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ORIGINAL STUDY

Alternating levels versus all levels mini-plate fixation in open door cervical laminoplasty for treatment of degenerative cervical myelopathy

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To investigate clinical and radiological results of alternating levels compared with all levels mini-plate fixation in open door cervical laminoplasty for treatment of degenerative cervical myelopathy. From January 2011 to April 2014, 64 patients sustained degenerative cervical myelopathy, who underwent cervical laminoplasty with alternating levels (31 patients in group A) or all levels plate fixation (33 patients in group B) were included in this retrospectively study. Clinical and radiological results were calculated. The mean cost for group B was higher than group A($P < 0.05$). No statistical difference was found in the mean operation time, blood loss, axial symptoms, C5 palsy, improvement in japanese orthopedic association scores and neck disability index scores between group A and B. Open angle in mini-plate fixed levels was significantly more than that in suture fixed levels($P < 0.05$). No statistical difference was found in drift back of spinal cord, anterio-posterior diameter, Pavlov's ratio, cervical curvature index and cervical range of motion between mini-plate fixed levels and suture fixed levels. Open door laminoplasty at alternating levels mini-plate fixation is an economical surgical method and can obtain similar satisfactory clinical and radiological results compared to all levels mini-plate fixation.

Keywords: Alternating levels fixation ; mini-plate fixation ; degenerative cervical myelopathy ; open door laminoplasty.

INTRODUCTION

Laminoplasty is usually used to manage degenerative cervical myelopathy(DCM). Traditional open door laminoplasty is tethered using suture, commonly results in some complications because of the absence of rigid fixation *(5)*. Laminoplasty with a mini-plate can provide rigid fixation and has achieved satisfactory clinical outcomes *(1,8,15)*. At present, mini-plates are operated at all levels and also used at alternating levels (ie, C3, C5, C7) in clinical settings because of the high cost *(12,13,23)*. In a previous study, all levels fixation was more effective in maintaining the expansion of the spinal canal and can obtain better clinical improvement compared to alternating levels fixation *(21)*. However, another study demonstrates favorable neurologic recovery after both all levels fixation and alternating levels fixation *(19)*.

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The purpose of this retrospective study was to evaluate clinical and radiological results of all levels plate fixations compared with alternating levels plate fixation in open door cervical laminoplasty for treatment of degenerative cervical myelopathy.

MATERIALS AND METHODS

The clinical study proposal was subject to approval by the medical ethical committee of the authors' institution. From January 2011 to April 2014, 64 consecutive patients sustained multilevel degenerative cervical myelopathy, who underwent cervical laminoplasty with alternating levels plate fixation (31 patients in group A) or all levels plate fixation (33 patients in group B) were included in this retrospectively study. Pre-operative general information of patients was summarized in Table I.

The indications of these patients were as follows: (1) progressive neurological deficit due to DCM without radiculopathy, (2) X-ray, three-dimensional computed tomography(CT) scan, and magnetic resonance imaging(MRI) verifying multilevel cervical stenosis, spinal cord compression at three or more cervical levels, (3) acceptable cervical spine alignment without severe kyphotic deformity or exactly segmental instability. Clinical diagnosis was made by the medical history, physical examination, and radiological results including X-ray (plain, lateral, flexion, and extension positions), three-dimensional CT scans, and MRI. Patients with spinal cord tumor, cervical ruptured disc herniation, spinal cord injury, cervical kyphosis and cervical instability were excluded. The decompression segments were C3–C7 in all patients.

All patients were made to sign an informed consent after being informed of the procedure. All surgical procedures were performed under general anesthesia with endotracheal intubation. The head was supported by a Mayfield head holder and the neck was maintained in slight flexion position. Somatosensory and motor evoked potentials and triggered electromyography were recorded intraoperatively in all patients.

