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Minimally Invasive Decompression and Fusion With Percutaneous Facet Cages vs Traditional Lateral Mass Screw Fixation for Cervical Spondylotic Myelopathy: A Retrospective Comparative Study

Authors' Contribution:
Study Design A
Data Collection B
Statistical Analysis C
Data Interpretation D
Manuscript Preparation E
Literature Search F
Funds Collection G

AE 1 İsmail İştemen
B 2 Mahmut Ferat
C 2 Durdu Mehmet Babaoğlan
D 1 Can Sezer
F 2 Erencan Kılcı
ABEF 2 Deniz Dükünlü
D 1 Mehmet Volkan Harput
C 3 Rıdvan Açıkalın

1 Department of Neurosurgery, Adana Faculty of Medicine, University of Health Sciences, Adana, Türkiye
2 Department of Neurosurgery, Adana City Hospital, Adana, Türkiye
3 Department of Neurosurgery, Medicalpark Mersin Hospital, Mersin, Türkiye

Corresponding Author: İsmail İştemen, Kışla Mahallesi, Dr. Mithat Özsan Bulvarı, 4522. Sokak No: 28, Yüreğir/Adana, Türkiye, e-mail: drismailistemen@gmail.com
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Background: Comparative clinical data evaluating percutaneous facet cage (PFC)-based minimally invasive decompression against traditional laminectomy and lateral mass screw (LMS) fixation in patients with cervical spondylotic myelopathy (CSM) remain limited. We compared the clinical and radiological outcomes of these 2 surgical strategies.

Material/Methods: We retrospectively reviewed 76 patients with CSM operated on between 2020 and 2024. Patients were categorized into 2 groups: the LMS group (n=46): laminectomy with LMS fusion; and the PFC group (n=30): speculum-assisted laminotomy with PFC fusion. Clinical outcomes were assessed using modified Japanese Orthopaedic Association, Neck Disability Index (NDI), visual analog scale (VAS), and Oswestry Disability Index (ODI) scores. Radiological parameters included cervical lordosis, T1 slope, cervical sagittal vertical axis, foraminal height, and fusion rate. Complications and perioperative data were compared.

Results: The PFC group had better perioperative outcomes and numerically fewer complications, and achieved superior NDI, VAS, and ODI scores at 1 year, while both groups improved significantly in all clinical outcomes. Radiologically, foraminal height increased significantly in the PFC group. No significant differences were found between the groups in terms of fusion rates, cervical sagittal vertical axis, or cervical lordosis.

Conclusions: In this retrospective cohort, minimally invasive decompression combined with PFC was associated with shorter operative time, lower blood loss, and shorter hospital stay than conventional laminectomy with LMS fixation. Neurological recovery and radiological outcomes were comparable between groups, while pain and disability scores favored the PFC group. Minimally invasive decompression with PFC fusion is a viable alternative for elderly patients, those with multiple comorbidities, or those at high risk of perioperative bleeding.

Keywords: Spinal Cord Compression • Spinal Fusion • Spinal Stenosis

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Introduction

Cervical spondylotic myelopathy (CSM) is a progressive disease that affects the muscles, discs, facets, and ligaments, causing degenerative changes [1]. CSM is the most common form of spinal cord injury in adults and accounts for most non-traumatic spinal cord injuries [2]. Spondylosis generally begins with degenerative changes in the intervertebral disc space and leads to secondary changes in surrounding structures. CSM develops through a combination of static and dynamic degenerative mechanisms, including intervertebral disc degeneration, osteophyte formation, facet arthropathy, ligamentous hypertrophy, and progressive cervical canal narrowing, ultimately resulting in spinal cord compression and neurological impairment [2,3]. Neck pain and radicular arm pain are also common due to spondylosis and foraminal stenosis. The management of CSM depends on symptom severity, neurological status, sagittal alignment, number of involved levels, and the predominant site of compression. Current clinical guidelines recommend surgical intervention for patients with moderate or severe CSM, while patients with mild disease may be managed with either surgery or a supervised trial of structured rehabilitation, provided that neurological deterioration prompts operative treatment [4]. Surgical treatment options are divided into anterior and posterior surgical techniques. Multilevel discectomies and corpectomy procedures are the main anterior surgical methods. In clinical practice, anterior approaches are generally favored when compression is predominantly ventral and limited to 1 or 2 levels [5]. The literature reports posterior decompression and fusion surgery—traditional laminectomy and fusion with lateral mass screws (LMS)—as an effective and safe method for patients with CSM [6]. However, conventional posterior fusion requires extensive paraspinal muscle dissection, broad exposure of posterior elements, and multilevel instrumentation. These factors can increase operative time, blood loss, postoperative axial pain, and wound-related morbidity. Surgical complications and limitations may not be well tolerated by older adult patients, those with multiple comorbidities, or those at high risk of perioperative bleeding. Consequently, minimally invasive surgical techniques are needed for such patients. Percutaneous facet cage (PFC) placement has recently been reported in the literature as a minimally invasive method. Clinical series using posterior cervical facet systems have also reported satisfactory fusion rates and improvement in pain and disability scores in selected cases of cervical radiculopathy [7-9].

