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Changes in canal diameter and cervical lordosis in patients who underwent en-bloc laminoplasty for the treatment of cervical spinal stenosis

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ABSTRACT

Objectives: Cervical spinal canal-expanding laminoplasty has been recognized as an alternative to cervical laminectomy, especially in multilevel cervical myelopathy due to spinal stenosis. This study aimed to determine the effects of En-block laminoplasty on cervical sagittal balance, cervical spine biomechanics and whether it is sufficient to preserve cervical canal diameter and lordosis and whether it causes additional lordosis or kyphosis in cases of cervical narrow spinal canal.

Methods: Thirty-eight cervical narrow canal patients operated on between 2008 and 2020 were retrospectively evaluated and the results of 24 laminoplasty patients were evaluated. Spinal tomography results for the evaluation of canal diameter changes and X-ray results for cervical sagittal balance evaluation were compared with each other in the early postoperative period and 3 years later. For cervical lordosis assessment, Cobb and C2-C7sagital vertical axis measurements were performed using the PACS system.

Results: Fifteen patients were male and 9 were female. The mean age was 65.55±11.56 years (min-max: 58-84) and the mean follow-up period was three years. Two patients had one level stenosis, 4 had two levels, 7 had three levels, and 11 had four or more levels. Radiculopathy was present in 17 patients (71.8%) and myelopathy in 7 patients (29.1%). There was no statistically significant difference in the frequency of myelopathy/radiculopathy between genders. When all distances were considered, no statistical difference was observed in the early postoperative period (median ten days) and late postoperative period (median 3 years) in terms of canal diameters. No measurement value could be obtained for any level diagnosed as restenosis or requiring reoperation. Loss of lordosis was measured in only one patient. Otherwise, lordosis was preserved in all cases at late conversion.

Conclusions: The results of our study showed that en-block laminoplasty after the cervical narrow spinal canal was sufficient to maintain the cervical canal diameter in the long term with appropriate patient and surgical technique.

Keywords: Cervical spinal stenosis, en-bloc laminoplasty, cervical canal diameter, cervical lordosis, laminoplasty

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Compression of the cervical spinal cord from the anterior side by the vertebral corpus and degenerated intervertebral disc protruding posteriorly and from the posterior side by thickening of the ligamentum flavum and lamina is called cervical spinal stenosis. Between the C3 and C7 levels, the diameter of the spinal canal in the sagittal plane (anteroposterior) is 15-25 (mean 17) mm. There is no consensus on the value required for the diagnosis of cervical stenosis. It is possible to define 10-13 mm as relative and 9 mm and below as definite cervical stenosis [1].

Impairment in neurologic functions may vary from mild to severe and the modified Japanese Orthopedic Association (mJOA) [2] and Nurick [3] scoring systems are most commonly used in neurologic functional evaluation. Patients with an mJOA score above 15 points are considered mildly affected patients. Patients with an mJOA score of 12-15 are considered moderately affected patients. Patients who are considered severely disabled have a mJOA score below 12. While multi-level pathologies are more common in men, single-level pathologies are more predominant in women [4].

The disease progresses with symptoms and signs related to spinal cord and root compression. Neck pain and restriction in neck movements are present. As the condition progresses, sensory changes such as dysesthesia, clumsiness in the hands, and impaired sensation of vibration and joint position may be observed. Atrophy and weakness in the small muscles of the hands are common. In the lower extremities, myelopathy findings such as spastic gait, hyperreflexia, and babinski signs are typically added [5].

Cervical spinal canal widening laminoplasty has been accepted as an alternative to cervical laminectomy, especially in multilevel cervical myelopathy due to spinal stenosis [6, 7]. The purposes of the method are to widen the cervical spinal canal, to preserve posterior bone structures and cervical motion, to prevent instability and deformity, to prevent the development of postlaminectomy membrane seen after laminectomy, to be applicable at multiple levels, and to avoid complications of anterior surgery such as dysphagia, hoarseness, instrument failure, and lack of fusion [8]. Cervical laminoplasty is preferred in cases such as cervical spondylotic myeloradiculopathy, congenital cervical narrow canal, and especially multi-level posterior compression. Significant anterior compression, active posterior infection, history of radiotherapy, and kyphosis are contraindications for laminoplasty [9].

