

# Anterior Cervical Reduction Decompression Fusion With Plating for Management of Traumatic Subaxial Cervical Spine Dislocations

Ahmed Shawky Abdelgawaad, MD, MHBA<sup>1,2</sup> ,  
 Arsany B. S. Metry, MBBCh<sup>2</sup>, Belal Elnady, MD<sup>2</sup>,  
 and Essam El Sheriff, MD<sup>2</sup>

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## Abstract

**Study Design:** Prospective case series.

**Objective:** To evaluate the efficacy of anterior-only approach, for treatment of type C F4 (AO classification) traumatic subaxial cervical spine injuries.

**Methods:** Patients with type C F4 traumatic cervical injuries presenting to a tertiary center between June 2017 and July 2018 were included. Outcome measures included self-reported measures (Neck Disability Index, visual analogue scale, and return to work), radiological measures (local segmental angle, Ishihara curvature index, cervical lordosis angle, and step-off distance), fusion state, and neurological state according to American Spinal Injury Association (ASIA) Impairment Scale (AIS).

**Results:** Twenty-one cases were operated by anterior approach with mean age  $39.1 \pm 13.8$  years. The most common injury was at C4-5 (47.6%). Six out of 7 cases (85.7%) with preoperative neurological impairment showed late follow-up improvement by one or more grade in AIS. Complete anatomical reduction and imaging measures did not correlate significantly to the self-reported outcome measures. Median value of local segmental angle improved from  $-16^\circ$  ( $-11^\circ$  to  $-20^\circ$ ) preoperatively to  $0^\circ$  ( $-7^\circ$  to  $8^\circ$ ) at late follow-up. The cervical lordotic angle and Ishihara curvature index improved from  $35^\circ$  ( $29^\circ$  to  $43^\circ$ ) and 6.92 ( $-2.7$  to 28.9) preoperatively, to  $44^\circ$  ( $33^\circ$  to  $51^\circ$ ) and 18.7 ( $-3.5$  to 26.9) at the late follow-up, respectively. Step-off distance decreased postoperatively, however; complete reduction could not be achieved.

**Conclusion:** Surgical treatment of lower cervical traumatic instability by anterior decompression and fusion is efficient regarding fusion state and patients' satisfaction. The anterior approach can be recommended in cases with neurological impairment and in patients with medical comorbidities or when a short operative time—compared with combined approach—is preferred.

## Keywords

anterior cervical decompression and fusion, cervical spine injury, cervical discoligamentous injury, cervical spine fractures, cervical spine subluxation

## Introduction

In 2013, the most common cause of spinal cord injury worldwide was cervical spine injury accounting for 43.9% to 61.5% of all cases.<sup>1</sup>

Most patients with a cervical spine injury, were in their prime age and leading an active lifestyle prior to injury. With any traumatic spine injury, it is critical to assess the spinal stability. In case of subaxial cervical spine, this is commonly done using the 3-column theory. If only 1 column is disrupted, the risk of

<sup>1</sup> Spine Center - Helios Klinikum Erfurt, Erfurt, Germany

<sup>2</sup> Department of Orthopedics and Trauma, Assiut University School of Medicine, Assiut, Egypt

### Corresponding Author:

Ahmed Shawky Abdelgawaad, Spine Center, Helios Klinikum Erfurt, Nordhaeuser Street 74, 99089 Erfurt, Germany.  
 Email: [ahsh313@yahoo.com](mailto:ahsh313@yahoo.com)



spinal cord injury is low because the other 2 columns can maintain the structural integrity of the spine. If 2 columns are injured, the cervical spine can move as 2 independent units with the potential to cause severe cord compromise.<sup>2</sup>

Management of cervical spine fractures varies from external fixation, in the form of orthosis or halo fixation to surgical decompression and internal fixations based on the type of fracture, instability, or presence of cord compression.<sup>3</sup> The main objectives of surgical management of traumatic injuries to cervical spine are decompression of nervous structures and stabilization of the injured vertebral segment. This allows an early mobilization and recovery of the patient, treating associated injuries, boosts rehabilitation, and facilitates returning to their professional activities.<sup>4</sup>

The options of surgical approach for unilateral or bilateral facet injuries include a stand-alone anterior or posterior approach, a combination of both and a staged anterior/posterior/anterior approach. However, there is substantial controversy regarding the most appropriate surgical management,<sup>5</sup> and literature suggests that it depends on approach preferred by the surgeon.

