CLINICAL ARTICLE

Novel Three-Holed Titanium Plate Fixation during Open Door Laminoplasty for Cervical Spondylotic Myelopathy: Comparison with Conventional Titanium Plate

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Objective: For reconstructing the posterior cervical muscular–ligament complex, attachment points and various modified techniques were designed and applied in clinical practice. This study investigated the clinical and radiographic outcomes of open door laminoplasty with modified centerpiece mini-plate fixation and extensor attachment point reconstruction in the treatment of cervical spondylotic myelopathy (CSM).

Methods: Sixty-nine patients with CSM who underwent C3–C7 open door laminoplasty at our hospital from January 2016 to May 2018 were divided into two groups: 37 and 32 patients underwent laminoplasty with modified and conventional centerpiece titanium plate fixation (MPF and CPF groups), respectively. Changes in cervical spinal angle (CSA), cervical range of motion (ROM), posterior cervical muscle atrophy, neurological function (Japanese Orthopaedic Association [JOA] score), Neck Disability Index (NDI), and axial symptom severity were compared between the two groups.

Results: There were no significant differences in operative duration (136.7 ± 23.9 *vs* 128.3 ± 21.5 min, $t = 1.525$, $p > 0.05$), volume of intraoperative blood loss (275.9 ± 33.1 *vs* 268.2 ± 31.6 ml, $t = 0.984$, $p > 0.05$), lamina open angle (41.2° ± 4.5° *vs* 39.4° ± 4.1°, $t = 1.726$, $p > 0.05$), and spinal cord drift distance (2.4 ± 0.3 *vs* 2.3 ± 0.4 mm, $t = 1.184$, $p > 0.05$) between the two groups. After surgery, JOA score significantly increased ($p < 0.05$), and neurological recovery rates were similar (62.7% *vs* 63.4%, $t = 0.208$, $p > 0.05$). The NDI score was significantly decreased in both the groups ($p < 0.05$); however, the MPF group recovered to a greater degree than the CPF group (8.3 ± 1.2 *vs* 9.8 ± 1.4) ($t = 4.793$, $p < 0.05$). There was no significant change in cervical ROM postoperatively compared with preoperatively in either group ($p > 0.05$). CSA decreased from 21.7° ± 2.8° to 18.3° ± 2.1°, and posterior cervical muscle cross-sectional area decreased from 35.2 ± 4.9 cm^2 to 31.0 ± 4.1 cm^2 in the CPF group ($p < 0.05$), but no significant change was observed in the MPF group (20.6° ± 2.5° to 20.4° ± 2.6°and 35.9 ± 5.1 to 34.1 ± 4.6 cm^2, respectively) ($p > 0.05$). Postoperative axial symptom severity was significantly worse in the CPF group than in the MPF group ($Z = -2.357$, $p < 0.05$).

Conclusions: As an improvement to the conventional titanium plate, the modified centerpiece titanium plate effectively provides an attachment point for the posterior muscle–ligament complex, reducing posterior cervical muscle atrophy and improving neck function, without inflicting additional surgical trauma.

Key words: Axial symptoms; Centerpiece titanium plate; Cervical spondylotic myelopathy; Open door laminoplasty

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Introduction

Cervical spondylotic myelopathy (CSM) is a common degenerative disease of the spine. The main pathogenic factors of CSM in clude disc herniation, posterior osteophyte hyperplasia, posterior longitudinal ligament ossification, and ligamentum flavum thickening, which compress the spinal cord and cause varying degrees of neurological impairment.[1] Patients with CSM with severe spinal cord compression or multi-segmental compression (≥3 levels) are often treated surgically with the posterior cervical approach. Open door laminoplasty is a classic posterior decompression technique that has numerous advantages, including relative simplicity, a short learning curve, adequate spinal cord decompression, minimal loss of cervical motion segments, and a relatively complete cervical spinal canal after surgery.[2–3]

With the development and clinical application of various types of internal fixation device, vertebral laminar fixation with open door laminoplasty has gradually transitioned from the initial silk suspension to suture anchor fixation and titanium mini-plate fixation, with the centerpiece titanium plate being the most representative among the many available titanium mini-plates.[3,4] Of these three methods, the fixation strength of the titanium mini-plate is the greatest. Thus, it is advantageous in terms of achieving immediate stability, bony fusion, and long-term cervical spine stability.[3,5]

