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Comparison of Midline Splitting versus Unilateral Open Door Laminoplasty and Its Impact on Patient Outcomes

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Background: Laminoplasty is a common and effective surgery for decompression of the spinal cord in multilevel cervical myelopathy. The midline splitting technique (MST) and the unilateral open door technique (UODT) are the two most commonly performed laminoplasty techniques with continuous debate on which is preferable. This study aimed to add light to the matter by comparing and exploring the possible causes of different outcomes.

Methods: A total of 101 patients who underwent laminoplasty for degenerative cervical myelopathy were included in this study. Radiographic measurements including C2–7 Cobb angle, C2–7 range of motion (ROM), Pavlov ratio of the most compressed level, and canal area with diameter were compared. Modified Japanese Orthopedic Association (mJOA) score and complications including C5 palsy, axial neck pain, hinge fractures, and spacer displacement were also compared. Statistical analysis was performed using independent samples *t*-test, chi-square test, Fisher's exact test, and linear mixed model.

Results: C2–7 ROM, canal diameter, Pavlov ratio, and mJOA score did not demonstrate differences between the two techniques. The UODT group had greater postoperative canal expansion but had more loss of C2–7 lordosis than did the MST group. Of the complications, hinge fractures were more common in the UODT group, with more loss of C2–7 lordosis in patients with hinge fractures. On the other hand, spacer displacement occurred only in the MST group, with lesser canal expansion in patients with spacer displacement.

Conclusions: The two laminoplasty techniques both demonstrated effectiveness in treating patients with multilevel cervical myelopathy. However, care should be given to avoid hinge fractures and spacer displacement since both can possibly lead to unfavorable outcomes.

Keywords: *Cervical spine, Myelopathy, Laminoplasty, Midline splitting, French door, Open door*

There are many different surgical options available for multilevel compressive myelopathy of the cervical spine. Traditionally, laminectomy was commonly performed for decompression of stenosis. However, studies found that the posterior neural arch was responsible for load transmission in the cervical spine and loss of integrity of posterior arch-facet complex can result in instability.[1)] Laminoplasty was developed to address post-laminectomy kyphosis caused by iatrogenic destabilization of the cervical spine and is currently accepted as an effective surgical

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technique for treatment of multilevel cord compression due to cervical spondylotic myelopathy and ossification of posterior longitudinal ligaments.[2] Many cervical laminoplasty techniques were developed to open the spinal canal by reshaping the lamina while preserving the posterior elements. After numerous modifications of these techniques, two main types are currently performed: midline splitting technique (MST) and unilateral open door technique (UODT). The posterior midline surgical approach and the extent of dissection are not very different between the two techniques. The key differences between the two techniques are the means of maintaining the reshaped laminae. The MST utilizes allo-bone or hydroxyapatite spacers and sutures to maintain the opened laminae, while the UODT uses titanium plates with screws to maintain the opened laminae.

While there have been numerous investigations comparing the two techniques, they have divergent results in comparing the outcomes, and controversy remains as to which technique is superior. In addition, previous studies compared the outcomes, but did not explore the possible causes of different outcomes. Therefore, this study aimed to add light to the controversy by comparing the radiographic and clinical outcomes of the two techniques and to possibly identify whether the different methods of maintaining the reshaped lamina had any effect on the outcomes.

METHODS

Study Population

This study was approved by the Institutional Review Board of Hallym University Sacred Heart Hospital (No. 2020-02-014-001). The institutional review board waived the informed consent for this study owing to the retrospective nature of the study. Patients who underwent laminoplasty for cervical myelopathy between 2010 and 2018 were included in this study. All methods were carried out in accordance with the original and amended Declaration of Helsinki. Patients with previous cervical spine surgery, patients who had other procedures with laminoplasty (anterior cervical discectomy and fusion or posterior fusion), patients who had myelopathy due to tumor, infection, or trauma, and patients with less than 6 months of follow-up were excluded. A total of 101 patients were included. Of those, 67 patients underwent MST laminoplasty and 34 patients underwent UODT laminoplasty.

Surgical Techniques

The midline splitting technique

A posterior midline exposure was performed, and cervical laminae were exposed laterally to the medial aspect of the facet joints while avoiding injury to the facet capsules. After flavectomy of above and below the intended levels of decompression, the laminae and spinous processes of involved levels were split using a threadwire saw (Mani Diamond Tomita Saw, Mani Inc.) along the midline. Then, bilateral gutters for the hinges were carefully made with a high-speed burr at the transitional area between the facet joint and the laminae. The split laminae were opened bilaterally in sequence like French doors along the decompression zone. Finally, allobone graft spacers (Laminar Spacer-K, CG Bio) were placed to maintain the opening, and non-absorbable sutures were used to hold the spacers in place (Fig. 1).