The aim of this study was to evaluate the early results of stand-alone anterior management of type C F4 subaxial cervical spine injuries. Type C is defined as translational injury in any axis, which includes injuries with displacement or translation of one vertebral body relative to another, in any direction. Injuries where the anterior and posterior vertebral elements are distracted, is classified as translational injuries. F4 injuries include injuries at the tip of the inferior articular process of the cephalad vertebrae rests on the superior tip of the superior articular process of the caudal vertebrae, or an injury resulting in the inferior facet of the cephalad vertebrae translating over the superior articular surface of the caudal vertebrae and remaining ventral to the superior facet of the caudal vertebral body.<sup>6</sup>

## Materials and Methods

This is a case series study conducted on patients with traumatic subaxial cervical spine instability at the trauma unit of a tertiary center from June 2017 to July 2019. This study was approved by the institutional review board of the university hospitals where it was conducted.

### Inclusion Criteria

Acute traumatic cases of adult patients with subaxial cervical spine injury, presented to the Trauma Unit of a tertiary center with type C F4 cervical spine injury according to AO classification.

### Exclusion Criteria

Patients with indications of cervical corpectomy and decompressed spinal canal stenosis and central cord syndrome without any evident instability were excluded from our study.

## Preoperative Data

All the patients, who were presented with neurological impairments within 24 hours of trauma incidence received methylprednisolone. In the indicated cases, skull tongs were applied except in those patients whose neurological status could not be determined (such as sedated or intubated patients) and patients with concomitant upper cervical injury and MRI was not available, and patients with skull or brain injury. The following data was recorded: (1) detailed history (sex, age, mechanism of injury—whether it is low or high energy trauma, any comorbidities and occupation); (2) patients were classified based on AO subaxial cervical spine classification; (3) patients were assessed neurologically by the American Spinal Injury Association (ASIA) impairment scale (AIS); and (4) radiological examination.

Following parameters were measured by X-ray on cervical spine (anteroposterior and lateral): (1) Local segmental angle formed between 2 lines; one extended from the upper end plate of the proximal vertebra to the injured facets and the other from the lower end plate of the distal vertebra to the injured facets (negative value was put for kyphotic status while positive one for lordotic status). (2) Ishihara curvature index: It is the ratio of the summation of 4 lines drawn from a point at the middle of posterior borders of C3, C4, C5, and C6 perpendicular to a straight line drawn from inferior-posterior borders of C2 to C7, over the length of the line from C2 to C7. (3) Cervical lordosis angle: It is the angle between a line drawn extending from the anterior tubercle of C1 to the posterior margin of the spinous process of the same vertebra, and other line drawn parallel to the inferior endplate of C7. (4) Step-off distance: It is the distance between the 2 lines tangential to the posterior vertebral body wall of the cephalic and caudal vertebrae, measured at the posteroinferior corner of the superior vertebra.

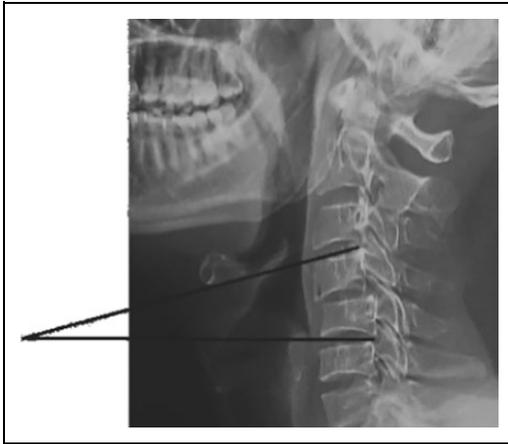
Computed tomography (CT) scan on the cervical spine was performed for evaluation of the bony structures, the extent of encroachment on the spinal canal by vertebral displacement or retro-pulsed bone fragments and the stability of facet joints.

Magnetic resonance imaging (MRI) was performed to evaluate spinal cord signal, canal compression, and disc status.

