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Comparison of radiographic parameters after anterior cervical discectomy and fusion with semiconstrained translational versus rotational plate systems

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ABSTRACT

Objective: A plate is commonly applied after anterior cervical discectomy and fusion (ACDF); particularly in cases of multilevel fusion. Recent comparative studies have focused on constrained versus semiconstrained plates, however little data is available to assess differences between semiconstrained plates.

Patients and Methods: A retrospective review of 60 consecutive adult patients undergoing a 1, 2 or 3 level ACDF with a lordotic allograft for treatment of symptomatic cervical spondylosis was conducted at a single center. The cohort was separated into two groups depending on the cervical plating system used. Patients in the first group had a semiconstrained translational plate and those in the second group had a semiconstrained rotational plate. Plain neutral radiographs were assessed preoperatively, immediately after surgery and at most recent follow-up. The measured radiographic parameters focused on sagittal alignment, adjacent segment pathology, fusion rate and implant failure.

Results: There were 30 patients in each group. There were no significant differences in demographic characteristics or distribution of levels fused between groups. All patients had at least 6 months of follow-up and mean follow-up was 14.8 ± 6.2 months in the translational plate group and 13.1 ± 4.8 months in the rotational plate group ($p = 0.227$). Significant improvement in sagittal segmental alignment was noted in both groups following surgery. The translational plate group improved from 1.0 ± 7.5 degrees to 4.8 ± 7.6 degrees ($p = 0.03$) and the rotational group improved from 2.7 ± 9.1 degrees to 8.4 ± 7.8 degrees ($p = 0.001$). This significant sagittal correction was maintained through follow-up for those in the rotational plate group; 5.5 ± 9.1 degrees ($p = 0.002$). However, a partial loss of segmental lordosis was observed in the translational plate group leading to a failure to maintain significance of the lordotic correction; 1.7 ± 8.3 degrees ($p = 0.280$) over the follow-up period. Segmental fusion rates were not significantly different between groups. However, there was a higher rate of screw breakage within the rotational plate group (4 instances versus 0 instances in the translational plate group).

Conclusion: This comparative cohort series suggests that performing an ACDF with a lordotic allograft using either semiconstrained translational or rotational plate system allows for correction and maintenance of cervical alignment, however the rotational plate appears more effective at maintaining segmental lordotic correction. Further prospective controlled study will be needed to determine if this may come at the expense of greater rates of instrumentation failure in the rotational plate group.

1. Introduction

Anterior cervical discectomy and fusion (ACDF) using a plate is a well-established surgical technique for the treatment of symptomatic cervical spondylosis. Anterior cervical plates are generally classified as either constrained or semiconstrained [1]. Within the latter category,

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they can be either semiconstrained, translational plate or semiconstrained, rotational plate [1]. These semiconstrained cervical plates are designed to promote load sharing. Biomechanical studies have demonstrated that semiconstrained systems allow more load transmission through the entirety of the graft [2,3]. Theoretically, this should reduce cranial and caudal migration of the plate, mitigate adjacent segment degeneration and improve fusion rates.

Much recent focus has been on comparative study of constrained to semiconstrained plates [4,5], however much less attention has been directed toward comparison between semiconstrained devices [6]. In this study the authors compare the radiographic findings of patients undergoing 1–3 level ACDF using lordotic allografts with either a translational plate or rotational plate system.

2. Patients and methods

2.1. Patient population

Consecutive cases of ACDF performed at a single tertiary care institution by the two senior authors (R.G.F. and V.C.T.) between June 2013 and August 2015 were screened retrospectively. Those who underwent a 1–3 level ACDF for symptomatic cervical spondylotic pathology using a translational plate (Swift, DePuy Synthes, Raynham, MA, USA) or a rotational plate (Venture, Medtronic, Memphis, TN, USA) were included. Patients who had surgery due to trauma, infection, or tumor were excluded. Further, patients were excluded if there was only one postoperative plain radiographic film, follow-up less than 6 months, a multilevel non-continuous ACDF, a four or more level ACDF or a combined anterior and posterior cervical procedure. The cohort was divided into two groups based upon the plating system used (translational versus rotational plate). The study design was approved by the institutional review board at Rush University Medical Center, Chicago, IL.