A posterior median incision was carried out. Along C3–C7 spinous processes and laminas, bilateral paraspinal muscles were subperiosteally dissected to expose the cervical spine from the inferior portion of the C2 lamina to the superior portion of the T1 lamina, and extended laterally for complete exposure of the dorsal cortex of the bilateral facet joints. The paraspinal muscle of C2, especially the semispinalis, was preserved to prevent possible post-operative kyphosis. When detachment of the semispinalis at C2 was necessary, the muscle and tendons were repaired at the end of the surgery. Interspinous ligament was cut off in C2–C3 and C7–T1, and C3-C7 spinous processes were shortened. The more severe side was taken as the open side and the other side served as the hinged side. The slotting site located on the margin between the lamina and the lateral mass. Gutters

Table I. — Pre-operative general information

	Group A	Group B	P value
Number(n)	31	33	
Sex(Male/Female)	17/14	17/16	0.808
Age (years)	58.06±9.74	54.24±9.71	0.121
OPLL/CSM(n)	7/24	10/23	0.485
Levels of compression 3/>3(n)	18/13	21/12	0.789
JOA score	9.35±1.28	9.70±1.24	0.281
Cost (USD)	8843.4±333.1	11628.1±627.7	0.000
Blood loss(ml)	280.48±51.76	280.76±40.64	0.981
Operation time(min)	137.1±15.37	140.91±18.89	0.381

CSM cervical spondylosis myelopathy, OPLL ossification of the posterior longitudinal ligament, JOA japanese orthopaedic association.

were established on both sides of the laminae by completely removing the dorsal cortex and thinning the ventral cortex. On the hinge side a 2mm burr was used to grind the whole thickness of the dorsal cortex; on the open door side a 3mm burr was used to grind the whole thickness of dorsal and ventral lamina cortices. C3–C7 laminas were overturned to the another side and were opened carefully using repetitive movements. During elevation of the laminae, fibrous adhesions between the dura and ligamentum flavum were divided using nerve dissectors. Epidural venous plexus hemorrhage was controlled with bipolar electrocautery or application of Surgicel (Johnson & Johnson, USA).

The hinge was maintained open with an appropriate size titanium miniplate (10- or 12-mm plate) and screws (6 or 8 mm in length; Arch Laminoplasty System, Synthes, West Chester, Pennsylvania, United States) fixed to the lamina and the lateral mass, each with 2 screws. The screws are inserted to anchor the plate to the laminar and the lateral mass of the same level. Deserving attention, the position of the plate should be adjusted toward the superior portion of the lateral mass to avoid penetration of the screws into the subjacent facet joint. Five levels (C3-C7) fixation was placed in group B. In group A, sutures are passed through the holes that were initially prepared at the bases of the C4 and C6 spinous processes. The laminae, via the sutures, are secured to the soft tissues including the fascia which maintains the "open door" (Figure. 1a, b).

Drainage tubes were commonly placed in all operations and were removed 72 hours after operations. Considering the stability of the elevated laminae, isometric and isotonic muscle exercises of the posterior neck were recommended after surgery as soon as possible. The collar was recommended to be worn for 2 weeks post-operatively in order to limit cervical spine flexion and extension, after which patients were encouraged to perform a gradual mobilization inflexion-extension, rotation, and side bending as tolerated.

Follow-up was carried out 1 week after operation and patients returned for clinical evaluation at one, three, six and 12 months and annually thereafter. Plain anterio-posterior, lateral and inflexion-extension radiographs before surgery, after surgery and during each return visit were obtained for radiographic analysis. As for CT and MR scans; all patients had it just after surgery and one year later.

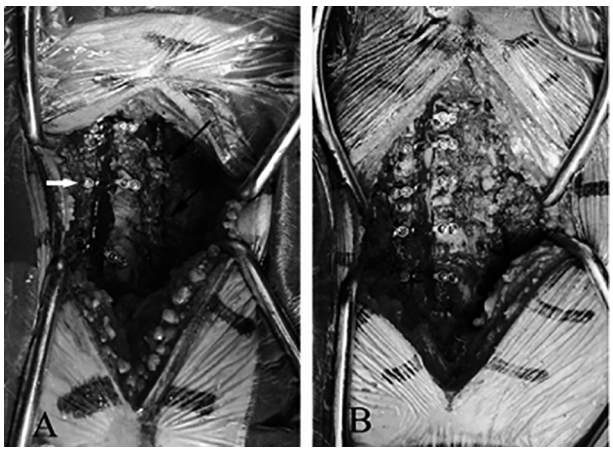

Fig. 1. — Intraoperative view: Open door laminoplasty at alternating levels mini-plate fixation (A) and all levels mini-plate fixation (B), shows the suture (black arrows) and mini-plate fixations (white arrows)

