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Posterior Dynamic/Semi-Rigid Stabilization as an Effective Treatment for Cervical Spinal Stenosis

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ABSTRACT

AIM: To investigate the short- term results of dynamic/semi-rigid stabilization in patients with cervical spinal stenosis and compare them with patients for which decompression and pos-terior cervical fusion was performed.

MATERIAL and METHODS: 28 patients were included in this study. Group 1 was the semi-rigid group (four male, ten female), group 2 was the fusion group (nine male, five female). We compared the clinical status of the patients pre-operatively, first and twelfth month post-operatively using the Visual Analog Scale (VAS) and Neck Disability Index (NDI). Also radiologically, the pre-operative and on the postoperative first and twelfth month, cervical sagittal vertical axis (cSVA), cervical lordosis (C0-2) (C2-7) and T1 slope were measured.

RESULTS: Our results showed that there was a significant improvement on the VAS and NDI score after semi-rigid and fusion surgery ($p<0.001$). Also the cervical lordosis was obtained in both groups ($p=0.033$). Although, no significant differences was found between both groups regarding the change of variables over time between post-operative first and twelfth month.

CONCLUSION: Although, posterior dynamic stabilization has been previously used in thoracic and lumbar pathologies before, there is no crucial evidence about their effects in cervical stenosis. This study states, that semi-rigid instrumentation is as effective in clinical and radiologic out-comes as posterior fusion surgery in periods of one year. Also, the lower risk of adjacent-segment disease and pseudoarthrosis and preservation of cervical sagittal alignment are the main advantages of the new method.

KEYWORDS: Ervical spinal stenosis, Laminectomy, Posterior dynamic stabilization, Semi-rigid stabilization

ABBREVIATIONS: ASD: Adjacent segment disease, **C0-C2L:** C0-C2 lordosis, **C2-C7L:** C2-C7 lordosis, **CS:** Cervical stenosis, **CSM:** Cervical spondylotic myelopathy, **CSVA:** Cervical sagittal vertical axis, **CT:** Computed tomography, **MEP:** Motor evoked potentials, **PEEK:** Polyethyl ether ketone, **NDI:** Oswestry Disability Index, **SEP:** Somatosensory evoked potentials, **VAS:** Visual analogue scale

INTRODUCTION

Cervical stenosis (CS) is a progressive degenerative disease thar gradually increases with age (34). More than 50% of the middle-aged people show signs of CS on radiologic examinations although only 10% of them have symptoms of spinal cord compression or cervical radiculopathy (14). A number of factors including posterior longitudinal ligament and ligamentum flavum hypertrophy, disc degeneration and facet hypertrophy, and deformation of the vertebral body play a role in the pathophysiology of this disease (22). Although the clinical progress of CS is asymptomatic,

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it can also present with radiculopathy due to root compression or myelopathy associated with spinal cord compression (11). Surgical treatment is the gold standard in patients with moderate and severe CS. Laminectomy with fusion surgery or laminoplasty are up to date the two preferred options in surgery (15,18,30). The main pitfall in fusion surgery and decompression is adjacent-segment disease (ASD) and pseudoarthrosis (3,40). We performed decompression and dynamic/semi-rigid instrumentation in 14 patients with cervical spinal stenosis and compared their clinical and radiologic outcomes to the one with decompression and fusion surgery which has not been published in the literature before.

MATERIAL and METHODS

This prospective study was approved by the local committee at our institution in 09/06/2020 (ID: .3). Consent approval was obtained from all patients. Patients were divided into two groups: in group 1, 14 patients were included who underwent cervical laminectomy and dynamic stabilization with polyether ether ketone (PEEK) rods. For the 14 patients in group 2, laminectomy and posterior cervical fusion surgery was performed.

