

*Original Research Article*

# Modified Z-plasty for Cervical Spine Myelopathy: A Not-So-Obsolete Method of Laminoplasty

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Abstract

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It is generally accepted that laminoplasty is a safe and reliable surgical treatment for cervical spine myelopathy (CSM) due to spinal canal stenosis. There are multiple techniques of laminoplasty for spinal cord decompression and most of them require expensive instruments to stabilize the laminae. From 2005 to 2015, we applied the modified Z-plasty (Sakou's technique) for CSM patients in an attempt to reduce the cost of treatment. This is a retrospective study. CSM patients treated by modified Z-plasty technique were selected. We applied Sakou's technique, according to which the laminae will be opened in different directions alternatively. We use the JOA score and recovery rate of Hirabayashi to assess the neurological recovery and the Neck Disability Index (NDI) for the cervical functional outcome. There were 42 patients with the mean follow-up duration of 10 years (5-15 years), male: female ratio of 3:1 and mean age of 61. The mean operating time and blood loss per lamina were 40 minutes and 45ml, respectively. The canal expanding index was 4.2mm (3-5 mm). The mean pre- and postoperative JOA score were 11.1 and 14.7, respectively ( $p<0.05$ ). For the axial pain, the mean NDI was 18 point with 88% of cases having an as good and very good cervical function. For complications, there were 3 cases of C5 palsy with full recovery after one year. Being considered as an old-fashioned surgery, the modified Z-plasty can still provide good clinical and radiological outcomes to cervical myelopathic patients. The absence of hardware such as titanium plates or hydroxyapatite spacers reduces the risk of infection and the cost of treatment. Considering the risk-benefit and cost-benefit ratio, this operation is suitable for low-income patients in developing countries.

**Keywords:** Cervical spine myelopathy, French door laminoplasty, Modified Z-plasty, Open door laminoplasty

## INTRODUCTION

Cervical spine myelopathy is a medical condition characterized by chronic compression of the spinal cord by spondylotic osteophytes, disc herniation, ossification of the longitudinal ligament (OPLL), hypertrophy or ossification of the ligamentum flavum etc. Surgery is indicated when conservative treatments fail, with the goal of enlarging the stenotic canal. It is generally accepted

that for multilevel stenosis (from 3 levels and above) with preserved cervical lordosis, laminoplasty is a reasonable choice as it can provide sufficient decompression as well as relatively avoid possible complications of laminectomy (eg restenosis, kyphotic deformity etc). Oyama and Hattori in 1973 have presented their original Z-plasty technique (Fig 1A) (Oyama et al., 1973), to which two

modifications including Sakou's (Fig 1B) (Tanimura et al., 1984) and Chiba university techniques were later proposed (Fig 1C) (Watanabe et al., 1987). The concept of enlarging the spinal canal by just opening the laminae without excising it became popular in Japan when Hirabayashi developed the open-door (Hirabayashi et al., 1983; Hirabayashi et al., 1999) and Kurukawa the French-door technique (Kurokawa et al., 1984). Naito et al in 1994 have conducted research comparing the three main methods of laminoplasty and concluded that all of them can provide similar decompressive effect and clinical outcome, but the Z-plasty was the most technically demanding and time-consuming of the three (Naito et al., 1994). After this study, Z-plasty became gradually obsolete as most of the spinal surgeons worldwide preferred either open-door or French-door methods. Despite that trend, from 2005 to 2015, the Z-laminoplasty was the technique of choice of our department of spinal surgery for multilevel cervical stenosis as it did not require any expensive devices to secure the laminae and provided good outcome.

## MATERIAL AND METHOD

This is a retrospective study. From 2005 to 2015, 97 CSM patients were operated with the Z-plasty technique in the department of Spinal Surgery B, Hospital for Traumatology and Orthopedics at Ho Chi Minh City, Vietnam. We invited them for final evaluation at our hospital by mail or phone call. There were 42 patients accepting to participate in this study with sufficient pre- and postoperative images. Informed consents were obtained from all patients.

### Indication of surgery

Patients with cervical myelopathic symptoms secondary to multilevel spinal stenosis (from three levels and above) with preserved cervical lordosis, Kline positive and no gross instability or severe axial pain.