The unilateral open door technique

A posterior midline exposure was performed, and cervical laminae were exposed laterally to the medial aspect of the facet joints while avoiding injury to the facet capsules. The hinge side gutter was made with a high-speed burr along the line of the medial margin of the facets until a greenstick deformation could be produced. Then, a gutter of the other side was made in a similar fashion, and the medial walls of the bony gutter were completely resected. Then, the edge of the resected border of the laminae was elevated like an open door. After opening the laminae, plates (Centerpiece, Medtronic Sofamor Danek) were applied and

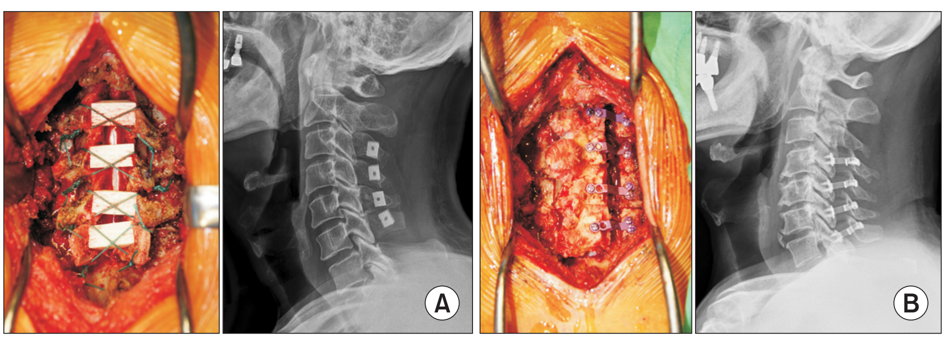

Fig. 1. (A) Midline splitting technique laminoplasty. (B) Unilateral open door technique laminoplasty.

mini screws were inserted (Fig. 1).

The surgical procedures were performed by three authors (THK, JKO, and SWK). All three surgeons were qualified and experienced spine surgeons. The surgical techniques were selected by the surgeons based on their preference and proficiency.

Radiographic Measurements

Patients' neutral plain cervical spine radiographs taken in standing position, computed tomography (CT), and magnetic resonance imaging (MRI) were collected preoperatively and postoperatively. Measurements were done using picture archiving and communication system (Infinitt M6 6062 workstation, Infinitt Healthcare). C2–7 Cobb angle was measured between the lower endplates of C2 and C7. C2–7 range of motion (ROM) was assessed as the difference between C2–7 Cobb angle of flexion and extension radiographs. Pavlov ratio of the most compressed level was calculated by dividing the spinal canal diameter by the vertebral body diameter. All X-ray measurements were done at preoperative, postoperative 3 months, and last follow-up. Canal area and canal diameter of involved levels were measured in preoperative and postoperative MRIs, and the mean values were used for analysis.

Clinical Outcome Parameters

Modified Japanese Orthopedic Association (mJOA) score was collected. The mJOA score assesses motor dysfunction in the upper and lower extremities, sensory function in the upper extremities, and bladder function and does not include a scale for sensory function in the trunk and lower extremities. Total score ranges from 0 to 18. The mJOA score was assessed at preoperative, postoperative 3 months, and last follow-up.

Postoperative complications including C5 palsy, axial neck pain, kyphosis development, hinge fractures, and spacer displacements were reviewed as these complications might affect clinical outcomes.[3] Kyphosis development was defined as C2–7 Cobb angle less than 0°. A hinge fracture was defined as complete discontinuity of both the outer and inner cortices.[4,5] Hinge fractures were identified using postoperative MRI or CT scans (Fig. 2). Spacer displacement was defined as a change of distance from the posterior margin of the vertebral body to the center of the spacer between immediate postoperative and follow-up lateral radiographs (Fig. 3).[6]

Statistical Analysis

After normality tests, continuous variables were compared using the independent samples *t*-test and categorical variables were compared using the chi-square test or the Fisher's exact test between the two groups. Linear mixed model was applied to analyze the sequential change of radiographic parameters over time. All statistical analyses were performed using IBM SPSS statistics ver. 26 (IBM Corp.). Results were considered significant when the *p*-value was < 0.05.

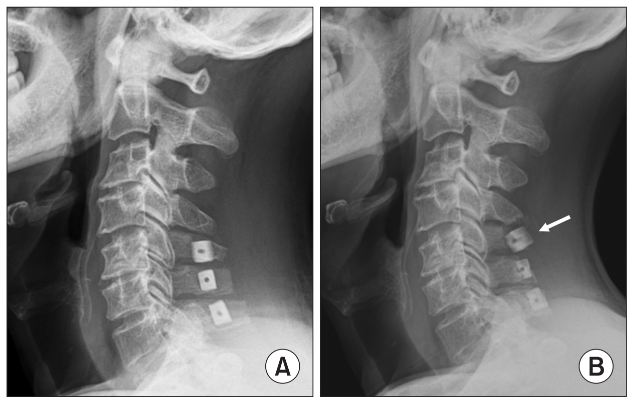

Fig. 3. (A) Immediate postoperative image. (B) Spacer displacement (arrow) during follow-up.