Despite these encouraging findings, comparative clinical data evaluating PFC-based minimally invasive decompression against traditional laminectomy and LMS fixation in patients with CSM remain limited. Therefore, in the present study, we aimed to compare perioperative, clinical, and radiological outcomes between minimally invasive decompression with speculum-assisted laminotomy and fusion with PFC and conventional posterior decompression and fusion with LMS. We hypothesized that minimal invasive decompression combined with PFC would reduce perioperative burden, including operative time, blood loss, and length of hospital stay, and improve patient-reported pain and disability outcomes compared with traditional laminectomy with LMS. We further hypothesized that neurological recovery, fusion rate, and cervical sagittal alignment would be comparable between the 2 techniques.

Material and Methods

Study Population

The study included 76 patients diagnosed with moderate or severe CSM who underwent posterior decompression and fusion surgery (PFC or LMS) by the same senior surgeon in our hospital between 2020 and 2024. Patient files were retrospectively reviewed. This study was approved by the Ethics Committee of the Adana City Training and Research Hospital (18.12.2025-947). Informed consent was obtained from all patients before enrollment. Inclusion criteria were age between 45 and 80 years, cervical central and foraminal moderate and severe stenosis at the C4-C5 and C5-C6 levels on radiological imaging, presence of myelopathic findings, and neurodeficit. Surgical treatment is recommended for patients with moderate to severe myelopathy, as early intervention is associated with improved neurological recovery, whereas delayed surgery is linked to poorer clinical outcomes [2]. Exclusion criteria included prior anterior or posterior cervical surgery, stenosis due to trauma or oncological pathologies, cognitive impairments preventing study participation, and inability to attend follow-up. Patients with acute deterioration due to trauma were also excluded. Patients were allocated to surgical groups in a non-randomized manner. The choice of surgical technique (LMS vs PFC) was primarily based on surgeon preference and evolving institutional practice patterns over the study period. Although all patients were operated on between 2020 and 2024, minimally invasive decompression combined with PFC fusion was increasingly preferred during the latter part of the study period, particularly in the last 2 years.

In addition, patient-related factors influenced the selection of the surgical approach. In patients with higher perioperative risk, especially those classified as American Society of Anesthesiologists (ASA) class III or IV, the minimally invasive PFC technique was preferentially considered due to its lower expected surgical morbidity. For patients considered suitable candidates for both techniques, detailed information regarding the procedures, including their risks, benefits, and expected outcomes, was provided. Patient preference was then considered in the final decision-making process.

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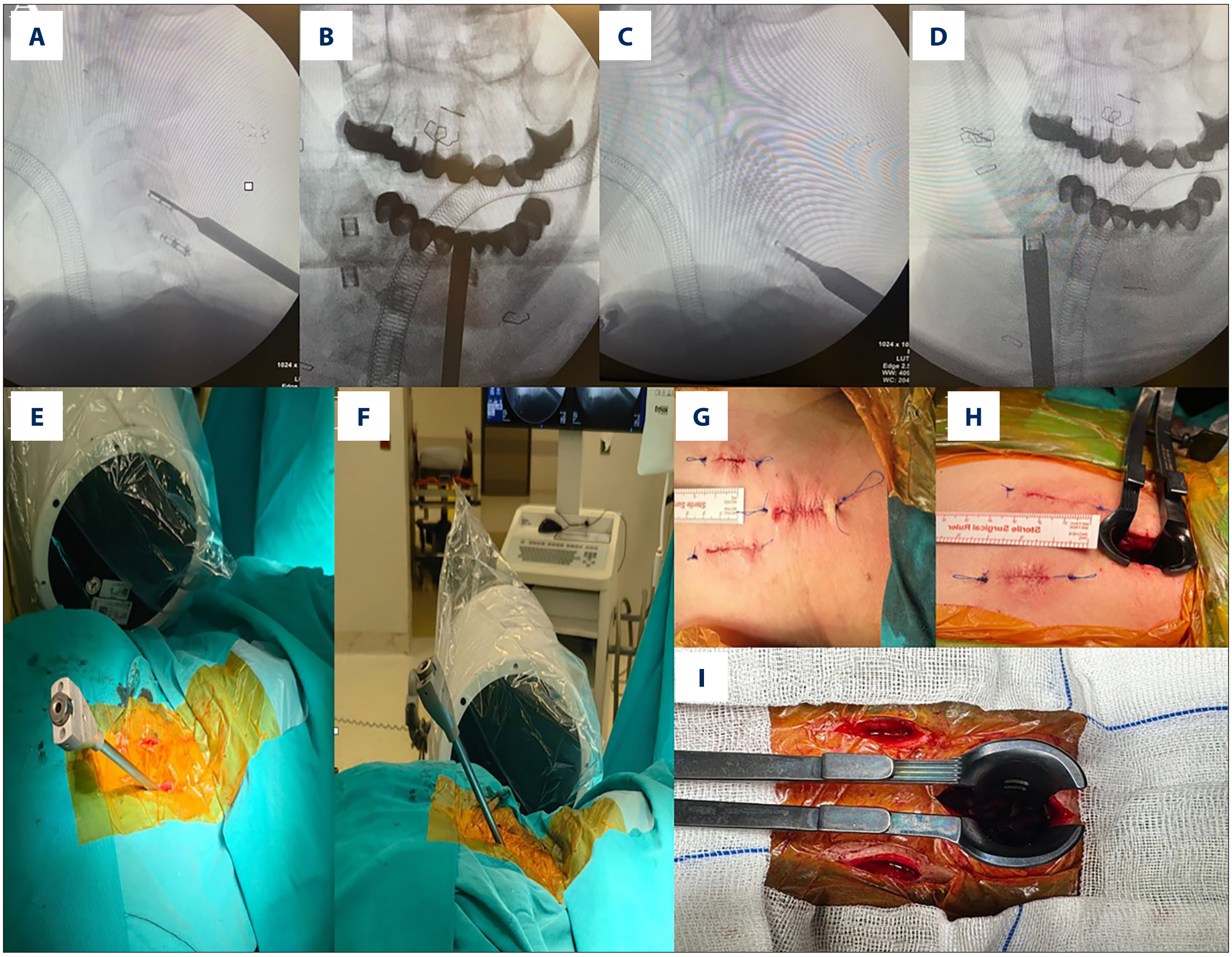


