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Mid- to long-term clinical outcomes of modified technique skip-level titanium plate fixation in cervical laminoplasty compared to continuous fixation

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Abstract

Purpose To compare the efficacy and safety of skip titanium plates combined with adjacent spinous process suture suspension versus continuous titanium plate fixation in cervical laminoplasty.

Methods A retrospective analysis of 125 patients (62 men, 63 women, average age 60.9 ± 10.4 years) with multilevel cervical spondylotic myelopathy who had cervical laminoplasty with Arch titanium plate fixation from January 2012 to March 2024 in our hospital was done. Patients were stratified into two cohorts based on the fixation technique: Group A ($n=64$): Modified technique of skip-level titanium plate fixation (Arch titanium plates at C4 and C6 levels combined with adjacent spinous process suture suspension)Group B ($n=61$): Continuous plating (Arch titanium plates applied sequentially from C3 to C7).The comparative analysis focused on perioperative parameters (operative duration, intraoperative blood loss, length of hospital stay), economic factors (hospital costs), and various clinical indicators.

Results The average follow up period was (73.0 ± 38.4) months. Both groups showed no significant differences in gender, age, and disease duration ($P>0.05$). Group A had lower hospitalization costs, intraoperative blood loss, operation time, and postoperative hospital stay compared to Group B ($P<0.05$). Postoperatively, both groups had significant improvements in JOA scores and NDI ($P<0.005$), but there were no significant differences in postoperative scores and improvement rates between the two groups ($P>0.05$). At 3 months postoperatively and at the last follow-up, the C2-7 Cobb angle and cervical curvature index decreased compared to preoperative values ($P<0.05$), with a significant difference in the C2-7 Cobb angle at the last follow-up ($P<0.05$). The sagittal diameter of the spinal canal from C3 to C7 significantly increased ($P<0.05$), but there were no significant differences in the improvement of C3, C5, and C7 between the two groups ($P>0.05$). At 3 months postoperatively, the opening angles of the C4 and C6 laminae in Group A were smaller than those in Group B ($P<0.05$), but there were no significant differences at the last follow-up ($P>0.05$). The healing of the C4 and C6 laminae in Group B was superior to that in Group A ($P<0.05$),

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but there were no differences in healing at the last follow-up ($P > 0.05$). The incidence of axial symptoms was similar (10.9% in Group A and 14.8% in Group B, $P = 0.523$).

Conclusions During C3-7 laminoplasty, the clinical efficacy of the method combining mini titanium plate fixation (at C4 and C6) with suture fixation is comparable to that of continuous fixation. Moreover, it has an advantage in cost control.

Keywords Cervical laminoplasty, Titanium plate fixation, Spinous process suture, Cost reduction

Introduction

Multisegmental cervical spondylotic myelopathy is a common cause of spinal cord dysfunction in adults. Laminoplasty, as a surgical intervention, achieves satisfactory clinical outcomes through spinal cord decompression and expansion [1, 2]. However, traditional laminoplasty often employs sutures for fixation, which carries the risk of suture breakage and potential fixation failure [3]. In cervical posterior open-door laminoplasty, ensuring the secure fixation of the lamina is a critical step, while reclosure of the lamina remains a major challenge [4]. Lamina reclosure can lead to neurological deterioration, potentially necessitating reoperation [5, 6].

To address these issues, the mini titanium plate fixation system was introduced in 1996, aimed at maintaining the lamina in an open state postoperatively [7]. There are varying recommendations regarding the number and placement of titanium mini-plates. Studies indicate that a skip placement of titanium plates can achieve satisfactory outcomes, with a sufficient number of plates avoiding unnecessary rigidity, prolonged surgical time, increased trauma, and financial burden [8–10].

Many previous studies have focused on the clinical and radiological comparisons between alternating segment fixation (such as C3, C5, and C7) and full-segment miniplate fixation [9, 11]. However, research specifically targeting intermittent fixation at the C4 and C6 segments is relatively scarce. In cervical posterior surgery, it has been observed that the lateral mass and spinous process of C3 are smaller compared to lower segments, and the cranial portion of the C3 lamina is overlapped and obstructed by the distal portion of the C2 lamina, necessitating additional exposure for proper instrumentation at C3. In contrast, placing plates at C4/C6 may preserve more muscle attachments and better maintain cervical lordosis [6, 12]. Research has found that preserving the posterior ligamentous-muscular complex can maintain cervical lordosis and reduce the incidence of postoperative axial symptoms; thus, modified surgical approaches should emphasize the preservation of posterior midline structures and sagittal balance of the cervical spine [6].

For patients requiring decompression and fixation from C3 to C7, we adopted a modified surgical approach, performing intermittent fixation only at C4 and C6, combined with suture lifting of adjacent spinous processes. We compared this method with continuous Arch titanium plate fixation in cervical posterior open-door laminoplasty to evaluate the clinical efficacy and radiological parameters of the novel modified surgical approach.

Methods

Study design

This study is a single-center retrospective study, and its research protocol has been rigorously approved by the relevant institutional ethics committee, with approval numbers XYFY2024-KL338-01. During the study, we fully ensured the informed consent of patients and their families, clearly explaining the details of the study to them and obtaining their verbal consent. This study has been registered with the China Clinical Trial Registry (ChiCTR), and the registration number obtained is ChiCTR2400087531.

Patients

We utilized the hospital information system (HIS) to retrieve data on 894 patients who underwent posterior cervical surgery for multisegmental myelopathic cervical spondylosis at Xuzhou Medical University Affiliated Hospital from January 2012 to March 2024. Inclusion criteria:1. Diagnosed with cervical myelopathy.2. Imaging shows compression of ≥ 3 cervical spinal segments.3. Underwent laminoplasty with mini titanium plate fixation (C3-C7).

Exclusion criteria

Patients with acute traumatic etiology.2. Patients with cervical kyphosis > 10°0.3. Patients with significant cervical instability.4. Patients who underwent anterior surgery followed by posterior surgery.5. Patients with incomplete follow-up data.The inclusion and exclusion criteria were referenced from the guidelines published by the American Academy of Orthopaedic Surgeons, which are widely recognized and accepted [13].

Based on the above criteria, a final total of 125 patients who underwent single-door posterior cervical surgery were included. These 125 patients were divided into two groups based on the number of micro titanium plates used during the surgery: Group A (the modified technique of skip-level titanium plate fixation) with 64 cases, in which the Arch titanium plates were used for fixation

on the open-door sides of C4 and C6 (Fig. 1); and Group B (the continuous fixation) with 61 cases, in which the Arch titanium plates were used for fixation on the open-door sides of C3 - C7 (Fig. 2).