## Operative Data

The intraoperative data, including operative time, blood loss, and intraoperative adverse events was recorded. Cases were operated by surgeons with variable levels of experience, including senior surgeons (more than 10-year experience) and junior ones (less than 10-year experience).

Reduction was achieved in a stepwise approach; first manipulation under fluoroscopy (achieved reduction in 11 patients), failing which open reduction using convergently positioned Casper screws was used to create local kyphosis at the dislocated segment (achieved reduction in 8 patients). In cases where, both these approaches failed a small Cobb periosteal elevator was inserted in the empty disc space to the posterior corner of the inferior vertebra, leveraging the upper vertebra (achieved reduction in 1 case).



**Figure 1.** Local segmental angle.

Smith-Robinson approach<sup>7</sup> using either a transverse skin incision or a longitudinal one on the right side of neck was performed. A polyether ether ketone (PEEK) cage with bone graft (from the removed bone of the osteophytic endplates) and/or bone substitutes (10 patients local graft, 6 patients local graft + calcium hydroxyapatite, 5 patients calcium hydroxyapatite) were inserted following the discectomy. A locked plate was fixed to the proximal and distal vertebra to stabilize the injured segment. Care was given to use bicortical screws.

### Postoperative Immobilization

External support was given with a rigid cervical collar for 3 weeks, followed by a soft one for another 3 weeks, according to our institutional recommendations.

### Research Outcome Measures:

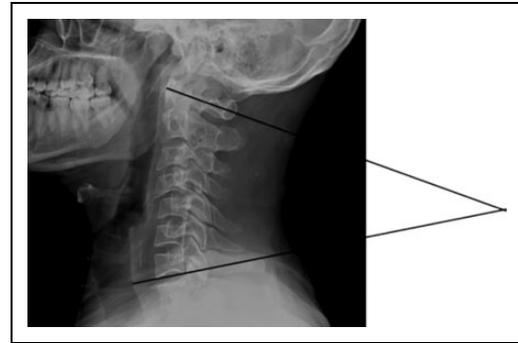
1. Self-reported measures included Neck Disability Index (NDI), visual analogue scale (VAS), and return to work.
2. Physiological measures:

Different radiographic measures were documented such as local segmental angle (Figure 1), Ishihara curvature index, cervical lordosis angle (Figure 2), and step-off distance (Figure 3).

Fusion state was assessed by presence of crossing bone in anteroposterior and lateral X-ray films, mobility on dynamic films, cervical CT scan and measurement of interspinous movement (ISM). ISM is the difference (in millimeters) in the interspinous process distance between the flexion and extension cervical radiographs, used to measure interspinous motion, at each fused cervical level. The most identifiable landmark around the tip of the spinous process, at each level was employed for both the flexion and extension views, on the same monitor simultaneously (Figure 4).

### Follow-up

Three follow-up visits were scheduled as following: after 6 weeks (early postoperative), for neurological examination



**Figure 2.** Cervical lordosis angle.



**Figure 3.** Step-off distance.

and plain X-ray, after 6 months, for clinical and neurological evaluation, and after 12 months (late postoperative: for neurological examination and plain X-ray, dynamic films (flexion and extension views), cervical CT scan, NDI, and VAS).

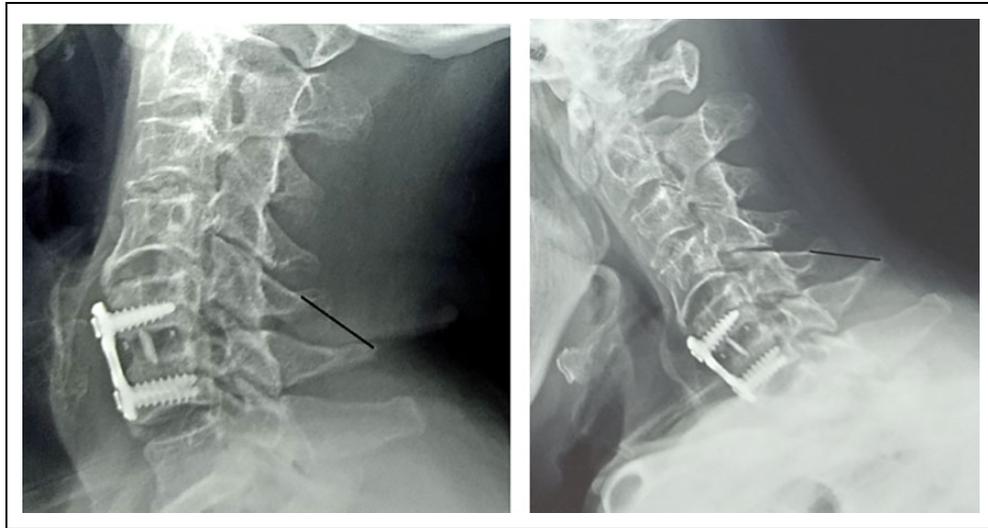
All patients were adequately counseled about their injuries, management options available (including 360-degree fusion), and possible complications. A special consent form to participate in this study was signed either by patient himself or a first-degree relative in presence of a witness, in cases where patient was unable to sign. The research was approved by an independent institutional ethical committee.