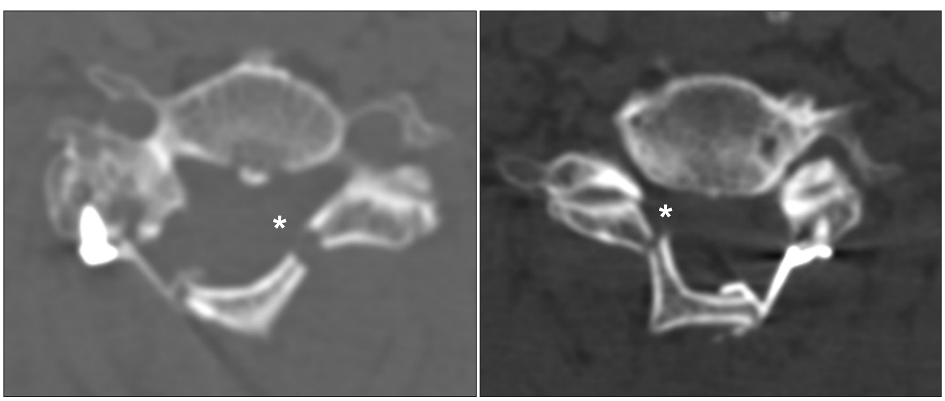

Fig. 2. Hinge fracture defined as complete discontinuity of both the outer and inner cortices (asterisks).

RESULTS

Patient Demographics

A total of 101 patients were included. Of the patients, 67 were treated with MST and 34 with UODT. Mean age, male to female ratio, underlying pathology, treated levels, operation time, estimated blood loss, and follow-up months did not demonstrate any significant difference between MST and UODT groups (Table 1).

Comparison of Radiographic Parameters between the MST and UODT Groups

C2–7 Cobb angle did not reveal any statistically significant difference between MST and UODT groups preoperatively (14.19 ± 10.06 vs. 15.89 ± 12.54, p = 0.464), postoperatively (12.60 ± 12.56 vs. 9.65 ± 15.77, p = 0.309), and at last follow-up (12.05 ± 10.31 vs. 9.99 ± 12.91, p = 0.387). C2–7 ROM demonstrated no significant difference between MST and UODT groups preoperatively (30.50 ± 13.71 vs. 27.73 ± 12.49, p = 0.358), postoperatively (18.91 ± 13.35 vs. 17.55 ± 9.03, p = 0.644), and at last follow-up (18.84 ± 12.79 vs. 20.87 ± 13.93, p = 0.498). Pavlov ratio of the most compressed level was not statistically different between MST and UODT groups preoperatively (0.67 ± 0.14 vs. 0.67 ± 0.13, p = 0.956), postoperatively (1.08 ± 0.18 vs. 1.03 ± 0.18, p = 0.174), and at last follow-up (1.06 ± 0.18 vs. 1.01 ± 0.16, p = 0.158).

Canal area did not demonstrate significant difference preoperatively (182.37 ± 28.79 vs. 192.41 ± 36.60, p = 0.158). However, postoperative canal area was larger in the UODT group than in the MST group (314.79 ± 42.37 vs. 265.91 ± 53.66, p = 0.003). Canal diameter did not demonstrate any significant difference between MST and UODT groups preoperatively (10.56 ± 1.53 vs. 10.66 ± 1.34, p = 0.764) and postoperatively (17.36 ± 3.27 vs. 17.00 ± 1.30, p = 0.555) (Table 2).

Comparison of Clinical Outcomes and Postoperative Complications between the MST and UODT Groups

The mJOA score at baseline (13.82.04 ± 2.20 vs. 14.24 ± 2.35, p = 0.384), postoperative (16.00 ± 1.63 vs. 16.47 ± 1.44, p = 0.158), and at last follow-up (16.33 ± 1.60 vs. 16.74 ± 1.42, p = 0.213) did not demonstrate any statistically significant difference between the two groups. The mJOA recovery rate at last follow-up also did not demonstrate any significant difference (61.28 ± 31.27 vs. 70.80 ± 28.94, p = 0.141).

Postoperative complications were compared. C5 palsy occurred in 14 out of 67 cases in the MST group and 2 out of 34 in the UODT group and it did not reveal statistical significance (p = 0.051). Axial neck pain occurrence (22 out of 67 in the MST group vs. 6 out of 34 in the UODT group, p = 0.107) also was not statistically different between the groups. The two groups demonstrated no

Table 1. Patient Demographics: Overall and by Laminoplasty Techniques

Variable	Total (n = 101)	MST (n = 67)	UODT (n = 34)	*p*-value
Age (yr)	66.26 ± 10.07	65.25 ± 8.22	68.24 ± 12.89	0.226
Sex				0.452
Female	19 (18.8)	14 (20.9)	5 (14.7)	
Male	82 (81.2)	53 (79.1)	29 (85.3)	
Etiology				0.116
OPLL	30 (29.7)	22 (32.8)	8 (23.5)	
CSM	45 (44.6)	25 (37.3)	20 (58.5)	
Combined	26 (25.7)	20 (29.9)	6 (17.6)	
Operation level	3.95 ± 0.92	4.03 ± 0.89	3.79 ± 0.98	0.226
Operation time (min)	242.45 ± 79.77	248.76 ± 69.67	230.00 ± 96.61	0.319
EBL (mL)	706.93 ± 394.53	692.54 ± 421.51	735.29 ± 339.24	0.609
Follow-up duration (mo)	22.39 ± 10.32	21.99 ± 11.79	23.18 ± 6.60	0.517

Values are presented as mean ± standard deviation or number (%).
MST: midline splitting technique, UODT: unilateral open door technique, OPLL: ossification of posterior longitudinal ligament, CSM: cervical spondylotic myelopathy, EBL: estimated blood loss.