Surgical method

After general anesthesia, the patient is placed in a prone position, with the shoulders and head fixed using a brace, and the area is routinely disinfected and draped. An incision is made in the midline of the posterior neck to fully expose the bilateral laminae of segments C3-C7. The lamina with more severe symptoms is chosen as the opening side, and a bone groove is made with a drill 3 mm from the inner edge of the bilateral laminae, quickly grinding open the lamina from the cortical bone to the dura mater sac. A "V" shaped bone groove is made on the opposite lamina as a hinge for the door axis side.

In group A, the modified technique of skip-level titanium plate fixation group lifts the lamina towards the door axis side, and at C4 and C6, appropriately sized micro titanium plates are selected and fixed to the spinous process and posterior lamina, reinforced with self-tapping screws. Holes are drilled at the base of the spinous processes of C3, C5, and C7, and sutures are threaded through the bone holes and fixed above the adjacent C4 or C6 micro titanium plate spinous process fixation point, creating an upward diagonal tension (Fig. 3). After flushing the surgical incision, excess bone is implanted into the groove on the door axis side of C3-C7 and around the small joints, and gelatin sponge is used to cover the small joints to the posterior lamina. Finally, the incision is sutured to complete the surgery.

In group B(the continuous group), five titanium plates are placed on C3-C7 to complete the expansion and shaping of the spinal canal. One drainage tube is placed in the surgical area, and the standard for removing the drainage tube postoperatively is a drainage volume of < 50 ml within 24 h. On the first day after surgery, a neck brace is worn to get out of bed, and patients are instructed to begin neck muscle exercises, with neck brace protection for 2 weeks.

Observation indicators

Comparing the surgical situations and general characteristics of two groups of patients, including surgical time, intraoperative blood loss, postoperative hospital stay, and material costs. Additionally, the preoperative and follow-up assessments include the Neck Disability Index (NDI), Japanese Orthopaedic Association (JOA) score, and JOA improvement rate. The JOA improvement rate is calculated as follows: (final follow-up score - preoperative score) / (17 - preoperative score) × 100%.

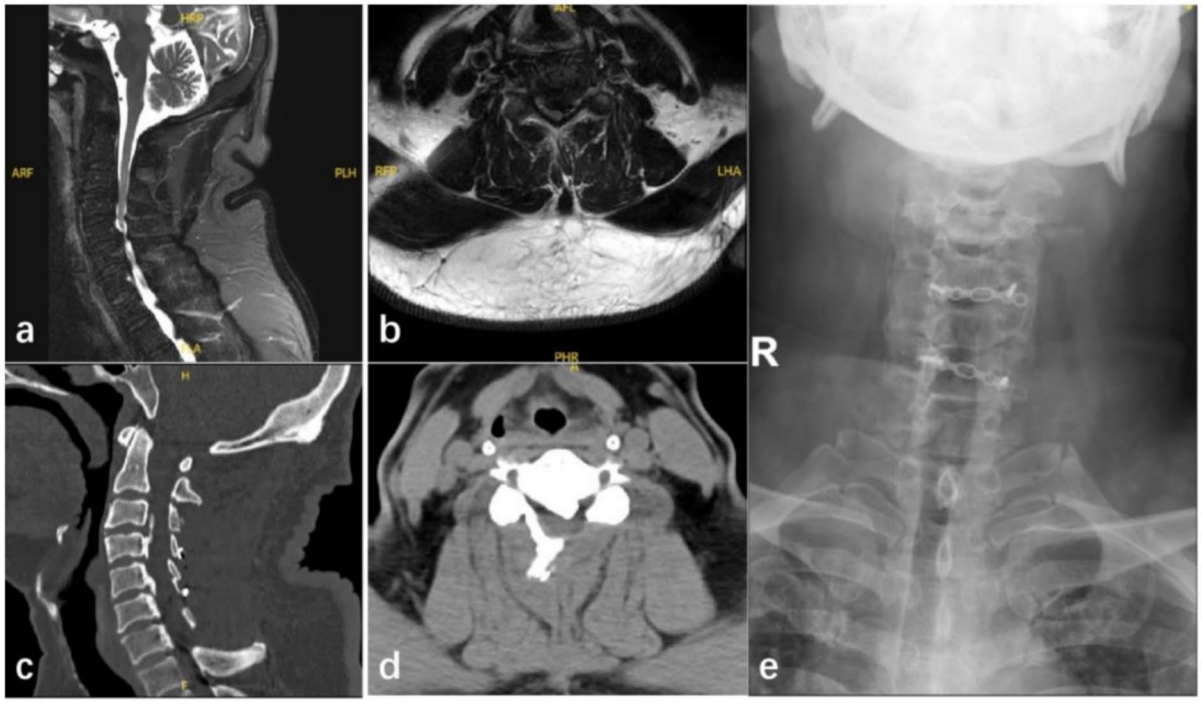

Fig. 1 is atypical case of the modified technique of skip-level titanium plate fixation. a: Preoperative sagittal MRI shows multiple stages of spinal cord compression; b: Preoperative coronal MRI shows spinal canal stenosis; c: Postoperative CT shows significant enlargement compared to preoperative; d: Postoperative CT shows good expansion and satisfactory healing on the lateral side of the door axis; e: Postoperative X-ray shows no obvious loosening or displacement of the mini plate