2.2. Surgical technique

All surgeries in the translation plate group were performed by the same surgeon (R.G.F). After discectomy and uncoforaminotomy, an appropriately sized 6 degree lordodic allograft (Spinalgraft, Memphis, TN) was selected and tapped into position in each disc space. A translational plate with features of internal shortening (Swift, DePuy Synthes, Raynham, MA, USA) was placed and fixed with self-tapping fixed angle screws. All surgeries in the rotational plate group were performed by the same surgeon (V.C.T.), After discectomy and uncoforaminotomy the interspace was widened with a drill parallel to the endplates to create bleeding bone on these surfaces while being careful to preserve enough endplate to minimize subsidence. An appropriately sized corticocancellous allograft (Cornerstone, Medtronic, Memphis, TN, USA) was selected, drilled into lordosis, and tapped into position in each disc space. A rotational plate (Venture, Medtronic, Memphis, TN, USA) was placed and implanted with self-tapping variable angle screws. Of note, the majority of patients in the rotational plate group had screws placed with bicortical purchase based upon the surgeon's preferred technique while those in the translational plate group had screws placed with monocortical purchase in the vertebral body.

2.3. Radiographic parameters

Upright neutral lateral cervical spine radiographs were assessed by the first and second authors (B.W.B. and M.K.) in the preoperative, immediate post-operative and most recent follow-up. Neither reviewer participated in the surgeries. In cases of disagreement between the two reviewers, the mean value was assigned. Measured alignment parameters included: C2–7 lordosis, C2–7 sagittal vertical alignment (C2-7 SVA) and sagittal segmental alignment. The sagittal segmental alignment parameter was defined as the Cobb angle formed by the superior endplate of the uppermost vertebral body and the inferior endplate of the lowermost vertebral body involved in the fusion. Radiographic parameters related to the adjacent segments were also collected. Adjacent-level ossification was graded as follows: grade 1 if the ossification extended across $< 50\%$ of the disc space, grade 2 if the ossification extended across $\geq 50\%$ of the disc space, or grade 3 if there was complete bridging of the adjacent disc space [7]. The plate-to-disc space distance was defined as the distance measured between the tip of the plate and the adjacent disc space at the cranial and caudal end of the plate [8]. Bony fusion was assessed using static lateral plain film radiographs at the last follow-up time point. Fusion was classified as the presence of bridging bone across the graft into the adjacent endplates and/or bridging bone outside of the graft and no lucent lines (radiolucent line extending $> 50\%$ of the cortical–host bone interface) [9]. Additionally, all radiographic images were assessed for screw pullout, screw loosening or implant failure.

2.4. Statistical analysis

Raw data are presented using descriptive statistics. Continuous variables are presented as means with standard deviations and categorical data as frequencies with percentages. The goal of statistical analysis was to determine the effect of plate selection on the maintenance of post-operative radiographic correction, induction of segmental arthrodesis and avoidance of adjacent segmental degeneration. To this end, we estimated the average effect of the plate selection on the change in a given parameter between the immediate post-operative timepoint and the last available follow-up timepoint. We controlled for patient level baseline covariates including age and gender, as well as number of levels fused and length of follow-up for each comparison. Additionally, for each measured outcome we controlled for the baseline status (adjacent disc-space ossification) or operative correction (C2-7 lordosis, sagittal segmental alignment, SVA). The level for accepting statistical significance was set at 0.05. Statistical analyses were performed using STATA version 15 (Stata Corp, College Station, TX).

3. Results

Each group was comprised of 30 patients (Table 1). There were no significant differences in demographic characteristics or number of levels fused between the two groups. There also were no significant differences in pre-operative radiographic parameters (Table 1). The mean follow-up time for Group 1 was 14.8 ± 6.2 months (range 6.2–24.8 months) and for Group 2 was 13.1 ± 4.8 months (range 6.0–31.6 months).

Table 1
Baseline group comparisons.

	Translational Group (n = 30)	Rotational Group (n = 30)	p value
Female Gender	12 (40.0%)	17 (56.7%)	0.196
Age	55.4 ± 13.0	57.3 ± 12.4	0.557
Levels			0.957
1 Level Fusion	10 (33.3%)	9 (31.0%)	
2 Level Fusion	14 (46.7%)	15 (51.7%)	
3 Level Fusion	6 (20.0%)	5 (17.2%)	
Cervical Alignment Parameters			
C2-7 lordosis (degrees)	12.7 ± 11.1	16.6 ± 14.9	0.262
Segmental Alignment (degrees)	0.9 ± 7.5	2.7 ± 9.1	0.425
Cervical SVA (cm)	2.1 ± 11.7	2.6 ± 14.8	0.180
Adjacent Segment Ossification			
Cranial Segment	11 of 29 (37.9%)	10 of 29 (34.5%)	0.785
Caudal Segment	5 of 24 (20.8%)	2 of 26 (7.7%)	0.181

