A Comparative Analysis of Plate/Graft Failure with Correction Following Circumferential Cervical Spinal Surgery

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ABSTRACT

Object: To evaluate the incidence of failure of fixed versus dynamic plates following multilevel circumferential cervical procedures addressing multilevel ossification of the posterior longitudinal ligament and spondylolisthesis. Two to four level anterior cervical corpectomy with fusion (ACF) was accompanied by simultaneous C2-T1 posterior wiring and fusion (PWF).

Methods: Fixed Plating System "Constrained" Orion (Sofamor Danek, Memphis, TN, USA) plates, employing a fixed plate/fixed screw design, were applied in 2 level ACF (6 patients), 3 level ACF (14 patients), and 4 level ACF (2 patients). "Semi-constrained" Atlantis plates (Sofamor Danek, Memphis, TN, USA), utilizing a fixed plate/variable screw design, were used in the next 16 patients undergoing 2 level ACF (5 patients), 3 level ACF (9 patients), and 4 level ACF (2 patients). Orion plated patients had iliac crest autografts while Atlantis plated received fibula strut allografts. The integrity of the graft and plate, as well as the status of the fusion, was documented on static X-rays at four week intervals, with dynamic X-rays and 2D CT studies ordered three, six, and 12 months postoperatively.

Dynamic Plating System In addition, 25 comparable patients undergoing 2 level ACF (11 patients), 3 level ACF (9 patients), and 4 level ACF (2 patients) combined with PWF received dynamic ABC plates (Aesculap, Tuttlingen, Germany).

Results: Two Orion plates and three Atlantis plates failed (13%). One of the two Orion plates which extruded inferiorly was removed six months postoperatively for persistent dysphagia, while all three Atlantis plates which extruded inferiorly along with the grafts required urgent anterior plate and graft replacement. Only one of the 25 patients receiving ABC plates required a secondary PWF for partial pseudarthrosis 6 months postoperatively.

Conclusions: Fixed plate failures, encountered in 13% of circumferential procedures, were largely attributed to increased graft shielding with reduced graft compression, while the success of dynamic plates was primarily due to reduced graft shielding and increased graft settling.

Key word: fixed plating, circumferential cervical surgery anterior posterior fusion

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INTRODUCTION

Significant failure rates have been reported following non-plated and plated multilevel anterior cervical corpectomy with fusion (ACF) procedures performed with or without simultaneous posterior fusion (PF) (ACF) [10, 21, 22]. Saunders observed a 10% rate of inferior graft extrusion following 31 non-plated 4 level ACF [21]. Epstein observed a 14% incidence of graft extrusion after 22 non-plated 2-4 level ACF accompanied by 7 level posterior wiring and fusion (PWF) [10]. The addition of fixed plates to long anterior constructs without accompanying posterior fusion did not avoid plate and graft extrusion as reported by Vaccaro, et. al. wherein 9% of two level ACF, and 50% of three level ACF grafts and plates failed [22]. Our plate and graft failure rates following the application of 22 "constrained" Orion Plates (Sofamor Danek, Memphis TN, USA), and 16 "semi-constrained" Atlantis Plates (Sofamor Danek, Memphis TN, USA) applied in patients undergoing multilevel circumferential cervical procedures were reviewed and the results compared with the use of dynamic ABC plates in a similar group of patients.

MATERIALS and METHODS

< Fixed Plating Systems >

Clinical Data: Thirty-eight patients undergoing circumferential surgery utilizing fixed anterior cervical plates averaged 52 years of age, and included 22 males and 16 females (Table 1). Preoperative evaluations included both MR and CT-based studies demonstrating multilevel OPLL, spondylosis, and stenosis. Preoperatively, patients exhibited a moderate to severe myelopathy (average Nurick Score of 3.7). Postoperatively, patients improved to showing a mild residual myelopathy (average Nurick Score of 0.8). Patients were followed for a mean duration of 4.7 years.

"Constrained" and "Semi-constrained" Plates: The fixed plates applied averaged 81 mm in length, with a range of 55 to 110 mm. The "constrained" Orion fixed plate and fixed screw system which allowed for no plate migration, was applied in the first 22 patients undergoing 2 level ACF (6 patients), 3 level ACF (14 patients), and 4 level ACF (2 patients) accompanied by C2-T1 PWF. The "semi-constrained" Atlantis fixed plate with variable screw system allowing for up to 2-3 mm of plate migration due to 17 degree toggling of the cephalad and caudal screws, was applied in the subsequent 16 patients undergoing 2 level ACF (5 patients), 3 level ACF (9 patients), and 4 level ACF (2 patients) accompanied by C2-T1 PWF.