SPSS version 20 was used for statistical analysis, including descriptive statistics and tests of significance (*T* test and chi-square).

## Results

### Patients' Demographics

Twenty-one patients were included in this study; of whom 19 were males (90.5%). Their ages ranged from 17 to 60 years (mean  $39.1 \pm 13.8$  years). Manual labor was the most common occupation among these patients.



**Figure 4.** Measurement of interspinous movement.

### *Mechanism of Trauma*

The most common cause of trauma was road traffic accidents (57% motor car accidents and 14% motor bike accidents).

### *Level of Injury*

Twenty patients had single-level injury, and 1 patient had double-level injury. The most common injury level was at C4-5 (10 patients, 47.6%). Six patients had associated disc herniation where the injury level was C3-4 in 1 case, C4-5 in 2 cases, C5-6 in 3 cases. One case had injury at C4-5 associated with fracture C6 (A2 according to AO classification), for which a longer plate fixing C4-7 was done. In another case, the injury level was at C4-5, and associated with spinal canal stenosis at C5-6, for which double level anterior cervical discectomy and fusion was done.

### *Self-Reported Measures*

The mean value of the subjective evaluation of NDI at late follow-up was 16.3% with a standard deviation of 11.3%. No significant correlation was found between NDI and late kyphotic angle. The median value of VAS for pain, at late follow-up was 0 with interquartile range of 0 to 2. Eleven patients (52.4%) reported that they returned to work, whereas 6 patients (28.6%) reported failure to return to their index job (3 of them due to neurological impairment). Furthermore, 2 patients (9.5%) returned to work but with constrained manual duties and 2 patients had never worked before their accidents.

### *AO Classification*

One out of the 21 patients showed type A2 injury (coronal split or pincer fractures) in one level and type C injury in another. F4 subtype (pathologic subluxation or perched/dislocated facet) was detected in all patients; however, 1 patient revealed F4

subtype in one facet and F1 subtype (non-displaced facet fractures) in the other one. Thirteen patients (61.9%) had bilateral facet dislocation or subluxation, and 8 patients (38.1%) had unilateral facet subluxation (5 were on right side while 3 were on left side). According to case-specific modifiers category, M2 subtype (critical disc herniation) was detected in 5 cases (24%) while M3 subtype (stiffening/metabolic bone disease) was detected in one patient, who had diffuse idiopathic skeletal hyperostosis. Seven patients (33%) had N3 subtype (incomplete spinal cord injury).

### *Operative Data*

The median value and interquartile range of the period between admission day and the operation day was 3 days (range 2-4 days). Seventeen cases of 21 (81%) were operated upon by junior surgeons while only 4 cases (19%) were operated upon by senior surgeons. Other operative data (blood loss and operative time) is presented in Table 1.

### *Imaging Studies (Table 2)*

The median value and interquartile range are given in Table 2.

### *Complications*

(1) Neurological complications: 2 (9.5%) patients deteriorated postoperation by 1 or 2 grades of AIS (one deteriorated from grade E to grade C, and the other from grade C to grade B); however, both of them improved during late follow-up. This deterioration might be attributed to the manipulations done, to achieve reduction. At late follow-up, 2 (9.5%) patients developed radiculopathy (both of them were grade D preoperatively) (Table 3). (2) Mechanical complications: only 1 case lost reduction at late follow-up; as a result, revision by posterior approach was planned. (3) Dysphagia: 3 patients (14.3%) complained of persistent dysphagia at late follow-up.