Laminoplasty in cervical spinal stenosis was first described by Hirabayashi [6]. It was developed by Shaffrey's and O'Brien using implants. Recently, en-bloc C3-6 laminoplasty has been adopted and popularised by preserving the nuchal ligament attached to the C7 spinous process to prevent axial neck pain [10]. In this method, if C6-7 levels are also affected, C7 archocristectomy is recommended.

In this study, the results of 24 cervical spinal stenosis patients operated with En-Block Lamino-

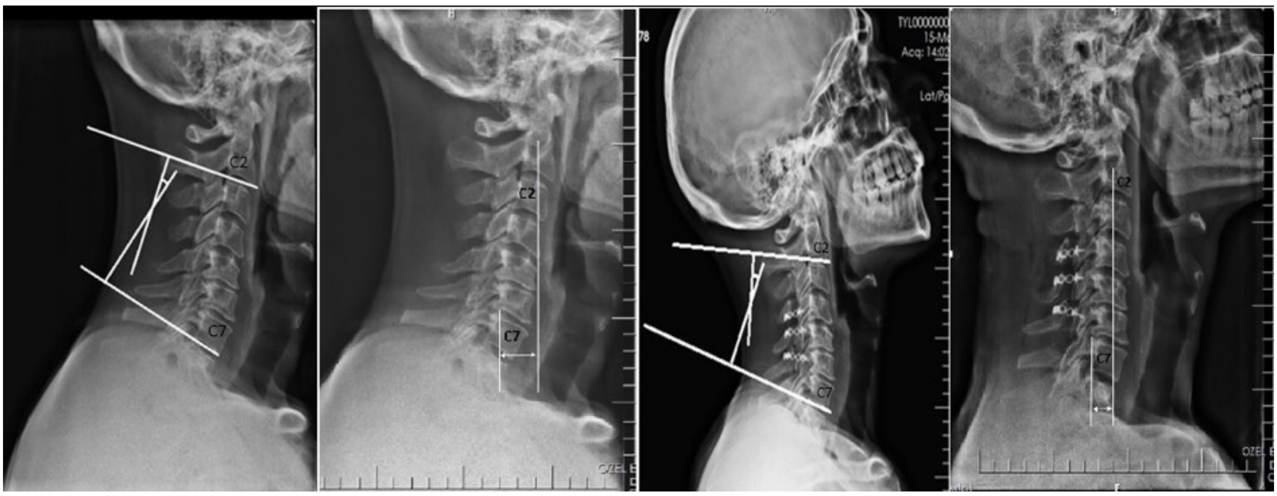

Fig. 1. Cervical Cobb angle and C2-C7 sagittal vertical axis measurement.

plasty were evaluated. Changes in cervical sagittal balance and enlarged canal diameter in the late postoperative period were evaluated. Late cervical canal diameter changes and cervical biomechanical changes were investigated.

METHODS

The results of 24 patients who underwent en-bloc laminoplasty for cervical spinal stenosis between 2008 and 2020 in our clinic were evaluated retrospectively. All patients in our series were operated with the hardware-assisted en-bloc laminoplasty technique [10, 11]. Patients who underwent postoperative revision surgery received additional treatments such as infection, malignancy, and radiation therapy, and whose radiologic images could not be obtained completely were excluded from the study. One side of the lamina is cut with a high-speed drill, preferably on the side where the clinical finding is dominant. On the other side, only the outer cortex is cut and the inner cortex of the inner lamina is left untouched. The lamina is then lifted with small angled curettes. The ligamentum flavum, interspinous, and supraspinous ligament are preserved. The removed lamina is then fixed with mini-plates.