Laminoplasty involves extensive dissection of the posterior cervical extensor muscles. In patients with a short muscular neck, partial dissection of the semispinalis cervicis away from its C2 spinous process attachment is required to allow adequate opening of the vertebral laminae.[6] In addition, removal of the spinous process before vertebral lamina opening leads to loss of a wide range of muscle attachment points, resulting in postoperative posterior cervical muscle atrophy, which further weakens the effects of anti-axial load and stretch stress and may lead to changes in the cervical curvature, decrease cervical stability, and increase the incidence of postoperative axial symptoms.[7,8]

To reconstruct the muscle attachment points, a new centerpiece titanium plate was designed, in which the laminar side of the plate features an additional hole that allows direct suturing of the posterior cervical extensor muscles. The conventional centerpiece titanium plate does not provide muscle attachment points. The muscles on both sides are often stitched end-to-end when stitching the incisions, which causes muscle–skeletal separation. Nevertheless, the modified centerpiece titanium plate does provide effective muscle attachment points for key muscles, such as the semispinalis cervicis, trapezius, erector spinae, splenius capitis, and splenius cervicis muscles.

In this study, we aimed to (i) demonstrate the severity of muscle–ligament complex destruction during laminoplasty; (ii) explain the design of the modified centerpiece titanium plate and describe its advantages in reconstructing the muscle–ligament complex and promoting clinical efficacy; and (iii) explore the influence of modified centerpiece mini-plate fixation and extensor attachment point reconstruction on axial symptoms.

Methods

Patients

The clinical data of 69 patients with CSM who underwent C3–C7 open door laminoplasty at Tianjin Hospital from January 2016 to May 2018 were retrospectively analyzed. Patients were divided into two groups: 37 patients underwent laminoplasty with modified centerpiece titanium plate fixation (MPF group) and 32 patients underwent laminoplasty

TABLE 1 Comparison of the characteristics of patients between the two groups

Variables	MPF group (37 cases)	CPF group (32 cases)	t/χ^2 value	*p* value
Sex (cases)				
Male	20	15	0.354	0.552
Female	17	17		
Age (years) mean ± SD	63.7 ± 15.3	62.5 ± 14.4	0.333	0.739
Disease course (months) mean ± SD	19.9 ± 5.1	18.7 ± 4.9	0.992	0.325
Follow-up period (months) mean ± SD	16.3 ± 3.8	17.2 ± 4.0	0.957	0.342
ISI (cases)				
Yes	24	20	0.042	0.839
No	13	12		
Pathogenic types (cases)				
Cervical disc herniation	19	15	0.548	0.908
Ligamentum flavum hypertrophy	3	4		
Cervical disc herniation with ligamentum flavum hypertrophy	9	8		
Developmental spinal stenosis	6	5		

Scores are the mean ± standard deviation. The values are given as the mean and standard deviation. ISI, increased signal intensity.

with conventional centerpiece titanium plate fixation (CPF group). There were no significant differences in gender, age, disease course, follow-up period, ratio of increased signal intensity in the spinal cord, and type of pathology between the two groups ($p > 0.05$) (Table 1). The study was approved by the Medical Ethics Committee of Tianjin Hospital (2020YLS088). All patients provided written informed consent.

Inclusion and Exclusion Criteria

The patient inclusion criteria were as follows: (i) symptoms and signs of typical CSM; (ii) anormal cervical curvature and spinal cord compression at ≥3 levels; and (iii) clinical and radiographic follow-up of at least 12 months. Patients with coagulation disorders, concurrent thoracic or lumbar spinal stenosis, multi-level cervical instability, cervical kyphosis, posterior longitudinal ligament ossification, tumor, fracture, or infection were excluded.

Surgery

After induction of general anesthesia, the patient was placed in the prone position with the head fixed in a Mayfield head frame and the neck slightly flexed. First, a posterior midline incision was made to dissect through the centre of the nuchal ligament and expose the spinous processes. The posterior cervical muscles were then detached from the subperiosteum on both sides of the spinous process to expose the vertebral laminae and lateral masses. Second, a high-speed drill with a diameter of 3 mm (Stryker, USA) was used to create bilateral slots at the line of transition between the vertebral laminae and lateral masses. The side with fewer symptoms or less severe symptoms was used as the hinge side, and the cortex inside the vertebral lamina was retained. The side with more symptoms or symptoms of greater severity was used as the open side, and the medial and lateral cortices of the vertebral lamina were removed. Third, the spinous process was trimmed to the appropriate length, and the ligamentum flavum between the C2/C3 and C7/T1 vertebral laminae was separated. After clamping the root of the spinous process, the lamina was slowly opened to 35°–45°.