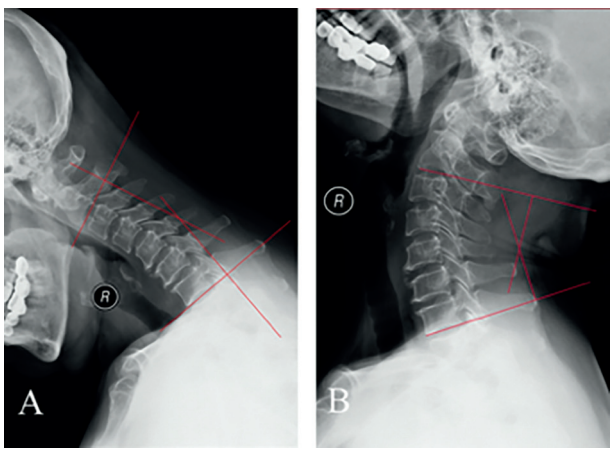

Fig. 2. — Lateral radiographs of flexion (A) -extension (B) were used to measure cervical range of motion (ROM) as the sum of the C2-C7 Cobb angle which is made by the 2 perpendicular lines of the inferior endplate of C2 and C7

To evaluate the clinical outcome, neck disability index (NDI) scores were achieved during the pre-operative and post-operative periods. Neurologic conditions were assessed using the Japanese orthopaedic association (JOA) scores which were determined to evaluate the clinical efficacy and the quality of life experienced by the patients. The recovery rate (RR) of the JOA score, which

Fig. 3. — Lateral radiograph showing evaluation of the cervical curvature index (CCI) with the Ishihara method: CCI = (a1+a2+a3+a4)/A

indicates the degree of normalization after surgery, was calculated using the Hirabayashi formula: [(post-operative JOA score - pre-operative JOA score)]/(17 - pre-operative JOA score) × 100%]. Post-operative outcomes were evaluated 12 months after the surgery. Operative time, blood loss and cost were noted. Complications including infection, hardware failure, lamina reclosure, cerebrospinal fluid leakage, kyphosis, and C5 palsy were also recorded till the final follow up for all patients.

Range of motion (ROM) of the cervical spine was assessed by measuring the difference in the lordotic angle of flexion and extension using the Cobb's method (Fig. 2). Cervical lordosis was measured on lateral radiographs using the cervical curvature index(CCI) (Fig. 3), as described by Ishihara *(17)*. Pavlov's ratio was measured on lateral radiographs (Figs. 4). Open angle (Fig. 5) and Pavlov's ratio was used to evaluate spinal canal expansion. Anterio-posterior diameter(APD) of the C3 to C7 spinal canal was measured using Wolf's method on CT scan *(22)* (Fig. 6). To estimate the drift back of the spinal cord, the average distance from the anterior wall of the spinal canal to the posterior edge of the spinal cord at each disk level between C2/3 and C6/7 was measured on T2-weighted MRI (Fig. 7).

