

# Anterior Plating for Cervical Traumatic Fractures: An Analysis of Graft Height and Segmental Lordosis Preservation

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## Abstract

Study Design: A 5-year retrospective review of cases treated for traumatic cervical spine injuries.

Objective: To assess the clinical impact of the biomechanical properties for cervical plates systems on patient's radiological outcome. This was addressed by comparing the degree of graft height and lordosis loss between constrained fixed angle plates, semiconstrained rotational angle plates, and semiconstrained with translational and rotational angle plates (Synthes CSLP, Codman, Medtronic Atlantis, and ABC Aesculap)

Methods: This investigation comprised a total of 70 cases, including 61 cases of single-level ACDF and 9 cases of two or more level ACDF. There were 24 cases of CSLP, 15 cases of Atlantis, 13 cases of Codman and 18 cases of ABC plates used. Digitized lateral cervical spine x-rays were done at each patient follow up. Computer-assisted measurements of Cobb angles and graft height, allowed a recording of any loss in lordosis or graft height for each construct. Post-operative follow-up lasted up to 18 months.

Results: Loss of cervical lordosis from the ABC, Codman, Atlantis and CSLP plates were 4.16 degrees, 6.1 degrees, 6.45 degrees, 10.3 degrees on average respectively. Loss of graft height was 10.4% for the ABC, 37.2% for the Codman, 19.4% for the Atlantis and 31.8% for the CSLP implants. There were a total number of 2 plate fractures (CSLP constructs), 7 cases of graft extrusion (4 CSLP, 1 Atlantis, 2 Codman), and 2 cases of screw breakage (1 CSLP and 1 Atlantis).

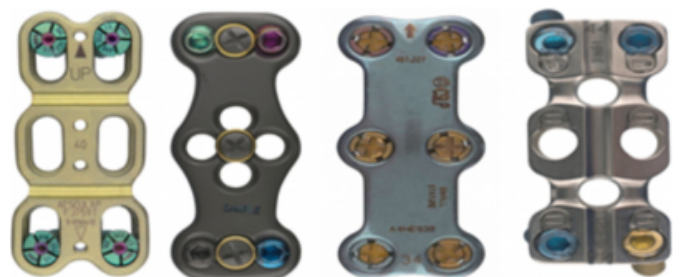
Conclusion: The semiconstrained translational, and rotational angle plates fared best with regards to loss of cervical lordosis and graft subsidence ( $p < 0.05$ ). This observation suggests that differences in plate design may have significant effects on subsequent segmental arthrodesis.

## INTRODUCTION

The use of anterior plating for cervical trauma is well established both in the literature and clinical practice.<sup>12, 13, 14, 15, 16</sup> Recently, several studies have demonstrated the enhanced stability provided by these plates<sup>1, 2, 3, 4</sup> in achieving a rapid optimal fusion. Decreased complications from graft displacement, plate fractures, restoration of normal lordotic curve, and reduction of pseudoarthrosis rate, have also been reported as potential advantages of anterior cervical stabilization.<sup>20, 21, 22</sup> The numerous commercially available plate designs differ significantly with regards to their biomechanical properties. These plates include constrained, semi-constrained, rigid, and dynamic types of screw-plate interfaces (Figure 1).

## Figure 1

Figure 1: Photographs of the 4 different plating devices used. From left to right: the ABC (semiconstrained translational and rotational), the Atlantis (constrained/semiconstrained rotational), the CSPL (constrained), and the Codman (semi-constrained rotational) plate.



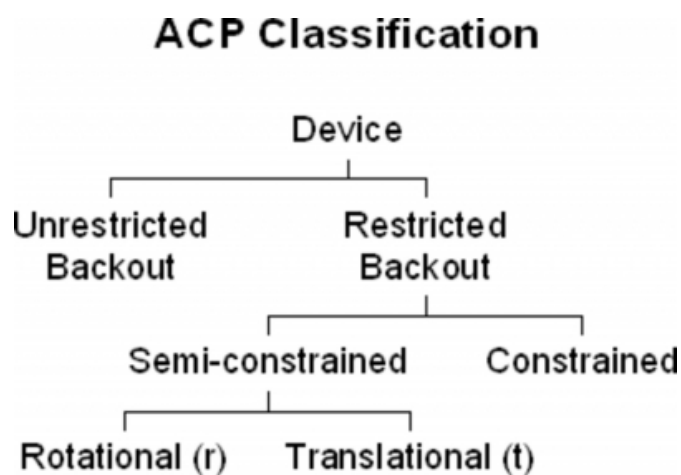
Several authors have demonstrated that, these differences in the physical properties of the plates result in significantly different in-vitro biomechanical and load-sharing profiles. 17,