The modified centerpiece titanium plate (Beijing Fule Medical Equipment Co., Ltd.) has three holes at the lamina end. The distal hole is nonlinear with the other two holes at the proximal end and is upturned at an angle of 30°, which is convenient for thread penetration and fixation. In the conventional centerpiece titanium plate, there are two holes at the lateral mass end arranged longitudinally and parallel to the plate principal axis (Figure 1C).

In the MPF group, the appropriate length of modified titanium plates was selected and then the plates were inserted into the gap between the laminae and lateral masses at the C3, C4, and C7 segments (Figure 1D). The remaining segments were fixed with conventional titanium plates. Screws with a length of 6 and 8 mm were used to fix the plates to the lamina and lateral mass, respectively. The stripped semispinalis cervicis and multifidus muscles were sutured to the reserved additional hole of the C3 titanium plate, and the remaining posterior cervical muscles were sutured to the reserved additional hole of the plates at other levels (Figure 1E). In the CPF group, conventional centerpiece titanium plates (Medtronic Sofamor Danek, USA) were used for fixation, and the posterior cervical muscles and fascial layers were sutured to the corresponding contralateral layer (Figure 2).

All patients were administered prophylactic antibiotics plus 40 mg of methylprednisolone for 3 days. Surgical drains were removed when the drainage volume decreased to <30 ml over 24 h. All patients were allowed to perform out-of-bed activities with neck support.

Evaluation Criteria

The 17-point Japanese Orthopaedic Association (JOA) scoring system was used to evaluate neurological recovery before and after surgery.[1] The recovery rate was calculated as follows: (postoperative score − preoperative score) ÷ (17 − preoperative score) × 100%. Axial symptoms were recorded as postoperative neck pain with neck stiffness, shoulder stiffness, or both. Postoperative axial symptoms were evaluated according to the method of Hosono *et al.*[9] and graded as severe (analgesic or local injection regularly required), moderate (physiotherapy or therapeutic compress regularly required), or mild (no treatment required). The Neck Disability Index (NDI) scoring system was used to assess neck pain and neck function preoperatively and postoperatively.[2,4]

Imaging Evaluation

Cervical curvature was evaluated according to the cervical spine angle (CSA) using Harrison's method.[10] Specifically, two lines were drawn parallel to the vertebral posterior margins of C2 and C7, and CSA was defined as the angle between the intersection of the two lines (Figure 1A,F). Cervical range of motion (ROM) was measured as follows[11]: the trailing edge lines at C2 and C7 were measured in the flexed (a_1) and hyperextended (a_2) positions. ROM was defined as $a_1 + a_2$. Spinal drift distance (d) was the difference between the postoperative distance (d2) and preoperative distance (d1) between the posterior superior edge of the C5 vertebra and the anterior edge of the spinal cord on the midline image of sagittal magnetic resonance imaging (MRI)[12] (Figure 1B,G). The lamina open angle (a) was defined as follows: in the cross-sectional computed tomography image of each vertebral body, the angle between the point line of the medial facets and the line of the portal axis and the edge of the open lamina was measured as follows: $a = (a_3 + a_4 + - a_5 + a_6 + a_7) \div 5$ (Figure 1D).[13] The cross-sectional area of the posterior cervical muscles, including the trapezius, splenius capitis, semispinalis capitis, semispinalis cervicis, multifidus, longissimus capitis, longissimus cervicis, levator scapulae, posterior scalene, medial scalene, and anterior scalene muscles, was measured at C3/C4 and C4/C5 on