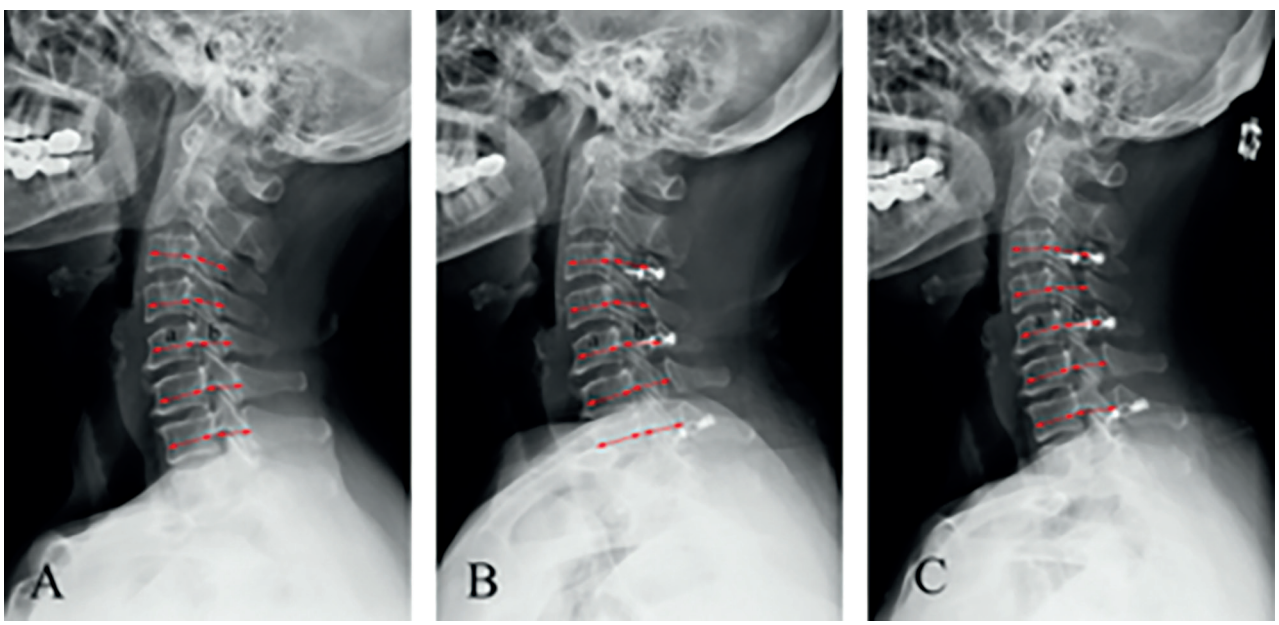

Fig. 4. — Measurement of the pre-operative(A), Post-operative (B) and final follow-up (C) Palov's ratio on lateral radiograph. The Palov's ratio=b/a

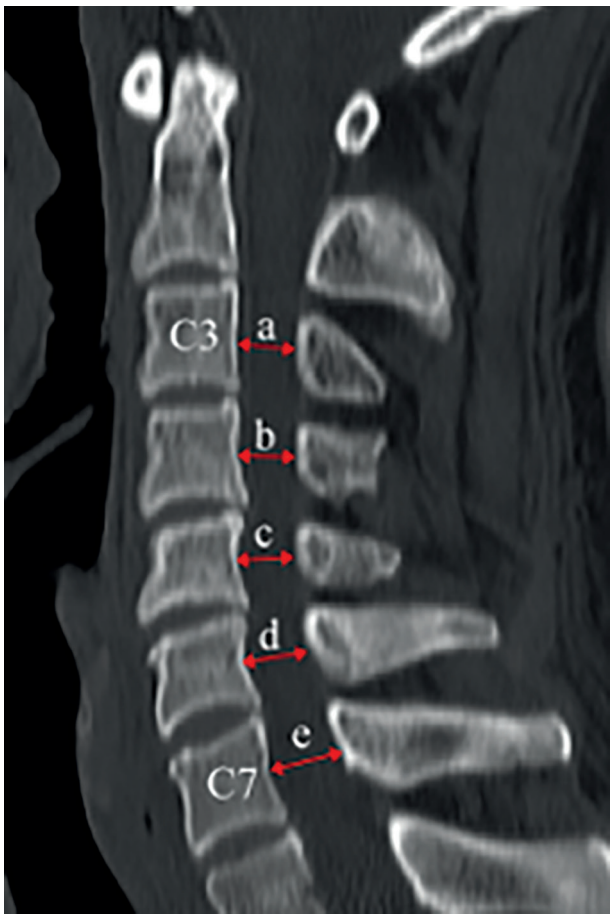

Fig. 5. — Sagittal CT showing the mean anterio-posterior diameter (APD) to evaluate the C3 to C7 spinal canal: APD=(a+b+c+d+e)/5

All results were performed twice, with a week interval in between the two measurements, by two of the authors, and the mean data were evaluated.

Data were presented as means ± standard deviation (SD). Statistical analysis was carried out using SPSS statistical software package 18.0 for Windows (SPSS Inc, Chicago, USA). A Student's t-test was used for statistical analysis of the difference in the mean values between the two groups. A paired t-test was performed to statistically analyze the difference between the pre-operative and post-operative score changes in each group. The Chi-square test for independence was used in the comparison of patients demographic data. The Fisher test was used in the comparison of incidence of post-operative axial symptoms and C5 palsy between groups A and B. A two-sided p value of <0.05 were considered significant.