Inclusion criteria were as follows:

1. Patients older than 45 years,
2. Patients with clinically and radiographically confirmed cervical stenosis,
3. Patients who could not be treated by medical and physical therapy,
4. Patients with two-level or more stenosis,
5. Patients with neutral or lordotic cervical sagittal balance,
6. Patient with a cervical sagittal vertical axis (CSVA) less than 30 mm.

Patients younger than 45 years of age and those with kyphotic and congenital CS were not included in the study. Clinical status of the patients were assessed both pre-operatively and at postoperative first month and 12th month using the Visual Analog Scale (VAS) and Neck Disability Index (NDI). Pre- and post-operative cervical sagittal balance parameters of the patients were examined radiologically.

The CSVA of the patients was assessed by measuring the distance from a vertical line from the center of C2 to the posterior superior point of C7. Cervical C0-C2 lordosis (C0-C2L) was obtained at the angle between the C0 and C2 superior endplate line. Cervical C2-C7 lordosis (C2-C7L) was attained by rating the angle between the inferior endplate of C2 and the superior endplate of C7. T1 slope was assessed by measuring the angle between the line along the superior endplate of T1 and a perpendicular to the horizontal line (Figure 1). All radiologic evaluations were performed using the Surgimap software *(Globus Medical, Methuen, MA, USA).*