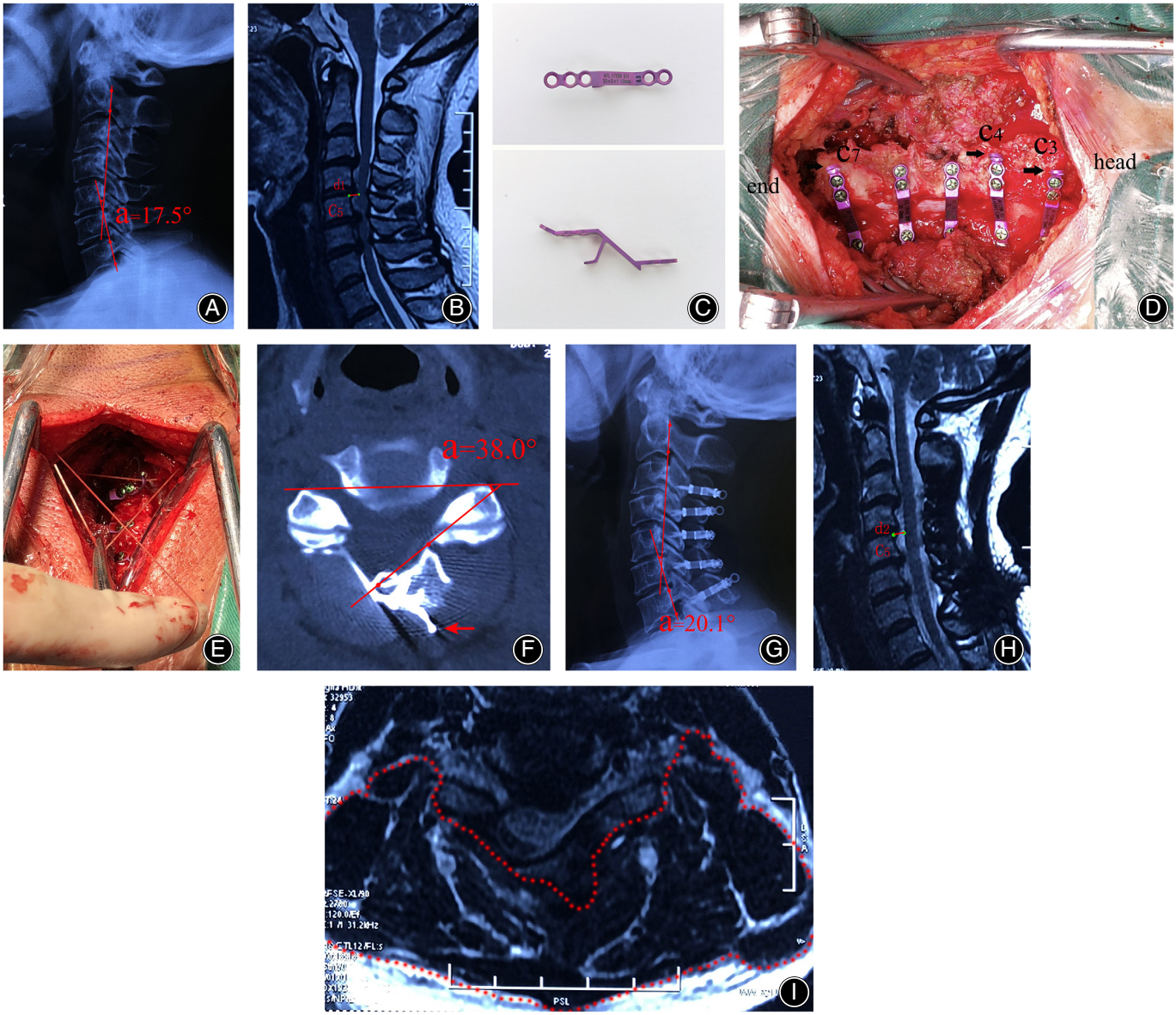

FIGURE 1 A 59-year-old male patient presented with numbness in the limbs and walking asthenia for 20 months. (A) Preoperative plain radiography showed hyperosteogeny at the anterior and posterior margins of the cervical vertebrae (cervical spine angle [CSA] = 17.5°). (B) Sagittal magnetic resonance imaging (MRI) showing disc herniations at the C3–C7 segments with ligamentum flavum hypertrophy. The spinal cord was compressed and appeared "beaded." (C) Front and side images of the modified centerpiece titanium plate. (D) Intraoperative picture illustrating the modified centerpiece titanium plate fixed at C3, C4, and C7 (black arrow). (E) Rebuilding of the posterior cervical muscles to the reserved additional hole. (F) Postoperative computed tomography showing that the C3 lamina open angle was 38.0°. The preformed hole (red arrow) was used to suture the posterior cervical muscles. (G) Plain radiography 1 year after surgery shows the open door laminoplasty with modified centerpiece plates at C3, C4, and C7 (CSA = 20.1°). (H, I) Postoperative MRI showing that the spinal canal was open with adequate decompression and sufficient spinal cord posterior drift. The cross-sectional area of the posterior cervical muscles was 34.7 cm^2