In the study, axial cervical spinal tomography results were evaluated to assess postoperative late changes in cervical canal diameter. For the evaluation of the cervical sagittal balance, the measurement values of the early and late postoperative radiographs were compared. Standard cassettes and radiographs taken with the same device (Multifunctional Radiograph Unit Siemens-Germany) were used for radiologic evaluation. For sagittal plane imaging, radiographs were obtained from 1.8m in the lateral direction, in the neutral position, standing, and with C4 centralized. Picture Archiving and Communication Systems (PACS) software was used. For the evaluation of cervical lordosis and axial cervical balance, measurements were made with the Cobb angle and C2-C7 sagittal vertical axis method. In the Cobb method, the angle between the lower-end plateau of the C2 vertebra and the lower-end plateau of the C7 vertebra is calculated. For the C2-C7 sagittal vertical axis measurement, the distance between the C2 plump line and the posterior-superior end-plate of C7 is measured (Fig. 1) [12]. The study was approved by the Erciyes University institutional ethics committee (2023/279).

Statistical Analysis

Statistical analysis IBM SPSS Statistics 21.0 (SPSS Inc, Chicago, IL, USA) software was performed. The conformity of the data to normal distribution was analyzed by the Shapiro-Wilk test, and histogram and Q-Q graphs were evaluated. Data were expressed as median (1st-3rd quartile). Wilcoxon test was used for comparisons between periods (early and late postoperative period). The relationship between categorical variables was evaluated using Pearson's chi-square (χ^2) test (and Fisher's exact test). A value of $P<0.05$ was considered statistically significant.

RESULTS

Of a total of 24 patients, 15 (62.5%) were male and 9 (37.5%) were female. The mean age of the patients was 65.55±11.56 (min-max: 58-84) years. The mean age of males was 62.86±9.75 (min-max: 58-84) and the mean age of females was 61.53±14.01 (min-max: 59-81). Radiculopathy was present in 17 patients (71.8%) and myelopathy in 7 patients (29.1%). Two patients (8.3%) had one level stenosis, 5 patients (16.6%) had two levels, 7 patients (29.1%) had three levels and 11 patients (45.8%) had four or more levels. In total, 24 patients underwent laminoplasty at a total of 78 distances.

When the canal diameters were evaluated in individual distances, no statistically significant difference was found in the early and late canal diameter measurements in a total of 62 distances in C3-4/ C5-6/ and C6-7 distances (P=0.822, P=0.732, and P=0.509, respectively). In the C4-5 distance, a significant difference was found in a total of 16 distances (P=0.003) (Table 1).

Although statistically significant narrowing was observed in some distances in tomography measurements performed after an average of three years considering all distances, no measurement value could be obtained for any level diagnosed as restenosis or requiring reoperation. However, the median canal diam-

Table 1. Postop early and late mean values of canal diameters according to distances

Levels	Channel diameter (mm) (Postop 10. day)	Channel diameter (mm) (Postop 3. year)	P value
C3-4 (n=6)	13.85 (13.28-14.20)	13.80 (13.40-14.03)	0.822
C4-5 (n=16)	14.00 (12.98-14.53) a	13.90 (13.03-14.43) b	**0.003**
C5-6 (n=30)	14.10 (13.55-14.28)	14.00 (13.45-14.53)	0.732
C6-7 (n=26)	14.00 (13.70-14.53)	14.00 (13.23-14.90)	0.509

Data was shown as median (1st-3rd quartile). Postop=postoperative
The different lowercase letters indicate the difference between groups.

Table 2. Early and late postoperative averages of canal diameters

	Channel diameter (mm) (Postop early)	Channel diameter (mm) (Postop 3. year)	P value
Channel diameters (n=24 patients) (n=78 levels)	14.00 (13.40-14.35)	13.90 (13.28-14.53)	0.906

eter measurements of all distances at the 10th postoperative day and 3rd-year follow-up were 14.00 (13.40-14.35) and 13.90 (13.28-14.53), respectively. There was no statistically significant difference in canal diameter between early and late postoperative values (P=0.906) (Table 2).

The median preop/postop jobb angle values were 9.80 (4.20-13.55) degrees 9.70 (4.40-13.10) degrees (P=0.974) and the median C2-C7 sagittal vertical axis values were 41.10 (22.20-54.10) mm - 40.20 (21.50-55.80) mm (P=0.937) (Table 3).

