
Comparable clinical and radiological outcomes between skipped-level and all-level plating for open-door laminoplasty

1

2 **Abstract**

3 **Purpose:** To compare the clinical and radiological outcomes between skipped-level and all-level
4 plating for cervical laminoplasty.

5 **Methods:** Patients with CSM treated by open-door laminoplasty with minimum 2-year
6 postoperative follow-up were included. All patients had opening from C3-6 or C3-7 and were
7 divided into skipped-level or all-level plating groups. Japanese Orthopaedic Association (JOA)
8 scores and canal measurements were obtained preoperatively, immediate (within 1 week)
9 postoperatively, and at 2 weeks, 6 weeks, 3, 6 and 12 months postoperatively. Paired t-test was
10 used for comparative analysis. Receiver operating characteristic analysis was used to determine
11 the canal expansion cut-off for spring-back closure.

12 **Results:** A total of 74 subjects were included with mean age of 66.1 ± 11.3 years at surgery. Of
13 these, 32 underwent skipped-level plating and 42 underwent all-level plating. No significant
14 differences were noted between the two groups at baseline and follow-up. Spring-back closure
15 was observed in up to 50% of the non-plated levels within 3 months postoperatively. The cut-off
16 for developing spring-back closure was 7mm canal expansion for C3-6. No differences were
17 observed in JOA scores and recovery rates between the two groups. None of the patients with
18 spring-back required reoperation.

1 **Conclusions:** There were no significant differences between skipped-level and all-level plating
2 in terms of JOA or recovery rate, and canal diameter differences. This has tremendous impact on
3 saving costs in CSM management as up to two plates per patient undergoing a standard C3-6
4 laminoplasty may be omitted instead of four plates to every level to achieve similar clinical and
5 radiological outcomes.

6

7 **Key Words:** cervical spondylotic myelopathy; plates; spring-back; skipped-level; laminoplasty

8 **Level of Evidence:** III

1 **Introduction**

2 Cervical spondylotic myelopathy (CSM) is the leading cause of spinal cord dysfunction
3 worldwide and is caused by narrowing of the cervical spinal canal leading to symptomatic cord
4 compression.[1] The prevalence in the Japanese population has been reported to be 1.9-4.3%.[2]
5 Furthermore, an increasing number of surgeons are performing prophylactic or early
6 decompression in cases of asymptomatic or “silent” myelopathy to avoid catastrophic spinal cord
7 injuries.[3] Posterior surgical approaches allow for indirect decompression without destabilizing
8 intervertebral discs and in general carries less risk of postoperative instability and adjacent level
9 degeneration as compared with anterior discectomy and fusion.[4]

10 Expansive open-door laminoplasty, first reported by Hirabayashi *et al*[5,6] in 1983, is a
11 commonly adopted technique to manage CSM and avoids problems related to laminectomy such
12 as instability, kyphosis and perineural adhesions. Traditionally, stay sutures have been used to
13 anchor the spinous process to the facet joint capsule to maintain the hinge opening.[5-7]
14 However, increased laminar closure or spring-back has been reported with this technique.[8,9]
15 Spring-back phenomenon or closure, has a reported rate of 10%[9] depending on its definition,
16 and is a major concern in laminoplasty as closure of the laminae opening can lead to re-
17 narrowing of the spinal canal and recurrence of symptoms. Since then, mini-plates have been
18 used as a more rigid fixation alternative to maintain the laminae opening.[10,11] Despite
19 apparent clinical benefits[8], mini-plates are costlier. As healthcare providers, this increased cost
20 is a factor that should be considered when designing a management strategy.

21 As such, the main aim of this study is to determine any clinical and radiological
22 differences between skipped-level and all-level plating laminoplasty for CSM. It is also
23 important to determine whether the specific level omitted is important and the timing of spring-

1 back if it occurs. An additional objective is to determine whether the degree of canal expansion
2 has bearing on the risk of spring-back development.