### Operative technique

The patient was placed in a prone position on the surgical frame. The head is firmly held in the neutral position by the Mayfield tong. The midline skin incision from C2 to C7 spinous processes was used on a systematic basis. We then exposed through the avascular plane between two layers of the nuchal ligament down to the tips of the spinous process from C3 to C6. Care was taken during exposure in order to preserve the attachment of the sub-capital muscle at C2 and that of the nuchal ligament at C7 vertebra. The laminae from C3 to C6 were exposed with cautery bilaterally until the facet joint then blunt

dissection continued the work in an attempt to protect the capsules. Yellow ligaments between C2 and C7 levels were removed in order to facilitate the opening of the laminae to both sides. The laminae were then opened in the zigzag fashion (for example the C3 lamina was opened to the left side, the C4 lamina to the right side and C5 to the left side and C6 to the right side). Two-millimetre burr was used to make a hole at the cutting edge of each lamina. The laminae were held against each other in the open position by non-absorbable suture through the aforementioned drill holes (Fig 1B). The incision was then drained and closed in layers. The patient was instructed to wear hard collar continuously in the next six weeks and on an intermittent basis during six weeks after, alternatively with rehabilitation exercises to restore the cervical range of motion.

### Neurological evaluation

Pre- and postoperative neurological status of each patient was evaluated using the Japanese Orthopaedic Association (JOA) system. To assess the neurological recovery, the recovery rate proposed by Hirabayashi and colleagues was calculated by the following formula:  $\text{recovery rate (\%)} = \frac{[\text{postoperative score} - \text{preoperative score}]}{[17 [\text{full}] - [\text{preoperative score}]} \times 100$ . Neurological outcome was classified by the Hirabayashi's classification, according to which 75% to 100% was designated as very good, 50 to 74% as good, 25 to 49% as fair, and 0 to 24% as poor.

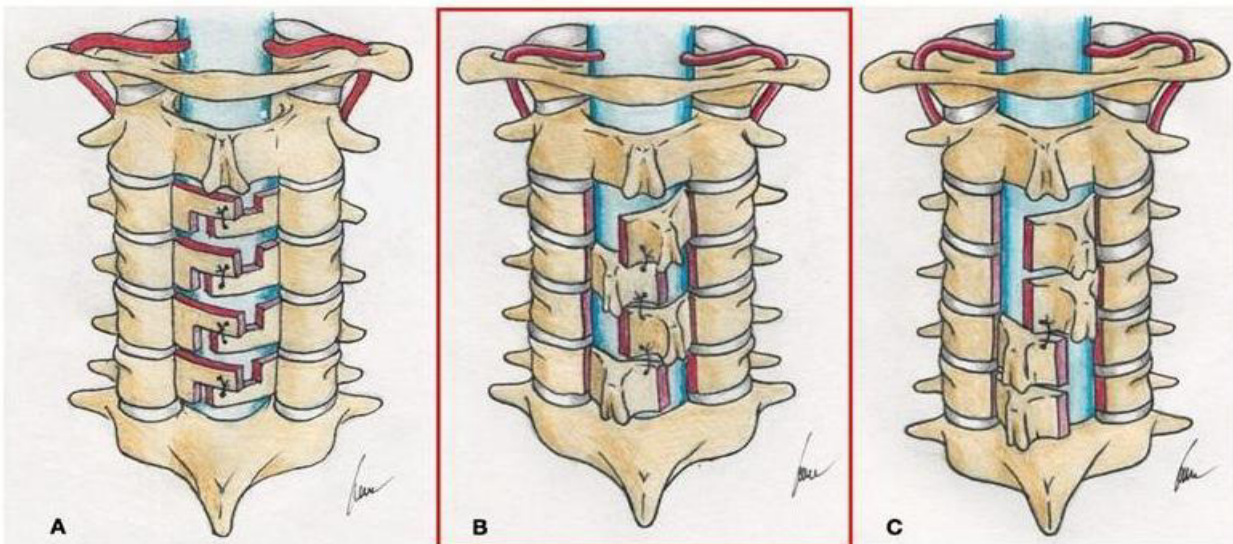
### Clinical evaluation

The neck pain or discomfort was evaluated by using the Neck Disability Index (NDI) system. The Neck Disability Index (NDI) is designed to measure neck-specific disability. The questionnaire has 10 items concerning pain and activities of daily living including personal care, lifting, reading, headaches, concentration, work status, driving, sleeping and recreation. Figure 1, Figure 2, Table 1-3