No lordosis loss was observed in the early postoperative period and three years after the operation except in one patient. Cervical lordosis loss was observed in one patient in the late postoperative period (Jobb angle changed from 10.40 to 4.10, sagittal vertical axis changed from 46.20 mm to 20.10 mm). In the early postoperative period, axial neck pain was observed in 2 patients, which lasted for several weeks and was controlled with medical treatment (Figs. 2 and 3).

Table 3. Cervical lordosis evaluation averages

	Channel diameter (Postop early)	Channel diameter (Postop 3. years)	P value
Cervical jobb angle (degree) (n=24)	9.80 (4.20-13.55)	9.70 (4.40-13.10)	0.974
Sagittal vertical axis (mm) (n=24)	41.10 (22.20-54.10)	40.20 (21.50-55.80)	0.937

Data was shown as median (1st-3rd quartile). Postop=postoperative

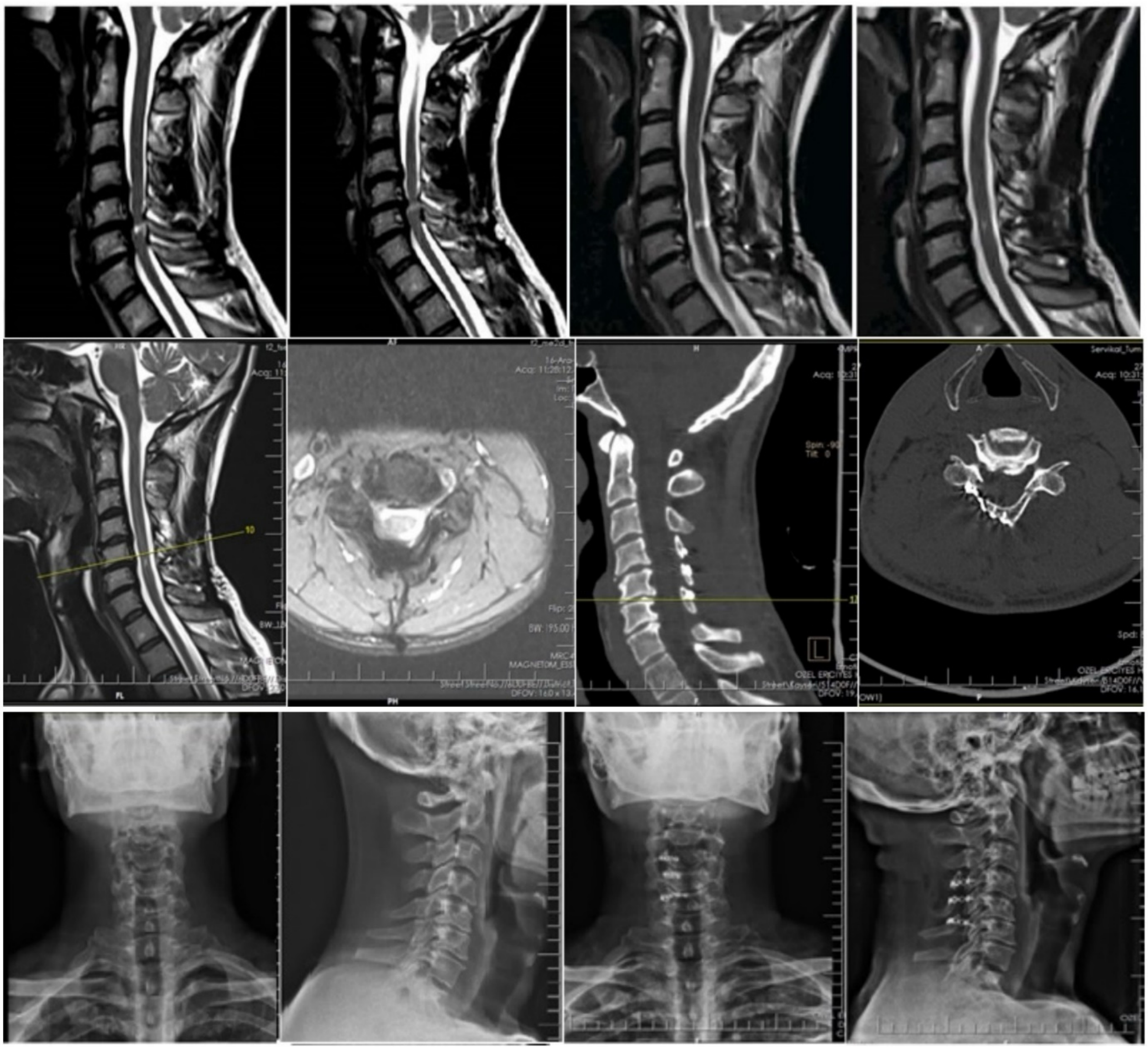

Fig. 2. Preoperative (left two) – postoperative (right two) MR/CT/CR (in order from top to bottom) results of a patient with cervical stenosis.

DISCUSSION

Laminoplasty is a method considered as a smooth transition between laminectomy and laminectomy and instrumentation and fusion. Krita first described the use of laminoplasty in cervical myelopathy in 1968 [13]. There are studies that the method is sufficient to maintain the diameter of the cervical canal and does not cause additional lordosis or kyphosis, preserves the cervical sagittal balance, and does not disrupt the biomechanics of the cervical spine. Expanding Z-laminoplasty was the first type of laminoplasty described by Oyama and Hattori [14] in 1972. Hirabayashi *et al*. [7] described a simpler method, open-door laminoplasty, in 1977. The most commonly used methods today are Hirabayashi's open-door laminoplasty and Kurokawa's double-door laminoplasty - spinous process separation.