transverse MRI using Auto CAD software (Autodesk Inc., San Rafael, CA, USA)[7,14] (Figure 1H). To ensure measurement accuracy, two independent radiologists evaluated the images, and each parameter was measured three times and averaged.

Statistical Analyses

All statistical analyses were conducted using SPSS software version 20.0 (IBM, Chicago, IL, USA). Repeated measures at different time points were compared using the repeated measures analysis of variance. Continuous variables were

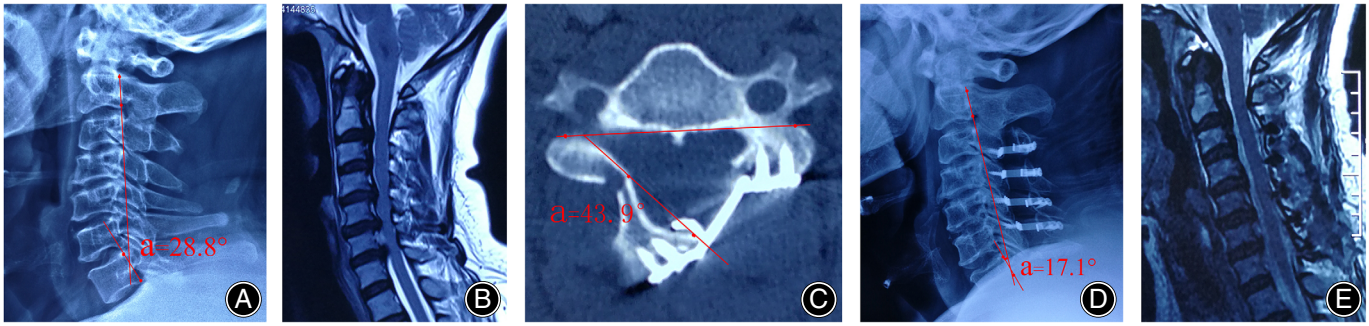

FIGURE 2 A 61-year-old female patient presented with numbness in the upper limbs and asthenia for 18 months. (A) Preoperative plain radiography showing degenerative changes in the cervical vertebrae (cervical spine angle [CSA] = 28.8°). (B) Preoperative magnetic resonance imaging (MRI) showing cervical disc herniation at the C2–C7 segments and multi-segmental spinal cord compression. (C) Postoperative computed tomography showing that the lamina open angle at C4 was 43.9°. (D) Plain radiography 1 year after surgery showing laminoplasty with the conventional centerpiece titanium plate at the C3–C7 segments (CSA = 17.1°). (E) Postoperative MRI showing adequate decompression and significant posterior spinal cord drift

TABLE 2 Comparison of intraoperative and postoperative data between the two groups

Groups	Operative duration (min) mean ± SD	Intraoperative blood loss (ml) mean ± SD	Lamina open angle (°) mean ± SD	Spinal cord drift distance (mm) mean ± SD
MPF group (37 cases)	136.7 ± 23.9	275.9 ± 33.1	41.2 ± 4.5	2.4 ± 0.3
CPF group (32 cases)	128.3 ± 21.5	268.2 ± 31.6	39.4 ± 4.1	2.3 ± 0.4
t value	1.525	0.984	1.726	1.184
p value	0.132	0.548	0.328	0.240

Scores are the mean ± standard deviation. The values are given as the mean and standard deviation.

compared between the two groups using the independent two-sample *t*-test. Proportions and grades were compared using the chi-square test and the Kruskal–Wallis rank-sum test, respectively. A two-tailed p value of < 0.05 was considered statistically significant.