< Dynamic Plating Systems >

Clinical Data: The 25 dynamic-plated patients averaged 53 years of age (range 42-70 years old), and included 17 males and 8 females (Table 1). Preoperative MR and CT studies similarly demonstrated OPLL and spondylosis. Preoperatively, patients exhibited an average Nurick Score of 3.5 (moderate/severe myelopathy), while postoperatively they improved demonstrating a Nurick Score of 0.4 (radiculopathy/mild myelopathy). Patients were followed for a mean duration of 2.2 years.

Dynamic Plates: Dynamic plates which averaged 79 mm in length (range of 58 to 103 mm) were employed to perform 2 level ACF (12 patients), 3 level ACF (11 patients), and 4 level ACF (2 patients) with PWF. On six week, three, and six month postoperative lateral plain films, dynamic plates allowed for an average of 6.5 mm (range 5-9 mm) of cephalad and 5.8 mm (range 3-9 mm) of caudal plate migration.

Radiographic Follow-Up: Static X-rays (every 4 weeks), and dynamic X-rays, and 2D CT studies obtained 3, 6, and 12 months postoperatively were performed in all patients to document fusion progression.

Operative Procedures: Anterior cervical corpectomy with fusion (ACF), averaging 3 levels (range 2-4 levels), was performed using reversed iliac crest autograft in the first 22 patients in whom Orion plates were applied, and fibula allograft was used in 16 additional patients receiving Atlantis plates. For those 25 receiving dynamic plates, fibula strut allografts were placed. Grafts were placed into partial perforations in otherwise intact cephalad and caudal vertebral end plates, following removal of the anterior superior and anterior inferior cortical vertebral...
Nancy E. Epstein: A Comparative Analysis of Plate/Graft Failure with Correction Following Circumferential Cervical Spinal Surgery

Table 1: Multilevel Anterior Corpectomy and Fusion (ACF) With Posterior Wiring and Fusion (PWF) Using Fixed-Plates

<table>
<thead>
<tr>
<th>Data</th>
<th>Non-Dynamic Plated Multilevel ACF/PWF (38 Patients)</th>
<th>Dynamic-Plated Multilevel ACF/PWF (25 Patients)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Average Age Range</strong></td>
<td>52 years (28-72)</td>
<td>53 years (42-70)</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>22</td>
<td>17</td>
</tr>
<tr>
<td>Females</td>
<td>16</td>
<td>8</td>
</tr>
<tr>
<td><strong>Average Number of Anterior Corpectomy Levels</strong></td>
<td>3</td>
<td>2.6</td>
</tr>
<tr>
<td><strong>Average Plate Length (Range)</strong></td>
<td>81 mm (55-110 mm)</td>
<td>79 mm (58-103 mm)</td>
</tr>
<tr>
<td>2 Level ACF</td>
<td>21</td>
<td>12</td>
</tr>
<tr>
<td>3 Level ACF</td>
<td>23</td>
<td>11</td>
</tr>
<tr>
<td>4 Level ACF</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td><strong>Average Time To Fusion Range</strong></td>
<td>4.8 months (Range 3-8 months)</td>
<td>4.5 mo (Range 3-9 mo)</td>
</tr>
<tr>
<td><strong>Average Follow-Up Interval</strong></td>
<td>4.7 years</td>
<td>2.2 years</td>
</tr>
<tr>
<td><strong>Neurological Outcome</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Preoperative Nurick Score</td>
<td>3.7</td>
<td>3.5</td>
</tr>
<tr>
<td>Average Postoperative Nurick Score</td>
<td>0.8</td>
<td>0.4</td>
</tr>
<tr>
<td><strong>Caudal Plate:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extrusion</td>
<td>5 (13%)</td>
<td>0</td>
</tr>
<tr>
<td>Migration</td>
<td>10 (26%)</td>
<td>0</td>
</tr>
<tr>
<td>Pseudarthrosis</td>
<td>0</td>
<td>1 (4%) Partial Pseudarthrosis</td>
</tr>
</tbody>
</table>