Figure 1. Intraoperative images illustrating the minimally invasive posterior cervical decompression and fusion technique with percutaneous facet cage placement at the C4-C5 and C5-C6 levels. Lateral and anteroposterior fluoroscopic images demonstrating percutaneous instrumentation and facet cage placement (**A-D**). Intraoperative setup showing patient positioning, C-arm fluoroscopy orientation, and insertion of the percutaneous facet cage cannula (**E, F**). Final operative stages, including speculum-assisted laminotomy performed under microscopic visualization (**H, I**) and postoperative skin closure (**G**).

This allocation strategy reflects real-world clinical practice but may introduce selection bias, which was considered during the interpretation of the study results.

Based on the above selection criteria and clinical decision-making process, patients who underwent 2 different surgical techniques were retrospectively identified and included in the study as 2 groups: the LMS group (n = 46): laminectomy and LMS fusion; and the PFC group (n = 30): speculum-assisted laminotomy with PFC fusion.

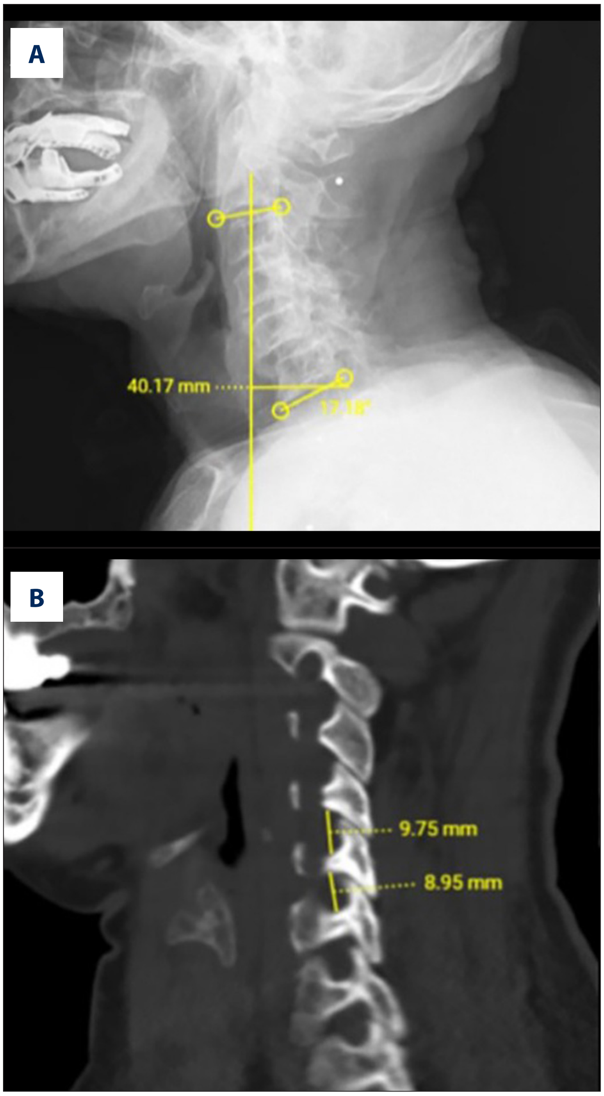
Surgical Techniques

LMS Group: Laminectomy and Fusion with LMSs

Patients were operated on under general anesthesia, in the prone position, using fluoroscopy. Open surgery was performed using a posterior midline skin incision at C3-C7. Subperiosteal muscle dissection was performed between the C3-C7 levels, extending to the lateral borders of the vertebrae. The lateral masses of the C4-C5-C6 vertebrae were exposed. LMSs were placed using the Anderson method under neuromonitoring guidance [10], and then C4-C5 laminectomies were performed with a high-speed drill. Autograft was used to achieve fusion. The patient's head was elevated, cervical lordosis was achieved, and a rod was placed.