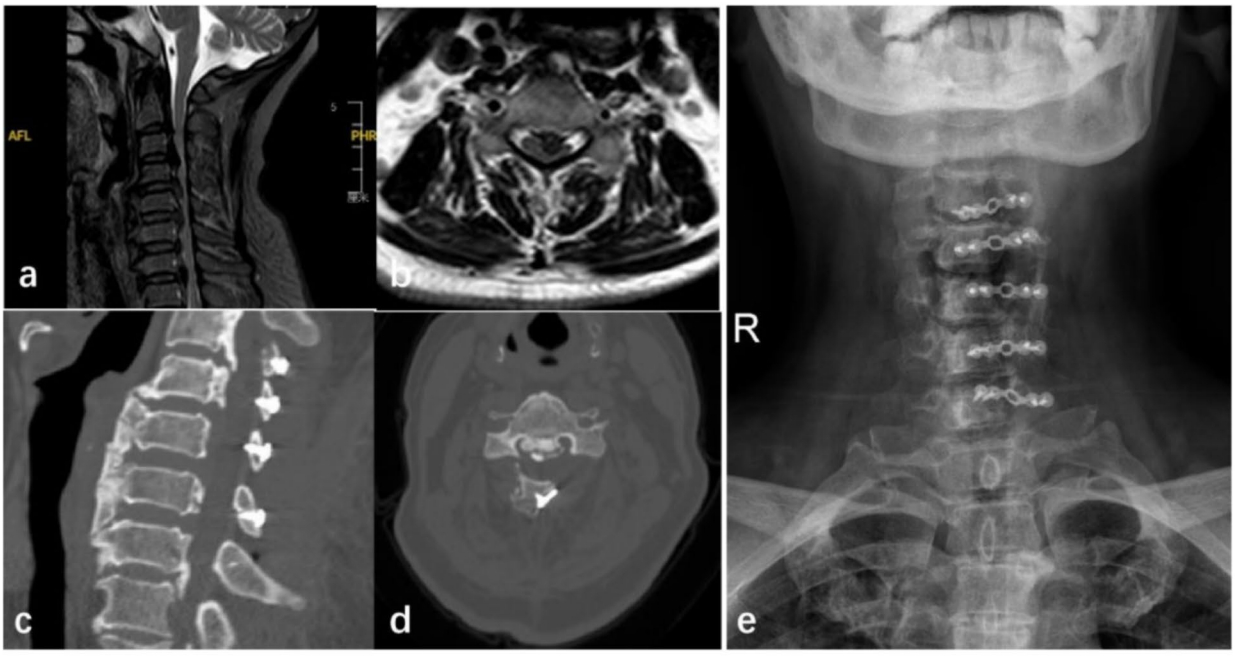

Fig. 2 is a typical case of continuous fixation. a: Preoperative sagittal MRI shows multiple stages of spinal cord compression; b: Preoperative coronal MRI shows spinal canal stenosis; c: Postoperative CT shows significant enlargement compared to preoperative; d: Postoperative CT shows good expansion, with no obvious healing on the lateral side of the door axis; e: Postoperative X-ray shows no obvious loosening or displacement of the mini plate

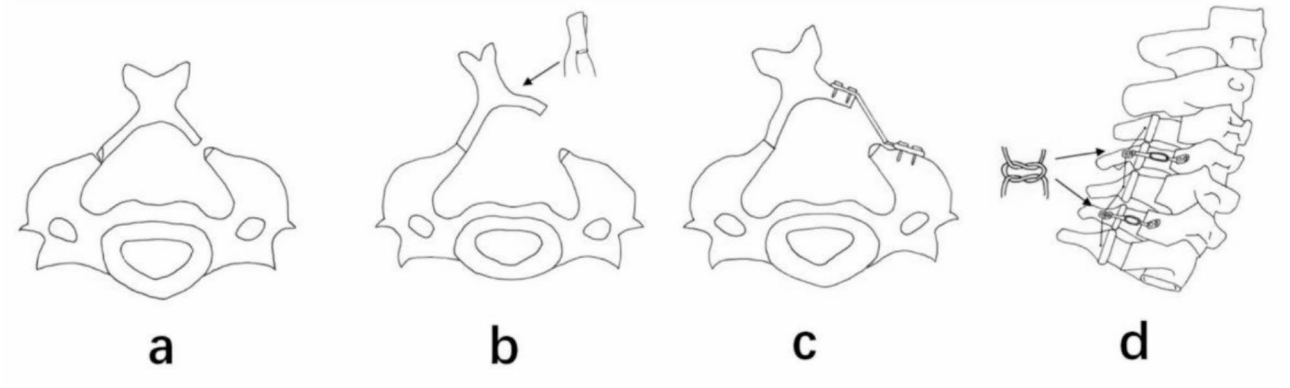

Fig. 3 **a**: Select the lamina on the side with more severe symptoms as the incision side. Use a drill to create a bony groove 3 mm from the inner edge of the bilateral laminae. Grind the lamina open from the cortical bone to the dural sac, while creating a "V"-shaped bony groove on the contralateral lamina as a hinge for the door axis. **b**: Elevate the lamina towards the hinge side and drill holes at the base of the spinous processes of C3, C5, and C7. **c**: At C4 and C6, select appropriately sized micro titanium plates, fix them onto the spinous processes and posterior laminae, and reinforce them with self-tapping screws. **d**: Drill holes at the base of the spinous processes of C3, C5, and C7. Pass sutures through the bone holes and secure them to the adjacent C4 or C6 micro titanium plate spinous process fixation points, forming upward diagonal tension to fix the micro titanium plates together with the adjacent spinous processes

The imaging observation indicators include: (1) Lamina opening angle (see Fig. 4a); (2) Sagittal diameter of the spinal canal (see Fig. 4b); (3) Cervical curvature (measured using the Giovanni D value method) (see Fig. 4c); (4) C2-C7 Cobb angle (see Fig. 4d); cervical mobility: the difference in C2-C7 Cobb angles in flexion and extension positions; and the healing status of the C4 and C6 segmental doors, referring to the definitions by Rhee et al. [14]. The observation indicators for complications include: spinal cord injury, dura mater tear, screw loosening, reclosure, axial symptoms, C5 nerve root paralysis, and cervical kyphosis.

Statistical analysis

Statistical analysis of the data was performed using SPSS 23.0 software. For measurement data that met the normal distribution, results were expressed as $\bar{x} \pm s$. Within-group comparisons were conducted using paired t-tests