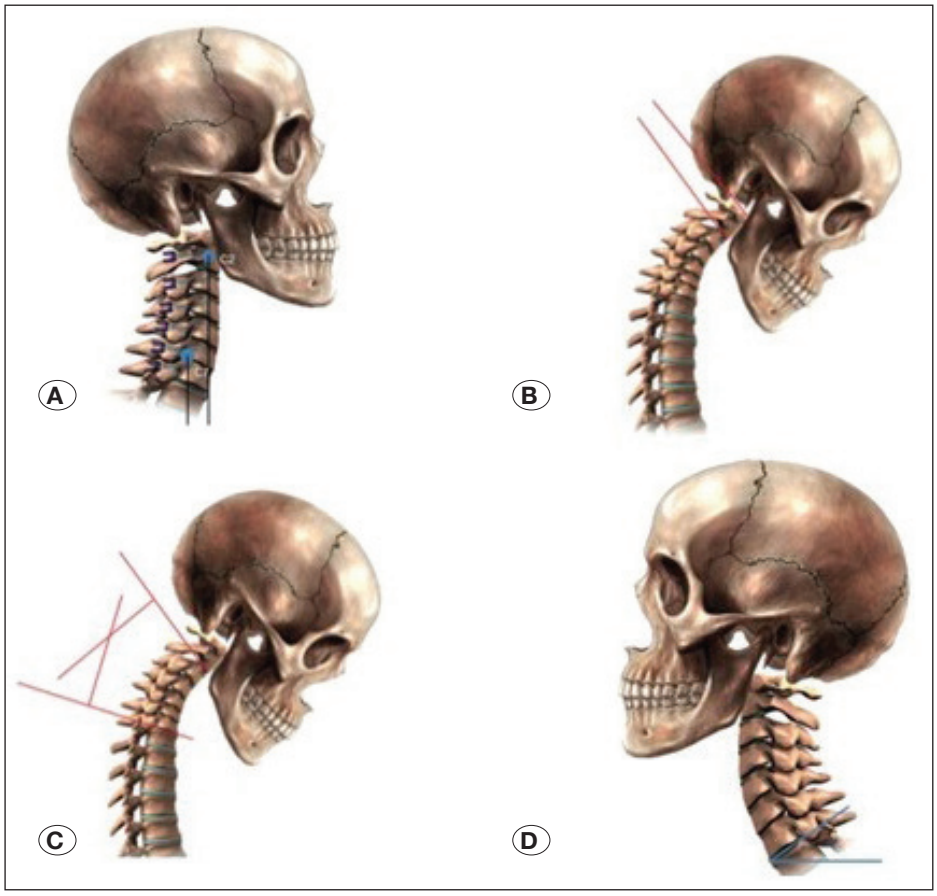

Figure 1: Measurement of cervical sagittal parameters. **A)** CSVA (Cervical Sagittal Vertical Axis). C2-C7 SVA: the distance from the C2 center of gravity perpendicular to the ground plane at the upper superior edge of the line of C7. **B)** C0-C2 Cervical Lordosis. Cervical lordosis (C0-C2): the angle between the lines passing through the upper end plates of C0 and C2. **C)** C2-C7 Cervical Lordosis. Cervical lordosis (C2-C7): the angle between C2 and C7 lines passing through the upper end plates of C2 and C7. **D)** T1 Slope Angle. T1 Slop Angle: the angle between the line passing through T1 upper end plate and the horizontal line.

The PEEK rods used in group 1 allow physiological motion of the spine and also help the vertebra to distribute the load properly on the bone, thus decreasing the stress on the screw system and reducing the possibility of implant failure and ASD (Figure 2).

Surgical Technique

The entire surgical procedure was performed under general anesthesia with the patient in the prone position with a neutral or mild flexion of the cervical region. We performed intraoperative neurophysiological monitoring throughout the procedure, in which somatosensory evoked potentials (SEP) and motor evoked potentials (MEP) were checked constantly. Under the fluoroscopic C-arm the surgical level was determined. After cleaning and draping the surgical field a vertical skin incision between C3-C6 was performed. Subcutaneous tissues and paraspinal muscles were retracted bilaterally with blunt dissection and monocautery. The levels were again confirmed by the C-arm. Laminectomy and flavectomy were performed using Kerrison rongeurs. The level and number of laminectomies depended on each case. In our inclusion criteria we just included patients with two or more levels of stenosis No facetectomies have been performed to avoid further instability. Lateral mass screws were inserted to the determined levels by the free hand technique. The position of each screw was checked with the C-arm. PEEK rods were put bilaterally for patients in group 1. For the ones in group 2, titanium rods were used. After carefully hemostasis, the layers were closed properly according to anatomical structures (Figure 3).

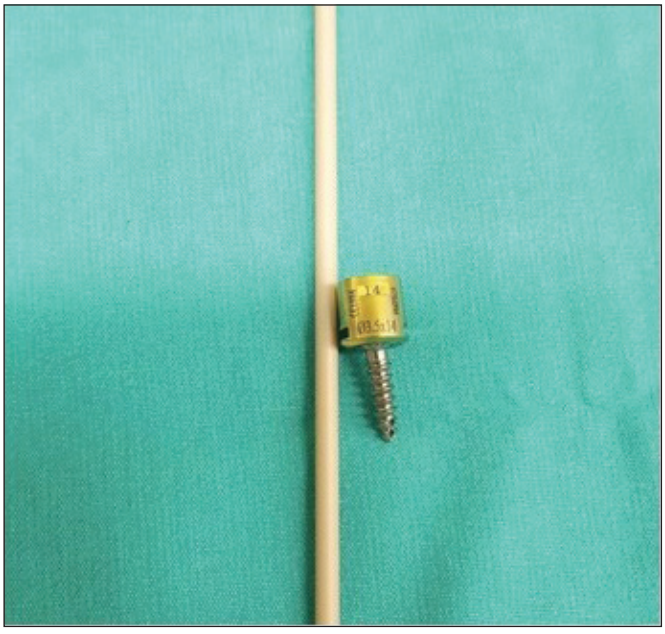

Figure 2: Polyether ether ketone (PEEK) rod.

Statistical Analysis

We examined the compliance of the numerical values with the normal distribution using histograms and the Shapiro Wilk test. The Chi-square test was used to compare the proportions in different groups. The Student's t-test was used to compare means. A repeated measures two way ANOVA was performed to compare the effect of groups on the changes in variables over time. An overall p-value of less than 0.05 was considered statistically significant. All variables were normally distributed. Statistical analysis was performed using the IBM SPSS Statistics for Windows, version 26 *(IBM Corp., Armonk, N.Y., USA)*.