18, 19

Some of the clinical concerns that regarding anterior plating include the incidence of hardware failure, fusion rate, stress-shielding properties, and the risk of pseudoarthrosis. This has led some surgeons to propose a classification scheme based on these differences in plate-screw interface. 32 (Figure 2)

**Figure 2**

Figure 2: Anterior cervical plating (ACP) classification as described by Haid et al. 32



Whether or not bench-top engineering differences in plate design have a clinical impact on these parameters has not been conclusively shown. The purpose of this study was thus to examine whether these fundamental variations in plate structural design are associated with differences in radiographic outcome after anterior plating for traumatic cervical injury.

**METHODS AND MATERIALS**

**STUDY DESIGN AND PATIENT DEMOGRAPHICS**

This was a 5-year retrospective investigation of 70 cases conducted at two institutions. Patients admitted with a diagnosis of anterior cervical spine trauma were collected from two major metropolitan trauma centers, namely the Los Angeles County Hospital in Los Angeles, California and the Cook County/Rush Hospital in Chicago, Illinois. There were a total of 61 cases of single-level injury and 9 cases of two-level anterior column injury. The classifications of injury for the single-level cases involved 17 compression type

fractures, 10 hyperflexion/avulsion fractures, 3 chance fractures, 10 unilateral perched facets, 5 bilateral locked facets, 5 fracture dislocations and 11 classic burst fractures. The 9 cases of two-level injuries were comprised of 3 compression and burst fractures, 3 unilateral locked facet and compression, 2 fracture dislocations with C2 fracture, 1 bilateral locked facet with adjacent burst fracture, and 1 multilevel compression fracture.

**SURGICAL APPROACHES AND IMPLANTS USED**

Anterior cervical decompression, grafting, and instrumentation were used to treat these patients at the two major metropolitan trauma centers. Although the majority of patients underwent anterior surgery, there were a few cases of posterior surgery as well. The specific operative procedures were as follows: 4 patients had a single level anterior cervical discectomy and fusion (ACDF), 3 patients underwent a single-level ACDF and a posterior surgery, 49 patients had a single-level anterior cervical corpectomy and fusion (ACCF) alone, 5 patients had a combined single-level ACCF and a posterior surgery, 6 patients had a two or more level ACDF/ACCF procedure combined with a posterior procedure, and 3 patients had a complex staged procedure.

There were several goals achieved by the surgical intervention. These included; a decompression of the neural elements by removing fractured retropulsed bone, foreign bodies or devitalized tissue. A restoration of the cervical alignment and lordosis, as well as anterior load bearing, anterior and posterior tension bands was also accomplished.

The graft types used comprised 58 cases of fibular allograft, 4 cases of iliac crest allograft, 7 cases of iliac crest autograft and 1 case of fibular autograft. Four different types of cervical plating systems were used during surgery; the semiconstrained translational rotational ABC Aesculap, the semiconstrained rotational Codman, the fixed angle constrained CSLP, and the semiconstrained rotational Atlantis plates (Figure 1). The effect of their biomechanical properties on radiologic outcome was assessed by serially measuring the resultant loss of cervical lordosis, and graft height.

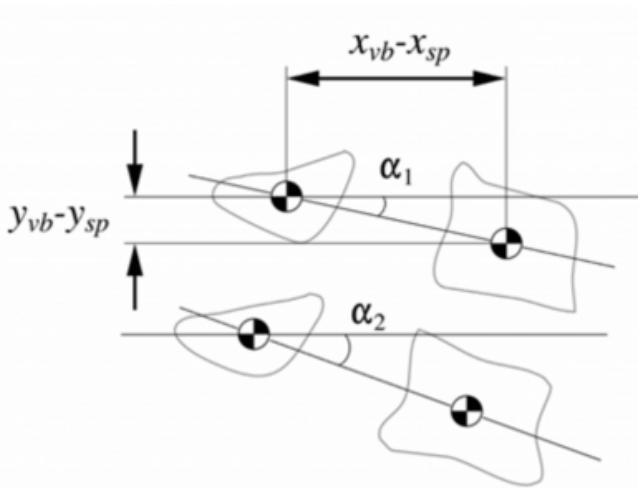
**METHODOLOGY OF X-RAY SCANNING**

Lateral cervical spine radiographs were performed peri-operatively and post-operatively. With the use of computer-assisted digitization methods, a center of each vertebral body was localized at the intersection of two diagonals originating