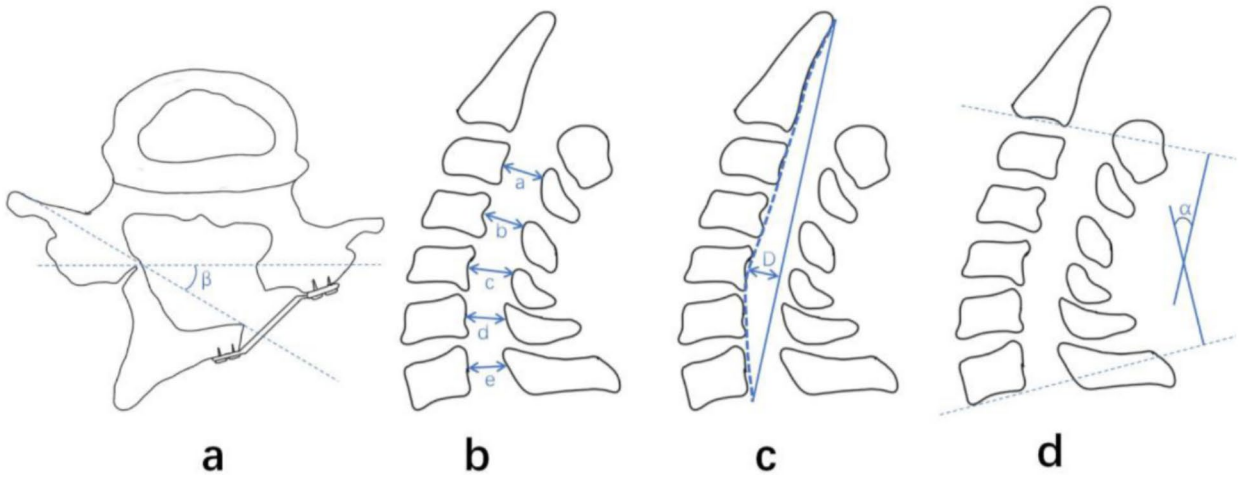

Fig. 4 **a**: Lamina opening angle. The angle is measured on a CT axial view between the line parallel to the connection of the posterior walls of the bilateral transverse foramen and the tangent line of the inner edge of the lamina. b: Sagittal diameter of the spinal canal. The distance between the posterior edge of the vertebral body and the anterior edge of the lamina is measured on a lateral X-ray. **c**: Cervical curvature. The cervical curvature is evaluated on a lateral cervical X-ray by measuring the vertical distance (D value) between the line connecting the C2 vertebral body and the lower edge of the C7 vertebral body and the apex of the cervical curve. **d**: C2-C7 Cobb angle. On a lateral cervical X-ray, the extension lines of the inferior endplates of the C2 and C7 vertebral bodies are drawn, and the angle between these two lines is measured

Table 1 Comparison of baseline characteristics between the two groups of multisegment spinal cord type cervical spondylosis patients

Item	A Group ($n=64$)	B Group ($n=61$)	t/χ^2/Z Value	PValue
Age (years, ± s)	61.9 ± 10.9	59.8 ± 9.98	1.115	0.267
Gender (cases, male/female)	31/33	31/30	0.71	0.790
Duration of disease [months, M(Q1, Q3)]	22(17, 26)	24(19, 28)	1.322	0.332
Developmental spinal canal stenosis [cases (%)]	46(71.9)	42(68.9)	0.137	0.711
Spinal canal stenosis [cases (%)]	59(92.2)	61(100)	4.964	0.026
Disc herniation [cases (%)]	58(90.6)	60(98.3)	3.535	0.060
Ossification of the posterior longitudinal ligament [cases (%)]	20(31.3)	25(41.0)	1.284	0.257
Segments of spinal cord compression [cases (%)]			0.511	0.474
3 segments	38(59.4)	40(65.6)		
4 segments	26(40.6)	21(34.4)		
Changes in spinal cord signal [cases (%)]	16(25.0)	9(14.8)	2.049	0.152
Follow-up time (months, ± s)	69.7 ± 41.6	76.4 ± 34.8	-0.850	0.395

or repeated measures ANOVA, while between-group comparisons used independent samples t-tests. For data that did not meet the normal distribution, results were expressed as M(Q1, Q3), and pairwise comparisons were conducted using the Wilcoxon signed-rank test. Categorical data were expressed as frequency (%), and between-group comparisons used the χ^2 test. A two-tailed test was performed with $\alpha = 0.05$.

Results

Based on the inclusion and exclusion criteria, a specific number of cases were finally included. Among them, there were 62 males, accounting for 49.6%; and 63 females, accounting for 50.4%.

Specifically, in group A, there were 31 male participants and 33 female participants; in group B, there were 31 male participants and 30 female participants(Table 1). The average age of the patients was (60.9 ± 10.4) years, and the duration of the disease was (22.3 ± 5.7) months. All patients received outpatient follow-up and completed cervical X-ray and CT examinations during the follow-up, which lasted from 6 to 125 months, with an average of (73.0 ± 38.4) months. Comparisons showed no statistically significant differences between the two groups in terms of gender, age, disease duration, follow-up time, causes of spinal cord compression, segments of spinal cord compression, and MRI spinal cord signal changes ($P > 0.05$) (see Table 1).

The comparison between the two groups of patients regarding hospitalization costs, intraoperative blood loss, surgical duration, and postoperative hospital stay showed that the A group had lower values than B group, with a statistically significant difference ($P < 0.05$) (see Table 2).

In the intra-group comparisons of gender within Group A (modified the technique of skip-level titanium plate fixation) and Group B (continuous plating), the

Table 2 Comparison of surgical conditions between the two groups of multisegment spinal cord type cervical spondylosis patients

Item	A Group ($n=64$)	B Group ($n=61$)	t/ Value	PValue
Hospitalization costs (yuan)	34904.0 ± 1343.9	57426.7 ± 2039.5	-72.536	< 0.001
Intraoperative blood loss (ml)	274.9 ± 45.0	301.4 ± 47.2	-3.217	0.002
Surgical time (h)	2.0 ± 0.5	2.3 ± 0.6	-3.305	0.001
Postoperative hospital stay (d)	9.5 ± 3.3	9.4 ± 3.0	0.235	0.919

hospitalization costs for male patients in Group A were 34,480.7 ± 1,353.2 yuan, while female patients had costs of 35,301.7 ± 1,225.7 yuan. In Group B, male patients incurred expenses of 56,534.8 ± 1,715.7 yuan, and female patients had expenses of 58,348.3 ± 1,957.6 yuan. In both groups, female patients had higher hospitalization costs than male patients (Fig. 5a). However, no significant differences were observed between male and female patients within each group regarding intraoperative blood loss (Fig. 5b), operation time (Fig. 5c), and postoperative length of hospital stay (Fig. 5d).

For inter-group comparisons between the same gender (male-to-male and female-to-female comparisons), significant differences were found in hospitalization costs (Fig. 5a). Both male and female patients in Group A (modified the technique of skip-level titanium plate fixation) had significantly lower expenses than their counterparts in Group B (continuous plating), indicating that the skip fixation approach in Group A was more cost-effective for both genders compared to the continuous plating in Group B. In terms of intraoperative blood loss (Fig. 5b), inter-group gender comparisons showed that among male patients, Group A had a lower