3

4 **Methods**

5 Patients with multi-level CSM treated by open-door laminoplasty during the period of
6 November 2010 to June 2014, with minimal follow-up of 2 years, were included in this
7 retrospective study. Ethics was approved by the institutional review board. All patients with
8 expansive open-door laminoplasty from C3-6 or C3-7 were included (**Fig. 1**). C7 was included if
9 C6/7 compression was significant. All patients with ossification of posterior longitudinal
10 ligament, laminoplasties anchored by stay sutures or by a hybrid of plate and sutures were
11 excluded.

12 During surgery, the C2 paraspinal muscles were preserved as much as possible. The
13 interspinous ligaments must be preserved during dissection. Laminotomies were performed
14 down to dura at C2/3 and C6/7 or C7/T1. The ligamentum flavum at these levels were cut only
15 on the open side up to 50% of the midline. The open side was determined preoperatively based
16 on the more severe side clinically. A high-speed spherical burr was used, under cool saline
17 irrigation, to open the lateral margin of the lamina on the open side first before the hinge side
18 gutters were made. Only the lateral cortex and cancellous bone were removed on the hinge side
19 by the burr prior to opening by gentle force to prevent hinge fracture. The intersegmental
20 ligamentum flavum was cut on the open side to allow opening of the lamina to at least 50% of
21 the midline. Appropriate sized plates were selected with two laminar and two lateral mass screws
22 inserted per plate. Intraoperative radiographs were used to confirm no penetration into the facet
23 joints. Rigid cervical neck collars were used for 3 weeks postoperatively in all patients.

1 Patients were separated into two groups: those with skipped-level (one or more levels not
2 plated) and all-level plating laminoplasty. Of the 74 subjects, 32 underwent skipped-level plating
3 and 42 underwent all-level plating. Out of the skipped-level plating, C4 (n=29) was the most
4 common level skipped followed by C5 (n=5), C6 (n=10) and C3 (n=2). All patients with C3-7
5 laminoplasty had C7 plated and all patients with C3-6 had C6 plated. For the 32 skipped-level
6 plating, 10 patients received C3-7 laminoplasty while the remaining 22 patients received C3-6
7 laminoplasty. Nine of the patients had two levels not plated for C3-6 laminoplasty. The other 23
8 patients had single level non-plated laminae, of which 10 had C3-7 laminoplasty. Decision for
9 which laminae to skip was based on the surgeon's intraoperative assessment of stability. In
10 essence, end-levels were generally plated and intervening levels were skipped.

11 Clinical symptomatology and signs were compared at baseline and at postoperative 1
12 year. The improvements with surgery was also compared between the two groups. Japanese
13 Orthopaedic Association (JOA) scores were obtained preoperatively, immediate (within 1 week)
14 postoperatively, and at 2 weeks, 6 weeks, 3, 6, 12 months postoperatively, and at final follow-up.
15 Recovery rate was calculated using the Hirabayashi formula: recovery rate (%) = (postoperative
16 JOA - preoperative JOA) / (17 [full score] - preoperative JOA) x 100. Similarly lateral cervical
17 spine radiographs were obtained at each follow-up time-point for the anteroposterior canal
18 diameter measurements. All lateral radiographs were obtained with the patient erect, standing
19 against a board with set shoulder position. Patients were advised to have a horizontal gaze during
20 the imaging. The focus film distance was set as 180cm while centering at the angle of mandible.
21 The exposure was 62-peak kilovoltage and 8-10 milliamperage-seconds of x-ray energy. All
22 canal diameter measurements were collected on these radiographs using the DICOM based
23 Radworks 5.1 (Appicare Medical Imaging BV, Zeist, The Netherlands) computer software

1 program. The anteroposterior canal diameter were measured using Wolf's method[9,12,13], from
2 the middle of the posterior border of the vertebral body to the anterior border of the lamina. Any
3 spring-back closure was defined as >1mm loss of initial expansion.[12] This criterion was
4 adopted for its strict definition.