**Table 1.** Operative Data.

Variables	Mean $\pm$ SD
Blood loss, mL	416.7 $\pm$ 82.7
Operative time, min	65.2 $\pm$ 15.1

**Table 2.** Imaging Studies.

	Preoperative	Late Postoperative	P
Local segmental angle, deg	-16 (-11 to -20)	0 (-7 to 8)	<.001
Ishihara curvature index	6.92 (-2.7 to 28.9)	18.7 (-3.5 to 26.9)	<.001
Cervical lordosis, deg	35 (29-43)	44 (33-51)	.003
Step-off distance, cm	0.9 (0.7-0.95)	0.6 (0.5-0.75)	.001
Interspinous movement, mm	—	0.6	—

**Table 3.** Neurological Status Preoperative, Postoperative, and at Late Follow-up (12 Months).

Preoperative	Postoperative	Late Follow-up
A	0	0
B (2 cases)	2 B	1 C and 1 D
C (1 case)	B	C
D (4 cases)	4 D	4 E
E (14 cases)	1 C 13 E	14 E

## Discussion

Subaxial cervical spine subluxations and dislocations represent a common injury pattern in active age group. Decision making regarding reduction and surgical approach is still controversial. The AO subaxial cervical spine injuries classification is the most recent universally accepted classification. Type C F4 injuries represent a complex injury pattern. Treatment goals are reduction, decompression, fusion, and stabilization. Different studies reported the use of anterior only approach for treatment of such injuries (Table 4).<sup>4,8-19</sup> This study focuses on the treatment of complex Type C F4 injuries through anterior only approach. Also, we use the AO classification trying to standardize a common language to describe these injuries. The anterior approach allows easy decompression of the discoligamentous material, which is the most common cause of neurological deterioration in lower cervical spine trauma.

This study reports 21 patients with traumatic subaxial cervical spine injuries. All patients had type C F4 injuries according to the AO classification. Although the local segmental angle improved (increased) at late follow-up, the injured segment was not fully rectified and did not return to the normal lordotic state. This was independent of unilateral or bilateral facet dislocation, as no correlation was detected. On the other hand, there is no significant decrease in late follow-up of local

segmental angle compared to early follow-up. Moreover, the normal lordotic state of cervical spine was restored, evidenced by the increase in cervical lordotic angle and Ishihara curvature index during the late follow-up compared to preoperative state. Partial reduction of the injured segment was achieved in all cases, as the step-off distance decreased postoperatively. However, complete reduction was not achieved as the median value of step off distance is 0.6 cm postoperatively, while the normal value should not exceed 0.35 cm.<sup>20</sup>

In this study, the anterior approach alone was relatively safe in neurologically free patients with low risk of neurological affection postoperatively. As was shown, only one out of 14 neurologically free cases (7.1%) deteriorated postoperatively but improved at late follow-up. In the current study, 6 out of 7 cases (85.7%) with preoperative incomplete paralysis, showed late follow-up improvement by one or more grade in their AIS. Fusion was 100% documented with CT scan and ISM at the final follow-up. All patients had reported low scores of NDI and VAS. Also, 6 patients (28.6%) reported failure to return to work (three of them due to neurological impairment). Moreover, it was observed that complete anatomical reduction and accurate imaging measures do not correlate significantly to the self-reported outcome measures.

Although, the anterior approach alone can reduce a dislocated cervical segment, but it could not restore normal anatomical alignment in few cases. The results of Defino et al<sup>4</sup> were comparably better, as the reported local segmental angle at late follow-up was at range of  $7.55^\circ \pm 5.09^\circ$  of lordosis but there was a loss of  $5^\circ$  lordosis at late follow-up compared with early follow-up. Also, Gao et al<sup>21</sup> showed a better result of  $5.2^\circ \pm 8.6^\circ$  lordosis. Contouring of the plate before its application to the cage while performing anterior-only approach is recommended, in order to restore the normal segmental lordotic state.