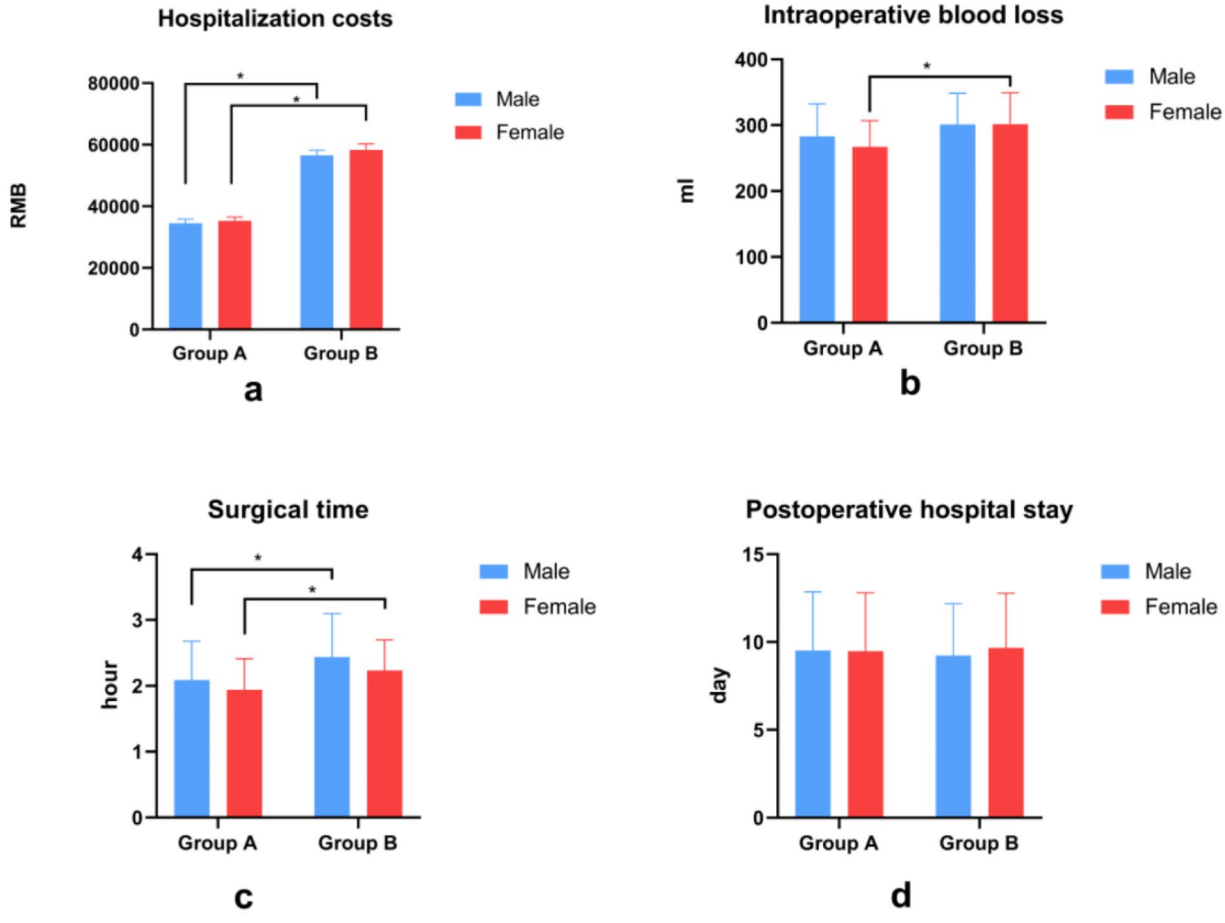

Fig. 5 **a**: Group A (modified the technique of skip-level titanium plate fixation) and Group B (continuous plating) comparison of hospitalization costs by gender. **b**: Group A (modified the technique of skip-level titanium plate fixation) and Group B (continuous plating) comparison of intraoperative blood loss by gender. **c**: Group A (modified the technique of skip-level titanium plate fixation) and Group B (continuous plating) comparison of surgery duration by gender. **d**: Group A (modified the technique of skip-level titanium plate fixation) and Group B (continuous plating) comparison of postoperative discharge time by gender

mean blood loss (283.1 ± 49.3 ml) compared to Group B (301.3 ± 47.3 ml), but this difference was not statistically significant. Conversely, among female patients, Group A exhibited a significantly lower blood loss (267.1 ± 39.8 ml) than Group B (301.5 ± 47.9 ml), suggesting a gender-specific benefit of the skip fixation technique in reducing blood loss for female patients.

In the intergroup comparison (Fig. 5c), the average operative time for female patients in Group A (modified the technique of skip-level titanium plate fixation) was 1.9 ± 0.5 h, less than the 2.2 ± 0.5 h in female patients of Group B (continuous plating), with the difference being statistically significant. For male patients, the operative time in Group A (2.1 ± 0.6 h) was significantly shorter than that in Group B (2.4 ± 0.7 h), indicating that both male and female patients receiving the skip fixation technique experienced a significant reduction in operative time.

In addition, postoperative length of hospital stay (Fig. 5d) showed significant differences in both intra-group and inter-group gender comparisons.

Both groups of patients demonstrated significantly higher postoperative Japanese Orthopedic Association scores (JOA) and Neck Disability Index (NDI) scores compared to preoperative values, with a statistically significant difference ($P < 0.001$) (Table 3). However, there were no statistically significant differences in postoperative NDI scores, JOA scores, or the improvement rates of JOA scores between the two groups ($P > 0.05$). The postoperative JOA and NDI scores of the patients in both groups were significantly higher than those before the operation ($P < 0.005$) (Table 3). However, there were no statistical differences in these two scores and the improvement rate of JOA scores between the two groups after the operation ($P > 0.05$) (Table 3). At 3 months after the operation and the last follow - up, the C2–7 Cobb angle and cervical curvature index in both groups were reduced compared with those before the operation ($P < 0.05$) (Table 3). At the last follow - up, there was a difference in the C2–7 Cobb angle between the two groups ($P < 0.05$). At 3 months after the operation and the last follow - up, the cervical range of motion in both groups was reduced compared with that before the operation ($P < 0.05$). At the last follow - up, the cervical range of motion in Group A was greater than that in Group B ($P < 0.05$) (Table 3).

At 3 months after the operation and the final follow up, the sagittal diameter of the spinal canal at each segment from C3 to C7 in both groups of patients increased compared with that before the operation, and the differences were statistically significant ($P < 0.05$). However, at 3 months after the operation and the final follow up, there were no statistically significant differences between the two groups in terms of the improvement of the sagittal diameter at the fixed segments of C3, C5, and C7 ($P > 0.05$) (see Fig. 6).

At 3 months after the operation, the lamina opening angles at C4 and C6 in Group A were significantly smaller than those in Group B($P < 0.05$), while there were no significant differences at the final follow - up ($P > 0.05$) (see Fig. 7).

At three months after the operation, the healing of the lamina at C4 and C6 in Group B was better than that in Group A ($P < 0.05$). However, at the final follow up, there were no differences in the healing of the lamina between the two groups ($P > 0.05$) (see Table 4).