5 Three independent readers performed all measurements of cervical spine radiographs.
6 Assessment of inter-rater and intra-rater reliability was assessed using intraclass correlation
7 coefficient (ICC). Inter-rater or intra-rater reliability was determined as good with ICC between
8 0.75 to 0.9, moderate if 0.5-0.75 and poor if less than 0.5. The clinical symptomatology and
9 signs are dichotomous dependent variables, thus McNemar test was used to determine
10 differences between the two groups and from baseline to postoperative 1 year. Paired t-test was
11 used for analysis of difference between outcomes, in terms of post-operative expansion of spinal
12 canal, improvement in JOA score and recovery rate. Receiver operating characteristic (ROC)
13 analysis was utilized to determine the cut-off values of canal expansion with which spring-back
14 occurred. The 95% confidence intervals (CIs) were listed when appropriate and a p-value of
15 <0.05 was considered significant.

16

17 **Results**

18 A total of 74 subjects (18 females) were included in the study with mean age of
19 66.1 ± 11.3 years at the time of surgery (**Table 1**). Mean JOA score preoperatively was 9.4 ± 3.5
20 (range 1.5-14.5). The follow-up period ranged from 4 years 10 months to 5 years 11 months.
21 Good intra-rater reliability was shown in both pre-operative and post-operative measurements of
22 canal diameter at both plated and non-plated vertebral levels. For preoperative measurements,
23 ICC ranged from 0.826 to 0.915, with $p < 0.05$. As for the postoperative measurements, ICC

1 ranged from 0.878 to 0.936 and 0.855 to 0.884 with $p < 0.001$ at plated and non-plated vertebral
2 levels respectively. Similarly, good inter-rater reliability was achieved.

3 At baseline, most patients were significantly myelopathic with involvement of upper and
4 lower limb numbness, clumsiness, and gait disturbances (**table 2**). Most patients had
5 improvements in symptoms showed by the reduction of patients with these myelopathic
6 symptoms at postoperative 1 year. When comparing between skipped-level and all-level groups
7 (**table 3**), significant improvements were observed between upper and lower limb numbness,
8 upper limb clumsiness and gait disturbance. Limited improvements were observed for Hoffman's
9 sign and Romberg test at postoperative 1 year.

10 No significant differences in canal expansion were noted between the two groups at
11 baseline and at follow-up (**Fig. 2**). Looking specifically at the non-plated levels within the
12 skipped plating group however, reductions were observed for C4 at postoperative 6 weeks
13 (6.2 ± 1.2 to 5.6 ± 1.2 ; p -value 0.087), C5 at postoperative 2 weeks (6.5 ± 2.4 to 5.4 ± 2.7 ; $p = 0.249$),
14 and C6 at postoperative 6 weeks (3.7 ± 1.7 to 2.6 ± 1.8 ; $p = 0.061$). Hence, the reductions occurred
15 early within 6 weeks postoperatively.

16 In general, spring-back closure was observed in 26.8% of non-plated vertebral levels at 2
17 weeks postoperatively, with more than 50% closure at 3 months postoperatively. There was an
18 incidence of 67.9% ($n = 19$), 50% ($n = 2$) and 100% ($n = 9$) of closure at levels C4, C5 and C6
19 respectively at the 12-month postoperative time-point for these non-plated levels. The cut-offs at
20 which spring-back occurred were generated via ROC analysis and listed in **table 4**. C7 was not
21 analysed since all patients had plating. In general, an expansion of more than 7mm was required
22 to have reduced risk of any spring-back.

1 No difference in JOA scores ($p=0.294-0.850$) nor recovery rate ($p=0.189-0.864$) was
2 observed between the two groups at all postoperative time points. Comparable improvements
3 (**Fig. 3**) in JOA scores and recovery rate were observed in both groups at all follow-up time-
4 points. No patients required reoperation. No complications of immediate postoperative drop in
5 JOA scores, screw pullout or iatrogenic destabilization with postoperative spondylolisthesis were
6 observed.