PFC group: Speculum-Assisted Laminotomy and PFC Fusion

Patients were operated on under general anesthesia, in the prone position, using fluoroscopy. A 1.5-cm incision was made 3 to 4 cm lateral to the midline and 5 to 6 cm inferior to the C5-C6 level. The cages filled with putty graft were then placed percutaneously in the bilateral C4-C5 and C5-C6 facet joints following



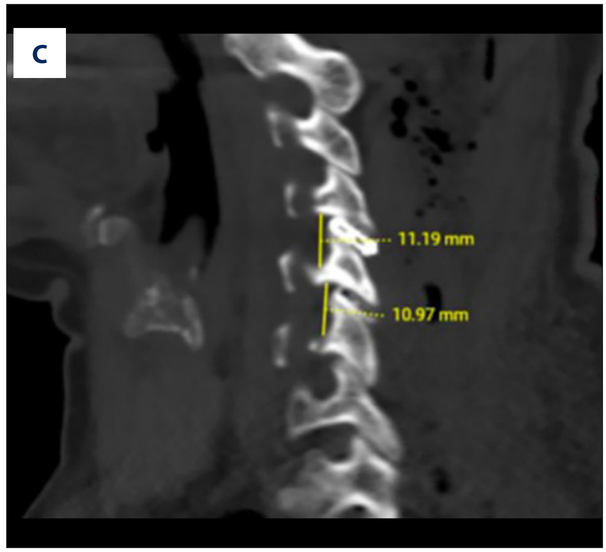


Figure 2. Radiological assessment of cervical alignment and foraminal height in a representative patient. Lateral radiograph demonstrating measurement of the C2 sagittal vertical axis (C2-SVA) (**A**). Preoperative sagittal computed tomography (CT) image showing foraminal height measurements at the involved levels (**B**). Postoperative sagittal CT image demonstrating restoration of foraminal height following percutaneous facet cage placement (C).

decortication (**Figure 1**). This allows for secondary foraminal decompression. Then, a 2- to 3-cm long skin incision was made in the midline at the level of the C5 spinous process, partial muscle dissection was performed, and a speculum was placed (**Figure 1**). C4 and C5 hemilaminectomy and bilateral decompression with a unilateral approach were performed using a high-speed drill and Kerrison rongeur with microscopic technique. The spinous process and midline structures were preserved. With this method, muscle dissection was limited to the area where the laminotomy would be performed. Extensive muscle dissection down to the edges of the lateral mass and at multiple levels was not required. This minimized muscle damage, as well as damage to the posterior bone and ligamentous structures.

Clinical and Radiological Assessment

Patients were evaluated for age, sex, body mass index (BMI), comorbidity, clinical and radiological changes, length of hospital stay, surgical time, blood loss, and complications. Clinical changes were assessed using modified Japanese Orthopedic Association (mJOA), Neck Disability Index (NDI), visual analog scale (VAS), and Oswestry Disability Index (ODI) scores. Although the ODI was originally developed for lumbar spine disorders, it was included as a supplementary measure of overall disability and functional limitation. The NDI was used as the primary cervical spine-specific disability outcome measure. Radiologically, fusion rate, cervical lordosis (C2-C7 Cobb), foraminal height, T1 slope angle, and cervical sagittal vertical axis (C2-SVA) were evaluated. The distance between the lower edge of the upper pedicle and the upper edge of the lower pedicle was measured as the foraminal height (**Figure 2**). Multi-slice computed tomography (CT) was used to assess the fusion rate at 1-year follow-up. Assessments were made preoperatively, and on the control visits at 1 month and 1 year postoperatively.

Statistical Analysis

Statistical analysis was performed using IBM SPSS Statistics (version 25.0). Continuous variables are expressed as mean ± standard deviation, and categorical variables as frequencies and percentages.

Between-group comparisons were performed using independent samples *t* tests, and within-group comparisons were

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Table 1. Patient demographics.

	PFC n=30	LMS n=46	*P* value
Age	61.3±6.8	59.2±6.6	0.187
Sex			0.093
Male	19 (63.3%)	30 (65.2%)	
Female	11 (36.7%)	16 (34.8%)	
Body mass index	28.7±3.9	29.6±3.7	0.310
Smoking status			0.79
No	15 (50%)	21 (45.6%)	
Current	7 (23.3%)	14 (30.4%)	
Former	8 (26.7%)	11 (24%)	
Elixhauser comorbidity index	1.38	1.78	0.342
Blood loss (mL)	53.1±13.1	314.0±82.0	<0.001*
Operative duration (min)	73.0±7.4	228.0±13.7	<0.001*
Hospital stay	1.3±1.1	3.8±1.8	<0.001*
Complications (number of patients)	3 (10%)	8 (17.4%)	0.511
Instrument related complications	1 (3.3%)	4 (8.7%)	0.38
Dural injury	1 (3.3%)	2 (4.3%)	
Wound infection	1 (3.3%)	1 (2.2%)	
C5 nerve palsy	0	1 (2.2%)	
Reoperation due to complications	0	5 (10.9%)	

* $P<0.05$ was considered statistically significant.

performed using paired *t* tests. Categorical variables, including complication and fusion rates, were analyzed using the chi-square or Fisher exact test where appropriate. A *P* value <0.05 was considered statistically significant.