Table 2. Comparison of Radiographic and Clinical Outcome between MST and UODT

Variable	Total (n = 101)	MST (n = 67)	UODT (n = 34)	*p*-value
C2–7 lordosis (°)				
Preoperative	14.76 ± 10.92	14.19 ± 10.06	15.89 ± 12.54	0.464
Postoperative 3 mo	11.60 ± 13.72	12.60 ± 12.56	9.65 ± 15.77	0.309
Last follow-up	11.35 ± 11.23	12.05 ± 10.31	9.99 ± 12.91	0.387
C2–7 ROM (°)				
Preoperative	29.55 ± 13.30	30.50 ± 13.71	27.73 ± 12.49	0.358
Postoperative 3 mo	18.44 ± 11.98	18.91 ± 13.35	17.55 ± 9.03	0.644
Last follow-up	19.58 ± 13.17	18.84 ± 12.79	20.87 ± 13.93	0.498
Pavlov ratio				
Preoperative	0.67 ± 0.14	0.67 ± 0.14	0.67 ± 0.13	0.956
Postoperative 3 mo	1.06 ± 0.18	1.08 ± 0.18	1.03 ± 0.18	0.174
Last follow-up	1.05 ± 0.18	1.06 ± 0.18	1.01 ± 0.16	0.158
Canal area (mm^2)				
Preoperative	185.53 ± 31.61	182.37 ± 28.79	192.41 ± 36.60	0.158
Postoperative	277.51 ± 55.01	265.91 ± 53.66	314.79 ± 42.37	0.003*
Canal diameter (mm)				
Preoperative	10.59 ± 1.47	10.56 ± 1.53	10.66 ± 1.34	0.764
Postoperative	17.27 ± 2.92	17.36 ± 3.27	17.00 ± 1.30	0.555
mJOA score				
Preoperative	13.96 ± 2.25	13.82 ± 2.20	14.24 ± 2.35	0.384
Postoperative 3 mo	16.16 ± 1.58	16.00 ± 1.63	16.47 ± 1.44	0.158
Last follow-up	16.47 ± 1.55	16.33 ± 1.60	16.74 ± 1.42	0.213
mJOA recovery rate (%)	64.48 ± 30.69	61.28 ± 31.27	70.80 ± 28.94	0.141
C5 palsy				0.051
Yes	16 (15.8)	14 (20.9)	2 (5.9)	
No	85 (84.2)	53 (79.1)	32 (94.1)	
Axial neck pain				0.107
Yes	28 (27.7)	22 (32.8)	6 (17.6)	
No	73 (72.3)	45 (67.2)	28 (82.4)	
Kyphosis at last follow-up				0.202
Yes	12 (11.9)	6 (9.0)	6 (17.6)	
No	89 (88.1)	61 (91)	28 (82.4)	
Hinge fracture				0.002*
Yes	10 (9.9)	2 (3.0)	8 (23.5)	
No	91 (90.1)	65 (97.0)	26 (76.5)	
Spacer/plate displacement				0.009*
Yes	12 (11.9)	12 (17.9)	0	
No	89 (88.1)	55 (82.1)	34 (100.0)	

Values are presented as mean ± standard deviation or number (%).
MST: midline splitting technique, UODT: unilateral open door technique, ROM: range of motion, mJOA score: modified Japanese Orthopedic Association score.
*Indicates significance.

statistically significant difference in kyphosis development at last follow-up (6/67 in the MST group vs. 6/34 in the UODT group, $p = 0.202$). Hinge fractures occurred more in the UODT group (8/34) than in the MST group (2/67), which was statistically significantly different ($p = 0.002$). On the other hand, spacer displacement happened only in the MST group (12/67), which was statistically significant ($p = 0.009$) (Table 2).

Comparison of Radiographic Changes between the MST and UODT Groups

The C2–7 lordosis angle was not significantly different between the two groups at each measurement. However, lordosis angle loss at postoperative 3 months (MST, 1.59 ± 9.10 vs. UODT, 6.24 ± 10.47, $p = 0.023$) and at last follow-up (MST, 2.15 ± 8.70 vs. UODT, 5.90 ± 8.58, $p = 0.042$) demonstrated significant difference between the two groups (Table 3). Linear mixed model also represented significant changes in C2–7 lordosis angle over time between the two groups ($p = 0.042$). Patients in the MST group demonstrated slower loss of lordosis over the follow-up, during which patients in the UODT group demonstrated faster loss of lordosis during the first 3 months (Fig. 4). In addition, the number of patients with lordosis loss of more than 10° at postoperative 3 months was larger in the UODT group than in the MST group (8/67 vs. 10/34, $p = 0.030$) (Table 3).