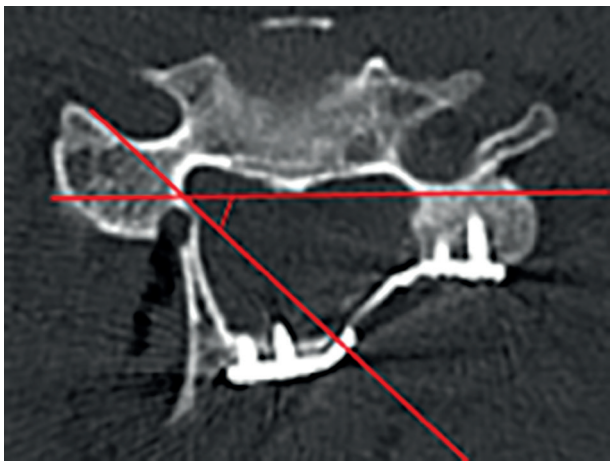

Fig. 6. — The postoperative axial CT showing the open angle which defined as the angle between the line connecting the medial end of the bilateral facet joint and the line connecting the bilateral end of the opened lamina

RESULTS

Three alternating levels (C3, C5, and C7) were fixed by mini-plates, the suture fixed levels were C4 and C6 in 31 cases (group A) consisting of 17 males and 14 females, 24 patients had cervical spondylotic myelopathy and 7 patients had ossification of posterior longitudinal ligament, the mean age was 58.06±9.74 years. Meanwhile, all levels (C3-C7) were fixed in 33 cases (group B) including 17 males and 16 females with mean age 54.24±9.71 years. 23 patients had cervical spondylotic myelopathy and 10 patients had ossification of posterior longitudinal ligament. The mean operation time was 137.1±15.37 min in groups A and 140.91±18.89 min in groups B respectively ($P > 0.05$). Blood loss was 280.48±51.76 ml in groups A and 280.76±40.64 ml in groups B respectively ($P > 0.05$). However, the mean cost of group B (11628.1±627.7 USD) was higher than group A (8843.4±333.1 USD) ($P < 0.05$). In total, 320 laminae was elevated, 258 laminae were fixed by plates, and 62 were fixed by suture. Of these patients, the mean follow up period was 37 months (range 24-60months).

JOA score improved from pre-operative 9.35±1.28 to 14.19±1.14 at last follow-up in group A and from 9.70±1.24 to 14.48±0.80 in group B, and this difference was statistically significant ($P < 0.05$). No difference of JOA score was observed