Results

A total of 76 patients were included in this study, with 46 in the LMS group and 30 in the PFC group. Twenty-seven patients were women and 49 were men. The mean age was 60.02 years (range, 47-78). No statistically significant differences were found in age or sex between the 2 groups. Similarly, the groups were similar in terms of BMI, smoking status, and comorbidities ($P>0.05$) (**Table 1**).

In the LMS group, the mean operative time was 228±13.7 minutes, patient blood loss was 314±82.0 mL, and the mean hospital stay was 3.8±1.8 days. In the PFC group, these values were 73± 7.4 minutes, 53.1±13.1 mL, and 1.3±1.1 days, respectively. Surgical time, blood loss, and hospital stay were statistically significantly lower in the PFC group ($P<0.001$) (**Table 1**).

Complications

Wound infection was observed in 1 patient in the LMS group; the patient recovered with antibiotic treatment and no revision was required. Two patients experienced dural injuries, and the dura was sutured. However, 1 patient underwent reoperation due to a cerebrospinal fluid leak. One patient underwent early reoperation due to screw malposition. During long-term follow-up, 3 patients underwent reoperation due to screw loosening. One patient developed C5 nerve palsy, which resolved completely within 1 year. In the PFC group, wound infection was observed in 1 patient and resolved with antibiotic treatment. One patient experienced a dural injury, which was repaired, and no cerebrospinal fluid leak was detected. No cage malposition was observed in the early postoperative

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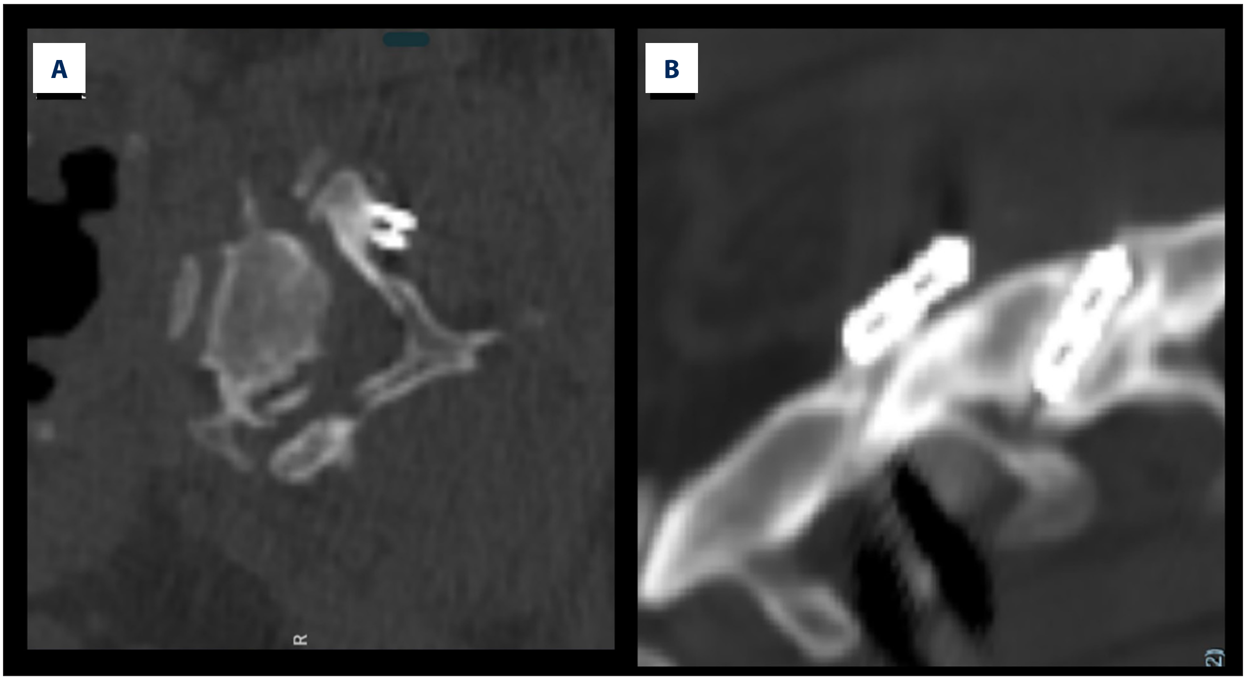

Figure 3. Follow-up computed tomography (CT) images demonstrating posterior displacement of a percutaneous facet cage in a representative patient during the late postoperative period. Axial (**A**) and sagittal (**B**) CT reconstructions show posterior migration of the facet cage without evidence of neurological compression, implant-related instability, or significant loss of alignment. The patient remained asymptomatic during follow-up, and no revision surgery was required.

period. During long-term follow-up, 1 patient's cage was displaced posteriorly, but the patient, who had no clinical symptoms, was not re-operated on (**Figure 3**). Complications occurred in 8 of 46 (17.4%) patients in the LMS group and 3 of 30 (10.0%) patients in the PFC group. Although complications were numerically more frequent in the LMS group, the difference was not statistically significant according to the Fisher exact test ($P=0.511$). Instrument-related complications were observed in 1 of 30 patients in the PFC group and in 4 of 46 patients in the LMS group (3.3% vs 8.7%). This difference was not statistically significant (Fisher exact test, $P=0.38$) (**Table 1**).