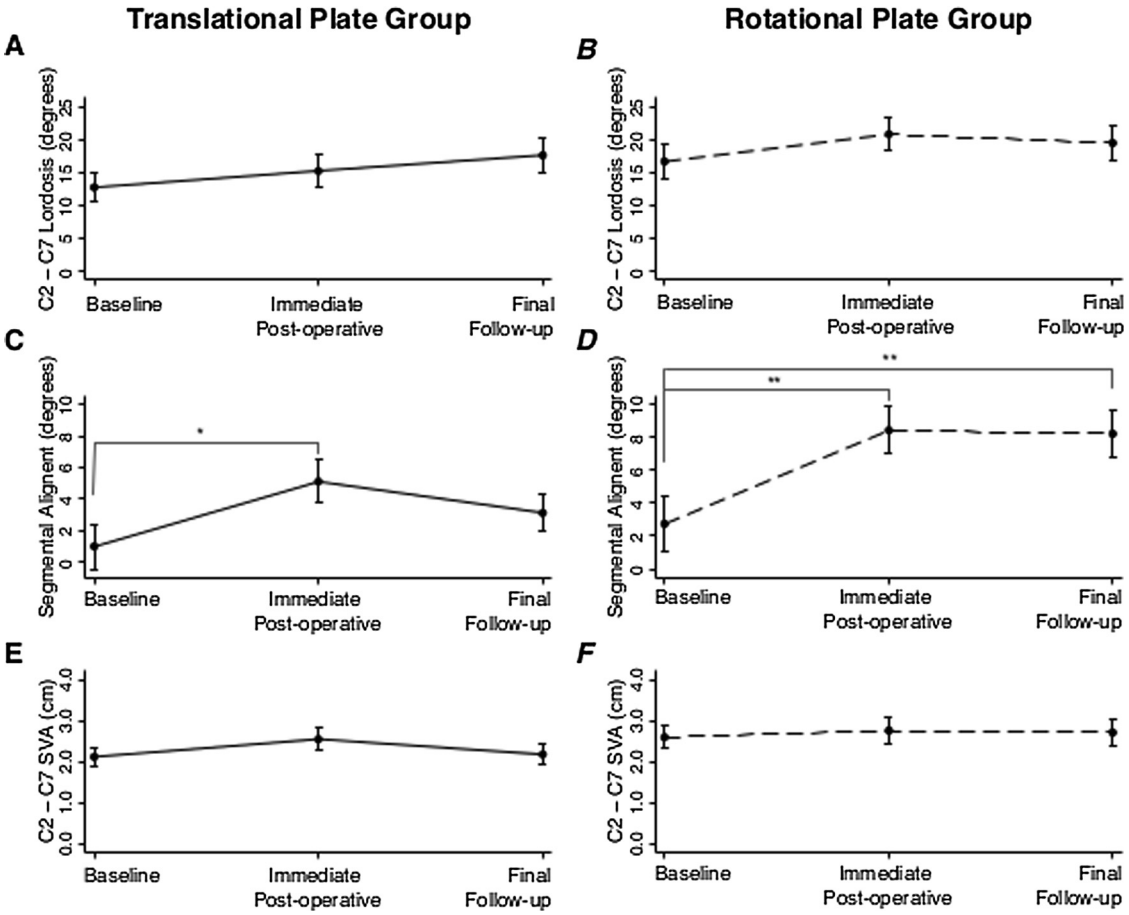

Fig. 1. Longitudinal assessment of sagittal alignment parameters across the three time points of the study.

3.1. Maintenance of alignment correction

In both groups there was improvement in C2-7 lordosis, though this did not reach statistical significance (Fig. 1 **A and B**). However, there was a significant change in sagittal segmental alignment over the segments fused between the preoperative baseline and the immediate post-operative imaging in both groups. In the translational plate group the sagittal segmental alignment improved significantly from 1.0 ± 7.5 degrees to 4.8 ± 7.6 degrees ($p = 0.03$) following surgery (Fig. 1 **C**). In the rotational plate group, the sagittal segmental alignment also improved significantly from 2.7 ± 9.1 degrees to 8.4 ± 7.8 degrees ($p = 0.001$) following surgery (Fig. 1 **D**). There was a reduction in the degree of improvement in the translational plate group (-2.0 ± 6.4 degrees) leading to a loss of significance in correction of the sagittal segmental alignment between the pre-operative image and the last follow-up image (Fig. 1 **C**). Conversely, in the rotational plate group, the loss of surgical correction of segmental alignment was substantially less (-0.2 ± 4.6 degrees) resulting in a maintenance of the significant difference is sagittal segmental alignment between pre-operative imaging and last follow-up imaging (Fig. 1 **D**). In both groups there was no significant change in C2-7 SVA across the timepoints of study (Fig. 1 **E and F**).