When compared with data from the literature, no significant difference was noted between anterior and posterior approaches regarding neurological state. The study by Nakashima et al<sup>22</sup> on posterior approach for cervical fracture dislocations with traumatic disc herniation showed that 9 of 12 incomplete paralysis patients (75%) showed postoperative improvement by more than 1 grade in their AIS. In addition, Brodke et al<sup>15</sup> also showed no significant difference between the 2 approaches as 70% and 57% of patients with neurological impairment improved when treated with anterior approach and posterior approach, respectively.

In this study, the fusion state was detected mainly by 2 measures. The first was CT scan at late follow-up, in which the presence of bridging trabecular bone between the endplates and presence of pseudoarthrosis were assessed. The second method was the measurement of ISM on dynamic views, and the median value was 0.6 mm. Riew et al<sup>23</sup> systematically reviewed and recommended the ISM measured to be less than 1 mm, confirms fusion. Accordingly, this study confirmed good state fusion after anterior cervical discectomy and fusion at late follow-up, efficiently.

According to Kown et al,<sup>12</sup> comparison between the anterior and posterior approach depicted no statistically significant

**Table 4.** Authors Who Have Demonstrated Safety of the Anterior-Only Approach.

Author(s)	Title of Article	Journal/Year	Approach	Follow-up Period	Summary of Conclusion
Vignesh Shyayee	Early outcome of surgical intervention in subaxial cervical spine injuries	<i>International Journal of Research in Medical Sciences</i> 2018	38 cases anterior approach 2 cases posterior approach	3 months	Majority of subaxial cervical spine fractures can be treated effectively with good outcome through anterior approach.
Chen Song	Anterior decompression and internal fixation for lower cervical spine dislocation	<i>International Journal of Clinical and Experimental Medicine</i> 2016	42 patients, anterior approach only	1 year	Anterior surgical fixation using titanium mesh cages and locking plates is a proper choice for short operation time, little hemorrhage volume, low complication rate, and high fusion rate.
Helton L.A. Defino	Treatment of traumatic dislocations of the cervical spine through anterior approach	<i>Acta Ortopedica Brasileira</i> 2015	20 anterior approach only	1-14 years	Anterior approach and fixation for single or double facet dislocation presented a high rate of good outcomes (clinically, X-rays, functional) and a low complication rate.
Abdul Satar and Zahid Wazir	Early outcome of surgical intervention in subaxial cervical spine injuries	28th International Pak Orthocon 2014	43 patients, anterior approach 5 cases posterior approach 2 cases combined approach	1 year	Majority of subaxial fractures can be treated effectively with good outcome through anterior approach.
Riaz A. Raja	Anterior decompression, fusion and plating in cervical spine injury: our early experience	<i>Journal of Ayub Medical College Abbottabad</i> 2008	37 patients, anterior approach only	1 year	The use of anterior cervical plating in cervical spine injuries enhances arthrodesis. Improved fusion rates, low complications and early rehabilitation justify the use of anterior instrumentation in cervical spine injury.
Brian K. Kwon	A prospective randomized controlled trial of anterior compared with posterior stabilization for unilateral facet injuries of the cervical spine	<i>Journal of Neurosurgery: Spine</i> 2007	20 patients for anterior approach and 22 patients for posterior approach	12 months	Both posterior and anterior surgical approaches are viable alternatives for treating these injuries, although they have different risk profiles. Further follow-up will be required to determine the long-term clinical significance of the radiographic differences between the two groups of patients.
Reindl R	Anterior reduction for cervical spine dislocation	<i>Spine Journal</i> 2006	41 patients, anterior approach only	1 year	Most subluxations/dislocations of the subaxial cervical spine can be reduced using Gardner-Wells traction and successfully stabilized with anterior surgery alone. If closed reduction fails, anterior open reduction is successful in most cases.
Ramazan Alper Kaya	Selection of the surgical approach for stabilization of subaxial cervical spinal injuries	<i>Turkish Neurosurgery</i> 2005	37 anterior, 4 posterior, 6 combined	18 months	The column affected by injury according to the 3-column theory, the presence of a retropulsed bone or a disc fragment causing spinal cord compression and the age at injury are the most important factors guiding the selection of the surgical approach for patients with subaxial cervical spine instabilities.
Johnson MG	The radiographic failure of single segment anterior cervical plate fixation in traumatic cervical flexion distraction injuries	<i>Spine Journal</i> 2004	87 cases, anterior approach only	6 months	Loss of postoperative alignment occurred in 13% of facet fracture subluxations treated with anterior cervical discectomy, fusion, and plating. Concern regarding mechanical failure of flexion/distraction injuries should be high when they are associated with fractures of either the facets or of the endplate. Endplate fracture was associated with both mechanical failure and pseudarthrosis.

