Clinical Application of a New Plate Fixation System in Open-door Laminoplasty

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Abstract

The purpose of this retrospective clinical series was to evaluate the benefits and complications of plate fixation for open-door laminoplasty in cervical spondylotic myelopathy with multilevel spinal stenosis compared with open-door laminoplasty without fixation. Forty-nine patients underwent open-door laminoplasty for cervical myelopathy with multilevel spinal stenosis with at least 13 months of follow-up. A plate was used as the sole method of fixation between the lateral mass and lamina with 3 screws. Computed tomography scans obtained pre- and postoperatively were assessed for plate complications and spinal canal enlargement. Pre- and postoperative neurological condition was assessed by the Japanese Orthopedic Association (JOA) myelopathy score. Overall cervical spine range of motion (ROM) was measured in full flexion and extension radiographs pre- and postoperatively.

No restenosis due to door reclosure was noted, and no plates failed. No screws were backed out or broken. Almost all patients showed neurological improvement. The JOA score increased by 3.9±0.7 points in the suture group and 4.3±0.8 points in the plate group (P<.05). The postoperative increase in mean anteroposterior diameter of the spinal canal from C3 to C7 was 4.5±0.6 mm in the suture group and 5.1±0.3 mm in the plate group. The greater mean anteroposterior diameter increase in the plate group was statistically significant (P<.01). The mean cervical ROM decreased in the plate and suture groups postoperatively (P<.001). No significant difference was found in mean cervical ROM reduction between the groups (P>.05). No difference in axial symptoms was found between the 2 groups.

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Figure: One-week postoperative anteroposterior (A) and lateral (B) radiographs of a patient with cervical spondylotic myelopathy with multilevel spinal stenosis who received plate open-door laminoplasty. We performed C3-C7 segment open-door laminoplasty with 5 centerpiece plates. Each plate was fixed to the spinous lamina and the lateral mass by 3 mini-screws.
Multisegmental cervical spondylotic myelopathy remains a pathophysiological and therapeutic challenge. Expansive laminoplasty has gradually become a preferred procedure for almost all patients with cervical spondylotic myelopathy with multilevel spinal stenosis. Hirabayashi et al\(^1\) introduced unilateral open-door laminoplasty, which has been widely used worldwide. In the classic open-door laminoplasty technique, the lamina door is tethered open via sutures through the spinous process and facet capsule or paravertebral muscle, which are then tied to prevent reclosure of the lifted lamina.

Although this technique has proven to be successful, its limitations include inadequate decompression on the hinge side, the potential for reclosing of the door, range of motion (ROM) restriction, and lack of a truly stable fusion.\(^2-4\) Therefore, a few fixations, such as sutures, bone struts, ceramic blocks, and suture anchors, were used in the open-door laminoplasty, but all of them were deficient in some way. Sutures may cut out, break, or stretch over time. Bone struts and ceramic blocks have the potential for graft kickout. Suture anchors may displace, and the suture may cut out or break.

Recently, a new plate fixation system was developed for open-door laminoplasty that fixes the free lamina and lateral mass. Rhee et al\(^5\) reported that a plate in open-door laminoplasty could maintain stable spinal canal expansion with high rates of hinge union. However, information is lacking about the benefits and complications of the plate. Since 2008, we have used the plate system in the open-door laminoplasty in patients with multisegmental cervical spondylotic myelopathy in our institution. The purpose of this study was to evaluate the benefits and complications of plate fixation in open-door laminoplasty for cervical spondylotic myelopathy compared with open-door laminoplasty without fixation.

### MATERIALS AND METHODS

Between January 2008 and January 2011, a total of 61 consecutive patients with cervical spondylotic myelopathy with multilevel spinal stenosis were assessed in our study. All patients met the following enrollment criteria: (1) a clear history of progressive neurological deficit; and (2) comparable radiography, magnetic resonance imaging (MRI), and computed tomography (CT) findings verifying multilevel cervical stenosis with or without ossification of the posterior longitudinal ligaments. Patients with serious systemic disease, such as acute cardiac accident or cerebral infarction, were excluded. Mean patient age at surgery was 58 years (range, 41-81 years). Thirty-eight patients (24 men, 14 women) underwent open-door laminoplasty with plate fixation, and 23 patients (16 men, 7 women) underwent open-door laminoplasty with suture. The choice of internal fixation used was randomized. Nine patients had 3 levels of decompression (C3-C5), 14 patients had 4 levels (C4-C7 = 7; C3-C6 = 7), and 38 patients had 5 levels (C3-C7). In the plate group, 6 patients used 2 plates, 27 patients used 3 plates, 3 patients used 4 plates, and 2 patients used 5 plates (Table 1).