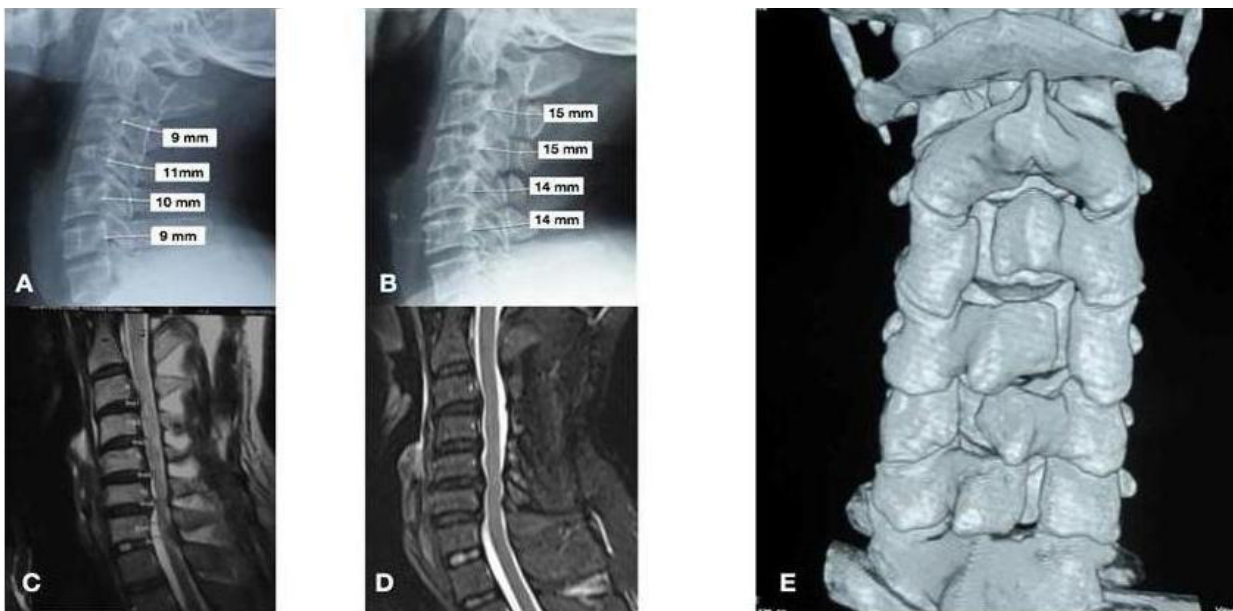
### Radiological evaluation

The enlarging of the spinal canal was assessed with lateral Xray. The pre- and postoperative AP distance of the spinal canal at each disc level from C3 to C6 was measured in all cases. The canal expanding index was defined as the difference between the final and preoperative AP diameter (in millimetre) of the spinal canal at each disc level.

Magnetic resonance imaging was also performed as a routine to evaluate the expansion of the thecal sac at each disc level after decompression. C2-7 lordotic angle



**Figure 1.** Original Z-laminoplasty (Hattori's method) (A) and modified techniques including Sakou's method (B), Chiba university method (C). Note that the technique of our department is Sakou's Z-plasty (in the red box). (Source: drawn by the corresponding author).



**Figure 2.** Illustration case: 60-year-old female patient underwent Z-plasty from C3 to C6 for multilevel cervical stenosis. Preoperative Xray (A) and MRI (C) showed acquired and congenital stenosis from C3 to C6 with well-preserved cervical lordosis. Final Xray (B) and MRI (D) after 15 years depicted wider spinal canal after Z plasty with mild residual stenosis at C5/6 and C6/7. The JOA score of this patient increased from 11 point preop to 16 at final follow up. CT scan reconstruction at final follow up showed the zigzag layout of the Z-plasty with a good bone fusion of the hinges.

was also measured on pre- and postoperative lateral Xray.

**RESULTS**

There were 42 patients recruited in this study with the

mean follow up duration of 10 years (5- 15 years), the male: female ratio of 3:1 and the mean age of the population of 65 (46- 82). The average operative time in total was approximately 140minutes (120–180 minutes) and 40 minutes per lamina (30-45 minutes). The average total blood loss was 130 ml (90–300 ml) and 45ml per lamina (25-75ml).

