Original Article

Comparing clinical outcomes of using 3 versus 5 titanium miniplates in laminoplasty for multilevel cervical myelopathy: A prospective cohort study

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A R T I C L E   I N F O

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A B S T R A C T

Study design: Prospective cohort study.

Objective: The aim of this study was to compare clinical outcomes, radiographic changes, and complications of cervical expansive open-door laminoplasty (EOLP) for cervical multilevel myelopathy, using either 3 or 5 titanium miniplates.

Summary of background data: Cervical EOLP is a common and effective operation for cervical myelopathy. Standard procedures utilise either 3 or 5 titanium miniplates; however, no definite conclusion has been given yet on the relationship between clinical outcomes and the quantity of titanium miniplates.

Method: We performed a prospective study of 92 patients who underwent EOLP with either 3 (n = 34) or 5 (n = 58) titanium miniplates at our institution from March 2012 to June 2016. Clinical and radiologic outcomes and complications were compared.

Result: Compared with the 5 titanium miniplates group, the 3 titanium miniplates group had shorter operation times and less blood loss (P < 0.05) and needed fewer costs (P < 0.01) during index hospitalisation. The preoperative cervical curvature angle decreased in both groups and revealed no significant differences. There was no significant difference between the two groups in the Japanese Orthopedic Association (JOA) score, JOA recovery rate, loss of range of motion (ROM), anteroposterior diameter (APD), or spinal canal complications (P > 0.05).

Conclusion: Cervical EOLP using 3 titanium miniplates is associated with shorter operation times, less blood loss, and lower operation costs compared with using 5 titanium miniplates. The translational potential of this article: Expansive open-door laminoplasty (EOLP) is an effective procedure for treating multilevel cervical spondylotic myelopathy. The present study indicated that 3 titanium miniplates could achieve similar clinical outcomes but with shorter operation times, less blood loss and operation costs compared with 5 titanium miniplates. These findings may provide some references for clinical applications.

Introduction

Cervical myelopathy (CM) is an age-related degenerative disease that causes narrowing of the spinal canal. The prognosis of untreated myelopathy is typically poor, and conservative treatment methods are largely ineffective in slowing neurological deterioration [1]. Cervical expansive open-door laminoplasty (EOLP) is an effective surgical method for treating various causes of CM; this treatment widens the spinal canal by reconstructing the lamina [2–4]. In the original method developed by Hirabayashi et al. opened laminas were fixed by sutures between the lamina and the paraspinal muscles [5]. However, the absence of rigid fixation caused many complications, such as axial symptoms, C5 nerve root palsy, and laminar reclosure [6,7]. Since then, many modifications to the EOLP procedure have been developed to secure the opened lamina [8,9].

Studies have shown that compared with traditional suture anchor fixation, titanium miniplates fixation is more effective in preventing EOLP complications [10,11]. EOLP with titanium miniplates is an effective treatment for CM patients, and two variations are commonly used at present [12]. One uses 3 titanium miniplates to expand the spinal canal (C3, C5, and C7), whereas the other uses 5 titanium miniplates (C3–C7). Currently, there is no consensus over which quantity of

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miniplates is more effective. Therefore, both EOLP with 3 and 5 titanium miniplates were compared by a prospective cohort study to determine the differences between the clinical choice of operation.

Materials and methods

Patient

We employed a prospective, comparative, single-institution trial of two surgical procedures for the treatment of CM. Consecutive patients in our hospital between March 2012 and June 2016 were included. Clinical diagnoses were made by physical examinations, radiography, and magnetic resonance imaging (MRI). The inclusion criteria were as follows: first, patients exhibited bilateral hand clumsiness or numbness and an unsteady gait after appropriate conservative management for CM; second, presence of positive myelopathic signs and symptoms, such as increased tendon reflexes and numbness in extremities, positive Hoffmann signs, and impaired toe-to-heel tandem gait; third, the CM stenosis spanned from C3 to C7 without segmental instability or kyphosis. The exclusion criteria were as follows: first, patients had previous cervical spinal surgery; second, patients presented with CM by spinal cord tumors, injuries, or any other disease; third, the follow-up period was less than 12 months.