Postoperatively, Group A had 2 cases (3.1%) of C5 nerve root paralysis, while Group B had 1 case (1.6%), with no significant difference between groups. All patients received treatment and had symptom resolution by the 3-month follow-up. The incidence of axial symptoms was similar (A Group: 10.9%, B Group: 14.8%, $P = 0.523$). Both groups showed significant improvement after rehabilitation and non-steroidal anti-inflammatory treatment. No cases of cervical kyphosis, reclosure of the lamina, or screw loosening were observed during the 3-month and final follow-up.

Table 3 Comparison of postoperative neurological function improvement and imaging observation indicators between the two groups of multisegment spinal cord type cervical spondylosis patients

Item	A Group ($n = 64$)			F/t value	*P* value	B Group ($n = 61$)			F/t value	*P* value
	Preoperative	Postoperative 3 months	Final follow-up			Preoperative	Postoperative 3 months	Final follow-up		
JOA score	9.3 ± 2.1	12.1 ± 1.3[a]	14.0 ± 2.0[a]	113.449	< 0.001	8.9 ± 1.8	12.4 ± 1.1[a]	14.3 ± 1.1[a]	233.018	< 0.001
JOA improvement rate (%)	-	54.9 ± 27.7	55.4 ± 30.9	0.0988	0.922	-	50.8 ± 19.0	54.7 ± 33.1	0.8065	0.422
NDI	30.4 ± 5.1	20.3 ± 4.3[a]	13.7 ± 4.7[a]	183.546	< 0.001	29.3 ± 6.0	19.6 ± 4.6[a]	13.3 ± 6.4[a]	117.194	< 0.001
Cervical curvature index	4.2 ± 1.1	2.9 ± 1.1[a]	3.5 ± 1.0[a]	26.226	< 0.001	4.1 ± 0.9	3.1 ± 0.9[a]	3.4 ± 1.0[a]	19.032	< 0.001
ROM	46.6 ± 6.7	33.7 ± 8.1[a]	39.3 ± 3.8[a]	61.157	< 0.001	44.2 ± 4.8	29.6 ± 4.7[ab]	36.1 ± 4.0[ab]	155.460	< 0.001
C2-7 Cobb angle (°)	11.8 ± 7.1	8.0 ± 3.7[a]	7.3 ± 5.1[a]	11.981	< 0.001	12.1 ± 7.8	9.1 ± 5.2[a]	9.1 ± 5.0[ab]	4.624	0.016

Note: JOA stands for Japanese Orthopedic Association; NDI stands for Neck Disability Index; ROM stands for Range of Motion; a: $P < 0.05$ indicates comparison with preoperative values within the same group; b : $P < 0.05$ indicates comparison between the two groups; "-" indicates no data

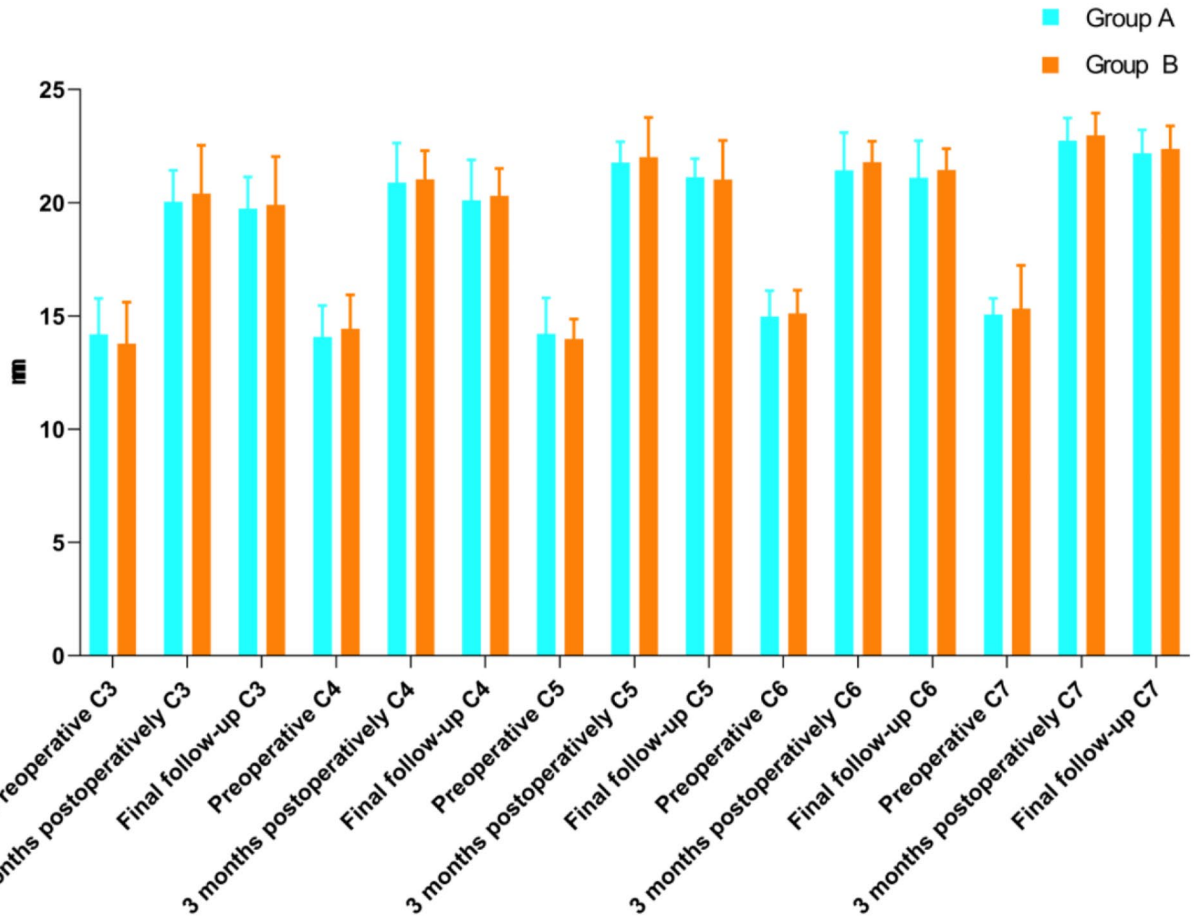

Fig. 6 Digital diameter of the Spinal Canal. The blue represents Group A, which corresponds to the modified technique of skip-level titanium plate fixation group, and the yellow represents Group B, the continuous group. The X-axis of Fig. 4 sequentially displays the sagittal diameter of the spinal canal at each segment from C3 to C7 at preoperative, 3 months postoperative, and the final follow-up

Discussion

The Hirabayashi method is commonly used to treat multisegmental cervical compressive myelopathy due to specific causes, where the key to C3-C7 laminoplasty is to adequately expand the spinal canal [1]. The reclosure rate of laminoplasty in traditional Hirabayashi unilateral open-door procedures ranges from 22.7–44.7% [15]. Many studies have improved surgical techniques, and in clinical practice, other fixation methods are often combined to enhance fixation effectiveness. Zhang et al. [11] reported a surgical method involving alternate level fixation (C3, C5, C7). Subsequent studies have shown that staged fixation does not cause any issues with the hinge bones [10, 16]. Li et al. [17] designed a method using simple sutures based on computer-aided technology. On this basis, we propose an improved method: using appropriately sized micro titanium plates for fixation at C4 and C6, while connecting them to the titanium plate fixation points at C4 and C6 through sutures passing through the bony holes of the spinous processes of non-titanium fixed segments (such as C3, C5, and C7). This creates an "upward diagonal tension" and integrates into a hybrid fixation system.