One of the points to be considered here is to preserve the structure of the nuchal ligaments adhering to the C6 and C7 spinous processes to prevent instability and kyphotic deformity in the C6/7 segment. Protection of the attachment site of the erector spinea muscles to C2 and preservation of the integrity of the nuchal ligaments are very important in flexion deformity Protection of the semispinalis cervicis adhering to C2 is important in preserving cervical motion and lordotic structure in the postoperative period. It has also been reported that not including C7 in laminoplasty has a positive effect on axial pain in the post-

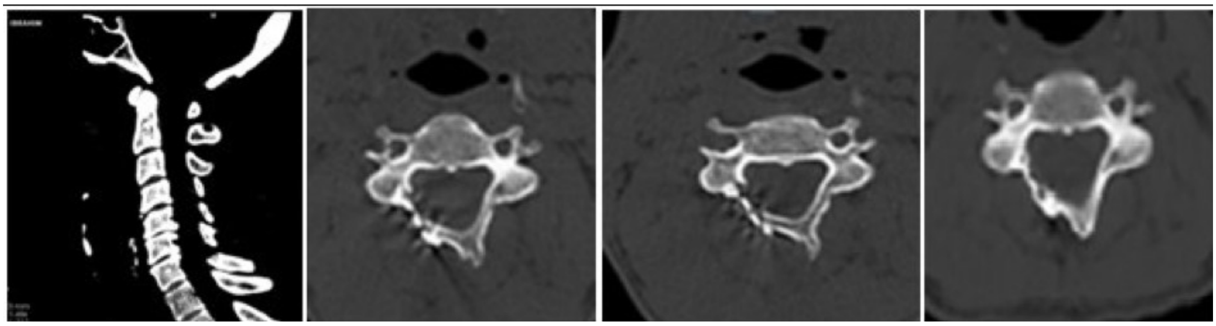

Fig. 3. Early and late canal diameter CT images.

operative period [15, 16]. In our series, when it was necessary to include C2 in the laminoplasty, laminoplasty was performed by dividing C2 in two over the spinous process. Thus, muscle attachment and ligament integrity were preserved. For C7, archocristectomy was performed to prevent axial neck pain. Although neurologic recovery after cervical laminoplasty is generally satisfactory, some problems are encountered. These problems can be categorized as early and late complications. The most important early complications are neurologic deterioration and C5 root deterioration. Neurologic deterioration may be due to inadequate decompression. There are series reporting C5 root paresis between 8-50% [17]. Instrumentation for lordosis with laminoplasty and the presence of C4 anterolisthesis are thought to be the factors in the formation of this complication and it is mostly temporary. Intraoperative electrophysiologic studies have reported that C5 root damage is not due to perop direct nerve or spinal cord damage [17]. In our series, postop C5 worsening was never observed.

