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Comparative effectiveness of all levels miniplate fixation versus a modified hybrid fixation in cervical expansive open-door laminoplasty

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Abstract

In this study, we first reported of a modified hybrid fixation method in expansive open-door laminoplasty (EOLP) in order to reduce medical costs. The purpose of the present study is to compare the surgical outcomes and cost-effectiveness of the modified fixation with all levels miniplate fixation in EOLP for multilevel cervical spondylotic myelopathy.

Data of 67 patients who underwent EOLP from July 2015 to June 2016 were retrospectively analyzed, with 33 in the modified group and 34 in the all miniplate group based on their surgical approaches. Laminae were kept open with alternate levels miniplate and anchor fixation in the modified group, while with all levels miniplate fixation in the all miniplate group. Medical costs and clinical results including Japanese Orthopedic Association (JOA) scores, Visual Analogue Scale (VAS) scores and occurrences of complications were investigated and compared between the 2 groups. After evaluation on X-ray, CT, and MRI, radiographic data reflecting cervical alignments, spinal canal enlargement and spinal cord decompression were collected and compared within each group and between the 2 groups.

After a follow-up period of about 18 months, no significant differences in operation time, intraoperative blood loss, complication rates, VAS scores, neurological recovery rates and postoperative hospital stays were observed between the 2 groups. However, EOLP with the modified fixation costed less. When comparing the 2 groups, cervical curvature index (CCIs) which reflected cervical alignments and anteroposterior diameters (APDs) reflecting spinal canal enlargement at all the follow-ups had no significant differences. Postoperative open angles which reflected spinal cord decompression of C4 and C6 were significantly smaller in the modified group. However, that difference was no longer detected at the final follow-up. Within each group, APDs increased significantly after surgery. However, no significant differences in CCIs and open angles at different follow-ups were observed in each group.

Compared with all miniplate fixation, the modified hybrid fixation in EOLP showed almost the same clinical and radiographic results. However, the modified hybrid fixation method could reduce costs.

Abbreviations: APD = anteroposterior diameter, CCI = cervical curvature index, EOLP = expansive open-door laminoplasty, JOA = Japanese Orthopedic Association, VAS = Visual Analogue Scale.

Keywords: cervical laminoplasty, cervical spondylosis, fixation, open-door

1. Introduction

Expansive open-door cervical laminoplasty (EOLP) was first developed by Hirabayashi 4 decades ago and until now it is still an important posterior decompression surgery for multilevel cervical spondylotic myelopathy.[1] Sufficient open-door angle and enlargement of the canal are critical for spinal cord to drift away from the anterior compression. Traditionally, fixation of the opened laminae with sutures has been used and was reported to gain neurologic recovery effectively.[2] However, this kind of fixation could not provide rigid fixation and complications including secondary narrowing of the spinal canal due to reclosure of the laminae, axial pain and loss of cervical ROM (range of motion) have been reported.[3–5] In 1996, O'Brien et al reported a new technique involving maxillofacial miniplates and screws for securing the laminae at the opened levels.[6] Miniplate fixation could provide rigid fixation and was promising to reduce these complications, since then, this technique became popular and was conducted extensively in EOLP.[7] Generally, miniplates are introduced at all the opened levels, but medical costs become high because of the expensive hardware. For reducing costs and

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obtaining promising outcomes at the same time, we conducted EOLP with alternate levels miniplate and anchor fixation in our department. Up to now, no studies on this modified hybrid fixation method have been reported in the literature.

In the present study, we compared the surgical outcomes of the modified fixation with all levels miniplate fixation in EOLP. The purpose of this study is to elucidate the feasibility and cost-effectiveness of the modified fixation procedure through clinical and radiologic analysis.

2. Methods

All study methods were approved by the Ethics Committee of Tongji Hospital of Tongji Medical College, Huazhong University of Science and Technology. All the subjects enrolled into the study gave written informed consents to participate.

2.1. Subjects

A total of 73 patients underwent cervical EOLP with the modified fixation or with all levels miniplate fixation from July 2015 to June 2016 in the orthopedics department of our hospital. Clinical diagnoses were made by symptoms, physical examinations and radiographic data. Exclusion criteria included cervical trauma, cervical tumor, anterior-posterior hybrid surgery and operation levels not from C3 to C7. Advantages and disadvantages of the 2 surgical procedures were thoroughly explained to the patients, all patients made their own decisions afterwards. The patients choosing EOLP with all levels miniplate fixation consisted the miniplate group and the remaining patients consisted the modified group. Finally, 67 patients consistent with inclusion and exclusion criteria were enrolled in the study. The data of the 67 patients were retrospectively analyzed. Of the 67 participants, 52 were men and 15 women with a mean age of 53.4 ± 10.8 (range 28–78) years old.