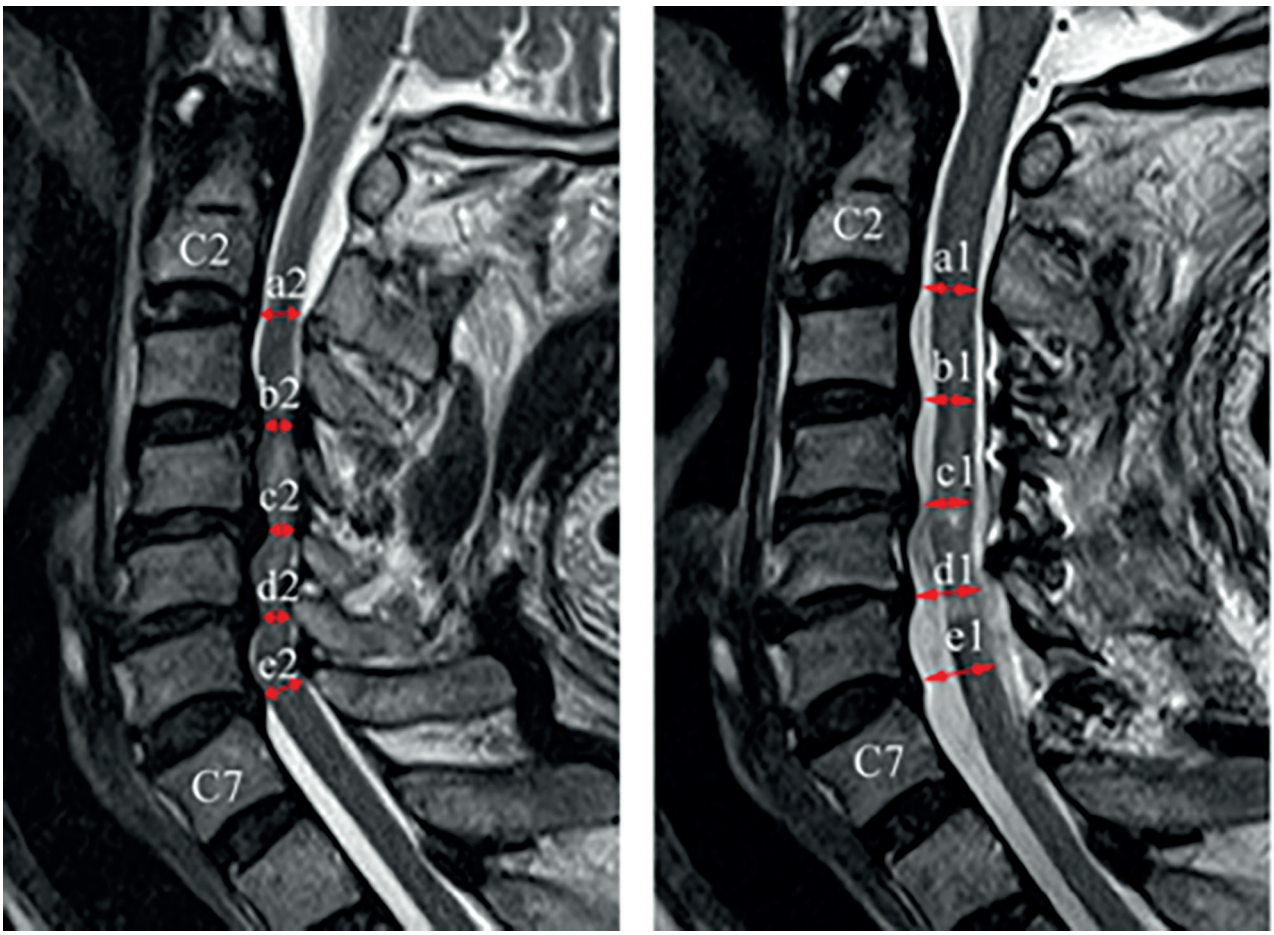

Fig. 7. — The average distance from the anterior wall of the spinal canal to the posterior edge of the spinal cord at each disk level between C2/3 and C6/7 was measured by T2-weighted MRI before (A) and after surgery (B). The spinal cord drift-back distance(mm) = [(a2-a1)+ (b2-b1)+ (c2-c1)+ (d2-d1)+ (e2-e1)]/5

between group A and group B pre-operatively ($P > 0.05$). The recovery rate (RR) of the JOA score was 63.14±12.78 in the group A patient and 64.54±13.09 in the group B patient. No difference of JOA recovery rate was found between group A and group B ($P > 0.05$).post-operative NDI was 7.23±6.19 in group A and 6.85±5.77 in group B, and significantly decreased compared with pre-operative 13.74±4.19 in group A and 13.70±3.50 in group B ($P < 0.05$). No difference of NDI was observed between group A and group B pre-operatively ($P > 0.05$).

Any post-operative complication was recorded. Axial symptoms after surgery were observed during follow-up examinations. No significant statistical difference was found in the incidence of axial symptoms between group A (3/31) and group B (3/33) ($P > 0.05$). There was no statistical difference in the incidence of C5 palsy between group A (2/31) and group B (3/33) ($P > 0.05$). C5 palsy was resolved completely by two weeks of conservative treatment. No neurological function aggravation, no infection, no cerebrospinal fluid leakage was discovered in any patients during the whole follow-up. All Clinical results and statistical results are shown in Table II.

All patients' imaging parameters were calculated by the same researcher in the authors' group.

Follow-up lateral cervical spine x-rays and CT showed that there were improvements in APD and Pavlov's ratio in all levels (mean APD increased from pre-operatively 10.04±0.59 mm to 17.17±1.19

Table II. — Clinical changes between group A and group B in open door cervical laminoplasty

	Number(n)	JOA score			RR	NDI score			C5 palsy	Axial symptoms
		pre-operative	Final follow-up	P value		pre-operative	Final follow-up	P value		
Group A	31	9.35±1.28	14.19±1.14	0.000	63.14±12.78	13.74±4.19	7.23±6.19	0.000	3	4
Group B	33	9.70±1.24	14.48±0.80	0.000	64.54±13.09	13.70±3.50	6.85±5.77	0.000	4	5
p		0.281	0.237		0.667	0.963	0.802		0.756	0.798

JOA japanese orthopaedic association, RR recovery rate, NDI neck disability index.