This design has the following functions and advantages: It effectively compensates for the discontinuity of staged fixation, enhancing overall stability. Zhang et al. [11] believe that fixation using titanium plates only at C4 and C6 is not ideal. In our approach, titanium plates are used for fixation at C4 and C6, while sutures are tightened to connect the micro titanium plates to the adjacent spinous processes. The sutures form upward diagonal tension between the fixation points, effectively maintaining the laminoplasty in the correct position and reducing stress concentration during postoperative healing, thereby helping to keep the laminoplasty open and preventing reclosure due to insufficient fixation after surgery. On the other hand, studies have shown that cervical kyphosis is a risk factor affecting the efficacy of laminoplasty [18]. Wu J et al. [12] found that 23.5% of patients with fixation at C3/C5 developed postoperative kyphosis, whereas

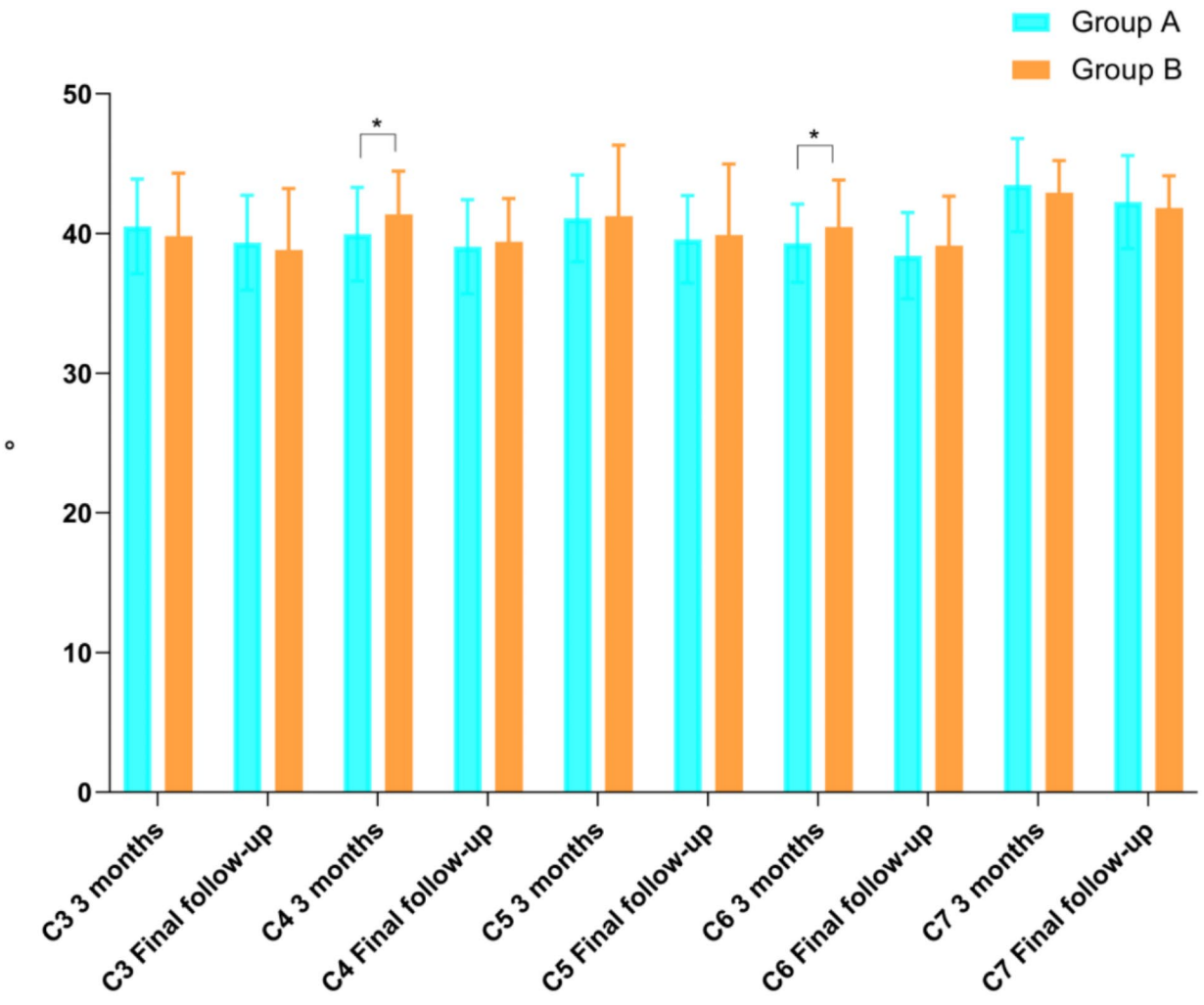

Fig. 7 Postoperative laminae opening angles: The blue represents Group A, which corresponds to the modified technique of skip-level titanium plate fixation group, and the yellow represents Group B, the continuous group. Figure 7 shows the angle of the lamina opening at C3-7 at 3 months postoperative and at the final follow-up

Table 4 Comparison of C4 and C6 lamina healing between the two groups of multisegment spinal cord type cervical spondylosis patients [cases (%)]

Item	A Group ($n=64$)	B Group ($n=61$)	χ^2Value	PValue
C4 Postoperative 3 months			13.472	< 0.001
Complete/Partial Healing	22(34.3)	41(67.2)		
Non-healing	42(65.6)	20(32.8)		
C6 Postoperative 3 months			12.319	< 0.001
Complete/Partial Healing	24(37.5)	42(68.9)		
Non-healing	40(62.5)	19(31.1)		
C4 Final follow-up			0.161	0.688
Complete/Partial Healing	61(95.3)	59(96.7)		
Non-healing	3(4.7)	2(3.3)		
C6 Final follow-up			0.002	0.973
Complete/Partial Healing	63(98.4)	60(98.4)		
Non-healing	1(1.6)	1(1.6)		

only 1.9% of patients with fixation at C4/C6 experienced kyphosis. This suggests that micro titanium plate fixation at C4 and C6 may be more beneficial for maintaining the physiological lordosis of the cervical spine. JPY et al. [10]suggested that patients undergoing standard C3-6 laminoplasty could save up to two titanium plates, while Wang et al. [9]laced central micro titanium plates at C3, C5, and C7, reducing costs by approximately 40% compared to traditional full-level fixation methods. Our improved method in C3-C7 laminoplasty can save three titanium plates, further reducing costs. Additionally, during surgery, it was observed that the cephalad portion of the C3 laminoplasty overlaps with the distal end of the C2 laminoplasty. This indicates that placing a titanium plate at C3 may require additional exposure to ensure proper instrument placement. Therefore, placing titanium plates at C4/C6 may be more advantageous for preserving more muscle attachment points.