(continued)

**Table 4.** (continued)

Author(s)	Title of Article	Journal/Year	Approach	Follow-up Period	Summary of Conclusion
Darrel S. Brodke	Comparison of anterior and posterior approaches in cervical spinal cord injuries	<i>Journal of Spinal Disorders &amp; Techniques</i> 2003	20 patients for anterior approach, 27 patients for posterior approach	6 months	Either anterior fusion with the addition of plate fixation or posterior fusion with lateral mass plate-screw fixation can effectively stabilize the injured segment in patients with unstable fractures after successful closed reduction. The decision may be based on surgeon preference and conditions of the patient.
Todorov I	Fractures of the lower cervical spine, posterior or anterior approach	<i>Acta Chirurgica Macedonica</i> 2002	30 cases, anterior approach 104 cases, posterior approach	10 years	The posterior approach and fixation with plates and screws in the articular mass, it is an excellent method in the treatment of the injuries affecting the middle segment of the vertebra. The anterior approach applied exclusively in cases with a fracture of the vertebral body (which is approximately one third of our series) as a rule, gives the expected results of decompression and solid fixation.
Bernardo J. Ordonez	Cervical facet dislocation: techniques for ventral reduction and stabilization	<i>Journal of Neurosurgery</i> January 2000	10 cases, anterior approach only	6 months	The authors conclude that a ventral surgical decompression, reduction, and stabilization procedure provides a safe and effective alternative for the treatment of patients with unilateral or bilateral cervical facet dislocation without significant bone disruption. Risk factors that appear to be associated with failed ventral reduction procedures include significant dorsal element disruption and comminuted fractures of the facet complex.
Mix Aebi	Treatment of cervical spine injuries with anterior plating. Indications, techniques, and results	<i>Spine Journal</i> 1991	86 patients, anterior approach only	40 months	The technique of anterior bone grafting and plating is shown to be straightforward, atraumatic, and reliable for predominantly anterior lesions as well as for posterior injuries when performed properly.

differences between the patients. This was supported by similar findings from Del Curto et al.<sup>24</sup>

The mean operative time in this study was  $65.2 \pm 15.1$  minutes, while mean blood loss was  $416.7 \pm 82.7$  mL. It is known that the anterior approach takes shorter operative time than the posterior approach, as Kown et al<sup>14</sup> reported that the mean operative time was 103 minutes and the average blood loss was less than 100 mL in posterior approach. Similar results were also reported by Yukawa et al<sup>25</sup> on posterior approach, in which the mean operative time was 101 minutes and the mean blood loss was 190 mL. This confirms that the anterior approach, which takes less operative time, is suitable for patients who cannot withstand a long time of anesthesia and for those with neurological impairment, as time is a critical factor for them. Nevertheless, this study shows that the anterior approach leads to more intraoperative blood loss, compared to posterior approach; however, this might also depend on the surgeon's experience.

Potential limitations of this study include the relatively small number of subjects in order to establish a significant correlation between the radiological findings and the type of injury or between the self-reported measures and the radiological findings. Moreover, the period of follow-up is short to give an accurate comment on mechanical failure or to detect any pathology that may appear in the adjacent segments.

## Conclusion

Surgical treatment of subaxial cervical traumatic injuries by means of anterior reduction decompression and fusion is efficient regarding fusion state and the patients' satisfaction. Compared with the combined anterior and posterior approach, the anterior-only procedure takes shorter time and appears to be less traumatic to patients. However, the angle of the injured segment does not return to its normal lordosis, and the full reduction is not achieved. Consequently, the anterior approach alone is recommended in cases with neurological impairment and in patients with medical comorbidities or when a short operative time is preferred.

## Declaration of Conflicting Interests

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## ORCID iD

Ahmed Shawky Abdelgawaad  <https://orcid.org/0000-0003-2083-7265>

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