The radiological and clinical outcomes are displayed in

**Table 1.** Clinical and radiological outcomes of 42 patients after undergoing decompression by Z-plasty

|                          | Preoperative      | Final follow up   | p     |
|--------------------------|-------------------|-------------------|-------|
| Clinical outcome         |                   |                   |       |
| mean JOA                 | 11.1              | 14.7              | <0.05 |
| mean Hirabayashi ratio   |                   | 68%               |       |
| mean NDI                 | 23                | 18                | >0.05 |
| Radiological outcome     |                   |                   |       |
| mean canal diameter      | 12.3mm            | 16.8mm            | <0.05 |
| mean expansion index     |                   | 4.2mm             |       |
| mean thecal sac diameter | 6.6mm             | 11.2mm            | <0.05 |
| mean C2-7 lordotic angle | 21.1 <sup>0</sup> | 19.3 <sup>0</sup> | >0.05 |

**Table 2.** Patients with spring-back closure as a complication

|           | Gender | Age | Preoperative canal diameter (mm) | Postoperative canal diameter (mm) | Final follow up canal diameter (mm) |
|-----------|--------|-----|----------------------------------|-----------------------------------|-------------------------------------|
| Patient 1 | Male   | 52  | 8                                | 14                                | 11                                  |
| Patient 2 | Male   | 59  | 9                                | 15                                | 12                                  |
| Patient 3 | Female | 62  | 8                                | 15                                | 11                                  |

**Table 3.** Comparing our surgical parameters with those of Naito's study

|                      | Surgical time per lamina (minute) | Blood loss per lamina (millilitre) |
|----------------------|-----------------------------------|------------------------------------|
| Open door (Naito)    | 29 ±6,2                           | 93 ±13                             |
| French door (Naito)  | 32 ±6,4                           | 90 ±11                             |
| Z-plasty (Naito)     | 48 ± 7,1                          | 121± 21                            |
| Z-plasty (Our study) | 40 ± 13                           | 45 ± 21                            |

table 1. The mean recovery rate of Hirabayashi was 68% with 75% of patients having from good to very good outcome. The NDI at final follow up was 18 with 88% of patients having from good to very good cervical function with minimal to mild pain during daily activities.

For complications, there was 3 case (7.2 %) having C5 palsy after the surgery. After checking with postoperative CT scans revealing no residual foraminal stenosis, the protocol was to wait and see and all three patients had full recovery one year after. In the other three patients (7.2 %), lamina closure has been detected by comparing the immediate postoperative x-ray and the final x-ray (table 2). However, this complication did not have any negative effect on the neurological recovery, therefore the protocol was also observing. There was one case of superficial infection well-controlled with an oral antibiotic. No dural tears or deep infections have been recorded.

## DISCUSSION

The Z-plasty technique has been described and reported by Oyama and Hattori in 1974. The original method was time-consuming and technical demanding when the Z-shaped cut line must be done at each lamina (Fig 1A)

(Itoh and Tsuji, 1985). In 1984 Tomimura and Sakou have modified this surgery by open each lamina as a whole in different directions in an attempt to simplify the procedure and reduce the time of surgery (Fig 1B) (Kawai et al., 1998). This is the technique our department of spinal surgery has been using from 2005 to 2015 before we switched to open door technique when titanium plates became available. Last but not least, in 1987 Watanabe proposed the Chiba university modification according to which the C3 and C4 laminae will be opened to one side and the other two to the other side (Fig 1C). Despite those modifications, the Z-plasty became gradually obsolete when Hirabayashi's (Oyama et al., 1973) and Kurukawa's techniques (Hirabayashi et al., 1999) have been presented in 1983 and 1984, consecutively.

However, those two latter techniques are not without drawbacks. For the open-door laminoplasty, the asymmetry of the two masses of paraspinal muscle could lead to suboptimal clinical and neurological outcome. On the one hand, the canal is opened to one side and hinged on the other and this can create an asymmetric expansion of the canal (Maeda et al., 2002; Azuma et al., 2010; Shaffrey et al., 1999). When bilateral foraminal stenosis exists, open door laminoplasty may increase the possibility of C5 nerve palsy due to inadequate foraminal decompression or asymmetrical decompression

(Komagata et al., 2004). On the other hand, unilateral open-door laminoplasty results in skeletal asymmetry and causes asymmetrical muscular approximation (Azuma et al., 2010; Chiba et al., 2002). Studies have demonstrated that patients treated with open door technique reported more axial pain than those with French door method (Okada et al., 2009).

For the French-door technique, the main issue is how to keep the laminar halves open bilaterally. The conventional technique requires expensive hydroxyapatite spacers that could be a problem for low-income patients, especially when the device is not covered by the insurance. One feasible solution is using iliac bone block, which in turn can lead to donor site complications (Dimitriou et al., 2011). Another alternative is harvesting strut graft from C3-C6 spinous processes (Nakashima et al., 2015). This technique appeared to be beneficial in the setting of cost-effectiveness and donor site complications. However, it was time-consuming and not very suitable for Vietnamese patients with relatively small size spinous processes.