Results

General Results

All patients underwent successful surgery without spinal cord injury or aggravation of neurological symptoms. The mean follow-up period was 22.9 ± 4.3 months (range, 14–32 months). No screw loosening, titanium plate displacement, fracture, or laminar collapse occurred during the follow-up period. There were no significant differences in operative duration (136.7 ± 23.9 *vs* 128.3 ± 21.5 min, t = 1.525, $p > 0.05$), volume of intraoperative blood loss (275.9 ± 33.1 *vs* 268.2 ± 31.6 ml, t = 0.984, $p > 0.05$), lamina open angle (41.2° ± 4.5° *vs* 39.4° ± 4.1°, t = 1.726, $p > 0.05$), and spinal cord drift distance (2.4 ± 0.3 *vs* 2.3 ± 0.4 mm, t = 1.184, $p > 0.05$) between the MPF and CPF groups (Table 2).

Imaging Results

The cervical ROM in each group did not significantly change after surgery when compared with the preoperative cervical ROM ($p > 0.05$). In the CPF group, the CSA (21.7° ± 2.8° *vs* 18.3° ± 2.1°, t = 3.652, $p < 0.05$) and cross-sectional area of the posterior cervical muscles (35.2 ± 4.9 *vs* 31.0 ± 4.1 cm^2, t = 2.934, $p < 0.05$) significantly decreased after surgery, while in the MPF group, the change was not significant ($p > 0.05$) (Table 3).

Recovery of Neurological and Neck Function

The JOA score significantly increased in both groups after surgery ($p < 0.05$), and the neurological recovery rates were similar between the two groups (62.7% *vs* 63.4%) (t = 0.208, $p > 0.05$). The NDI score showed significant decrease in both the groups ($p < 0.05$), but the MPF group recovered to a greater degree than the CPF group (8.3 ± 1.2 *vs* 9.8 ± 1.4) (t = 4.793, $p < 0.05$). Axial symptoms in the CPF group were more severe than in the MPF group (Z = 2.357, $p < 0.05$) (Table 4). No serious complications occurred during the perioperative period.

TABLE 3 Comparison of imaging changes between the two groups

Groups	Cross-sectional area of posterior muscles (cm^2) mean ± SD		ROM (°) mean ± SD			CSA (°) mean ± SD		
	preop	Final follow-up postop	preop	3 months postop	Final follow-up	preop	3 months postop	Final follow-up
MPF group (37 cases)	35.9 ± 5.1	34.1 ± 4.6	51.3 ± 5.2	48.4 ± 4.8	49.5 ± 5.0	20.6 ± 2.5	18.5 ± 2.3	20.4 ± 2.6
CPF group (32 cases)	35.2 ± 4.9	31.0 ± 4.1*	50.6 ± 4.9	47.4 ± 4.6	48.6 ± 4.7	21.7 ± 2.8	17.1 ± 2.0*	18.3 ± 2.1*
t value	0.579	2.934	1.135	1.636	0.792	1.711	2.677	3.652
p value	0.564	0.004	0.260	0.106	0.431	0.092	0.009	<0.001

Scores are the mean ± standard deviation. The values are given as the mean and standard deviation.; Abbreviations: CSA, cervical spine angle; ROM, range of motion.; * Compared with before surgery, $p < 0.05$.

TABLE 4 Comparison of neck function and neurological recovery between the two groups

Groups	NDI (%) mean ± SD		AS classification cases			JOA score mean ± SD			
	Preop	Final follow-up	Severe	Moderate	Mild	Preop	3 months postop	Final follow-up	Recovery rate (%) mean ± SD
MPF group (37 cases)	27.6 ± 4.9	8.3 ± 1.2[a]	2	8	27	7.5 ± 2.0	12.3 ± 3.1[a]	13.5 ± 3.5[a]	62.7 ± 13.8
CPF group (32 cases)	27.9 ± 5.1	9.8 ± 1.4[a]	3	15	14	7.7 ± 2.3	12.5 ± 3.2[a]	13.6 ± 3.4[a]	63.4 ± 14.1
z/t value	0.249	4.793		−2.357		0.382	0.263	0.119	0.208
p value	0.804	<0.001		0.018		0.703	0.793	0.904	0.835

Scores are the mean ± standard deviation. The values are given as the mean and standard deviation.; Abbreviations: AS, axial symptoms; JOA, Japanese Orthopaedic Association; NDI, neck disability index.; [a] Compared with before surgery, $p < 0.05$.