This study demonstrates that, in patients with multilevel cervical spondylotic myelopathy (CSM), changes in the Cobb angle, sagittal canal diameter, and laminar opening angle are crucial for postoperative mobility and functional recovery. Although surgery may lead to a reduction in cervical lordosis [19, 20], the Cobb angle in group A at the final follow-up was significantly smaller than that in group B. However, the physiological curvature in both groups remained within normal ranges and did not negatively impact surgical outcomes. Postoperatively, both groups exhibited a significant increase in the sagittal diameter from C3 to C7, indicating effective decompression achieved by the surgery. Studies have shown that an increase in the C2–C7 sagittal vertical axis (SVA) is positively correlated with improvement in cervical function scores (JOA) [21].It is generally accepted that a laminar opening angle between 30° and 45° can provide sufficient spinal cord decompression [15]. In our study, the laminar opening angles in both groups exceeded 30°, ensuring adequate decompression of the spinal cord. Although group A experienced some reduction in the laminar opening angle during the early postoperative period, there was no statistically significant difference between the two groups at the final follow-up, and clinical outcomes were comparable. Zhang et al. [11]found that skip-level fixation resulted in an average reduction of 4.52°in the opening angles of C3, C5, and C7, with this change mainly occurring within the first 6 months postoperatively.Despite a postoperative decrease in range of motion (ROM) observed in both groups, this did not affect the surgical efficacy. Both the Japanese Orthopaedic Association (JOA) scores and the Neck Disability Index (NDI) scores showed significant improvement compared to preoperative measurements, indicating that the clinical outcomes of the two fixation methods are comparable.

This study compared the modified skip-level titanium plate fixation technique with continuous titanium plate fixation, focusing on gender differences. It was observed that female patients in both groups had higher hospitalization costs than male patients, possibly due to undergoing more in-hospital examinations. Within each group, there were no significant differences between male and female patients in terms of intraoperative blood loss, operative time, and postoperative hospital stay. Gender differences affected intraoperative blood loss; specifically, female patients using the skip-level fixation technique experienced less blood loss, thereby reducing the risk of hemorrhage.Interestingly, in total hip arthroplasty (THA), patients with osteoporosis and female patients have been reported to exhibit lower blood loss during surgery [22]. Similarly, in orthognathic surgery, male patients showed significantly higher intraoperative and postoperative 48-hour blood loss compared to female patients [23]. It is speculated that, since all female patients in this study were postmenopausal and may have concomitant osteoporosis, their overall bone quality was lower than that of male patients, making laminar opening during surgery easier. Shortened operative times may also contribute to reduced blood loss.The modified fixation technique simplifies surgical steps, reducing operational difficulty and operative time; however, its impact on operative time in male patients was not significant, which may be attributed to the small sample size. Further prospective studies with larger sample sizes are needed to explore these findings more comprehensively.

The incidence of axial symptoms after fixation with mini titanium plates in unilateral open-door cervical spine surgery is 23%, making it a common complication [24, 25]. Although mini titanium plates were used at C4 and C6 to reduce damage, some patients still experienced axial pain, and there was no significant difference in incidence between the modified technique group and the continuous fixation group.The speculated reasons are as follows: First, unilateral opening of the lamina during unilateral open-door laminoplasty results in asymmetry of the spinal canal structure, causing postoperative drift of the spinal cord toward the open-door side. This drift stretches and compresses the nerve roots, leading to symptoms. Even though the modified technique reduces tissue damage, the existing asymmetry may still result in abnormal spinal cord drift. Second, the mechanism of axial symptom occurrence is complex [26]; preoperative cervical spine degenerative changes and other factors may increase the risk [15], and surgical improvements may not eliminate this risk. Third, intraoperative factors contribute as well. Although the modified technique aims to reduce damage, early-stage surgeon skill levels may not completely avoid injury to the small joints and posterior ligament structures, and an excessively large door-opening angle can affect cervical spine mechanical stability. Fourth, long-term use of rigid cervical collars restricts neck movement, leading to muscle adhesion and myofascial pain.However, the use of non-steroidal analgesics and neck exercises can help alleviate the pain.

This study has limitations: first, it is a retrospective single-center study design, and data collection may be biased due to selection preferences; second, the small sample size and single-center nature limit the generalizability of the results; third, the surgeons and patients chose the fixation method based on their financial situation, leading to selection bias, and there are differences in potential confounding factors such as nutrition and rehabilitation conditions between the two groups that are difficult to control. In the future, it is necessary to conduct large-scale prospective multi-center studies to verify the results and understand the effectiveness and durability of the treatment.

Conclusions

During C3-7 laminoplasty, the clinical efficacy of the method combining mini titanium plate fixation (at C4 and C6) with suture fixation is comparable to that of continuous fixation. Moreover, it has an advantage in cost control.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13018-025-05491-y.

Supplementary Material 1

Author contributions

Shuo Feng led the research and data analysis. QiRui Zhu participated in the research and analyzed relevant data. Yang Sun, ZiYao Ding, Heng-Heng Yu, and Ma - Ji Sun engaged in data collection, and preliminary analysis. For the manuscript, Shuo Feng and others drafted it based on findings, while QiRui Zhu created visual elements. Feng Yuan was key in conceptualizing the study, defining the problem, designing the framework, and planning the methodology. Feng Yuan also critically revised the manuscript to ensure high standards. All authors approved the final version.

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Data availability

No datasets were generated or analysed during the current study.

Declarations

Ethics approval

This study was approved by the Ethics Committee of the Affiliated Hospital of Xuzhou. Medical University (XYFY2024-KL337-01.)

Consent for publication

All the authors have reviewed and confirmed the accuracy of the whole manuscript.

Informed consent

All patients gave their oral consent to allow further scientific analysis using their anonymised data.

Competing interests

The authors declare no competing interests.

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