Clinical Outcomes

A significant improvement was found in mJOA scores between preoperative and 1-month and 1-year postoperative results in both groups ($P<0.001$). When the groups were compared, no statistically significant difference was found between preoperative and 1-year postoperative mJOA scores. ODI scores were significantly lower in both groups at the end of 1 month and 1 year, and when the 2 groups were compared; a significantly lower score was found in the PFC group at 1-year follow-up ($P<0.001$). A significant decrease was found in VAS radicular and neck pain in both groups at the 1-month and 1-year follow-up. Moreover, at 1-year follow-up, the PFC group demonstrated significantly lower NDI scores compared with the LMS group ($P<0.001$). VAS and NDI scores were found to be statistically significantly lower in the PFC group at 1 month and 1 year ($P<0.001$) (**Table 2**). A significant improvement was found in all clinical outcomes at the end of 1 year in both groups, but NDI, VAS, and ODI scores were found to be statistically significantly lower in the PFC group at 1-year follow-up ($P<0.001$) (**Table 2**).

Radiological Outcomes

Radiological evaluation revealed a statistically significant but slight loss of lordosis at 1 month and 1 year with both techniques. No significant difference was found between the 2 groups in the change in Cobb angle ($P>0.05$) (**Table 3**). C2-SVA values increased in both groups at 1 month and 1 year, paralleling the loss of lordosis. Similar to the Cobb angle findings, no significant difference was observed between the 2 groups ($P>0.05$) (**Table 3**). While T1 slope angles were initially similar between the 2 groups, they were significantly lower in the PFC group at 1 month and 1 year (**Table 3**). Foraminal height increased significantly in the PFC group at 1 month and 1 year ($P<0.001$), whereas a moderate decrease was observed in the LMS group. Compared with the LMS group, the PFC group demonstrated a significantly greater increase in foraminal height ($P<0.001$) (**Table 3**). No statistically significant difference was found between the groups regarding fusion rates ($P=0.645$).

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Table 2. Functional outcomes during follow-up.

Parameter	Timepoint	PFC (n = 30)	LMS (n = 46)	Between-group *P* value	Within-group *P* value
mJOA	Pre-op	10.83 ± 2.13	10.22 ± 1.07	0.10	–
	1 Month	14.70 ± 0.84	14.22 ± 0.99	0.03*	< 0.001* / < 0.001*
	1 Year	14.90 ± 1.03	14.80 ± 1.13	0.71	< 0.001* / < 0.001*
NDI	Pre-op	22.1 ± 4.17	21.8 ± 4.23	0.765	–
	1 Month	7.1 ± 1.4	14.61 ± 4.27	< 0.001*	< 0.001* / < 0.001*
	1 Year	6.3 ± 1.15	9.72 ± 3.61	< 0.001*	< 0.001* / < 0.001*
VAS radicular	Pre-op	8.3 ± 0.84	7.67 ± 0.84	0.002*	–
	1 Month	3.43 ± 0.73	4.41 ± 0.72	< 0.001*	< 0.001* / < 0.001*
	1 Year	1.2 ± 0.41	2.48 ± 0.62	< 0.001*	< 0.001* / < 0.001*
VAS neck	Pre-op	8.13 ± 0.82	8.24 ± 0.85	0.592	–
	1 Month	3.33 ± 0.66	3.83 ± 0.74	0.004*	< 0.001* / < 0.001*
	1 Year	1.23 ± 0.50	2.37 ± 0.64	< 0.001*	< 0.001* / < 0.001*
ODI	Pre-op	56.2 ± 9.89	57.35 ± 9.56	0.615	–
	1 Month	26.73 ± 6.42	29.65 ± 8.05	0.099	< 0.001* / < 0.001*
	1 Year	15.47 ± 4.61	21.30 ± 7.50	< 0.001*	< 0.001* / < 0.001*

Data are presented as mean ± SD. Within-group *P* values represent comparisons with preoperative values. * $P < 0.05$ was considered statistically significant. Abbreviations: mJOA, Japanese Orthopedic Association; NDI, Neck Disability Index; ODI, Oswestry Disability Index; VAS, visual analog scale.

Table 3. Radiological outcomes.

Parameter	Timepoint	PFC	LMS	Between-group *P* value	Within-group *P* value: PFC	Within-group *P* value: LMS
C2-C7 Cobb angle	Pre-op	16.2 ± 4.99	16.91 ± 3.38	0.794	–	–
	1 Month	14.4 ± 4.55	14.61 ± 3.28	0.755	< 0.001*	< 0.001*
	1 Year	14.8 ± 4.44	14.11 ± 3.15	0.272	< 0.001*	< 0.001*
C2-SVA	Pre-op	20.3 ± 3.63	18.61 ± 3.3	0.647	–	–
	1 Month	23.5 ± 3.07	20.91 ± 3.25	0.104	< 0.001*	< 0.001*
	1 Year	22.4 ± 2.81	21.3 ± 3.31	0.791	< 0.001*	< 0.001*
T1 slope	Pre-op	24.8 ± 2.12	24.41 ± 2.11	0.354	–	–
	1 Month	22.7 ± 1.78	24.5 ± 1.96	< 0.001*	< 0.001*	0.209
	1 Year	21.5 ± 1.53	23.8 ± 1.88	< 0.001*	< 0.001*	< 0.001*
Foraminal height	Pre-op	10.3 ± 1.18	10.91 ± 1.17	0.256	–	–
	1 Month	12.8 ± 1.06	10.61 ± 1.02	< 0.001*	< 0.001*	< 0.001*
	1 Year	12.5 ± 1.11	10.5 ± 1.03	< 0.001*	< 0.001*	< 0.001*
Fusion rate	1 Year	28/30 (93.3%)	44/46 (95.7%)	0.645	–	–