2.2. Surgical procedures

All surgeries were performed by 2 senior spine surgeons in our department. The procedures were performed according to techniques that had been used in previous studies with some modifications.[6] For all the patients, laminae from C3 to C7 were expanded. After receiving general anesthesia, the patient was positioned prone with the cervical spine in mild flexion. Bilateral paravertebral muscles were dissected after a posterior midline incision was made. Then the ligaments between C2 and C3 and between C7 and T1 were removed with a Kerrison rongeur. The opening side was determined by the dominant symptoms and preoperative imaging. After V-shaped gutters were created on both sides with a high-speed drill, the ventral cortex of the gutter on the opening side was then removed. After that, the laminae were opened carefully with removal of the adhesions of dural mater and ligamentum flavum at the same time.

In the miniplate group, appropriate size of miniplate was placed at each level. Two mini-screws in the lateral mass and 2 in the laminae were used to fix the plate tightly. In the modified group, appropriate size of miniplates were placed at C3, C5, and C7. Meanwhile, spinous processes at the other 2 segments were tied to anchors on the lateral mass tightly (Fig. 1). Centerpiece miniplates (Centerpiece plate, Medtronic Sofamor Danek, Memphis, TN) were used according to the surgeon's preference. A drainage tube was left in the wound and removed within 48 hours. All the patients were encouraged to perform isometric contraction of the neck extensor with manual resistance and required to wear a soft collar during routine walking for 4 weeks.

2.3. Evaluation

Clinical data including surgical duration, blood loss, postoperative hospital stays, medical costs were collected and compared between the 2 groups. Complications including infection, cerebrospinal fluid leakage, C5 palsy, axial pain and hardware failure were recorded until the final follow-up. Neurological

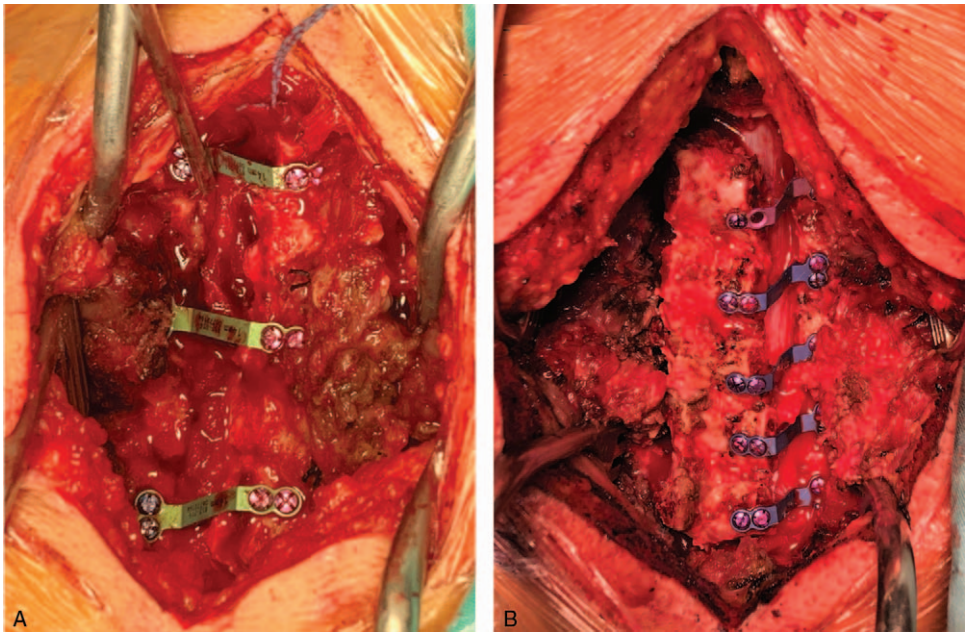

Figure 1. Intraoperative images illustrated the 2 fixation methods in EOLP. (A) The modified fixation method in EOLP, in which the C2 and C4 segments were fixed with anchor. (B) All levels miniplate fixation in EOLP. EOLP = expansive open door laminoplasty.

function was evaluated with the JOA scores, and neck pain was assessed using the VAS scores. The rate of recovery which indicates the degree of normalization after surgery, was calculated using the formula: recovery rate = (final follow-up JOA score – JOA score before surgery) / (17-JOA score before surgery) × 100%. The JOA scores, the VAS scores and the JOA recovery rates were compared between 2 groups.