Informed consent was obtained from 107 patients, and a total of 92 patients (85.98%) were successfully followed for more than 12 months. The 92 patients were divided into 2 groups based on the quantity of titanium miniplates. Thirty-four patients were enrolled in the 3 titanium miniplates group, and 58 patients were enrolled in the 5 titanium miniplates group.

EOLP was chosen by both the patient and the surgeon after careful discussion and assessment. The surgeries were performed by professionals with more than 10 years of experience in clinical laminoplasty. The quantity of titanium miniplates used was mainly decided by patients based on their financial situation and willingness.

Surgical technique

The open-door laminoplasty technique used generally followed the principles described by Itoh et al. Under general anesthesia, each patient’s neck was placed in a neutral position. The posterior approach was made from the lower laminar edge of C2 to C7 level using a midline longitudinal incision. The paraspinal muscle of C2, especially the semispinalis, was preserved to prevent possible postoperative kyphosis. The intervals between the junction of the lamina and the facet joints were bilaterally developed from C3 to C7. The side with more neurological deficits was opened, and a high-speed cutting burr was used to make a trough in the lamina just medial to each articular joint. Then, the outer cortex and cancellous bone were cleaned. The remaining inner cortex was removed with a special bone rongeur to expose the dural sac. On the hinge side, the outer cortex was rubbed using a high-speed cutting burr to make a bone groove of V shape. Cancellous bone and inner cortex remained as the hinge. The ligamentum flavum between the C2 to C3 and C7 to T1 vertebrae was cut to allow adequate mobilisation and rotation of the laminae. Next, the lamina on the opened side was moved laterally toward the hinged side and the ligamentum flavum on the edge of the lamina was removed. The decompression segment was C3–C7 in all patients undergoing EOLP. After that, appropriately sized miniplates were selected for each level to fit both the cut edge of lamina and the lateral mass. The C3, C5, and C7 segments were fixed in the 3 titanium miniplates group, and the 5 segments from C3 to C7 were fixed in the 5 titanium miniplates group. A negative pressure drainage tube was placed after fixation.

Postoperative management

All patients were given anti-inflammatory, detumescent, and neurotrophic drugs after operation. Antibiotics were given for one to two days to prevent subsequent infections.

Patients were braced in a cervical collar to immobilise the neck for 6 weeks and were mobilised to do out-of-bed activity 3 days postoperatively. All patients were taught to perform neck extension exercises while protecting their collar.

Clinical evaluation

Clinical results for both groups were compared as follows: (1) operation condition: operation time, blood loss, and operation costs. (2) Neurologic evaluation: The neurologic function of each patient was evaluated according to the Japanese Orthopedic Association (JOA) score, preoperatively and 1 week and 1 year postoperatively. The surgical outcomes were further evaluated using the JOA recovery rate (RR) [14]. The RR was calculated according to the following equation: RR = (postoperative score – preoperative score)/(17 – preoperative score) × 100%. (3) Cervical curvature angle (CCA): measuring angle of C2–C7 Cobb by the angles between the lines parallel to the trailing edge of C2 and C7 vertebral body. (4) Cervical range of motion (ROM): ROM change in the cervical spine was measured by the Cobb angle on lateral flexion and extension radiograms [15]. The loss of ROM after operation was calculated by (preoperative ROM – postoperative ROM)/preoperative ROM × 100%. (5) Compression ratio (CR) of spinal cord: anteroposterior (AP) and laterolateral (LL) spinal cord diameters were measured in an axial MRI, and the CR was considered in terms of AP/LL spinal cord diameter. (6) The anteroposterior diameter (APD) of the spinal canal: the APD of the vertebral canal for each level was measured from the middle of the posterior border of the vertebral body to the anterior cortex of the elevated lamina in lateral cervical spine X-rays. (7) Complications: these included infection, hematoma, axial symptoms (AS), CS nerve root palsy, and door reclosure. Axial symptoms were recorded according to the following four levels reported by Hosono et al. Good: no stiffness or pain; minor: symptoms after minor exertion or colds that resolve quickly, without significant effects on daily activities or neck motion; major: symptoms appear frequently, daily activities are affected, and physical therapy or analgesic pills are required; and severe: symptoms appear frequently and significantly affect daily activities, and analgesics or injection of anesthetics to the painful muscles are regularly needed. The patients without AS were classified as good or minor, and those with AS were classified as major or severe.