7

8 **Discussion**

9 Laminoplasty is the gold standard posterior surgical approach due to complications of
10 segmental instability, kyphotic deformity, worse neck range of motion, perineural adhesion and
11 late neurological deterioration in laminectomy.[14] It is ideally suited for multilevel disease due
12 to its extensile approach. However, due to similar effectiveness and safety as compared to
13 multiple anterior cervical discectomies and fusion, some surgeons prefer anterior surgery as
14 compared to laminoplasty.[15] The popularized expansive “open-door” technique has been
15 shown to achieve good clinical outcomes.[16] The traditional method for keeping the lamina
16 opening is by sutures but there is risk of spring-back phenomenon where recurrence of symptoms
17 may occur.[9] This complication has been reported in up to 40% of subjects[17], and hence
18 recent trends have adopted more rigid devices like mini-plates for fixation to help prevent
19 complications such as loss of fixation, hinge fracture and spring-back closure.[18-22] Titanium
20 plates for fixation have long lasting patency with biological healing of the laminar arch without
21 much complications.[22] We have an average of 5 year follow-up in our study which proves the
22 satisfactory results of both techniques utilizing these mini-plates. This mirrors the results from a
23 5-year follow-up report of plated laminoplasty.[23]

1 The main aim of study is to determine whether a less expensive fixation approach with
2 skipped-level plating can achieve similar clinical and radiological outcomes as all-level plating.
3 Our results suggest that there are no significant differences in canal expansion between the two
4 groups and at all levels from C3-7. By comparison, Yang *et al*[24] who studied plate fixation in
5 an alternating (C4 and C6 not plated only) fashion observed reduced openings at the non-plated
6 segments. Reduced opening is a concern for the effectiveness of decompression as there is less
7 space to accommodate movement of the cord in flexion-extension. A possible rationale for why
8 we did not observe this difference is our strict adherence to preserving the interspinous ligaments
9 and half of the ligamentum flavum intact. These soft tissue stabilizers are important to the
10 stability of the posterior column and as such less intersegmental motion is observed.[25,26] With
11 improved stability of the opened laminae as a unit, the plated segments provide adequate support
12 to uphold the non-plated segments. This was possible even in 2 non-plated levels out of 4 levels
13 total for C3-6 laminoplasty.

14 Besides the initial canal expansion, the changes that occur postoperatively prior to hinge
15 healing is important. Any reduction (1mm) in the canal diameter is considered as spring-back
16 which may lead to restenosis of the cervical canal with compromise of the decompressed spinal
17 cord.[12] With our length of follow-up, we can determine in the early and late follow-up whether
18 spring-back occurs. Results suggest that reductions in the canal diameter may occur in the early
19 phase at non-plated levels. This was only observed during the early follow-up at postoperative 6
20 weeks for C4 and C6, and postoperative 2 weeks for C5. The early findings may be related to the
21 increased mobilization exercise allowed by the patient after the wound pain and stiffness related
22 to the surgery has resolved. Given the absolute expansion, this is an insignificant amount of

1 reduction. Nevertheless, spring-back closure based on our criteria was common and occurred
2 most often at C6 or the junctional level.

3 It is possible through the tethering by the ligamentum flavum after opening the laminae to
4 a certain degree that the non-plated levels under tension do not experience spring-back.[25,26]
5 Hence, we specifically analyzed whether there is a cut-off for laminae opening that is associated
6 with less risk of spring-back. Our ROC analysis showed that in the non-plated levels from C3-6,
7 there is a high sensitivity and specificity for a canal expansion of approximately 7mm to not
8 result in spring-back closure. It is possible that with this 7mm opening that there is a threshold of
9 ligamentum flavum tension with which the non-plated levels are kept opened by the plated
10 levels. This postulation requires further study to verify.