Axial symptoms were defined as pain or muscle spasm distributed over posterior neck, shoulder and the suspensory muscles.[8] We considered significant axial symptom when a patient's VAS score was more than 3 before surgery or at the final follow-up. Segmental motor paralysis of C5 or C5 palsy was defined as weakness of the muscles controlled by C5 nerve root, which was considered to be attributed to nerve root lesions during surgery or tethering effect on the nerve root induced by excessive posterior shift of the spinal cord.[9]

X-ray films, CT or MRI scans were performed before surgery, after surgery and at the final follow-up. APDs were measured according to Wolf's method on lateral radiograph (Fig. 2).[10] Angles of the opened laminae were measured between the lines from hinge to the endpoints of the divided lamina using CT or MRI scans (Fig. 3). Cervical lordosis was measured on lateral radiograph using the CCI, as described by Ishihara (Fig. 4).[11]

2.4. Statistical analysis

Statistical analysis was performed using SPSS version 24.0 software (SPSS Inc., IL). Data were presented as mean ± standard deviation (SD). The independent-samples *t* test and Chi-square test were performed to analyze the differences between the two groups, and the paired sample *t* test was used for analyzing the differences of radiography data between different follow-ups in 1 group. Statistical significance was established at $P < .05$.

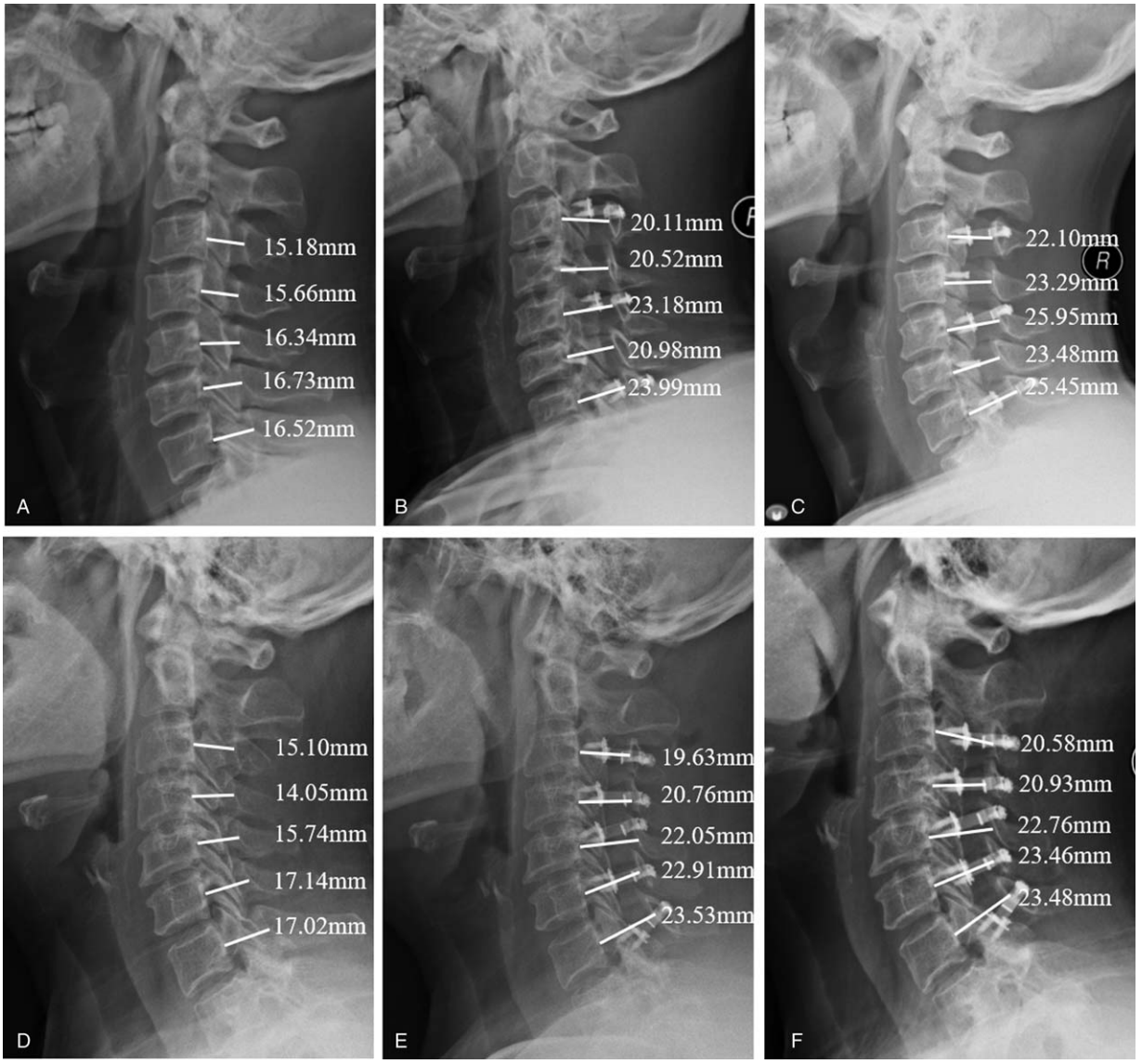