mm at the final follow-up in miniplate fixed levels and from 10.17±0.83 mm to 17.02±1.05 mm in suture fixed levels, mean Pavlov's ratio increased from 74.24±4.63 to 95.01±3.93 in miniplate fixed levels and from 74.29±4.62 to 95.57±4.10 in suture fixed levels) . No difference of APD and Pavlov's ratio was found between suture fixed levels and miniplate fixed levels pre-operatively ($P > 0.05$). There was no difference of the mean increased APD and Pavlov's ratio between miniplate fixed and suture fixed levels ($P > 0.05$). The mean value of post-operative open angle (41.31° ±4.31°degrees) in miniplate fixed levels was significantly more than that of post-operative open angle (38.63±4.14 degrees) in suture fixed levels($P < 0.05$). The mean open angle of CT scans was decreased at all levels (from 41.31° ±4.31° to 39.87°±4.29° in mini-plate fixed levels and from 38.63°±4.1444° to 33.835°±4.22° mm in suture fixed levels) at the final follow-up. ($P < 0.05$). MRI showed that the mean increase of 2.93±0.46 in group A and 3.30±0.49 mm in group B drift back of the spinal cord, together with the significantly increased cross sectional area of the dural sac, demonstrated satisfactory and stable spinal cord decompression. No difference of drift back of the spinal cord was found between group A and group B pre-operatively ($P > 0.05$).

The CCI was 22.30±2.43 pre-operatively and the value had decreased 20.93±2.47 at the final follow-up in miniplate fixed levels, and was 22.87±3.14 pre-operatively and had decreased 21.47±3.15 at the final follow-up in suture fixed levels. These changes were not significant. No difference of CCI was found between suture fixed levels and miniplate fixed levels pre-operatively ($P > 0.05$). Mean cervical ROM decreased from pre-operative 43.58±5.68 to post-operative 32.51±6.04 in miniplate fixed levels and from pre-operative 44.16±6.59 to post-operative 33.05±7.056 in suture fixed levels ($P < 0.05$).

CT scans showed osseous fusion on the hinge side in all patients through the follow up period. No kyphosis, no lamina reclosure, no implant failures such as screw looseness, shifting, or titanium miniplate fractures were discovered in any patients during the whole follow-up. All radiographic results and statistical results are shown in Table III.

DISCUSSION

Degenerative cervical myelopathy has recently defined as the overarching term for degenerative pathologies of the cervical spine including spondylosis and ligament ossification, which can result in spinal cord injury through static and dynamic injury *(11,14,16)*. Open door cervical laminoplasty is commonly used to manage degenerative cervical myelopathy and has satisfactory long-term fellow-up results *(4,5,7,12)*. However, the classical suture fixation do not provide rigid fixation and lead to the spring back closure phenomenon *(13)*. There have been various modifications and supplementary instruments for laminoplasty to maintain hinge patency and prevent reclosure of lamina, such as anchoring suture, spacer, allograft, auto-graft and mini-plate fixation *(13,18,24)*. However, suture anchors may displace, and the suture may cut out

Table III. — Radiologic changes between suture segments and mini-plate segments in open door cervical laminoplasty.

		Suture segments	Mini-plate segments	p value
Number(n)		62	258	
APD	Pre-operative	10.166±0.8262	10.039±0.5916	0.257
	Final follow-up	17.023±1.0512	17.172±1.1918	0.367
	p value	0.000	0.000	
Pavlov's ratio	Pre-operative	74.29±4.617	74.24±4.627	0.938
	Final follow-up	95.57±4.099	95.01±3.935	0.317
	p value	0.000	0.000	
Open angle	Post-operative	38.632±4.1444	41.305±4.3119	0.000
	Final follow-up	33.835±4.2223	39.870±4.2908	0.000
	p value	0.000	0.000	
CCI	Pre-operative	22.87±3.135	22.30±2.427	0.114
	Final follow-up	21.465±3.1529	20.931±2.4672	0.150
	p value	0.000	0.000	
ROM	Pre-operative	44.155±6.5899	43.577±5.6824	0.487
	Final follow-up	33.052±7.0558	32.510±6.0396	0.579
	p value	0.000	0.000	
Drift back of spinal cord		2.93±0.46(group A)	3.30±0.49(group B)	0.527

APD anterio-posterior diameter, CCI cervical curvature index, ROM range of motion.

and break, which cannot dispose of the problems associated with sutures *(6)*. Allogenic or autogenous bone grafts and spacers are limited by the spinous process size, donor site morbidity, difficulty in obtaining exact carpentry to hold the graft in place, and partial resorption and have a disadvantage such as root or cord compression due to graft kickout *(9,18)*. Compared to suture and spacer fixation, mini-plate fixation provides a rigid supporting structure for the expanded spinal canal to prevents reclosure of the opened lamina efficiently *(6,12,13)*.