### SURGICAL TECHNIQUE

Modifications were made to the original Hirabayashi et al\(^1\) laminoplasty in our surgical technique. A standard posterior exposure of the cervical spine was performed. The number of segments operated on depended on the pattern of spinal cord compression. Two hinges at bilateral junctions of the bilateral lateral mass and bone lamina were created by completely removing the dorsal cortex and thinning the ventral cortex with an electric drill. The ventral cortex in the open side was removed. In the plate group, the open side was stabilized with plates and mini-screws (Centerpiece; Medtronic Sofamor Danek, Memphis, Tennessee). Commonly, we chose the left side as the open-door side and the right side as the hinge side. The plate was measured to suit the space between the lateral mass and lamina, and a sufficient size (usually model #10-#12) was chosen to allow adequate expansion of the spinal canal. Two mini-screws were placed into the lateral mass through the plate, and another mini-screw was placed into the cut lamina through the plate to create stable fixation (Figure 1). In the suture group, the lamina...
The plate group comprised 38 patients, and the suture group comprised 23 patients. Operative time averaged 145 minutes in the plate group compared with 132 minutes in the suture group (P<.05), and blood loss averaged 350 mL in the plate group compared with 345 mL in the suture group (P<.05).

Postoperatively, results were investigated in 49 patients (32 from the plate group and 17 from the suture group) who were observed for at least 13 months postoperatively. The follow-up rate was 80.3%. Mean patient age in the plate group was 56 years (range, 41-67 years) and in the suture group was 59 years (range, 44-73 years). The plate group comprised 20 men and 12 women, and the suture group comprised 13 men and 4 women. Average follow-up was 19 months (range, 13-36 months) in the plate group and 20.5 months (range, 14-39 months) in the suture group (Table 2). No restenosis due to door reclosure was noted, and no plates failed. No screws were backed out or broken.

The JOA score system was used to evaluate neurological function. Almost all patients showed improvement. The mean JOA score increased postoperatively in the plate group (P<.05) and the suture group (P<.05) (A). The Japanese Orthopedic Association score increase was not significant between the groups (P>.05) (B).
Radiographically, no patient had progressive kyphotic deformity postoperatively compared with preoperative alignment. Bone fracture healing of the hinge side occurred earlier in the plate group. Mean AP diameter increased from 10.8 ± 1.7 mm to 15.9 ± 1.6 mm in the plate group (P < .001) and from 11.7 ± 1.1 mm preoperatively to 16.2 ± 1.4 mm postoperatively in the suture group (P < .001). This is an increase of 5.1 ± 0.5 mm in the plate group and 4.5 ± 0.6 mm in the suture group. The greater mean AP diameter increase in the plate group was statistically significant (P < .01) (Figures 4, 5).

Radiographically, mean cervical ROM decreased from 49.6° ± 6.9° preoperatively to 40.1° ± 4.0° postoperatively in the plate group (P < .001) and from 51.3° ± 8.1° preoperatively to 41.4° ± 5.1° postoperatively in the suture group (P < .001) (Figure 6). This is a decrease of 9.2° ± 5.3° in the plate group and 8.9° ± 4.3° in the suture group. No significant difference was found in reduction of mean cervical ROM between the 2 groups (P > .05) (Figure 7).

Complications included superficial wound infection in 4 patients (plate group = 2, suture group = 2), transient C5 root palsy in 2 patients (plate group = 1, suture group = 1), and postoperative cardiopulmonary events in 1 patient (suture group = 1). Eighteen patients (plate group = 12, suture group = 6) had axial pain at last follow-up.

DISCUSSION

Unilateral open-door laminoplasty was introduced by Hirabayashi et al.1 Because sutures in the original Hirabayashi et al1 open-door laminoplasty do not provide enough rigid fixation, they may cut out, break, or stretch over time, and the potential for reclosing of the door always exists.
Therefore, many fixation systems have been developed to replace sutures, such as bone struts, ceramic blocks, and suture anchors. Bone struts and ceramic spacers can keep the position of lamina, and bone healing can occur between the bone struts, lamina, and lateral mass. However, bone struts and ceramic spacers may kick out and lead to door reclosure. A serious clinical outcome can result if the bone struts or ceramic spacer dislodges into the spinal canal. Recently, suture anchors were used in open-door laminoplasty, and some studies reported excellent clinical results. However, the suture anchors may displace, and the suture may cut out and break. A new plate fixation system has been developed in open-door laminoplasty.

In the current study, bone-window CT scan was used for measuring the size of the spinal canal. Because AP diameter directly influences the compression ratio and canal area, we used AP diameter to assess canal expansion. We used CT scans to measure the spinal canal AP diameter as the evaluation of operative outcome. In patients with multilevel spinal stenosis, this method can measure the exact spinal canal size of segments C3 to C7. However, the diameter cannot reflect the real spinal canal size in some special segments with partial ossification of the posterior longitudinal ligament, which is not at the middle site of the vertebral body. Although this diameter is the shortest distance of the middle site of the vertebral body to the spinous process, it is not the narrowest site of the spinal canal in patients with ossification of the posterior longitudinal ligament. In the current study, 27 patients had ossification of the posterior longitudinal ligament; 18 patients and 32 cervical segments encountered this problem. To avoid this error, we used the mean AP diameter to minimize this systemic deviation.