The plate-to-disc distance at the cranial and caudal levels were both significantly greater in the rotational plate group (Table 2). In both groups the average plate-to-disc distance narrowed over the follow-up period, but these changed were not significantly different between the groups before or after adjustment for potential confounders (Table 2).

3.2. Adjacent segment ossification

The baseline adjacent segment ossification was not significantly different between the groups at both the cranial and caudal adjacent levels (Table 1). There also was no significant difference in rates of development of adjacent segment ossification. However, it is notable that there was a trend toward significance in the onset of adjacent segment ossification between groups at the caudal level after adjustment for potential confounders. Within the translational plate group, 17.4% of patients developed caudal adjacent segment ossification while only 3.9% of those in the rotational plate group did ($p = 0.054$) which may be seen in Table 3. An example of the radiographic evidence of the progression of an osteophyte at an adjacent cranial segment can be found in Fig. 2.

3.3. Non-union and implant failure

There was only one case of non-union in the translational plate group, which occurred within a 3-level fusion construct. Within the rotational plate group, there were three instances of non-union. One occurred in a patient who underwent a single level procedure and the other two occurred in patients undergoing two level procedures (Table 3). There were no findings of plate failure within the translational or rotational plate groups, yet there were four instances of screw breakage within the rotational plate group and none in the translational plate group. An example of screw breakage may be found in Fig. 3.

4. Discussion

In the present study the authors have compared two balanced

Table 2
Between group comparison of change in radiographic alignment and plate-to-disc distance parameters.

	Translation Group	Rotation Group	P value	Adjusted Diff. [95% CI]	P value
C2-C7 Lordosis (degrees)					
Baseline Correction	2.1 ± 9.9	4.1 ± 11.9	0.489	1.7 [−3.8, 7.3]	0.535
Change over follow-up	2.4 ± 10.0	−1.3 ± 10.4	0.169	−3.3 [−8.5, 2.0]	0.215
Segmental Alignment (degrees)					
Baseline Correction	3.8 ± 8.9	5.7 ± 8.7	0.426	1.7 [−1.6, 5.2]	0.292
Change over follow-up	−2.0 ± 6.4	−0.2 ± 4.6	0.221	2.4 [−.04, 5.3]	0.094
Cervical SVA (cm)					
Baseline Correction	0.4 ± 1.2	0.2 ± 1.1	0.375	−0.1 [−0.8, 0.6]	0.778
Change over follow-up	−0.4 ± 1.2	−0.1 ± 1.1	0.281	0.1 [−0.4, 0.6]	0.641
Cranial Plate-to-Disc Distance (mm)					
Baseline Distance	3.2 ± 2.7	4.4 ± 2.0	0.066	1.4 [0.2, 2.7]	**0.024**
Change over follow-up	−0.8 ± 1.0	−0.6 ± 1.2	0.531	−0.1 [−0.2, 0.01]	0.068
Caudal Plate-to-Disc Distance (mm)					
Baseline Distance	4.7 ± 2.4	6.7 ± 2.6	**0.003**	1.8 [0.5, 3.1]	**0.006**
Change over follow-up	−0.9 ± 1.5	−1.3 ± 2.6	0.429	0.1 [−0.1, 0.3]	0.217

groups of patients who underwent 1, 2 or 3 level ACDF using either a translational or rotational dynamic plating systems. The primary finding of the study is that improvement in segmental sagittal alignment is achieved and maintained with both plate systems. This improvement and maintenance of segmental sagittal alignment has been demonstrated to be associated with improvement in quality of life and disability metrics such as the Short Form-36 Physical Component Summary and Neck Disability Index scores [10]. Moreover, maintenance of segmental lordosis may be associated with a reduction in adjacent-level degeneration when compared to instances where cervical lordosis is lost following anterior fusion [11].