Nurick Grade: Grade 0=Intact, Grade I=Mild Myelopathy, Grade II=Mild/Moderate Myelopathy, Grade III=Moderate Myelopathy, Grade IV=Moderate/Severe Myelopathy, Grade V=Severe Myelopathy, Nurick Score obtained by assigning Arabic numbers to the different Nurick Grades given in Roman Numerals
Fig. 1 (Case 1): A 53 year old female had a C3-C7 ACF with an iliac crest autograft and Orion plate accompanied by a C2-T1 PWF. One month postoperatively, the six month postoperative midline sagittal 2D CT confirmed caudal graft and plate migration, leaving the screws in the C7-T1 interspace (double arrows). Note the hyperdense margin between the inferior iliac crest strut and the residual C7 vertebral body (curved arrow) indicating fusion. Dynamic X-rays also confirmed stability.

Figure 2 (Case 2): The 6 month postoperative 2D coronal CT scan in the same patient demonstrated caudal graft (single large arrow) migration with screw migration with screw extrusion into the C7-T1 interspace (double small arrows). As inferior and posterior fusion were now confirmed both on CT and dynamic X-rays, persistent dysphagia was treated with elective plate removal.

margins. Immediately following completion of the ACF with halo application, patients were then turned prone and a seven level C2-T1 posterior wiring with fusion (PWF) was performed. PWF utilized split fibula allografts wired to the base of the individual spinous processes with braided titanium cables. graft constructs were supplemented with iliac crest autograft. Operative procedures averaged 10 hours (range 9-14 hrs), requiring an average of 3 units of blood (range 1-10).

Halo Bracing and Time to Fusion: All 38 patients receiving fixed plates and 25 undergoing dynamic-plate procedures were immobilized in halo devices until fusion was radiographically proven. Fusion progression was documented on static X-rays, on dynamic X-rays, as well as 2D-CT studies performed at specific intervals. Fusion criterion included lack of bony lucency and the presence of bony trabeculation at the graft/vertebral body margin. Flexion and extension X-rays were used to demonstrate stability, and the presence or absence of active translation or angulation at the fusion site [11, 12, 23].

RESULTS

"Constrained" and "Semi-constrained" Plates: Five of 38 patients (13%) had graft and plate extrusion. Two of the 22 "constrained" Orion plates/graft extruded. A 56 year old female, one month following a C3-C7 Orion-plated ACF with PWF, developed caudal graft and plate migration and extrusion (Fig. 1). The patient, however, remained asymptomatic. The iliac crest autograft spontaneously fused to the residual C7 vertebral body within 6 postoperative months and she required no further surgery. A 44 year old male who had also undergone an Orion-
Figure 3 (Case 3): A 48 year old female with severe OPLL was managed with a C2-C7 ACF employing a fibula strut allograft and Atlantis plate, plus C2-T1 PWF. One month postoperatively, the caudal plate, screw (open arrow), and graft (curved arrow) extruded.

Figure 4 (Case 4): Lateral extension radiograph obtained 6 months postoperatively following C3-C7 ACF using fibula strut allograft and ABC plate with C2-T1 PWF. Note the 7 mm of cephalad and 5 mm of caudal plate migration over the screw heads respectively affixed to the C3 and C7 vertebrae.

plated C2-C7 ACF with PWF with severe cerebral palsy, demonstrated inferior plate and fibula strut graft extrusion on a 6 week postoperative CT study. Although he also fused six months postoperatively, persistent dysphagia necessitated elective plate removal (Fig. 2).

Two of the 16 patients undergoing multilevel Atlantis-plated ACF utilizing fibula strut allografts, demonstrated inferior plate and graft extrusion within the first postoperative month. A 74 year old male developed anterior plate and graft extrusion one month following a two level ACF performed within an Atlantis plate accompanied by a C2-T1 PWF necessitating emergent replacement of the anterior graft and Atlantis plate. A 48 year old woman with severe OPLL extending to and through the dura requiring wound-peritoneal and lumboperitoneal shunt placement also developed inferior graft and plate extrusion one month following an Atlantis-plated C2-C7 ACF with C2-T1 PWF (Fig. 3). A second surgery included replacement of the anterior fibula strut graft and plate. She again extruded the plate and graft four months later, requiring a third fusion including anterior fibula strut replacement from C2-C7, and the addition of a dynamic ABC plate). She fused after six months.

Fusion was documented an average of 4.8 months (range 3-8 months) postoperatively in 33 of the 38 patients who did not develop fixed-plate or graft extrusions.