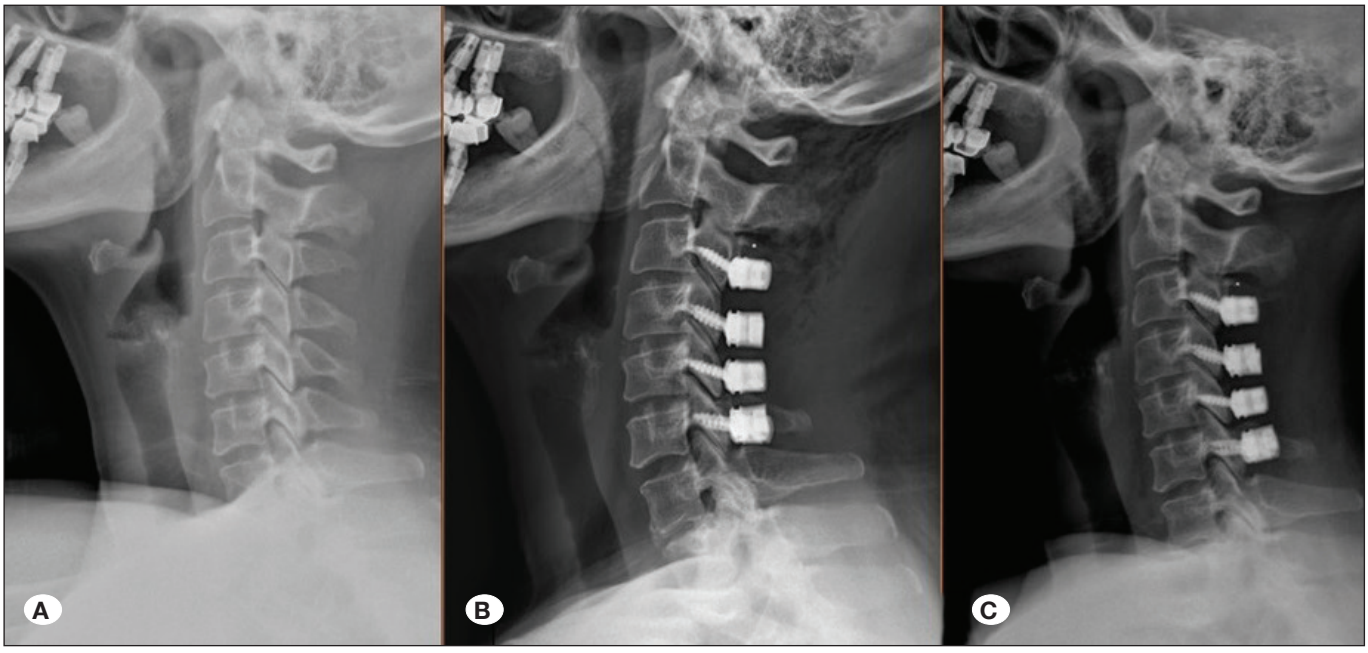

Figure 3: A) Preoperative, **B)** postoperative 1th month, **C)** postoperative 12th month (semi-rigid rod).

RESULTS

Group 1: Dynamic/semi-rigid stabilization:

14 patients, four male (26.6%) and 10 female (73.4%), with a mean age of 59 ± 9 (45-79) years, all underwent decompression and posterior dynamic stabilization due to CS. The patients' C0-C2, C2-C7, cSVA, T1 slope, VAS and NDI scores were evaluated pre-operatively and the postoperatively first and twelfth month (Table I).

Group 2: Fusion:

Among 14 patients, nine (64.3%) were male and five (35.7%) were female with a mean age of 59 ± 10 (46-78) years. All the patients in this group underwent decompression and posterior rigid stabilization (PRS) due to CS. The C0-C2, C2-C7, cSVA, T1 slope, VAS and NDI scores of the patients were evaluated preoperatively and on the postoperative first and twelfth month (Table I). No significant differences in changes were found in any of the variables.