Figure 2. Measurement of anteroposterior diameters according to Wolf's method in the 2 groups before surgery, after surgery and at the final follow-up. (A–C) Lateral X ray images of a 50 years old male patient in the modified group. (D–F) Lateral X ray images of a 55 years old female patient in the miniplate group. mm = millimeter.

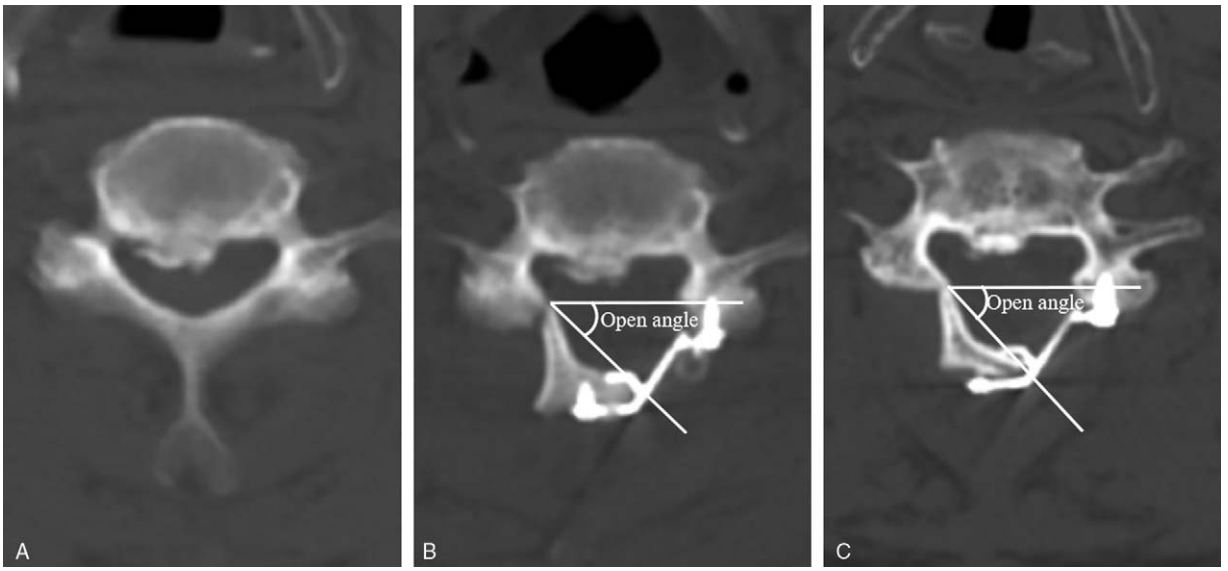

Figure 3. Measurement of open angles at C6 with axial CT scans before surgery (A), after surgery (B) and at the final follow-up (C).

3. Results

3.1. General data

There were 33 patients in the modified group and 34 in the miniplate group, respectively. The mean follow-up time for the modified group was 18.6 months, which was 18.9 months for the miniplate group. There were no significant differences in gender, age, operation time, blood loss and postoperative hospital stays between the 2 groups (Table 1). However, average medical costs in the modified group were significantly lower (Table 2). When we analyzed the costs in detail, the medication, hardware, nursing, and treatment costs in the modified group were much lower (Table 2).

3.2. Clinical results

Average JOA score significantly improved from 13.3 ± 3.4 before surgery to 15.6 ± 3.2 at the final follow-up in the modified group, which improved from 14.5 ± 2.1 to 16.1 ± 1.1 in the miniplate group significantly. The JOA recovery rates were $55.6\% \pm 65.2\%$ and $44.2\% \pm 49.2\%$ in the 2 groups, respectively. In the modified group, VAS scores before surgery and at the final follow-up were 2.0 ± 2.8 and 1.5 ± 2.2, which were 1.4 ± 3.0 and 1.7 ± 2.4 in the miniplate group. VAS scores and JOA scores before surgery and at the final follow-up, JOA recovery rates were not significantly different between the 2 groups (Table 1).

