005. p. 3-36.
26. Hori T, Kawaguchi Y, Kimura T. How does the ossification area of the posterior longitudinal ligament thicken following cervical laminoplasty? Spine (Phila Pa 1976) 2007;32:E551-6.
27. Iwasaki M, Kawaguchi Y, Kimura T, et al. Long-term results of expansive laminoplasty for ossification of the posterior longitudinal ligament of the cervical spine: more than 10 years follow up. J Neurosurg 2002;96(2 Suppl):180-9.
28. Chiba K, Ogawa Y, Ishii K, et al. Long-term results of expansive open-door laminoplasty for cervical myelopathy—average 14-year follow-up study. Spine (Phila Pa 1976) 2006;31:2998-3005.
29. Tokuhashi Y, Ajiro Y, Umezawa N. A patient with two surgeries for delayed myelopathy due to progression of ossification of the posterior longitudinal ligaments after cervical laminoplasty. Spine (Phila Pa 1976) 2009;34:E101-5.
30. Seichi A, Hoshino Y, Kimura A, et al. Neurological complications of cervical laminoplasty for patients with ossification of the posterior longitudinal ligament-a multi-institutional retrospective study. Spine (Phila Pa 1976) 2011;36:E998-1003.
31. Fargen KM, Cox JB, Hoh DJ. Does ossification of the posterior longitudinal ligament progress after laminoplasty? Radiographic and clinical evidence of ossification of the posterior longitudinal ligament lesion growth and the risk factors for late neurologic deterioration. J Neurosurg Spine 2012;17:512-24.