Data are presented as mean ± SD. Within-group *P* values represent comparisons with preoperative values. Fusion rates were compared using Fisher exact test. * $P < 0.05$ was considered statistically significant. Abbreviation: C2-SVA, cervical sagittal vertical axis.

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Discussion

Extensive laminectomy and fusion with LMSs via a posterior approach is a classic treatment method frequently used in patients with myelopathy due to cervical spondylotic spinal stenosis, with good results reported in the literature [6,11,12]. In our clinic, extensive laminectomy and fusion with LMSs have also been used for a long time as a conventional surgical treatment. However, these patients are often older and may have comorbidities and a history of anticoagulant medication use. Performing major surgery in these patients is challenging and unreliable. Therefore, minimally invasive techniques, which can shorten surgical time, reduce blood loss, and cause less muscle and soft tissue damage, might be necessary [7,8,13,14]. For this reason, in recent years, we have preferred using minimally invasive techniques rather than performing major surgery in patients with CSM. In our clinic, we perform foraminal decompression and fusion with a PFC, followed by a minimally invasive decompression with speculum assistance. In the present study, we compared this method with the conventional extensive laminectomy and fusion with LMSs.

The distribution of patients in both groups was similar in terms of age, sex, BMI, smoking status, and comorbidities. The length of hospital stay, blood loss, and surgery time were significantly shorter in the PFC group than in the LMS group, consistent with the literature [9,14,15]. McCormack et al published the results of 60 patients who used the DTRAX facet cage, noting that the minimally invasive technique resulted in faster recovery time, shorter hospital stay, and negligible blood loss. They also reported no vertebral artery injuries, nerve root injuries, spinal cord injuries, or reoperation requirements [8]. In our series, the complication rate was lower in the PFC group (PFC: 10% vs LMS: 17.4%), but this was not statistically significant ($P = 0.511$). Reoperation due to complications was required in 5 of 46 patients in the LMS group, whereas no patients in the PFC group required reoperation (10.9% vs 0%). Although the difference did not reach statistical significance (Fisher exact test, $P = 0.068$), a trend toward a lower reoperation rate was observed in the PFC group. In their study including 3401 patients, Choy et al reported that 4.97% of patients required reoperation after posterior cervical fusion [16]. Another serious complication of posterior cervical fusion surgery is C5 nerve palsy. Li et al added laminoplasty to the procedure to reduce the incidence of C5 nerve palsy, arguing that it may occur due to muscle damage, adhesions, post-laminectomy scar tissue, and excessive cervical spinal cord drift [17]. They reported reducing the incidence from 11.11% to 0%. We did not detect C5 nerve palsy in the PFC group, while it was temporarily detected in 1 patient in the LMS group, with complete recovery achieved via physiotherapy. Consistent with the literature, our study demonstrated that the PFC group, which used the minimally invasive technique, had better outcomes than the LMS group in terms of hospital stay, blood loss, and surgical time.

In our study, the clinical scales VAS, mJOA, NDI, and ODI showed significant improvements in both groups at early and late follow-ups. Kramer et al reported that VAS scores decreased satisfactorily in patients treated with facet cages. Siemionow et al reported significant improvements in NDI, VAS neck and arm pain, and 12-Item Short Form Health Survey scores with the DTRAX cage [18,19].

Goel suggests that the degenerative process develops due to facet instability and advocates for the therapeutic effect of facet fusion. He reports that the facet cage provides facet stability and increases foramen and disc height, providing secondary decompression of both the foramen and spinal canal. He reported a significant decrease in VAS arm and neck pain scores and a significant increase in mJOA scores [20].

Liu et al reported significant improvements in VAS arm and neck (5.4 to 3.1, 4.2 to 2.4), mJOA (11.03 to 14.03), and NDI (25 to 14) ($P < 0.05$) scores in the clinical evaluation of 36 patients who underwent lateral mass fusion [21]. The literature reports that both techniques provide significant improvements in clinical follow-up. In our study, while mJOA scores improved similarly in both groups, significantly better results were observed in the PFC group regarding VAS, ODI, and NDI scores at 1-year follow-up. The statistically similar mJOA values indicate that adequate decompression was achieved in both groups. Considering that PFC fusion may not adequately decompress the central canal, we routinely add speculum-assisted bilateral decompression with the unilateral approach. The PFC technique we described involves less muscle dissection, preserving midline bone structures and ligaments, which aids pain control and reduction of disabilities. Additionally, increased foramen height in the PFC group contributed to a decrease in VAS radicular pain scores, with even the initial VAS score being significantly higher in PFC group. Furthermore, the more rigid stability provided by the screw rod system may have contributed to limitations and pain.