Statistical analysis

Statistical analysis was performed using SPSS (Statistical Package for Social Sciences) version 21.0 (IBM SPSS, Chicago, IL, USA) statistical software. Continuous variables are presented as mean ± SD and compared by Student’s t-test. Categorical data are expressed as the number (percentage) and compared by Pearson’s chi-squared test. Significance was set at P < 0.01 or P < 0.05.

Table 1

| Variable                   | The 3 titanium miniplates group | The 5 titanium miniplates group | P value |
|----------------------------|---------------------------------|---------------------------------|---------|
| N                          | 34                              | 58                              |         |
| Age (y)                    | 63.2 ± 6.1                      | 60.7 ± 7.2                      | 0.093   |
| Male                       | 25 (73.5%)                      | 48 (74.1%)                      | 0.949   |
| Underlying condition       |                                 |                                 |         |
| Hypertension               | 5 (14.7%)                       | 7 (12.1%)                       | 0.967   |
| Diabetes                   | 2 (5.9%)                        | 3 (5.2%)                        | 0.740   |
| Cardiovascular disease     | 1 (2.9%)                        | 1 (1.7%)                        | 0.723   |
| Follow-up (mo)             | 29.6 ± 8.17                     | 32.26 ± 9.45                    | 0.176   |

Values are expressed in mean ± standard deviation. Abbreviations: N = number; Mo = months; y = years.
Results

Preoperative results

All 92 patients were successfully operated on and had a minimum of 12 months follow-up (range 16–55 months). The key demographic baseline parameters and systemic conditions of patients, such as hypertension and diabetes, are summarised in Table 1. All baseline characteristics were balanced between the two groups.

Operation outcomes

The operative surveys between the two groups are shown in Table 2. The average time of operation was 1.22 ± 0.65 h in the 3 titanium miniplates group and 2.37 ± 1.07 h in the 5 miniplates group. The average blood loss was 358.27 ± 101.51 ml in the 3 miniplates group and 410.33 ± 138.25 ml in the 5 miniplates group. Compared with the 3 miniplates group, the 3 miniplates group had shorter operation times (P < 0.001) and lower blood loss (P = 0.030).

The average length of stay following index surgery was five days. As shown in Table 2, the costs associated with index surgery were significantly higher in patients undergoing EOLP with 5 titanium miniplates (P < 0.001*).

Functional results

The postoperative changes in the mean JOA score and the recovery rate of the JOA score between the two groups are shown in Table 3. For the 3 titanium miniplates group, mean JOA score improved to 12.9 ± 0.8 at 1 week postoperatively (recovery rate 48.10% ± 9.26%) and to 15.1 ± 1.0 at 1 year postoperatively (recovery rate 75.95% ± 10.47%). In the 5 titanium miniplates group, mean JOA score improved to 13.1 ± 1.1 at 1 week postoperatively (recovery rate 51.85% ± 11.23%) and to 14.8 ± 1.0 at 1 year postoperatively (recovery rate 72.84% ± 10.84%). There were no statistical differences in the JOA score and associated recovery rate between the two groups.

Table 4

Comparison of radiographic results of two groups (X ± s).