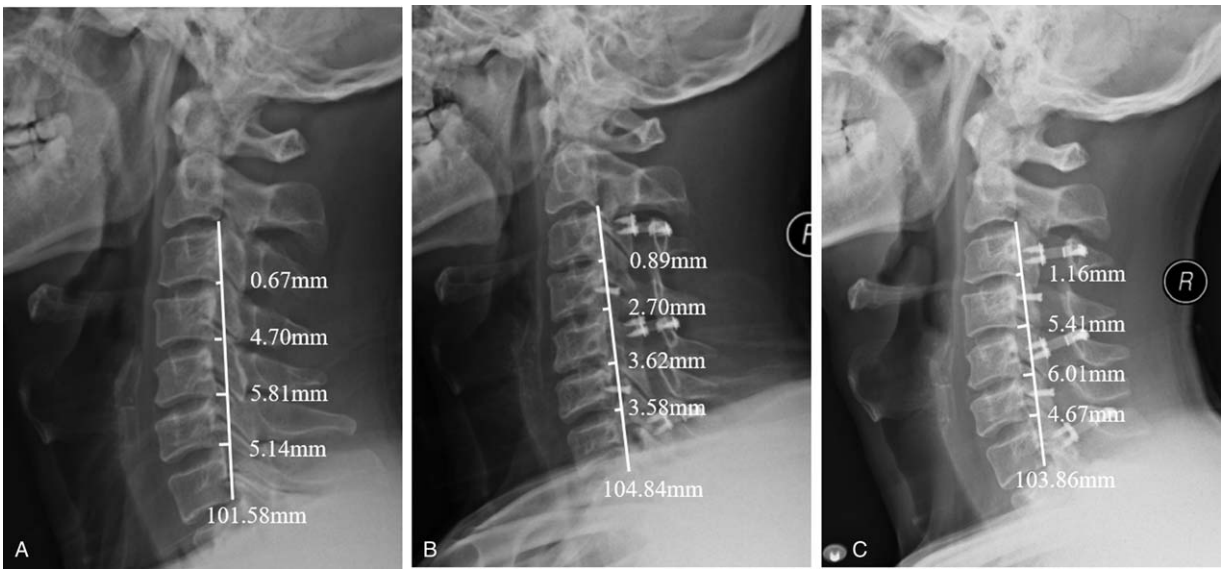

Figure 4. (A–C) Cervical curvature indexes were measured as described by Ishihara before surgery (A), after surgery (B), and at the final follow-up (C). mm = millimeter.

Table 1

Comparison of clinical data between the 2 groups.

	Modified group	Miniplate group	P
N	33	34	
Age (y)	52.1 ± 10.3	54.6 ± 11.2	.35
Gender			.13
Male	23	29	
Female	10	5	
OP time (min)	177.5 ± 45.5	191.2 ± 49.1	.25
Post-OP hospital stays (d)	7.9 ± 2.3	8.8 ± 2.0	.08
Blood loss (ml)	471.1 ± 198.1	611.6 ± 416.3	.19
VAS score			
VAS before surgery	2.0 ± 2.8	1.4 ± 3.0	.45
VAS final follow-up	1.5 ± 2.2	1.7 ± 2.4	.80
JOA score			
JOA before surgery	13.3 ± 3.4	14.5 ± 2.1	.11
JOA final follow-up	15.6 ± 3.2	16.1 ± 1.1	.45
JOA recovery rate (%)	55.6 ± 65.2	44.2 ± 49.2	.45

JOA = Japanese Orthopedic Association, OP = operation, VAS = Visual Analogue Scale.

Table 2

Detailed cost analysis of the 2 groups.

	Modified group (yuan)	Miniplate group (yuan)	P
Nursing and treatment	4603.2 ± 1666.4	5662.0 ± 1580.4	.01
Medication	15507.9 ± 6563.2	23993.4 ± 5570.3	< .001
Examination	4469.6 ± 1664.0	4362.1 ± 1285.2	.77
Surgery	9754.8 ± 2499.9	10179.0 ± 1686.0	.42
Hardware	80078.5 ± 14851.5	101587.6 ± 19828.4	< .001
Total	107707.2 ± 10915.3	154489.6 ± 11920.9	< .001

3.3. Complications

Neurologic deterioration, defined as decreasing of JOA score at the final follow-up compared with preoperative JOA score, was not noted until the final follow-up, and no patient needed revision surgery during our follow-up. Only 1 patient in the modified group experienced dural tear, whose pressured drainage was removed 1 week after surgery. Finally, the patient recovered without sequelae. One patient in the modified group exhibited poor wound healing that required prolonged antibiotic treatment and wound dressing, and it was healed in 3 weeks without debridement at last. Two patients in the modified group and 1 patient in the miniplate group exhibited transient postoperative C5 palsy, the symptoms improved significantly in 3 months after conservative therapy. There were 5 patients with significant axial pain before surgery in each group, 1 in the modified group and 4 in the miniplate group still had significant axial pain until the final follow-up after physical therapy. There were 2 and 3 new patients in each group developed significant axial pain after surgery, without significant axial pain before surgery. We observe no miniplates dislodged or broken and no laminae screws back-out until the final follow-up.