In the late period, the issues reported and discussed are decreased neck movements, kyphotic deformity and axial neck pain. Two patients complained of axial neck pain lasting longer than six months. It was controlled with medication and exercise. Spinal cord sagittal diameter between C3-C7 is 8 mm and sagittal canal diameter is 17-18 mm. When the sagittal canal diameter is between 13 mm and 17 mm, symptomatic spondylosis is present, while myelopathy is very rare. Patients with a canal diameter of 10-13 mm have a risk of cervical spondylotic myelopathy, and patients with a canal diameter of less than 10 mm often have myelopathy [18]. The key point for a successful laminoplasty is the enlargement and preservation of the spinal canal. Preservation of motion and lordotic alignment are also the main goals. Although the classical open-door laminoplasty has satisfactory results and reclosure has not been demonstrated radiologically, several techniques, mostly implant-assisted, have been described to preserve canal width [19]. These methods provide stable fixation for the elevated lamina but are often complex and difficult procedures. Several studies have demonstrated the superiority of open-door laminoplasty over other techniques in terms of its effectiveness in increasing the sagittal diameter of the spinal canal and its low complication rate [20]. Yang *et al*. [21] reported that in the classical technique, loosening sutures may become dislodged and the raised lamina may reclose. On the other hand, this can be overcome by bone healing and/or uncomplicated secure fixation [22, 23]. Recurrent stenosis or early closure after laminoplasty has been reported with rates up to 10% most commonly at the C5 or C6 levels [24]. No recurrent stenosis was detected in our patient series. There was no statistically significant difference between the initial postoperative values and the values measured three years later, and there was no statistical difference between single or multiple distances in terms of re-closure. One patient developed stenosis in the upper adjacent segment.

The effects of laminoplasty on cervical lordosis were evaluated by direct radiography. Cobb, Tangent angles, effective cervical lordosis, and C2-C7 sagittal vertical axis measurements are the most commonly used methods to evaluate cervical lordosis by direct radiography. In the Cobb method, the angle between the lower-end plateau of the C2 vertebra and the lower-end plateau of the C7 vertebra is measured, and in the Tanjant method, the angle between the C2 posterior corpus and the C7 posterior corpus is measured. The line drawn between the posterior lower end of the C2 vertebral corpus and the posterior lower end of the C7 vertebra is used to calculate the effective lordosis. Cobb and Tanjant's methods of cervical angle measurements have high reliability in the evaluation of cervical lordosis and are the most commonly used methods in practice [23]. However, the use of the lower-end plateaus of the vertebrae in the Cobb method and the diagnostic accuracy of this method due to degenerative diseases are lower than the Tanjant method using the posterior edges of the vertebral corpus [25]. C2-C7 sagittal vertical axis is used to measure the regional sagittal alignment of the cervical spine [12]. In a study, it was reported that effective lordosis measurement in patients was more sensitive in showing osteophytes extending into the spinal canal without disrupting cervical lordosis, in addition to showing cervical lordosis, and was therefore simpler and more reliable than the Cobb and Tanjant methods [26]. In recent studies, it has been found that cervical parameters with simpler features are more preferred and the detection error is lower [27]. In our study, Cobb angle and C2-C7 cervical vertical axis measurements were used in the evaluation.

In recent years, there has been increasing interest in the sagittal alignment of the cervical spine and its relationship with clinical outcomes. It is known that cervical lordosis is generally not physiological and should not be followed in all patients undergoing surgery. It is increasingly recognized how these angular parameters (lordosis or kyphosis) interact with translational parameters reflecting the overall cervical spine and spinal balance, which in turn influence patient outcomes. Cervical kyphosis associated with cervical sagittal imbalance is known to lead to worse postoperative outcomes, and this dichotomy in outcomes has not been shown to improve even with alignment correction [28].