Effect of Hinge Fractures on Radiographic Changes

Patients with hinge fractures had more loss of C2–7 lordosis at last follow-up than patients without hinge fractures (10.66 ± 7.19 vs. 2.61 ± 8.63, $p = 0.005$). Also, loss of cervi-

Table 3. Comparison of Radiographic Changes between MST and UODT

Variable	Total	MST (n = 67)	UODT (n = 34)	*p*-value
C2–7 lordosis loss (°)				
Postoperative 3 mo	3.16 ± 9.78	1.59 ± 9.10	6.24 ± 10.47	0.023*
Last follow-up	3.41 ± 8.80	2.15 ± 8.70	5.90 ± 8.58	0.042*
C2–7 ROM loss (°)				
Postoperative 3 mo	11.16 ± 11.15	11.93 ± 10.88	9.81 ± 11.73	0.462
Last follow-up	9.43 ± 11.75	11.11 ± 10.29	6.62 ± 13.59	0.110
Canal area increase (mm^2)				
Postoperative	94.72 ± 46.94	83.98 ± 44.67	127.71 ± 38.64	0.002*
Canal diameter increase (mm)				
Postoperative	6.10 ± 3.47	6.27 ± 3.93	5.57 ± 1.02	0.287
Pavlov ratio increase				
Postoperative 3 mo	0.39 ± 0.13	0.41 ± 0.13	0.36 ± 0.13	0.043*
Last follow-up	0.37 ± 0.12	0.39 ± 0.13	0.34 ± 0.10	0.043*
Lordosis loss > 10°				
Postoperative 3 mo				0.030*
Yes	18 (17.8)	8 (11.9)	10 (29.4)	
No	83 (82.2)	59 (88.1)	24 (70.6)	
Last follow-up				0.102
Yes	23 (22.8)	12 (17.9)	11 (32.4)	
No	78 (77.2)	55 (82.1)	23 (67.6)	

Values are presented as mean ± standard deviation or number (%).
MST: midline splitting technique, UODT: unilateral open door technique, ROM: range of motion.
*Indicates significance.

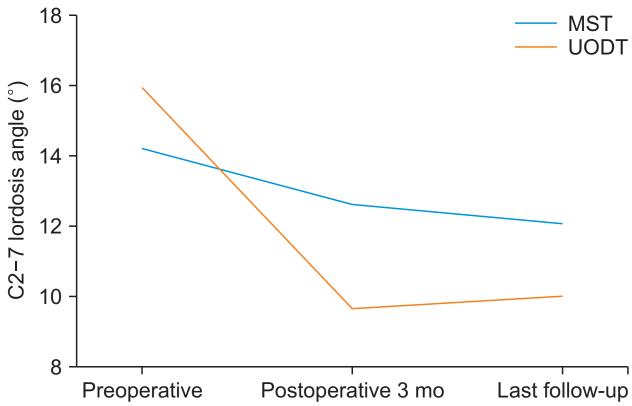

Fig. 4. Comparison of C2–7 lordosis angle of the midline splitting technique (MST) and unilateral open door technique (UODT) over time.

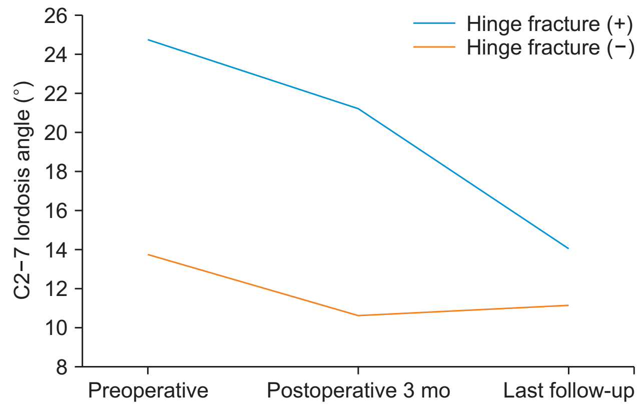

Fig. 5. Comparison of C2–7 lordosis angle of the patients with hinge fractures over time.

Table 4. Effect of Hinge Fracture on Radiographic Changes

Variable	Total	Hinge fracture (–) (n = 91)	Hinge fracture (+) (n = 10)	*p*-value
C2–7 lordosis loss (°)				
Postoperative 3 mo	3.16 ± 9.78	3.12 ± 9.84	3.53 ± 9.74	0.900
Last follow-up	3.41 ± 8.80	2.61 ± 8.63	10.66 ± 7.19	0.005*
C2–7 ROM loss (°)				
Postoperative 3 mo	11.16 ± 11.15	11.98 ± 10.94	2.93 ± 10.72	0.058
Last follow-up	9.43 ± 11.75	10.25 ± 11.65	1.43 ± 10.22	0.058
Canal area increase (mm^2)				
Postoperative	94.72 ± 46.94	93.83 ± 36.92	94.82 ± 48.29	0.962
Canal diameter increase (mm)				
Postoperative	6.10 ± 3.47	4.50 ± 1.38	6.28 ± 3.60	0.236
Pavlov ratio increase				
Postoperative 3 mo	0.39 ± 0.13	0.39 ± 0.13	0.45 ± 0.98	0.185
Last follow-up	0.37 ± 0.12	0.37 ± 0.12	0.39 ± 0.10	0.727
Lordosis loss > 10°				
Postoperative 3 mo				0.378
Yes	18 (17.8)	15 (16.5)	3 (30)	
No	83 (82.2)	76 (83.5)	7 (70)	
Last follow-up				0.009*
Yes	23 (22.8)	17 (18.7)	6 (60)	
No	78 (77.2)	74 (81.3)	4 (40)	

Values are presented as mean ± standard deviation or number (%).
ROM: range of motion.
*Indicates significance.