3.4. Radiologic evaluation

All these measurements were independently performed by 2 orthopedic doctors in the author's group. No implant failure was discovered and osseous fusion of the hinge side was confirmed in all the patients at the final follow-up. CCIs and APDs before surgery, after surgery, at the final follow-up were not significantly different between the 2 groups (Table 3). The postoperative open angles in the modified group at C4 and C6, which were fixed with anchor, were significantly smaller than those in the miniplate group (Table 4). However, open angles at C3, C5, and C7 had no significant differences between the 2 groups at that time (Table 4). At the final follow-up, we observed no significant differences in open angles at all the levels between the 2 groups (Table 4).

In the modified group, CCI increased from 6.9% ± 12.8% before surgery to 8.5% ± 10.4% after surgery and 8.4% ± 13.8% at the final follow-up. Meanwhile, CCI increased from 7.2% ± 9.8% before surgery to 8.1% ± 11.8% after surgery and 8.1% ± 10.5% at the final follow-up in the miniplate group. The differences were not statistically significant. Compared with postoperative open angles, open angles at the final follow-up neither had significant differences in each group (Table 4). We also observed that APDs at all levels significantly increased after surgery in both groups (Table 5). However, APDs at the final follow-up slightly decreased compared with postoperative APDs in each group, though no significant differences were observed (Table 5).

4. Discussion

Since the introduction of EOLP by Hirabayashi about 40 years ago, suture fixation of the opened laminae had been an important method.[1] However, as many studies had shown, laminae reclosure was reported to be a common yet serious complication, which could cause neurologic deterioration during the follow-up.[3,4,12] Chen et al defined laminae reclosure as a 10% decrease in Pavlov's ratio at 2 consecutive follow-up time points, whose study shown that laminae reclosure rate was 36.5% for the suture group at the final follow-up and 3 patients experienced secondary decompression surgery because of neurologic deterioration.[3] A 10% decrease in APD and a decrease of 10° in open angle were used as criteria of reclosure by Lee et al.[4] Reclosure rates of 44.7% and 22.7% were reported in their study.[4] Though the

Table 3

Comparison of anteroposterior diameter between the 2 groups.

	APD (mm)								
	Pre-OP			Post-OP			Final follow-up		
	Modified group	Miniplate group	P	Modified group	Miniplate group	P	Modified group	Miniplate group	P
C3	15.2 ± 1.1	15.5 ± 1.4	.49	23.3 ± 2.4	23.2 ± 2.5	.89	22.3 ± 1.4	22.1 ± 2.1	.70
C4	14.7 ± 1.3	14.8 ± 1.4	.75	22.6 ± 2.3	22.8 ± 2.1	.61	22.1 ± 1.3	21.9 ± 2.0	.77
C5	15.1 ± 1.2	15.7 ± 1.5	.12	24.1 ± 2.1	23.6 ± 2.2	.42	23.6 ± 1.4	22.5 ± 2.0	.06
C6	16.2 ± 1.2	16.3 ± 1.5	.74	24.6 ± 2.2	25.0 ± 2.0	.54	23.7 ± 1.6	24.1 ± 1.7	.46
C7	16.3 ± 1.2	17.0 ± 1.7	.06	25.7 ± 2.6	25.1 ± 2.3	.39	25.0 ± 2.1	24.5 ± 1.9	.55

APD = anteroposterior diameter, mm = millimeter, OP = operation.

Table 4

Comparison of open angles between the 2 groups and within each group.