Discussion

In clinical practice, the modified centerpiece titanium plate was found to be simple and convenient to use and does not increase the operative time and surgery complexity. Additionally, the two titanium plates at the head end (C3 and C4) provided firm anchors and attachments for the cervical semispinalis muscle, while the titanium plate at the tail end (C7) could be a perfect replacement for the C7 spinous process and an essential fulcrum for the posterior cervical extensor muscles.

Destruction and Reconstruction of the Cervical Muscle–Ligament Complex during Laminoplasty

The posterior cervical muscle–ligament complex is an important structure for maintaining the stability of the cervical vertebrae. It is mainly composed of the spinous processes, supraspinous ligament, interspinous ligaments, and muscle tissues attached to the spinous processes, and it plays an important role in maintaining the biomechanical stability and physiological curvature of the cervical spine.[14] During open door laminoplasty, pruning or excision of the spinous processes causes damage to the supraspinous ligament and interspinous ligaments and removes the spinal attachment points of the posterior cervical muscles. Destruction of the muscle–ligament complex and loss of muscle attachment points can result in posterior cervical muscle atrophy, and weakening of the tension band can lead to loss of the cervical curvature and even cervical kyphosis.[2,7,9,15] When performing open door laminoplasty at C3–C7, to fully expose the superior border of the C3 lamina and the ligamentum flavum between the C2/C3 laminae, partial dissection of these mispinalis cervicis from the C2 spinous process is required.[6] If reconstruction is not properly performed at the end of surgery, iatrogenic muscle injury may result.

The semispinalis cervicis arises from the transverse process of the upper thoracic vertebrae and ends at the C2–C5 spinous processes. From a physiological perspective, the most important point is its attachment to C2. Studies have shown that the semispinalis cervicis is the most important posterior cervical extensor muscle because its contraction accounts for 37% of the total contraction distance during posterior cervical extension.[7] Therefore, reconstruction of muscle attachment points and maintenance of the mechanical strength of the muscle–ligament complex has become an

area of investigation for spinal surgeons seeking to improve outcomes after open door cervical laminoplasty.

Cheng *et al.*[16] first split the extensor muscle attachment points from the C2 spinous process before opening the laminae and reattaching the muscles to the C2 spinous process with a suture-replacing wire to retain the integrity and mechanical strength of these mispinalis cervicis. Umeda *et al.*[17] described C4–C6 laminoplasty with C3 and C7 partial laminectomies or C3 laminectomy and C7 dome decompression to maintain the integrity of the semispinalis cervicis and the nuchal ligament. Chen *et al.*[18] first isolated the muscle along the spinous process unilaterally to expose the laminae, and then cut off the muscle–ligament complex together with the spinous process from the root during piezosurgery. After the laminae were opened, the spinous process stump and muscle were reattached to the laminar cortex to preserve the unilateral paraspinal muscle complex. Although the above innovative techniques can reconstruct and preserve the integrity of the posterior cervical muscles using different methods, they all increase surgical complexity.

Comparison with the Conventional Centerpiece Titanium Plate

To resolve this problem, we modified the conventional titanium plate to facilitate reconstruction of the muscle attachment point. The conventional centerpiece titanium plate used to fix the lamina to the lateral mass has a "Z" shape with two holes at each end.[5,13,17–19] Considering that the root of the original spinous process is shifted to the contralateral side after lamina opening, it is difficult to achieve reconstruction of the muscle attachment points at the midline. Therefore, we modified the centerpiece titanium plate by appropriately extending the length of the titanium plate on the side of the lamina and adding a hole at the distal end (to form a total of three holes). During surgery, the medial two holes were used to fix the lamina, whereas the distal hole was used to reconstruct the semispinalis cervicis and anchor and suture the cervical extensor muscles.

Advantages of Surgery Using the Modified Centerpiece Titanium Plate

This study revealed no significant difference in operative duration (136.7 min *vs* 128.3 min) or volume of intraoperative blood loss (275.9 ml *vs* 268.2 ml) between the study groups, indicating that the modified centerpiece titanium plate did not increase the complexity of surgery. In addition, postoperative neurological function significantly improved in both groups, and the neurological recovery rates at the final follow-up were similar between the two groups. In addition, there was no significant loss of cervical ROM in either group after surgery. However, the cervical curvature and cross-sectional area of the posterior cervical muscles remained well-maintained in the MPF group, but they significantly decreased in the CPF group. Moreover, the NDI score in the MPF group recovered to a greater degree than that in the CPF group.