We examined the statistical significance of the variation of the variables over time and whether this variability differed between the groups. The variation of C2-C7, VAS and NDI variables over time were statistically significant (p=0.003, p<0.001, 0<0.001, respectively). There was no statistical difference between the groups in the change of variables over time (Table II).

DISCUSSION

General understanding of cervical spondylotic myelopathy

Surgery is the gold standard for the treatment of cervical spondylotic myelopathy (CSM), particularly in moderate and severe cases. In mild cases, however, conservative treatment

Table I: Comparison of Group 1 and Group 2

	Total (n=28)	Group 1 (n=14)	Group 2 (n=14)	p-value
Gender, man (%)	13 (46.4)	4 (26.6)	9 (64.3)	0.058
Age, mean ± SD (range)	59 ± 9 (45-79)	59 ± 9 (45-79)	59 ± 10 (46-78)	0.875
Preoperative				
C0-C2	17.9 ± 7.1	18.7 ± 6.9	17.1 ± 7.4	0.570
C2-C7	25.1 ± 11.6	20.8 ± 12.2	29.4 ± 9.6	0.046
cSVA	15.9 ± 8.2	16.9 ± 7.8	14.9 ± 8.8	0.508
T1 SLOPE	27.5 ± 7.1	27 ± 6.8	27.9 ± 7.6	0.736
VAS	9.3 ± 7.6	9.4 ± 0.6	9.1 ± 0.9	0.331
NDI	77.7 ± 4.8	78.7 ± 4.7	76.7 ± 4.7	0.240
Postoperative 1th month				
C0-C2	20.6 ± 7.1	22.4 ± 7.1	18.6 ± 6.9	0.157
C2-C7	17.3 ± 10.3	15.2 ± 10.4	19.4 ± 10.1	0.290
cSVA	19.4 ± 9.4	20.2 ± 9.8	18.7 ± 9.2	0.680
T1 SLOPE	26.4 ± 7.5	26.6 ± 6.3	26.2 ± 8.7	0.891
VAS	2.6 ± 1.8	2.6 ± 2	2.5 ± 1.7	0.838
NDI	16.2 ± 16.9	16.8 ± 19.1	15.6 ± 15	0.856
Postoperative 12th month				
C0-C2	17.5 ± 7.5	18.7 ± 8.7	16.3 ± 6.3	0.423
C2-C7	17.8 ± 9.7	15.4 ± 9.3	20.3 ± 9.9	0.192
cSVA	18.3 ± 8.8	18.2 ± 9.5	18.5 ± 8.4	0.917
T1 SLOPE	25.2 ± 8	24.4 ± 6.6	26 ± 9.3	0.595
VAS	1.6 ± 1.4	1.7 ± 1.4	1.6 ± 1.5	0.796
NDI	10.8 ± 14.1	11.6 ± 14.8	10.1 ± 13.9	0.780

VAS: *Visual analog scale,* ***NDI:*** *Neck Disability Index,* ***CSVA:*** *Cervical sagittal vertical axis,* ***C0-C2L:*** *C0-C2 lordotic angle,* ***C2-C7L:*** *C2-C7 lordotic angle.*