Although loss of lordosis can occur with laminoplasty, it is usually not associated with the type of severe kyphosis that can be seen after multilevel laminectomy alone [23, 25]. In addition, cervical lordosis decreases with age, especially between 50-60 years. The disc physiologically loses its elasticity and flexibility due to dehydration during its normal life cycle. This changes the height and shape of the discs, which plays a role in the loss of lordosis. Therefore, this decrease in lordosis may be related not only to surgery but also to aging-related changes [10]. In addition, greater cervical lordosis (especially in patients with postoperative lordosis greater than 20°) has been reported to result in less neck pain in patients undergoing laminoplasty [29]. Lin *et al*. [30] studied preoperative patients with cervical spondylotic myelopathy (CSM) and investigated whether cervical sagittal parameters were related to the progression of patients with CSM. They reported that whether in the surgical or non-surgical group, the recovery of patients with C2-7 Flexion > 29° was better than the recovery of patients with C2-7 Flexion ≤ 29°. In another study, it was reported that preoperative cervical sagittal balance indices were related with the clinical outcomes of posterior longitudinal ligament ossification (OPLL) patients after laminoplasty [31]. Disruption of the posterior tension band, resection of 50% of the facet joint and capsule, and incorrect case selection (cases with a lordotic angle of less than 10° and kyphotic deformity) play an important role in postoperative kyphosis and related axial pain [23]. It has been reported that adverse radiological changes and axial neck pain after cervical laminoplasty are mostly caused by neck muscle destruction, especially separation of muscle insertions from the spinous processes of C2 and C7, diffuse atrophy of the muscles related to the nuchal ligament, ischemia of the shoulder muscles and delayed union of the facet joints [10]. Li *et al*. [32] analyzed the relationship between changes in cervical curvature, spinopelvic sagittal parameters and clinical efficacy after posterior laminoplasty and showed that it was correlated with changes in cervical sagittal alignment after laminoplasty. Therefore, they stated that patients should be examined preoperatively with a full-length spine film to evaluate cervical and spino-pelvic sagittal balance. There are also studies indicating that laminoplasty does not cause worsening axial neck pain in properly selected cases [25,26]. Stephens *et al*. [33] reported that laminoplasty did not cause worsening axial neck pain and was associated with significant improvements in other clinical and myelopathy outcomes in an appropriately selected group of patients with myelopathy who did not have significant diffuse axial pain preoperatively and had appropriate sagittal alignment (C2-7 neutral/lordotic). A systematic meta-analysis compared cervical sagittal parameters between patients with cervical spine disorders and asymptomatic controls. The findings showed that the T1 slope was significantly lower among patients with cervical spine disorder compared to controls and higher for the spine cranial angle [34]. In this study, cervical lordosis loss was observed in only one patient in the three-year follow-up measurements of patients who underwent laminoplasty.

Limitations

The number of cases is not sufficient, patients could not be divided into subgroups due to the small number, and clinical findings could not be standardized. Some of the additional factors that may affect the picture could not be excluded (DM, Osteoporosis, Rheumatological diseases), The causes of stenosis could not be standardized.

CONCLUSION

The results of our study showed that en-block laminoplasty after the cervical narrow spinal canal was sufficient to maintain the cervical canal diameter in the long term with appropriate patient and surgical technique selection and did not cause additional lordosis or kyphosis, the cervical sagittal balance was preserved and the biomechanics of the cervical spine were not impaired. We think that a longer control series will be useful in this regard. We think that a more long-term control series will be useful in this regard.

Authors' Contribution

Study Conception: MM, RKÇ; Study Design: MM, RKÇ; Supervision: MM, RKÇ; Funding: N/A; Materials: N/A; Data Collection and/or Processing: MM, RKÇ; Statistical Analysis and/or Data Interpretation: MM, RKÇ; Literature Review: MM, RKÇ; Manuscript Preparation: MM, RKÇ and Critical Review: MM, RKÇ.

Conflict of interest

The authors disclosed no conflict of interest during the preparation or publication of this manuscript.

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