Kokubun et al reported that patients with multilevel spinal stenosis with a mean AP diameter ≤12 mm would have more chance of developmental canal stenosis. In the current study, the mean AP diameter increased from 10.8±1.7 mm preoperatively to 15.9±1.6 mm postoperatively in the plate group and from 11.7±1.1 mm preoperatively to 16.2±1.4 mm postoperatively in the suture group. This is a mean AP diameter increase of 5.1±0.5 mm in the plate group and 4.5±0.6 mm in the suture group, similar to increases between 5.0 and 5.4 mm reported in other studies. The mean postoperative AP diameter increased significantly in the 2 groups. This indicates the effectiveness of the laminoplasty procedure to expand the spinal canal. The greater AP diameter increase was seen in the plate group. The plate offered enough strength and good stability to support the lamina, so the canal diameter could be designed larger in the plate group than in the suture group. This was the most important advantage of the plate in open-door laminoplasty. At follow-up, the AP diameter in the plate group experienced nearly no change and in the suture group was slightly smaller, but it was not statistically significant.

With suture fixation, premature laminoplasty closure has been reported at rates ranging from 1.5% to 34%. However, during our follow-up, we found no door reclosure in any patient. Rhee et al reported that the plate could promote hinge-side ventral fracture bone healing. We found the same phenomenon in some patients in our institution.

We measured functional and neurological outcome with the JOA score. In our series, almost all patients showed neurological improvement postoperatively. The ratio of JOA score improvement rates was 47.8% in the plate group and 42.4% in the suture group, which is similar to others reported in the literature. The JOA score increase was higher in the plate group, but it was not statistically significant between the 2 groups. Using a plate in open-door laminoplasty may not contribute to neurological improvement more than using sutures would. The greater expansion of the spinal canal in the plate group may not result in better clinical improvement.

Axial symptoms occurred in 18 (36.7%) patients (plate group=12, suture group=6). No significant difference existed in the occurrence rate of axial symptoms (37.5% in the plate group vs 35.3% in the suture group) between the 2 groups. The plate offered stronger support and better stability, but did not reduce axial symptoms. First described in 1996, axial pain is defined as pain from the nuchal to the periscapular or shoulder region. Factors associated with axial pain are unclear. Hosono et al reported that axial symptoms may be caused by several things, including nuchal muscle intraoperative injury, destruction of facet joints, intraoperative nerve root damage, and hinge side nonunion. The reconstruction of posterior elements at laminoplasty is expected to relieve axial symptoms. One study reported that neck muscle strength and axial symptoms were strongly correlated. It has also been reported that successful reconstruction of the lamina
of vertebral arches is essential because sinking or nonunion of the expanded lamina can induce postoperative axial pain.\(^\text{18}\) Sakaura et al\(^\text{19}\) reported that the muscles at the cervicothoracic junction around the C7 spinous process played a central role in the development of this postoperative axial pain. Because the C7 spinous process is the origin of the trapezius, rhomboid minor muscles, and nuchal ligament, sacrificing this spinous process can cause great damage to the posterior musculature of the cervical spine. In the current study, the C7 spinous process was retained in 12 patients at follow-up, and axial pain occurred in 2 of them.

Axial symptoms are strongly correlated with cervical ROM. Many systematic reviews on neck pain and headache have demonstrated that ROM is the most frequently reported objective outcome measure in published trials.\(^\text{20}\) In our series, mean cervical ROM was decreased in both groups. This may be related to the axial symptoms. Postoperative reduction of mean cervical ROM was 9.2°±5.3° in the plate group and 8.9°±4.3° in the surgery group. No significant difference existed in ROM change and the occurrence rate of postoperative axial symptoms between the 2 groups. Patients with serious axial symptoms had severely reduced cervical ROM. Patients with axial symptoms would be more likely to reduce their cervical spine movement due to pain.

Operative time was slightly higher in plate group compared with the surgery group. The additional time for plate and screw fixation averaged 13 minutes. Compared with total operative time, this additional time is tolerable. Average intraoperative blood loss was not significantly different between the 2 groups. No restenosis due to door reclosure was noted, and no plates failed. No screws were backed out or broken. Rhee et al\(^\text{5}\) experienced screw backout in open-door laminoplasty, but it did not influence the plate fixation, and no complications occurred. The laminar part of the plate is an open-mouth shape. It can contain the lamina, and the lower part of the mouth can offer good support. We usually used 3 screws to fix the plate. The plate size was the #10 or #12 model, and the screws were 5 or 7 mm long. Postoperatively, the patients received cervical brace support for 3 months. Adequate plate size, screw length, and cervical brace support was important to prevent internal fixation failure. Rigid internal fixation was critical to the expansion of the spinal canal.

The advantages of the plate over other forms of laminoplasty fixation include: (1) the plate can provide enough strength to create immediate hinge stability postoperatively; (2) contrary to suture fixation, the plate can maintain greater expansion of the spinal canal and prevent reclosure of the open door; and (3) plate techniques are easier to grasp than some suturing or bone graft techniques. Disadvantages include: (1) increased treatment costs; and (2) when used in internal fixation, the possibility exists of internal fixation failure such as screw backout and broken plates.

REFERENCES