from its antero-superior, antero-inferior, postero-superior and postero-inferior reference points. After establishing a similar central point for the posterior vertebral elements, a straight line was formed to connect both centers of anterior and posterior vertebral elements. Horizontal lines passing through each center were also made, which could allow coordinates measurements on the adjacent and opposite side of the angle formed (Figure 3).

**Figure 3**

Figure 3: Schematic representation of the determination of the Cobb angle at graft and the graft height on digitized plain radiographs, using computer-assisted measurements as described by Herman and Geisler 41 .  $\tan \theta = (Y_{vb} - Y_{sp}) / (X_{vb} - X_{sp})$ , vb=Center field of vertebral body, sp=Spinous process center field.



Using digital measuring software, Cobb angles and graft heights were then calculated from these digitized radiographic images as described by Herrman and Geisler. 41 The initial lordotic angle and graft height at the operated motion segment were obtained from day 0 through day 1 (peri-operative) with follow-up lateral radiographs at an early (range 5-9 weeks), middle (4-6 months), and late interval (10-18 months). Graft height, segmental lordosis deformity, screw location, construct location and construct integrity were recorded at each follow-up encounter. Only radiographic data was recorded with clinical information noted in cases of construct or graft migration / failure. No clinical outcome vehicles were used in this study, given the heterogeneity of our spinal injuries and group of treating surgeons at two hospitals.

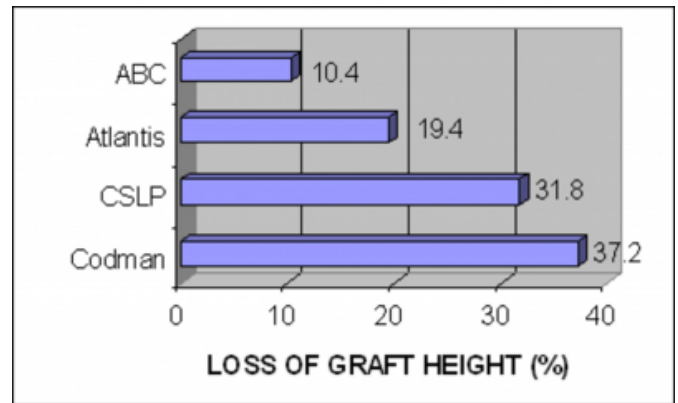
**RESULTS**

**RADIOGRAPHIC FINDINGS ON VARIOUS PLATING SYSTEMS**

Of the 70 cases: 18 were treated with ABC plate (variable angle, dynamic), 24 were treated with CSLP type plates (fixed angle, rigid), 15 were treated with Atlantis Plates (variable angle, rigid), and 13 were treated with Codman Plates (fixed angle, rigid). (Table 1, figure 4 and 5)

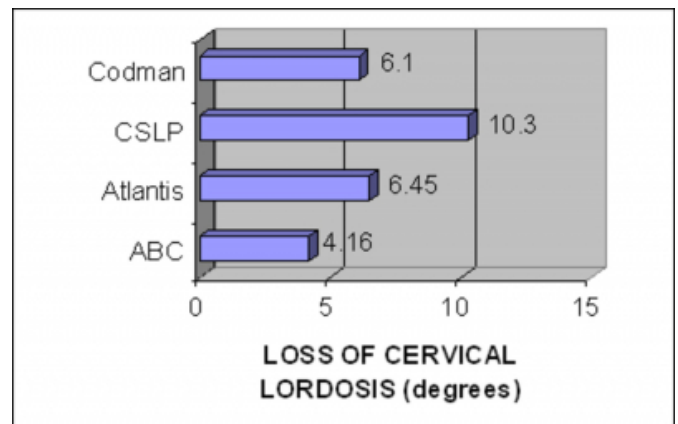
**Figure 4**

Figure 4: The semiconstrained plates yielded better results with the translational type doing best. Their percent average loss of graft subsidence (10.4%) over one year was much lower than other implants.