Radiologically, we observed statistically significant but measured slight loss of lordosis and a slight increase in C2-SVA parallel to this loss of lordosis in both groups. The T1 slope angle was statistically significantly lower in the PFC group at both time points. Although loss of lordosis is a potential concern with facet distraction, literature reviews have reported no significant loss after single and multilevel cage placement [9]. The most comprehensive study by Tan et al also reported no significant loss of lordosis even in multilevel facet cage placement [22]. Goel also reported a slight but nonsignificant loss [20]. Although statistically significant differences were observed in various alignment parameters (Cobb angle, C2-SVA,

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T1 slope) in our study, the magnitude of these changes was minimal. Also, these small magnitude changes in Cobb angle and C2-SVA were statistically similar in both groups. The significantly lower T1 slope angle in the PFC group can be explained by the fact that PFC, being a minimally invasive technique, allows for the preservation of range of motion and may involve more active compensatory mechanisms. This may also have a positive impact on scores such as ODI and NDI. All radiological parameters demonstrated significant within-group changes over time; however, between-group comparisons showed similar results for cervical alignment parameters, with the exception of foraminal height, which was significantly improved in the PFC group.

Foraminal height was significantly higher in the PFC group, suggesting effective secondary decompression via facet distraction, whereas a moderate decrease was observed in the LMS group. This may have contributed to the lower VAS arm pain scores in the PFC group. Maulucci et al demonstrated in a cadaver study that foraminal width increases with increasing cage size [23]. Goel also reported increased disc and foramen height [20]. In accordance with the literature, foramen height was significantly increased in the PFC group in our study. Clinical and biomechanical studies report that facet cage fusion provides sufficient stiffness and promotes adequate fusion [8,15,23-25]. Furthermore, Voronov et al demonstrated that facet cage fusion provides stability similar to that of traditional LMS fusion [24,25]. In our study, fusion rates were satisfactory in both groups, with no statistically significant difference.

Goel defines vertical instability (facet instability) as the primary pathology in CSM and advocates for facet stabilization without decompression. This concept begins with muscle weakness in the bipedal human spine. Subsequently, the foramen narrows due to facetal instability and retrolisthesis, ligaments thicken and calcify, and the disc space narrows and protrudes. Goel defined facet cages for fusion and has published series treating atlantoaxial instability and cervical and lumbar degenerative stenosis with facet cage fusion [20,26-28]. In accordance with this perspective, we applied facet cage fusion to provide facetal stability and increase foraminal height. We performed this procedure percutaneously to minimize muscle damage. We believe that muscle weakness is the initial stage of the process. While we agree on the importance of stabilization, unlike Goel, we believed decompression was necessary. Therefore, we performed a minimally invasive unilateral laminotomy for bilateral decompression using a speculum. This approach achieved clinical outcomes comparable to or better than those of conventional surgery while maintaining a substantially less invasive surgical profile.

An important consideration when interpreting our findings is that the 2 groups differed not only in the fixation construct but also in the overall surgical strategy. Patients in the LMS group underwent conventional open laminectomy and fusion, whereas patients in the PFC group underwent minimally invasive decompression combined with facet cage fusion. Therefore, the observed differences in perioperative outcomes and postoperative pain likely reflect the combined effect of the minimally invasive approach and the fixation strategy rather than the fixation construct alone. The purpose of the present study was to compare these treatment strategies as they are applied in routine clinical practice rather than to isolate the independent effect of the implant itself.

Limitations

The retrospective and nonrandomized design of the study introduces potential selection bias. Surgical technique allocation was influenced by surgeon preference, evolving practice patterns over the study period, and patient-related factors. In particular, the increased use of the PFC technique during the later study period and its preferential use in higher-risk patients (ASA III-IV) should be considered when interpreting the results. Consequently, unmeasured baseline differences may have influenced the observed outcomes. Additionally, the absence of advanced statistical modeling is a limitation of the present study. Furthermore, the relatively small number of patients in the PFC group may have limited the statistical power to detect differences in relatively infrequent outcomes such as complications, reoperations, and fusion rates. Therefore, the absence of statistically significant differences in these outcomes should be interpreted with caution.

Conclusions

Minimally invasive decompression combined with PFC fusion demonstrated significant advantages in terms of shortening operative time, reducing blood loss, and shortening hospital stay when compared with conventional laminectomy and LMS fixation. Both techniques provided comparable neurological recovery and similar radiological alignment and fusion outcomes. However, patient-reported outcomes, including ODI, pain, and disability scores, were more favorable in the PFC group.

These findings suggest that the PFC technique is a feasible alternative to traditional posterior cervical fusion, particularly in patients who may benefit from a less invasive approach. However, given the retrospective design, nonrandomized group allocation, and relatively short follow-up period, the results should be interpreted with caution. Further prospective studies with larger cohorts and longer follow-up are required to confirm these findings and to evaluate long-term outcomes, including adjacent segment disease.

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Department and Institution Where Work Was Done

Department of Neurosurgery, Adana Faculty of Medicine, University of Health Sciences, Adana, Türkiye.

Declaration of Figures' Authenticity

All figures submitted have been created by the authors who confirm that the images are original with no duplication and have not been previously published in whole or in part.

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