Table 5. Effect of Spacer Displacement on Radiographic Changes

Variable	Total	Displacement (–) (n = 55)	Displacement (+) (n = 12)	*p*-value
C2–7 lordosis loss (°)				
Postoperative 3 mo	1.59 ± 9.10	1.72 ± 9.19	1.00 ± 9.07	0.806
Last follow-up	2.15 ± 8.70	2.07 ± 9.25	2.48 ± 5.91	0.884
C2–7 ROM loss (°)				
Postoperative 3 mo	11.93 ± 10.88	11.26 ± 11.85	12.87 ± 7.93	0.806
Last follow-up	11.11 ± 10.29	11.07 ± 10.06	11.26 ± 11.85	0.962
Canal area increase (mm^2)				
Postoperative	83.98 ± 44.67	92.19 ± 39.85	33.33 ± 41.82	0.002*
Canal diameter increase (mm)				
Postoperative	6.27 ± 3.93	6.64 ± 3.92	3.83 ± 3.31	0.104
Pavlov ratio increase				
Postoperative 3 mo	0.41 ± 0.13	0.41 ± 0.13	0.41 ± 0.13	0.984
Last follow-up	0.39 ± 0.13	0.39 ± 0.13	0.42 ± 0.09	0.369
Lordosis loss > 10°				
Postoperative 3 mo				0.627
Yes	8 (11.9)	6 (10.9)	2 (16.7)	
No	59 (88.1)	49 (89.1)	10 (83.3)	
Last follow-up				0.678
Yes	12 (17.9)	11 (20.0)	1 (8.3)	
No	55 (82.1)	44 (80.0)	11 (91.7)	

Values are presented as mean ± standard deviation or number (%).
ROM: range of motion.
*Indicates significance.

cal lordosis of more than 10° at last follow-up was more common in patients with hinge fractures than in those without (6/10 vs. 17/91, $p = 0.009$) (Table 4). Linear mixed model also represented significant changes in C2–7 lordosis angle over time between the two groups ($p = 0.046$). While C2–7 lordosis loss of patients without hinge fractures reached plateau over time, lordosis of patients with hinge fractures continued to decrease over time (Fig. 5).

Effect of Spacer Displacement on Radiographic Changes

Spacer displacement occurred only in the MST group. Therefore, radiographic changes due to spacer displacement were compared within the MST group. Patients with spacer displacement had less expansion of canal area at postoperative follow-up than those without (33.33 ± 41.82 vs. 92.19 ± 39.85, $p = 0.002$) (Table 5).

DISCUSSION

Cervical laminoplasty is advantageous in minimizing cervical instability and kyphotic deformity. It is widely utilized and is known to achieve better outcomes and lower complication rates than conventional laminectomy. This study focused on comparing the impact of two most popular laminoplasty techniques on sustaining these advantages over time. The widely known complications of cervical laminoplasty were compared between the two techniques. The mean operative time, estimated blood loss, canal diameter, incidence of C5 palsy, and incidence of axial neck pain demonstrated no statistical significance between MST and UODT in this study. Recent meta-analyses comparing the two techniques reported similar results.[7-9]

The UODT was superior to the MST in achieving greater canal area in this study. However, the two techniques did not reveal any statistically significant differences in postoperative mJOA score and recovery rate. A study by Yamazaki et al.[10] revealed that transverse canal area can be used as a prognostic factor for patients. Another study by Zhang et al.[11] also found that an increased spinal cord area was related to the recovery rate of JOA score. On the other hand, some studies suggested that spinal canal area was not a reliable predictor of surgical outcomes.[12,13] Therefore, the relation of spinal canal expansion and neurological recovery of patients remain controversial and further research might be required. Some researchers suggested canal area of > 200 mm^2 or > 160 mm^2 should be achieved for a better prognosis.[14,15] In the current study, both techniques achieved this suggested goal, and this might have been the reason both techniques had similar postoperative mJOA scores and recovery rates regardless of the different spinal canal area expansion.

However, spacer displacement only occurred in the MST in our study, and this resulted in lesser canal expansion. Sasai et al.[16] also reported a similar result. On the other hand, similar to the result of our study, Rhee et al.[17] found that the UODT using plates were stable without any dislodgements. Kaito et al.[6] hypothesized that triangular construct by unilateral opening provided stronger resistance compared to the quadrangular construct by bilateral opening, and this structural advantage allowed stabilization of spacers. Although not found in this study, neurological deterioration caused by spacer displacement has been reported.[18] Therefore, care should be taken when positioning the spacer and firm fixation would be required when performing MST laminoplasty.