Usually, the plate is applied at each level. Recently, several authors have presented a new technique of cervical laminoplasty used at alternating levels titanium miniplates(i.e. C3, C5 and C7)in order to reduce the cost for the patients *(1,13,23)*. Whether they have comparable clinical efficacy or not is questionable since there is a lack of comparative data between the two kinds of plate fixation in the literature *(2,15,19,21)*. For patients using all levels plate fixation as our preceding operative method, the average cost from admission to discharge is $11628.1, which is relatively high. In order to reduce the patients' cost, the plate is applied at alternating levels (C3, C5, C7) in our research. The cost has a decrease to $8843.4.

Previous research works have reported a satisfactory neurological improvement after both suture fixation laminoplasty and laminoplasty with titanium mini-plates fixation even though a relatively long followup period *(1,5,13,15,19,21,23)*. In our research, the recovery rate are satisfactory. There was no difference in regard to functional improvement between alternating levels and all levels group.

Clinical outcomes are always associated with space provided for the drift back of the spinal cord after laminoplasty. Drift back of the spinal cord, together with a sufficiently open angle and enlargement of the cross sectional area of the dural sac, demonstrated satisfactory and stable spinal cord decompression. When comparing the radiographic results between mini-plate segments and suture segments, the mean APD and Pavlov's ratio were all improved with the final followup and showed no statistical difference. The mean

post-operative open angle in mini-plate fixed levels was significantly more than that in suture fixed levels. The mean open angle was decreased at all levels at the final follow-up. This may be due to osteoproliferation of the broken ends of the open side of suture fixation segments. In mini-plate segments, the plate restricted the osteoproliferation of ends. No reclosure or implant failure was detected during followup.

Laminoplasty preserved the skeletal structure of the cervical spine and partially reconstructed the muscular system. Reducing the effect of sagittal balance, thus, maintaining the cervical curvature. Our result showed that CCI did not decrease significantly compared with preoperation and no kyphosis has occurred at the final follow up. Normal cervical curvature and sagittal plane mechanical balance is the basis to maintain normal ROM in the cervical spine. Furthermore, sagittal plane mechanical balance and cervical curvature are maintained by the best tension of posterior cervical muscles and ligaments. Though, laminoplasty relatively preserves the posterior elements. Post-operative ROM in cervical spine decreased compared with that before operation. In our study, the percentage of ROM preservation was 73.32±22.39%. We suppose that this decrease of ROM may have occurred partly as a result of impingement of the opened lamina and leading to mild restriction of extension. We consider short duration for post-operative restriction is important for preserving cervical ROM and reducing incidence of axial symptom.

Complications of surgery did take place in our patient population. The most frequent post-operative complication was axial symptoms *(5)*. The exact reasons for axial symptoms are unclear, but the imbalance of posterior neck muscle distribution, destruction of the facet joint, the sinking or nonunion of the hinge of the expanded laminae, and inadequate dural expansion may be the related factors *(2,3,20)*. Wearing a longer time of cervical brace after the operation result in muscular dystrophy which is connected with the risk of axial symptoms *(9)*. Mini-plate fixation can provide stability once and can allow a patient to perform early post-operative activity. In our research, we reconstruct posterior cervical muscles during operation and encourage tolerable exercise with only two weeks of collars wearing. We thought the early post-operative exercise could significantly prevent muscular dystrophy. Thus reducing axial neck pain. C5 palsy is seen occasionally in patients treated with laminoplasty. The exact etiology of C5 palsy remains unclear; may be caused by the tethering effect of the C5 nerve root, segmental spinal cord disorder and an increase in post-operative cervical lordosis *(1,10)*. In our research, no difference of incidence of axial symptoms and C5 palsy was found between group A and B.

The shortcomings of our study lies in the fact that the results were obtained from the small patient population and the short follow-up duration study. A further limitation of this study seemed to be retrospective nature. Future studies, prospective investigations enrolling more patients through long-term followup period are needed to evaluate the clinical and radiographic efficiency of this miniplate Open door laminoplasty more reliably and objectively.

In conclusion, open door laminoplasty at alternating levels mini-plate fixation can obtain similar satisfactory clinical and radiological results compared to all levels mini-plate fixation. However, it is an economical surgical method for patients with degenerative cervical myelopathy.

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