**Figure 5**

Figure 5: The average loss in segmental cervical lordosis appears to be much lower for the semiconstrained translational plates (4.16°), when compared to other plates.



**Figure 6**

Table 1: The use of semiconstrained translational plating system showing a much reduced incidence of screw pull-out, construct failure and graft extrusion.

	CSLP	Atlantis	Codman	ABC
Screw Pullout/Damage (%)	13	20	31	11
Construct Failure (%)	13	7	0	0
Graft extrusion (%)	17	7	15	0

Of the 24 CSLP plated cases, there were 2 cases of plate fracture (one early interval, one middle interval), 2 other cases of upper screw partial pullout (middle interval), 1 frank screw fracture (early interval), and 4 overall cases of construct migration or extrusion.

Of the 13 Codman cases, there were 2 cases of partial upper screw pullout (middle interval), 2 cases of plate rotation anteriorly with upper screw pullout (middle interval), and 2 cases of frank construct migration or extrusion (one middle interval, one late interval). There were no cases of screw or plates breakage.

For the 15 Atlantis cases (10 fixed and 5 hybrid constructs), there was a single case of a screw fracture (fixed type construct in middle interval), 3 cases of upper screw partial pullout (one middle interval, one late interval, and one case of delayed late interval) graft extrusion / migration. No cases of plate fractures were observed.

For the 18 ABC plate cases, there were two cases of upper screw partial pullout (one middle interval, one late interval) with the late case also associated with rotation of the superior end of the plate. Zero cases of screw or plates breakage were noticed.

**GRAFT HEIGHT AND SEGMENTAL LORDOSIS**

After excluding all cases of frank construct failure, the radiographic 1-year outcome in term of subsidence (Figure 4) and lordosis (Figure 5) were as follows: Atlantis Plates: 19.4% average graft subsidence, 6.45 degrees average loss of lordosis; Codman Plates: 37.2% graft subsidence, 6.1 degrees loss of lordosis; ABC plates: 10.4% graft subsidence, 4.16 degrees loss of lordosis; and CSLP plates 31.8% graft subsidence 10.3 degrees loss of lordosis. For most cases without hardware failure, the majority (average 67%) of graft resorption and lordosis loss occurred between the time of operation and the early interval follow-up period (range 5-9 weeks).

As a variable, posterior surgery and type of graft were not

statistically significant with regards to graft height loss or lordosis. Posterior surgery and multi-level constructs were associated with a higher incidence of screw pullout and construct migration. However, this did not reach a statistical significance.

**DISCUSSION**

The use of anterior cervical plating for the treatment of unstable spinal injuries, is well established and has shown to restore structural integrity, spinal balance, and enhance overall successful arthrodesis.<sup>14, 23, 24, 25</sup> The specific benefits generated by anterior plating include the immediate stability, better restoration of the lordotic curve, shortened fusion time, improved fusion quality and a decreased rate of pseudoarthrosis. The combined use of bone graft and plate has been shown to further improve spinal stability.<sup>26, 37, 38, 39, 40, 41</sup> In cases where only bone graft is applied, both mechanical load and fusion must occur in the same material. Initial response to healing involves a softening at the interface of host vs. graft. If plate and screw support is used in addition to the bone graft, the plate can carry some of the mechanical load while the bone is healing. Moreover, sagittal balance has been shown to be better preserved with plate and screw additional support.(refs!!!)

In their study on anterior cervical plating<sup>33</sup>, DiAngelo et al were also able to demonstrate that ventral rigid implants would reverse load sharing at the strut-graft interface. On extension, increased loading would occur and the opposite would be observed during flexion.

Despite this better understanding of spinal stability nowadays, knowledge about the impact of each plate’s geometry and biomechanical properties on the functional recovery of patients has remained limited.