Table II: Comparison of the Effects of Groups on Changes in Variables Over Time

Variable	Group 1			Group 2			p-value*	
	Preoperative	Postoperative 1th month	Postoperative 12th month	Preoperative	Postoperative 1th month	Postoperative 12th month	Time	Group
C0-C2	18.7 ± 6.9	22.4 ± 7.1	18.7 ± 8.7	17.1 ± 7.4	18.6 ± 6.9	16.3 ± 6.3	0.066	0.629
C2-C7	20.8 ± 12.2	15.2 ± 10.4	15.4 ± 9.3	29.4 ± 9.6	19.4 ± 10.1	20.3 ± 9.9	**0.003**	0.418
cSVA	16.9 ± 7.8	20.2 ± 9.8	18.2 ± 9.5	14.9 ± 8.8	18.7 ± 9.2	18.5 ± 8.4	0.090	0.621
T1 SLOPE	27 ± 6.8	26.6 ± 6.3	24.4 ± 6.6	27.9 ± 7.6	26.2 ± 8.7	26 ± 9.3	0.102	0.540
VAS	9.4 ± 0.6	2.6 ± 2	1.7 ± 1.4	9.1 ± 0.9	2.5 ± 1.7	1.6 ± 1.5	**<0.001**	0.904
NDI	78.7 ± 4.7	16.8 ± 19.1	11.6 ± 14.8	76.7 ± 4.7	15.6 ± 15	10.1 ± 13.9	**<0.001**	0.941

VAS: *Visual analog scale,* ***NDI:*** *Neck Disability Index,* ***CSVA:*** *Cervical sagittal vertical axis,* ***C0-C2L:*** *C0-C2 lordotic angle,* ***C2-C7L:*** *C2-C7 lordotic angle. * P-value time compares statistical significance of the values for preoperative, postoperative 1st and 12th month. P-value group compares the differences between the groups.*

with close monitoring is recommended and surgery becomes essential in the event of progression of neurologic symptoms (28). Although there is no consensus on the optimal time of surgery, surgical intervention is recommended to prevent neurologic impairment in patients with progressive neurological deficits and in patients that have spinal cord compression with or without myelopathy but with radiculopathy (38).

Surgical treatment of CSM

There is also no consensus on the ideal surgical treatment for CSM. Available surgical approaches include anterior, posterior, or anterior-posterior combined surgical techniques. Among these, the posterior approach is commonly performed in patients with a preserved lordosis or a neutral cervical spine, whereas the anterior approach is mostly preferred in patients with a kyphotic alignment (21). Laminoplasty is a useful technique that provides biomechanical stability and physiologically allows neck movements. However, it carries the risk for postoperative kyphosis (1,6). According to some studies have shown that, postoperative kyphosis after laminoplasty has been reported in 70% but that only half of the patients present with clinical symptoms (4,19). These findings indicate that the clinical symptoms of kyphosis may not be consistent with their radiologic findings. On the other hand, there are also other studies with totally opposite results, stating that laminoplasty prevents the development of kyphosis development by preserving cervical lordosis, thereby providing clinical improvement (12,27). In contrast, several other studies indicate that although laminoplasty leads to reduced cervical lordosis, it may accelerate the progression of kyphosis as it compensates the lordotic loss in C2-C7 by modifying the C0-C2 lordotic angle (2,31). Laminectomy is another technique used in CSM. Ryken et al. reported a success rate of 44-92% in patients that underwent multilevel laminectomy (29). Van Geest et al. indicated that postoperative kyphosis (6-46%) and segmental instability that required stability (18%) were the most common complications after laminectomy (36). Another study reported that kyphosis after laminectomy occurred in 6% of the patients (17). Passias et al. showed that distal junctional kyphosis occurred in patients with marked preoperative cervical sagittal imbalance (C2-C7 SVA> 56.3 mm) (25). Some other studies reported that patients that underwent fusion surgery in the kyphotic posture had a more severe postoperative neck pain compared to patients that underwent fusion surgery in the lordotic posture (13,16). Similarly, Villavicencio et al. reported that patients that had fusion surgery in the lordotic posture had a more favorable Neck Disability Index (NDI) and Short Form-36 Physical Component Summary (SF-36 PCS) scores compared to patients that underwent the surgery in the kyphotic posture (37). Although the same study found no significant relationship between cervical sagittal alignment, Tang et al. revealed that patients with high C2-7 SVA values had worse NDI and SF-36 PCS scores. Additionally, the authors determined a preoperative C2-C7 SVA value of approximately 40 mm (35).