| Variable | The 3 titanium miniplates group | The 5 titanium miniplates group | P value |
|----------|---------------------------------|---------------------------------|---------|
| CCA, deg | Preop 21.2 ± 9.8 | 18.7 ± 8.3 | 0.515 |
| 3 mo postop 19.8 ± 8.6 | 16.9 ± 7.0 | 0.357 |
| Last follow-up 15.4 ± 8.2 | 13.7 ± 7.4 | 0.168 |
| ROM, deg | Preop 43.75 ± 12.86 | 40.25 ± 11.37 | 0.178 |
| Last follow-up 32.26 ± 10.01 | 30.94 ± 9.25 | 0.523 |
| The loss of ROM, % | 26.26 ± 8.31 | 23.13 ± 7.74 | 0.072 |
| Segments with stenosis | N 2.68 ± 0.59 | 2.84 ± 0.62 | 0.202 |
| Preop CR 0.47 ± 0.08 | 0.49 ± 0.08 | 0.374 |
| Postop CR 0.64 ± 0.06 | 0.65 ± 0.07 | 0.488 |
| APD, mm | Preop 10.35 ± 1.42 | 11.79 ± 1.65 | 0.102 |
| 1 wk postop 18.25 ± 3.18 | 18.72 ± 2.74 | 0.456 |
| Last follow-up 16.42 ± 2.53 | 17.32 ± 2.83 | 0.130 |

Values are expressed in mean ± standard deviation. CCA = cervical curvature angle; ROM = range of motion; CR = compression ratio; APD = anteroposterior diameter; N = number; Preop = preoperative; Postop = postoperative.

Radiographic evaluation

In the 3 titanium miniplates group, the average CCA decreased from 21.2° ± 9.8° preoperatively to 19.8° ± 8.6° at 3 months follow-up, and further to 15.4° ± 8.2° at the last follow-up. Similarly, in the 5 titanium miniplates group, the average cervical curvature angle decreased from 18.7° ± 8.3° preoperatively to 16.9° ± 7.0° at 3 months follow-up and further to 13.7° ± 7.4° at the last follow-up. There were no significant differences between the two groups in CCA (Table 4).

The mean ROM values of the 3 titanium miniplates group was 32.26° ± 10.01 at the last follow-up, with approximately 26.26% loss of ROM. The mean ROM of the 5 titanium miniplates group was 30.94 ± 9.25° at the last follow-up, with approximately 23.13% loss of ROM.

There were no significant differences between the two groups in the ROM and the loss of ROM (P > 0.05) (Table 4).

In the 3 titanium miniplates group, the average number of segments with the stenosis was 2.68 ± 0.59, and the mean spinal cord CR was 0.47 ± 0.08. Meanwhile, the average number of narrow segments in the 5 titanium miniplates group was 2.84 ± 0.62, and the spinal cord CR was 0.49 ± 0.08, showing no significant differences between the two groups (P > 0.05). At the last follow-up, reclosure of opened doors did not occur in either of the groups, and the spinal cord CR increased to 0.64 ± 0.06 and 0.65 ± 0.07 in the 3 and 5 titanium miniplates groups, respectively.

Lateral cervical spine X-rays showed that after surgery, the mean APD increased from 10.35 ± 1.42 mm to 18.25 ± 3.18 mm and 11.79 ± 1.65 mm to 18.72 ± 2.74 mm in the 3 and 5 titanium miniplates groups, respectively. At the last follow-up, the mean APD was 16.42 ± 2.53 mm in the 3 titanium miniplates group and 17.32 ± 2.83 mm in the 5 titanium miniplates group (Table 4). The mean APD of the spinal canal improved in both groups but the values were not significantly different from each other.

Complications

No mortality occurred after operation. Complications occurred in three cases in the 3 titanium miniplates group and in seven cases in the 5 titanium miniplates group at 6 months follow-up. The most common complication in EOLP is axial symptom; the 3 titanium miniplates group included two major cases of axial symptom and the 5 titanium miniplates group included four major cases and one severe case. Comparing the incidence between the two groups revealed no major differences based on the differing sample sizes (P > 0.05). Early neurological deterioration...
following the operation, such as C5 nerve root palsy, occurred in one case in the 3 titanium miniplates group and twice in the 5 titanium miniplates group; all cases recovered completely three months later. Other complications such as door reclosure did not occur in either of the groups. Typical cases of the 3 and 5 titanium miniplates groups are shown in Figure 1 and 2, respectively.