	Post-OP (°)			Follow-up (°)		
	Modified group	Miniplate group	*P*	Modified group	Miniplate group	*P*
C3	30.1±5.7	34.5±6.9	.06	34.0±4.9	31.8±7.1	.44
C4	28.4±5.3	35.1±6.4	.003	31.2±6.0	31.7±7.0	.87
C5	33.5±4.4	34.9±6.4	.52	33.8±5.0	31.5±5.9	.36
C6	29.9±6.3	37.9±6.0	.001	30.6±5.9	34.8±4.1	.07
C7	32.3±5.2	37.7±8.5	.07	33.9±5.3	34.2±6.0	.91
	Modified group (°)			Miniplate group (°)		
	Post-OP	Follow-up	*P*	Post-OP	Follow-up	*P*
C3	30.1±5.7	34.0±4.9	.08	34.5±6.9	31.8±7.1	.39
C4	28.4±5.3	31.2±6.0	.20	35.1±6.4	31.7±7.0	.25
C5	33.5±4.4	33.8±5.0	.89	34.9±6.4	31.5±5.9	.21
C6	29.9±6.3	30.6±5.9	.78	37.9±6.0	34.8±4.1	.17
C7	32.3±5.2	33.9±5.3	.09	37.7±8.5	34.2±6.0	.29

OP = operation.

incidence of reclosure varies with different criteria, that complication is still prevalent.

In order to reduce the incidence of reclosure, many modified fixation approaches had been reported, such as using autologous bone grafts, hydroxyapatite or other ceramic materials, titanium miniplates to provide rigid fixation.[13,14] Though a spacer stuck between the opened lamina could maintain a stable condition, it might run the risk of spacer kick-out and result in spinal cord compression. Compared with spacer fixation, miniplate fixation reinforced with screws could reduce the risk of instrumentation-related complications and now is widely applied in clinical practice.[14,15] Usually, miniplates were introduced at all levels in EOLP. However, studies began to perform modified approaches to reduce the number of miniplates used due to the high costs. Wang et al performed EOLP with alternate levels miniplate fixation, in which miniplates were used only at C3, C5, and C7.[16] Then they compared this fixation method with all levels miniplate fixation and found that though this modified mothed could reduce costs, its JOA recovery rate, mean open angle and APD were significantly lower.[16] They inferred that less spinal canal enlargement and reclosure of the unfixed levels might be the reason.[16] Wang et al and Yang et al also performed this modified approach, after a mean follow-up period of 59.2 months and 23.2 months, respectively, JOA scores at the final follow-up improved significantly compared with preoperative JOA scores.[17,18] However, radiologic evaluation showed that postoperative open angles and APDs of C4, C6 were smaller than C3, C5, C7.[17,18] Their radiologic results were coincidence with Wang's inference.

In order to avoid reclosure of the unfixed levels and reduce medical costs at the same time, we performed EOLP with alternate levels miniplate and anchor fixation. At last, the medication, nursing and treatment costs in the modified group were much lower. We considered that patients in the miniplate group were better off financially and were more likely to choose better medical services which led to these results. However, the hardware cost was obviously reduced due to less use of 2 miniplates. Unlike the procedure mentioned above, we adopted anchor fixation at segments C4, C6.[17] Until now, this hybrid fixation method has not been reported yet. In the present study, we evaluated the neurological and radiography results of the 2 groups with a follow-up period of about 18 months. We observed that JOA scores and JOA recovery rates were not statistically different between the 2 groups and no patient need revision

Table 5

Comparison of anteroposterior diameter at different timepoints within each group.

	APDs of the modified group (mm)								
	Pre-OP	Post-OP	*P*	Pre-OP	Follow-up	*P*	Post-OP	Follow-up	*P*
C3	15.2±1.1	23.3±2.4	<.001	15.2±1.1	22.3±1.4	<.001	23.3±2.4	22.3±1.4	.14
C4	14.7±1.3	22.6±2.3	<.001	14.7±1.3	22.1±1.3	<.001	22.6±2.3	22.1±1.3	.37
C5	15.1±1.2	24.1±2.1	<.001	15.1±1.2	23.6±1.4	<.001	24.1±2.1	23.6±1.4	.46
C6	16.2±1.2	24.6±2.2	<.001	16.2±1.2	23.7±1.6	<.001	24.6±2.2	23.7±1.6	.13
C7	16.3±1.2	25.7±2.6	<.001	16.3±1.2	25.0±2.1	<.001	25.7±2.6	25.0±2.1	.37
	APDs of the miniplate group (mm)								
	Pre-OP	Post-OP	*P*	Pre-OP	Follow-up	*P*	Post-OP	Follow-up	*P*
C3	15.5±1.4	23.2±2.5	<.001	15.5±1.4	22.1±2.1	<.001	23.2±2.5	22.1±2.1	.11
C4	14.8±1.4	22.8±2.1	<.001	14.8±1.4	21.9±2.0	<.001	22.8±2.1	21.9±2.0	.13
C5	15.7±1.5	23.6±2.2	<.001	15.7±1.5	22.5±2.0	<.001	23.6±2.2	22.5±2.0	.06
C6	16.3±1.5	25.0±2.0	<.001	16.3±1.5	24.1±1.7	<.001	25.0±2.0	24.1±1.7	.13
C7	17.0±1.7	25.1±2.3	<.001	17.0±1.7	24.5±1.9	<.001	25.1±2.3	24.5±1.9	.30