In a nutshell, the symmetry of the paraspinal muscles might have an important role in the postoperative outcome and beside French-door laminoplasty, only Z-plasty can meet that requirement. When systematically searching in the literature, we noticed that the concept of opening the laminae in the zigzag pattern is not entirely out of date. Iencean et al in 2007 have reported a case series of 23 patients treated by alternating open-door laminoplasty with satisfactory results (Iencean, 2007). The authors also open the laminae in different directions with a zigzag configuration. The only difference from our technique is the way they secure the open laminae by suturing the spinous processes to the capsule on the hinge side, similar to Hirabayashi's technique. Arantes et al in 2014 (Arantes et al., 2014) reported a case series treated by a technique similar to Chiba university technique (Watanabe et al., 1987), according to which two first laminae (C3 and C4) will be open to one side and the other two (C5 and C6) to the other side. Despite the new name "two-open-door laminoplasty", this is the modification of the original Z-plasty. In 2016, the team of Lee has proposed a novel en-bloc laminoplasty technique using a translaminar screw as fixation (Lee et al., 2016). They also preferred to open the laminae with a zigzag pattern in order to maintain the symmetry of the neck and preserve the nuchal ligament.

We have been using the Z-plasty method for most of our patients with the aim of reducing the cost of treatment, avoiding donor site morbidity and preserving the symmetry of the neck. Naito in 1994 has compared three different methods including open-door, French-door and Z-plasty. The conclusion was no differences in regards to neurological outcome and axial pain have been found, however, the Z-plasty was the least favourable choice because of the largest blood loss and longest surgical duration. Table 3 displays the surgical

parameters of Naito's and those of our study. It is noticeable that our surgical time per lamina is significantly shorter than that of the Z-plasty group of Naito. This difference can be explained by the fact that we used modified Z-plasty (Sakou's technique) whereas Naito et al have used the original one (Hattori method) with more complexity. Our surgical time per lamina was longer than that of the open-door and French-door groups but this difference has no clinical significance and can be compensated by the lower blood loss per lamina when compared with Naito's data.

The mean neurological recovery rate of our study (68%) was in line with that of laminoplasty studies in general (Oyama et al., 1973; Tanimura et al., 1984; Watanabe et al., 1987; Hirabayashi et al., 1983; Hirabayashi et al., 1999; Kurokawa et al., 1984; Itoh and Tsuji, 1985; Kawai et al., 1998; Naito et al., 1994; Wang et al., 2016). Our mean canal expansion index of 4.2mm was sufficient for optimal neurological decompression as recommended by Gu et al. (2015). Excessive opening of the lamina may cause the cord to migrate and extend posteriorly. In such cases, traction and tethering of the nerve root secondary to the posterior shift of the spinal cord may occur, which has been considered as the main factor in postoperative C5 nerve root palsy (Imagama et al., 2010; Tsuzuki et al., 1996; Uematsu et al., 1998). The decompression effect has been confirmed by final MRI scans showing the enlargement of the AP diameter of the thecal sac from 6.6 preoperative to 11.2mm at final follow up. For all operated patients, we never tried to enlarge the canal too widely and that might help to minimize the C5 palsy rate (3 cases, 7.2 %). To our understanding, our complication rate stayed within the acceptable range (Imagama et al., 2010; Tsuzuki et al., 1996; Uematsu et al., 1998). One potential and worrisome complication of Z-plasty is spring-back closure when the laminae were secured only by non-absorbable suture. Wang et al in their study has shown that spring-back closure with Hirabayashi technique could be as high as 10% (Wang et al., 2011). In our study, this undesirable event occurred in 7.2% and fortunately, it did not require any revision surgery. Last but not least, our patients reported mild to moderate axial pain at final follow up and for most of them, the neck discomfort did not aggravate with time. In agreement with other authors (Cho et al., 2010; Sakaura et al., 2008; Takeuchi and Shono, 2007), we tried our best to protect the soft tissue attachment at C2 and C7 spinous processes during exposure and took great care when closing the incision. Finally, the cervical lordosis of our patients has been well preserved, even in those with a follow-up duration longer than ten years.

## CONCLUSION

Being considered as an old-fashioned surgery, the Z-plasty is a safe and reliable technique that can provide

good clinical and radiological outcomes to cervical myelopathic patients. The absence of hardware such as titanium plates or hydroxyapatite spacers reduces the risk of infection as well as the cost of treatment. Considering the risk-benefit and cost-benefit ratio, this operation is highly suitable for low-income patients in developing countries.

### Conflict of Interest

The author state that they have no conflicts of interest.

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