Discussion

The first EOLP procedure had high complication rates until O’Brien et al. introduced reconstructive maxillofacial titanium miniplates in 1996 [9]. After nearly 20 years of development and innovation, EOLP has matured greatly and the risk of complications has decreased significantly [7,10]. Similarly, the overwhelming majority of patients in our study made a rapid recovery with no severe observed complications. Although titanium miniplates in EOLP have proven to be effective for CM patients [11], there is little guidance over what quantity of fixed segments provides better outcomes for patients. There is also little literature to explain the relationship between the quantity of titanium miniplates used in EOLP and its resulting clinical effects.

It is generally believed that the more the titanium miniplates used, the better the effect of spinal canal decompression, which lowers rates of door reclosure complications. Therefore, surgeons often prefer to fix more segments to increase the efficacy of the operation. However, comparing the clinical results from the 92 patients who underwent EOLP with titanium miniplates operation showed no significant difference between the 3 and 5 titanium miniplates groups in JOA RR, CCA, cervical ROM, and APD of the spinal canal. The incidence of complications such as axial symptoms, C5 nerve root palsy, and lamina reclosure had no statistically significant differences. Practically, we can consider both surgical methods to be effective for treating most patients with CM. Notably, however, the 3 titanium miniplates group showed significantly shorter operation times and less blood loss than the 5 miniplates group.

Intraoperative bleeding is a common complication in surgery and primarily results from direct vessel bleeding. Tung et al. reported that single-door laminoplasty may damage the epidural venous plexus and increase intraoperative bleeding [17]. Nonetheless, the 3 titanium miniplates group demonstrated a 16% decrease in intraoperative blood loss compared with the 5 titanium miniplates group, which experienced significantly higher trauma during surgery. As the spinal cord is delicate, the control of perioperative bleeding is an important issue for spinal surgeons [18,19]. Excessive blood loss may cause hypotension and inadequate oxygenation of organs, thereby increasing the risk of delayed postoperative recovery or perioperative morbidity. Another concern with regards to perioperative bleeding in spinal surgery is the risk of spinal epidural hematoma formation, which might lead to spinal cord or cauda equina compression [20,21]. Although a drain is used to prevent postoperative epidural hematoma formation [22], substantial bleeding through the drain often persists after the wound is closed. The 3 titanium miniplates group fixed less levels and consequently reduced soft-tissue injury. Therefore, EOLP with 3 titanium miniplates has an advantage in reducing the above-mentioned risk.

Meanwhile, there was a significant relationship between the operation cost and the quantity of titanium miniplate used in EOLP. Implant costs in the 5 titanium miniplates group was nearly 1.7 times those of the 3 titanium miniplates group. The total mean cost of 3 titanium miniplates
was ¥50,151.73 ± 18,997.27, which was significantly lower than the ¥84,289.51 ± 19,811.46 for the 5 titanium miniplates group. High operation cost has hindered the clinical application of titanium miniplates in EOLP. Using less titanium miniplates would reduce the cost of operation, which would not only help to lighten the patients’ burden, but also promote the further improvement and development of the operation.

Some surgeons also have attempted to prevent the problems, such as axial symptom and undesirable radiological changes, after EOLP by undergoing C3–6 or smaller laminoplasty [23]. Hosono et al. [24] reported that C3–6 laminoplasty took over C3–7 laminoplasty with significantly lower incidence of axial neck pain and other various benefits, such as shorter operative time and smaller operative wound. Although they declared both the patients showed satisfactory results, the APD of C6/7 was found to be significantly smaller in the C3–6 laminoplasty, which might result in spinal cord compression. Therefore, laminoplasty with C3–6 or smaller is an alternative for the patients who need shorter surgery areas, the reliability of which still needs to be verified in long-term follow-up studies.

The current study also has some potential limitations. First, the study was non-randomised and the sample size was relatively small. Second, the follow-up time is relatively short. To further confirm the differences in using 3 versus 5 titanium miniplates in EOLP, longer studies with higher sample sizes should be performed.

Conclusion

Cervical single EOLP with 3 titanium miniplates causes less blood loss and lowers operation time and costs compared with using 5 titanium miniplates. Both methods are suitable for treating most patients with CM.

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Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

We declare that we do not have any commercial or associative interest that represents a conflict of interest in connection with the work submitted.

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