APD = anteroposterior diameter, mm = millimeter, OP = operation.

surgery during the follow-up, which were different from Wang's study.[16] We considered the reason might be that anchor fixation at C4 and C6 could secure the opened laminae from reclosure after adjacent segments were rigidly fixed. Radiography results confirmed this. Compared with APDs in the miniplate group, APDs after surgery and at the final follow-up in the modified group were not significantly different, even not slightly smaller. We also observed that open angles of C4 and C6 after surgery in the modified group were statistically smaller than in the miniplate group, however, that difference disappeared at the final follow-up. We considered that laminae at C4 and C6 were not rigidly fixed in the modified group, they might be slightly opened during adhesion of the paraspinal muscle, and open angles of C4 and C6 at the final follow-up were indeed larger than those after surgery, though no significant differences were observed. All these results indicated that anchor fixation at C4 and C6 could secure the laminae from reclosure after adjacent segments were rigidly fixed, and EOLP with this modified fixation procedure was safe and effective.

As studies reported, all levels miniplate fixation could better maintain cervical range of motion and lordosis curve than suture fixation.[3,5] Mo et al. reported in their meta-analysis that, compared with anchor fixation, suture suspensory and titanium plate groups showed no significant difference in changes of cervical curvature, but significant difference was found between the 2 groups.[5] Lin et al reported in their meta-analysis that anchor fixation showed lower postoperative CCI compared with miniplate fixation.[19] But different from suture suspensory fixation and anchor fixation, fixation method in the modified group was a kind of hybrid fixation and results might be different. At last, we did not observe significant differences in CCIs at different time points between the 2 groups. It meant this modified method could also maintain a well cervical lordosis curvature compared with all levels miniplate fixation in a short follow-up time.

We further compared radiologic results at different follow-up time points within each group. We observed that APDs after surgery were significantly larger than APDs before surgery. However, APDs at the final follow-up were slightly smaller than after surgery. Similarly, no significant differences were observed between postoperative open angles and open angles at the final follow-up in each group. These results showed that the opened laminae did not reclose obviously over time. As reported by Matsumoto et al and Rhee et al, laminae reclosure mainly occurred in the first 6 months after surgery, for fusion of the hinge side after 6 months was likely to prevent laminae reclosure.[20,21] Therefore, we inferred that opened laminae in the 2 groups were unlikely to reclose after a follow-up period of 18 months. This inference requires a longer follow-up study to verify. As Du et al reported in their study, patients underwent cervical laminoplasty experienced a significant loss of CCI after a follow-up period of 9.17 years.[22] However, we did not find a significant change in CCIs in the 2 groups in our study. There were similar reports in a few studies. In the report of Wang et al, CCI in the alternate group slightly decreased from 0.22 ± 0.04 before operation to 0.21 ± 0.04 after a follow-up period of 59.2 months.[17] Chen et al reported in their study that lordotic angle in the all miniplate group even increased from $18.93° \pm 4.88°$ to $21.24° \pm 5.85°$ 1 year after surgery.[23] With a longer follow-up period, the results of CCIs and lordotic angle might be different.

Axial pain is a common complication after cervical laminoplasty. The reasons for axial neck pain still remain contentious. It is believed that destruction of the posterior structures, disturbance of the facet joints and severe neck pain before surgery may be related to axial pain after surgery.[24] Some reports also showed that preserving the extensor muscle insertion into C2 and C7 spinal processes can decrease the incidence of axial pain.[25] In the present study, we did not preserve the extensor muscle insertion point and only 5 patients suffered from significant axial pain before surgery. Regarding the relatively small sample size and the low incidence of axial pain, we failed to find out the involved mechanisms. Much about the same reasons, we also could not find out the possible mechanisms of C5 palsy.

Several limitations of this study should be mentioned. First, the sample size was small and the follow-up period was not long enough. Besides, the open angles were not all measured on the axial CT scans, which was best for the display of bony structures. Prospective, a larger sample size and a longer follow-up time randomized controlled trail is required to further elucidated this problem.

In conclusion, the modified hybrid fixation method in our study showed almost the same clinical and radiographic results compared with all miniplate fixation in EOLP. However, this modified fixation method could reduce medical costs by using fewer miniplates.

Author contributions

Conceptualization: Heng Zeng.
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