Comparison of the literature with our study

In our study, we found no significant difference was found between the fusion and the dynamic/semi- rigid group in terms of SSVA, C0-C2L, C2-C7L, and T1 slope values. Moreover, postoperative CSVA values had no remarkable effect on the VAS and NDI, which could be attributed to the determination of a preoperative CSVA value of <3 cm in both groups. In many studies, it is reported that the complications including pseudoarthrosis, ASD, and range of movement limitation in the lumbar region can be eliminated by posterior dynamic stabilization, which has recently emerged as a popular technique for pathologies in the lumbar spine (20, 33). The primary aim in performing dynamic stabilization in the lumbar region is to preserve ROM and to ensure lumbar stability (5,23,24). In patients who had posterior stabilization and fusion, ASD has been reported in 3.8%, pseudoarthrosis in 1.4%, and screw failure in 0.3% of the cases (8,9,39). The common opinion is that the incidence of ASD is increased in patients undergoing vertebral stabilization in the kyphotic posture, mainly due to the increased biomechanical load on the adjacent disc. Ensuring cervical lordosis leads to homogeneous distribution of the loads on the cervical posterior

column, thereby allowing the neck muscles to spend less energy (26,32). Hansen et al. noted that segmental or global kyphosis leads to an increased prevalence of ASD (7). Ikeda et al. reported that ASD was observed in 50% of the patients following fusion surgery and the authors also noted that the prevalence of the disease was 33% and 88% in patients with a lordotic and kyphotic alignment, respectively (10).

In our study, no ASD or pseudoarthrosis was neither seen in any patient in the fusion group as in the semi-rigid group throughout the one-year of radiological follow-up. We consider that the low prevalence of these diseases in our patients could be attributed to the selection of non-kyphotic patients before surgery in both groups and to the level of cervical lordosis which was within normal limits.

In this study, in accordance with the philosophy of the effect and use of the dynamic system on degenerative diseases, a dynamic/semi-rigid system was applied to 14 patients with clinically and radiographically confirmed cervical stenosis after providing wide decompression area via posterior laminectomy. In the early clinical follow-up of the patients, there was a significant decrease in VAS and NDI scores. It was observed that the results of cervical parameters obtained from preoperative scoliosis graphs and cervical parameters from postoperative scoliosis X-rays showed statistically significant stabilization. Moreover, the study also showed that cervical lordosis was preserved and that neither pseudoarthrosis nor ASD developed during one-year radiological follow-up. PEEK rods may soften over time, so a one year follow-up might have be a little short to have a final conclusion for the effectiveness for the usage of PEEK rods in CSM but can give us a general idea that it might be a useful surgical technique. Still a longer follow-up might be necessary to have more accurate results.

Our study was limited due to the short follow-up period and the small number of patients. For future studies a longer follow-up with a larger patient scale should be advised.

CONCLUSION

To our knowledge, posterior dynamic stabilization by laminectomy is a novel technique for the treatment of CS that has not been previously reported in the literature. The results of our study indicated that posterior dynamic/semi-rigid stabilization provided favorable radiologic and clinical outcomes in patients with CS. Although the patients had a short-term follow-up of just one year, the absence of ASD and pseudoarthrosis and the preservation of cervical sagittal alignment are the main advantages of this nuance technique.

Declarations

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Availability of data and materials: The datasets generated and/or analyzed during the current study are available from the corresponding author by reasonable request.

Disclosure: Authors declare no conflict of interest.

AUTHORSHIP CONTRIBUTION

Study conception and design: KP, SS
Data collection: OY
Analysis and interpretation of results: KP
Draft manuscript preparation: KP, IA
Critical revision of the article: AFO
All authors (KP, IA, SS, OY, AFO) reviewed the results and approved the final version of the manuscript.

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