Retention of cervical motion segments and adequate stability reconstruction are the basis for maintaining a normal cervical ROM.[14,16] A "Z-shaped" titanium plate has adequate strength and stiffness to allow stable reconstruction.[3,19] Lateral fixation allows each vertebral body to have independent motion, preventing significant loss of cervical ROM.[5,18–19] Our modified centerpiece titanium plate provides a new attachment point for the posterior cervical muscles, thus avoiding muscle atrophy. In addition, the tension band generated by the posterior cervical muscles can still maintain the cervical curvature. The implantation of the modified titanium plates at C3 and C7 made it difficult to sustain cervical semispinous muscle tension; hence, an extra plate was implanted at the C4 level. Moreover, the supporting point formed at the distal end of the titanium plate at C3, C4, and C7 can also increase the force arm length of the posterior cervical extensor muscles.[8,15,20] Muscle fatigue does not easily occur after frequent cervical flexion and extension, which may explain the mild axial symptoms reported by patients in the MPF group.

Effect of Modified Centerpiece Mini-Plate Fixation and Extensor Attachment Point Reconstruction on Axial Symptoms

Axial symptoms are common after laminoplasty and occur in 6%–60% of patients.[21] The primary manifestations are postoperative neck and shoulder pain accompanied by neck muscle stiffness, tension, discomfort, soreness, and/or swelling.[3,5,7,12,14,15,20] The mechanisms of postoperative axial symptom development remain unclear, but they may be related to posterior cervical muscle atrophy, a change in cervical curvature or lamina open angle, muscle–ligament complex injury, joint capsule damage, and cervical instability, among other factors.[2–5,7,9,12,14–21] Spinal surgeons have attempted to reduce axial symptoms by improving the surgical technique,[2,7,9,12,15] preserving muscle attachment points,[7,9,17,22] reconstructing the muscle–ligament complex,[18] implanting an appropriate internal fixation device,[5] and prescribing postoperative rehabilitation exercises[23] and physical therapy[24]; however, the results vary. In this study, although both groups underwent titanium plate fixation with plates of the same mechanical strength, the severity of axial symptoms was significantly lower in the MPF group than in the CPF group. In addition, the cross-sectional area of the posterior cervical musculature decreased significantly after surgery in the CPF group, but not in the MPF group. These findings demonstrate that the third hole provided by the modified centerpiece titanium plate can not only reconstruct the integrity of the semispinalis cervicis, but that it also acts as an effective attachment point to provide mechanical support to the cervical extensor muscles. This effectively maintains the mechanical strength and tension band effect of the posterior cervical muscles, reducing the occurrence of axial symptoms.

Strengths and Limitations

The modified centerpiece titanium plate could reconstruct the attachment points for the posterior cervical ligament complex without increasing the surgical trauma and treatment costs, thereby forming a benign chain reaction of maintaining cervical lordosis, reducing posterior cervical muscle atrophy, and decreasing postoperative axial symptoms.

This study has several limitations that should be noted. First, the clinical application time of the modified centerpiece mini-plate was short. Second, the number of samples included in the study was small, and there was a certain bias in patient selection and grouping. Third, the follow-up time was short. Therefore, to confirm the clinical efficacy of this approach, a large-scale, long-term, multicentre randomized controlled study is required.

Conclusions

On the basis of the conventional centerpiece plate, adding a hole at the distal end of the titanium plate was convenient for posterior cervical muscle–ligament complex reconstruction. This technique can maintain the cervical curvature, significantly reduce posterior cervical muscle atrophy, and decrease the severity of axial symptoms without increasing surgical trauma.

Author Contributions

Conceptualization, supervision, validation: F.L. and Y.L. Project administration: J.M. Methodology, investigation: X.D. and Y.H. Formal analyses and data curation: F.L. and J.M.

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Conflicts of Interest

All experimental protocols in this research were approved by the Ethics Committee of Tianjin hospital, and informed consent was obtained from all patients. The methods were carried out in accordance with the relevant guidelines, including any relevant details.

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