Of the known complications of laminoplasty, the deterioration of cervical sagittal alignment is an important matter as it can lead to poor outcomes.[19,20] The K-line, developed by Fujiyoshi et al.,[21] is utilized as a parameter that can combine sagittal alignment and the canal occupying ratio. It can predict whether sufficient posterior shift of the spinal cord can be achieved by surgery. Indirect decompression by posterior cord shift is as important as direct decompression after laminoplasty.[22] When loss of lordosis occurs, the K-line may be shifted, and it may lead to inadequate cord decompression.[23] In this study, loss of cervical lordosis was present in both techniques; however, the MST had less loss of lordosis compared to the UODT. This result is in line with previous studies.[24-27] Excessive enlargement of canal resulting in easy contact of posterior cervical elements in UODT and symmetrical cervical lamina opening of the MST having potential benefits were suggested as possible reasons for the difference of cervical lordosis and ROM loss in a study by Nakashima et al.[26]

In our study, hinge fractures were more frequently observed in the UODT than in the MST. Previous studies comparing both techniques often did not deal with this complication. Hur et al.[28] reported that the hinge angle could be a risk factor for hinge fractures in open door laminoplasty. It could be hypothesized that the UODT has a larger open angle than the MST does and unilateral opening causes more stress on the hinge than the symmetric, bilateral hinges in the MST, and this could be the reason for the difference in the incidence of hinge fractures. Also, patients with hinge fractures had more loss of cervical lordosis than those without. There are reports regarding axial neck pain associated with hinge fractures after laminoplasty.[29] It could be caused by destruction of posterior structures including spinous processes, ligaments, and muscles, leading to diminished cervical stability. Hinge fractures lead to failed reconstruction of stable laminar arch and therefore add to this decreased stability, which can cause more axial neck pain. The same explanation might be applied to the loss of cervical lordosis in hinge fracture patients in this study. The presence of hinge fractures can turn laminoplasty into laminectomy status with decreased stability and this can cause loss of lordosis. However, biomechanical studies with sophisticated designs would be required to further validate the relation of hinge fractures with loss of cervical lordosis.

This study is not without limitations. First, due to the retrospective nature of this study, not all hinge fractures were determined by postoperative CT, which was not included in the routine postoperative protocol. MRI scans included in the postoperative protocol was also used to detect hinge fractures. This might have created bias in determining hinge fractures. However, to minimize errors, only complete discontinuity of both the outer and inner cortices of the lamina clearly visible were included. As a result, reported hinge fracture rates were close to those in other studies that utilized CT scans to detect hinge fractures.[5,30] Secondly, retrospective data collection also hindered the determination of exactly when the hinge fracture or spacer displacement occurred, limiting the assessment of its impact on radiographic changes over time. Standardization of time in which these complications occurred might be required in future studies. Although hinge fracture and spacer displacement rates exhibited statistically significant difference between the two techniques, the small number of patients with hinge fractures or spacer displacement might have created bias in analysis. Therefore, no strong decision could be made on whether these differences made absolute impact on the different radiographic changes between the two techniques. Further studies might be required to validate hinge fractures or spacer displacements as the cause of different radiographic outcomes of the two laminoplasty techniques. Lastly, longer term follow-up of radiographic and clinical outcome might be required. Despite these limitations, to the best of the authors' knowledge, this is the first study to compare the means of preserving the reshaped lamiae and to assess its impact on radiographic and clinical outcomes of the two most popular laminoplasty techniques. This can potentially lead to more knowledge on the positive and negative consequences of both techniques.

In conclusion, the two laminoplasty techniques demonstrated effectiveness in treating patients with multilevel cervical myelopathy. However, care should be taken to avoid hinge fractures and spacer displacement since both techniques can possibly lead to unfavorable outcomes.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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REFERENCES

1. Pal GP, Sherk HH. The vertical stability of the cervical spine. Spine (Phila Pa 1976). 1988;13(5):447-9.
2. Choi SH, Kang CN. Degenerative cervical myelopathy: pathophysiology and current treatment strategies. Asian Spine J. 2020;14(5):710-20.
3. Weinberg DS, Rhee JM. Cervical laminoplasty: indication, technique, complications. J Spine Surg. 2020;6(1):290-301.
4. Park YK, Lee DY, Hur JW, Moon HJ. Delayed hinge fracture after plate-augmented, cervical open-door laminoplasty and its clinical significance. Spine J. 2014;14(7):1205-13.
5. Lee DH, Kim H, Lee CS, Hwang CJ, Cho JH, Cho SK. Clinical and radiographic outcomes following hinge fracture during open-door cervical laminoplasty. J Clin Neurosci. 2017;43:72-6.
6. Kaito T, Hosono N, Makino T, Kaneko N, Namekata M, Fuji T. Postoperative displacement of hydroxyapatite spacers implanted during double-door laminoplasty. J Neurosurg Spine. 2009;10(6):551-6.
7. Chen T, Zhang X, Meng F, et al. Open-door versus French-door laminoplasty for patients with multisegmental cervical spondylotic myelopathy: a systematic review and meta-analysis. World Neurosurg. 2021;155:82-93.
8. Luo W, Li Y, Zhao J, Gu R, Jiang R, Lin F. Open-versus French-door laminoplasty for the treatment of cervical multilevel compressive myelopathy: a meta-analysis. World

Neurosurg. 2018;117:129-36.

9. Wang L, Wang Y, Yu B, Li Z, Liu X. Open-door versus French-door laminoplasty for the treatment of cervical multilevel compressive myelopathy. J Clin Neurosci. 2015;22(3): 450-5.