In order to better understand the biomechanics attributed to each of these plates, one needs to carefully review what constitutes their fundamental structure. The constrained type (CSLP) plate is fixed, and uses fixed screws without allowing any motion upward or downward. This plate will thus limit compressive loading considerably, and maximize stress shielding. The semi-constrained type (Atlantis), is also a fixed plate and does not allow motion of the plate, but can use variable screws. Rotational motion of the screws at the screw-plate interface is permitted here. Hence, stress shielding effect and reduced compression are not as pronounced as in the case of a constrained plate. This particular construct, however, may also act as a rigid

construct when using fixed-angle cantilever screws. The dynamic type plate (ABC Aesculap), on the other hand, allows some level of screw motion cephalad and caudad which greatly lowers stress shield and resistance to compression. This ability for translation and rotation at the screw-plate interface permits desirable axial and angular deformation to occur. Certainly, assuming that the level of this dynamic motion remains somehow controlled.

These intrinsic features associated with each plate may thus result in differences pertinent to the degree of cervical lordosis restoration, anterior load bearing continuity as well as tension within the posterior elements. The properties of each plate are further important as they would allow different amounts of compressive loads on the spine. As described by the Wolff's law<sup>31</sup>, optimal bone healing must occur under compressive loads. Previous reports<sup>28, 29, 30, 34</sup> in concordance with Wolff's theory<sup>31</sup> have also shown that, successful spinal fusion occurs when the bone is exposed to compression forces. By allowing the graft to share the load, it would mature quicker and more fully. Cheng et al<sup>34</sup> concluded that, the spine should be exposed to 70% of the load in order to maximize arthrodesis and acute stability. Thus, the considerable load sharing properties of dynamic plates would be beneficial in preventing screws loosening and back out, while effectively stabilizing the spine to restore or preserve lordosis. A previous investigation by Brodke et al on biomechanical evaluation of load sharing and stiffness showed that, dynamic plates would load share more effectively than the locked cervical plates<sup>17</sup> when the graft was shortened by 10%. The ABC plates, in this study, shared a much higher percentage of applied axial load over a greater range in comparison to locked cervical plating systems. The recent use dynamic plating systems, has shown to improve rates of fusion, allow impressive preservation of lordosis, and lower rates of failure over other systems, which stress-shield.<sup>7, 8</sup> Early settling in the range of 1-2 weeks post operatively, has indeed been observed with the use of dynamic plate types.<sup>35, 36</sup>

Despite the heterogeneous nature of our study cohort, there were significant trends with regards to lordosis and graft height preservation between the various plate types. The dynamic plates and variable angle plates, indeed, fared much better with regards to maintenance of these two parameters. Overall, the dynamic plate was superior in maintaining the graft height and cervical lordosis ( $p < 0.05$ ). The more rigid implants with their greater stress shielding capabilities may

have allowed for non-union, delayed union or implant failure to occur. Kaiser et al reviewed 251 patients who underwent ACDF with the use of Orion, Codman and Atlantis plating systems. A trend toward higher rate of arthrodesis was observed with newer generation plates, with the Atlantis plating systems yielding a 98% fusion rate for single level lesion<sup>26</sup>. When comparing only the above two plating systems (Codman and Atlantis) in our data, the Atlantis plates were indeed noted to have lower percentage of screw pull out, construct failure, graft displacement or loss of graft height. The semiconstrained plates with translational and rotational angle, however, were much superior when making a comparison across all plates design used in our study. In other studies involving single level or multilevel anterior cervical corpectomies, the authors demonstrated that, in the absence of plating and when fully constrained or semi-constrained rotational only plates were used, constructs failure would occur most often<sup>27, 21</sup>. Their dynamic implants (semiconstrained with translational and rotational angle), however, did not show any graft/plate or vertebral body to graft dislocation.

In term of future studies, few authors have already started to compare unicortical vs. bicortical screws<sup>9</sup>, ability to vary screw insertion angle<sup>10</sup>, and direct comparisons of ease-of-use, rate of failure, and safety to patients between various plating systems<sup>11</sup>. Nevertheless, more data in this direction is needed, in order to provide valuable information for optimal spinal stability and fusion.

## STUDY LIMITATIONS

There were several major flaws with the design of the study including: different operative surgeons, heterogeneous fracture and injury patterns, different experience and comfort levels with the plating systems, patient selection biases, and heterogeneous operative and grafting techniques (iliac crest versus fibula, allograft versus autograft).

## CONCLUSION

Despite these study limitations, our observations suggest that improved load-sharing characteristics of plate designs tended to result in less graft resorption and thereby better maintenance of cervical lordosis. Thus the optimal anterior cervical plate for trauma should take into account these load-sharing and dynamic characteristics.

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