Dynamic Plates: One of the 25 patients undergoing circumferential surgery using dynamic plates developed a partial pseudarthrosis of the anterior and posterior construct as demonstrated on CT studies six months postoperatively. This patient had a secondary PWF and fused anteriorly and posteriorly after an additional 4 postoperative months. The remaining 24 patients demonstrated adequate postoperative fusion.
after an average of 4.5 months (range 3.5-9 months) (Fig. 4).

**DISCUSSION**

Significant reoperation rates following non-plated anterior cervical procedures, prompted the development of anterior cervical plates [3, 5-10, 12, 14, 17, 18, 20]. However, the addition of plating to anterior disectomy or corpectomy with fusion procedures increased fusion rates, but was associated with failures of fixed plates and graft extrusions. This occurred after using either a "constrained" design employing fixed screws, or a "semi-constrained" design, utilizing variable screws. Plate related failures typically occurred caudad rather than cephalad and included pseudarthrosis, plate extrusion, and graft or vertebral body fracture [1-4, 11, 13, 15-19].

Of the 38 fixed plates applied in this series of patients undergoing circumferential surgery for multisegmental OPLL, spondylosis, and stenosis, two "constrained" Orion plates employing a fixed plate and screw design, and three "semi-constrained" Atlantis plates, utilizing a fixed plate and variable screw design, failed (13%). The 2-3 mm of cephalad and caudal plate migration or "dynamism" fostered by the addition of variable angle screws which toggle up to 17 degrees, did not reduce the plate or graft extrusion rate. Biomechanically, both systems appeared to increase stress shielding while preventing graft settling and compression, thus contributing to inferior pistoning and extrusion of the plate and graft, contributing to construct failure.

Alternatively, greater success was experienced utilizing dynamic ABC plates to perform 25 comparable average three level ACF using fibula strut allograft with C2-T1 PWF. Only one of these patients developed a delayed partial pseudarthrosis six months postoperatively, necessitating a repeat posterior fusion. The other 24 patients fused within an average of 4 postoperative months, and have been followed an average of 2.2 postoperative years. Additionally, by the fourth postoperative week, routine radiographs demonstrated an average of 6.5 mm of cephalad and 5.8 mm of caudal plate/screw migration within the 10 mm slots in cephalad and caudal aspects of the dynamic plates. Such extensive migration at both ends of these dynamic plates reflected this plate's ability to successfully reduce stress shielding and foster graft settling, avoiding pistoning and plate extrusion with associated graft fracture and dislocation.

**CONCLUSIONS**

Fixed plates that increased stress shielding and reduced graft settling contributed to the 13% frequency of inferior graft/plate extrusions following 38 multilevel ACF/PWF. Remarkable improvement in results using dynamic plates for comparable circumferential procedures confirm that these dynamic systems can be effectively utilized for multilevel constructs, avoiding or reducing the frequency of failure often seen with other plate systems.

**REFERENCES**

7. Epstein NE: Vertebral body fractures following
Co-Editor's comment:
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This study demonstrates comparative analysis between fixed and dynamic anterior cervical plates after multi-level fusion including 2 to 4 corpectomies. Orion and Atlantis were representative of fixed plate system, ABC plates of that of dynamic plate system. Fixed plates system showed 13% of plate failure, on the other hand dynamic plates system did only 4%. However, the author has to mention each follow up periods. Because longer follow-up period group might show more incidence of delayed plate failure than shorter one did. However, the author showed very honest and interesting graft extrusion after surgery. Recently, there are many surgeries using anterior cervical plate for routine cervical disc disease. This paper is informative as a warning of anterior cervical plate especially in cases of corpectomy.

Co-Editor's comment:
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This article reported the efficacy of dynamic plating system (ABC plate) for multilevel circumferential cervical surgery comparing with fixed plating systems. The author stated that fixed plating systems increased stress shielding and reduced graft settling, causing inferior graft/plate extrusions following multilevel anterior and posterior fixation using long bone grafts. On the other hand, in the cases using dynamic plate systems, both cephalad and caudad screw/plate migration was demonstrated in the long-term postoperative radiographs. These plate/screw migrations reflected to reduce stress shielding and foster graft settling. Although we are not familiar with dynamic plate systems in anterior cervical fixation using long bone grafts, remarkable improvement of the surgical results in this report should be worth remembering in such complex surgical procedures.