10. Yamazaki T, Yanaka K, Sato H, Uemura K, Tsukada A, Nose T. Cervical spondylotic myelopathy: surgical results and factors affecting outcome with special reference to age differences. Neurosurgery. 2003;52(1):122-6.

11. Zhang KR, Yang Y, Liu H, et al. Is there any correlation between the recovery rate of JOA and the increasing of cervical spinal cord area after single-door cervical laminoplasty? Clin Neurol Neurosurg. 2022;213:107103.

12. Park JH, Ahn JS, Lee HJ, Shin BK. Comparison between radiological and clinical outcomes of laminoplasties with titanium miniplates for cervical myelopathy. Clin Orthop Surg. 2016;8(4):399-406.

13. Morio Y, Teshima R, Nagashima H, Nawata K, Yamasaki D, Nanjo Y. Correlation between operative outcomes of cervical compression myelopathy and MRI of the spinal cord. Spine (Phila Pa 1976). 2001;26(11):1238-45.

14. Kohno K, Kumon Y, Oka Y, Matsui S, Ohue S, Sakaki S. Evaluation of prognostic factors following expansive laminoplasty for cervical spinal stenotic myelopathy. Surg Neurol. 1997;48(3):237-45.

15. Hamburger C, Buttner A, Uhl E. The cross-sectional area of the cervical spinal canal in patients with cervical spondylotic myelopathy: correlation of preoperative and postoperative area with clinical symptoms. Spine (Phila Pa 1976). 1997; 22(17):1990-5.

16. Sasai K, Umeda M, Wakabayashi H, Maruyama T, Iida N, Akagi S. Comparison of bone bonding between spinous process-splitting laminoplasty and en-bloc laminoplasty using hydroxyapatite spacers in cervical spine: minimum 2 years follow-up. J JPN Spine Res Soc. 2007;18:371.

17. Rhee JM, Register B, Hamasaki T, Franklin B. Plate-only open door laminoplasty maintains stable spinal canal expansion with high rates of hinge union and no plate failures. Spine (Phila Pa 1976). 2011;36(1):9-14.

18. Nakane T, Deguchi M, Hayashi M, Kanemono T. Cervical laminoplasty by sagittal splitting of spinous process using lamina spacer. Cent Jpn J Orthop Trumat (Japanese). 2005; 48:459-60.

19. Suda K, Abumi K, Ito M, Shono Y, Kaneda K, Fujiya M. Local kyphosis reduces surgical outcomes of expansive open-door laminoplasty for cervical spondylotic myelopathy. Spine (Phila Pa 1976). 2003;28(12):1258-62.

20. Rhee JM, Basra S. Posterior surgery for cervical myelopathy: laminectomy, laminectomy with fusion, and laminoplasty. Asian Spine J. 2008;2(2):114-26.

21. Fujiyoshi T, Yamazaki M, Kawabe J, et al. A new concept for making decisions regarding the surgical approach for cervical ossification of the posterior longitudinal ligament: the K-line. Spine (Phila Pa 1976). 2008;33(26):E990-3.

22. Sodeyama T, Goto S, Mochizuki M, Takahashi J, Moriya H. Effect of decompression enlargement laminoplasty for posterior shifting of the spinal cord. Spine (Phila Pa 1976). 1999;24(15):1527-32.

23. Taniyama T, Hirai T, Yamada T, et al. Modified K-line in magnetic resonance imaging predicts insufficient decompression of cervical laminoplasty. Spine (Phila Pa 1976). 2013;38(6):496-501.

24. Ratliff JK, Cooper PR. Cervical laminoplasty: a critical review. J Neurosurg. 2003;98(3 Suppl):230-8.

25. Orabi M, Chibbaro S, Makiese O, Cornelius JF, George B. Double-door laminoplasty in managing multilevel myelopathy: technique description and literature review. Neurosurg Rev. 2008;31(1):101-10.

26. Nakashima H, Kato F, Yukawa Y, et al. Comparative effectiveness of open-door laminoplasty versus French-door laminoplasty in cervical compressive myelopathy. Spine (Phila Pa 1976). 2014;39(8):642-7.

27. Park JH, Roh SW, Rhim SC, Jeon SR. Long-term outcomes of 2 cervical laminoplasty methods: midline splitting versus unilateral single door. J Spinal Disord Tech. 2012;25(8): E224-9.

28. Hur JW, Park YK, Kim BJ, Moon HJ, Kim JH. Risk factors for delayed hinge fracture after plate-augmented cervical open-door laminoplasty. J Korean Neurosurg Soc. 2016; 59(4):368-73.

29. Xu D, Zhou C, Tao H, et al. Relationship between hinge fracture and postoperative axial symptoms after cervical laminoplasty. Br J Neurosurg. 2022 Feb 3 [Epub]. https://doi.org/10.1080/02688697.2021.1923647.

30. Fujishiro T, Nakano A, Baba I, Fukumoto S, Nakaya Y, Neo M. Double-door cervical laminoplasty with suture anchors: evaluation of the clinical performance of the constructs. Eur Spine J. 2017;26(4):1121-8.