11 Based on a non-inferiority principle, our technique with skipped-level plating provides
12 equal canal expansion as the all-level plating patients. This provides us with a less costly option
13 that will result in the same radiological outcomes. For the clinical outcomes, we used the JOA
14 score and recovery rate data to compare between groups. The rate of JOA and recovery rate
15 changes are consistent with what has been seen for alternate plating.[24,27] A comparable
16 difference from these studies is our use of multiple skipped levels in C3-6 laminoplasty. Our
17 results verify that any intervening levels from C3-6 or C3-7 without plating can still result in
18 good symptomatic recovery and none of the patients with spring-back required reoperation. This
19 is in line with the importance of maintaining interspinous ligament and ligamentum flavum
20 integrity. Of note is the omission of C7 as a possible non-plated level in this study, and as such,
21 whether or not C7 can also avoid plating needs to be addressed in future study. However, due to
22 the increased segmental motion at the cervicothoracic junction, the authors hypothesize that
23 further reductions in canal expansion would be observed. Due to laminotomies at C3/4 and C6/7

1 or C7/T1, plating is advised at the end segments. Hence surgeons should only consider skipping
2 C4-C5 for C3-6 laminoplasty and C4-6 for C3-7 laminoplasty. This can reduce implant costs by
3 50% for a C3-6 laminoplasty and 60% for a C3-7 laminoplasty. Cost concerns are valid
4 considering the cost-effectiveness benefits of routinely using plates in laminoplasty is still
5 debatable.[28]

6 Several limitations exist for this study. We were unable to generate a standardized
7 surgical procedure to compare between groups due to the study's retrospective nature. Having
8 standard skipped-level plating patients may allow a more even comparison for non-plated levels.
9 There is a wide spectrum of possible presentations for CSM. Although the JOA is a commonly
10 used method for assessment of clinical outcomes, it only focuses on the physical signs without
11 accounting for patient-perceived health-related quality of life. Future assessment using the
12 Japanese Orthopaedic Association Cervical Myelopathy Evaluation Questionnaire (JOACMEQ)
13 is more useful to not only cover the domains of the original JOA score but also patient-perceived
14 health status.[29-31] Furthermore, we do not have postoperative MRIs to assess any spinal cord
15 signal changes which may be useful to correlate the effects of our decompression surgery.[32]
16 Our use of lateral radiographs to define springback was to avoid radiation exposure with
17 computed tomography (CT). However, axial CT scans are most appropriate to study springback
18 phenomenon.

19 This is a novel study that presents compelling data that highlights the non-inferiority of
20 patients undergoing different combinations of skipped-level plating as compared with all-level
21 plating for laminoplasty. No significant differences between groups were observed for spring-
22 back closure at all levels without plating. Despite having some cases with early re-narrowing of

1 the canal, there was no effect on the JOA score or recovery rate. In addition, we proposed a
2 threshold of at least 7mm canal expansion to avoid spring-back closure.

3

4 **Conclusions**

5 In this modern age with an increasingly conscious society to health economics, any
6 management must also be balanced in terms of healthcare cost. It is our duty to select the best
7 and most cost-effective treatment option for patients. As evidenced in this study, skipped-level
8 and all-level plating for open-door laminoplasty yields similar clinical and radiological
9 outcomes. With no perceivable superiority with every level plating, the implications of cost
10 reduction with less plates used become more impactful and should be considered during
11 management planning.

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1 **Figure Legends**

2 **Fig. 1:** (a) Skipped-level plating at C4 and C6 for C3-7 laminoplasty; (b) Skipped-level plating at
3 C5 for C3-6 laminoplasty.

4 **Fig. 2:** Comparable canal diameter expansion is observed for (a) C3, (b) C4, (c) C5, and (d) C6
5 between skipped-level and all-level plating. Data are expressed in means with standard deviation
6 bars.

7 **Fig. 3:** Similar improvements in (a) Japanese Orthopaedic Association (JOA) scores and (b)
8 recovery rate were observed between skipped-level and all-level plating. Data are expressed in
9 means with standard deviation bars.