However, it is notable that some of the improvement of sagittal segmental alignment was lost over the follow-up period within the translational plate group though average segmental lordosis remained greater than baseline. Conversely, while sagittal segmental alignment was maintained through the follow-up period in the rotational plate group, there was a notably higher rate of pseudoarthrosis and screw breakage. This occurred in 4 separate instances, yet this was not observed in the translational plate group. This suggests the semi-constrained rotational plate design may predispose the screw-plate interface to greater forces resulting in failure at the interface. With our current study design this remains speculative, however there are some signals from the data that may support this. There was a non-statistically significant trend toward greater rates of fusion within the translational plate group (96.6% versus 91.4%). It could be surmised that the translational design of the plate permits greater load sharing across interface between the graft and the vertebral body and less force across the plate-screw interface. However, further dedicated study will be needed to demonstrate the validity of this suggestion.

There are limitations to this study which necessitate discussion. The primary limitation is the retrospective cohort comparison design. While the groups were balanced on observable covariates, such as demographic characteristics and radiographic measures of alignment, numerous other factors may potentially cofound the analysis. The most notable of these are our inability to control for inherent differences in the subtleties of surgeon driven patient selection and intraoperative technique. Most notably, the use of bicortical screw purchase in the

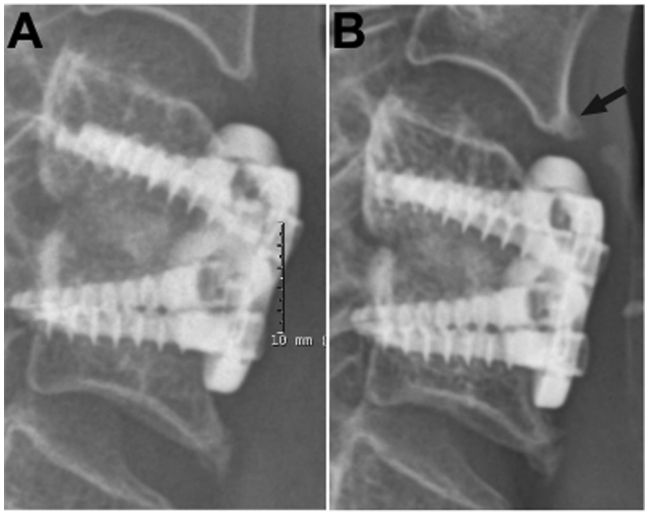

Fig. 2. Progression of segment ossification. A) Immediate post-operative image. B) Last follow-up demonstrating an osteophyte developing at the cranial adjacent segment (black arrow).

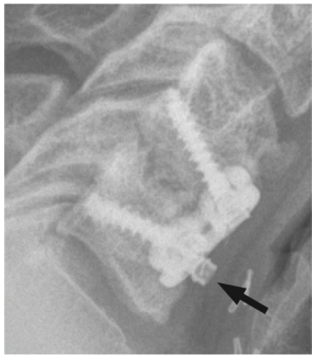

Fig. 3. Example of screw breakage (black arrow).

Table 3
Between group comparison of change in adjacent segment pathology and fusion rates.

	Translational Plate	Rotational Plate	P value	Adjusted OR [95% CI]	P value
Adjacent Segment Ossification					
Cranial worsening	5 of 28 (17.9%)	5 of 29 (17.2%)	0.951	1.2 [0.2, 5.9]	0.845
Caudal worsening	4 of 23 (17.4%)	1 of 26 (3.9%)	0.152	0.03 [0.001, 1.1]	0.054
Levels with Radiographic Fusion[a]	28 of 29 (96.6%)	32 of 35 (91.4%)	0.399	6.8 [0.7, 69.6]	0.105

[a] Comparison limited to those with > 12 months of total follow-up.

rotational plate group compared with monocortical screw purchase in the translational plate group [12]. In addition to these potential confounders there was also observed variability in follow-up times for each patient. Though, this potential bias was mitigated by ensuring that all patients included had at least 6 months of post-operative follow-up. Furthermore, multivariate regression techniques were incorporated to further account for the impact of between group confounding from variable follow-up. The relatively small cohort sizes prohibit extensive hypothesis testing or identification of smaller effect sizes within certain patient strata such as limiting the analysis to subgroups of patients with 1, 2 or 3 levels of fusion rather than combining all into a single more heterogenous cohort. In order to overcome some of these limitations, further prospective and potentially randomized study with a larger cohort will be needed.

5. Conclusion

Data from this comparative cohort study suggests that both a semiconstrained translational or rotational plate permits maintenance of improved segmental cervical alignment following 1 to 3 level ACDF with high rates of fusion across both groups. However, some element of loss of sagittal correction was noted within the translational plate group but conversely a higher rate of screw breakage was observed within the rotational plate cohort. This might suggest that the rotational plate may provide marginally greater support of sagittal correction but at the expense of greater forces at the screw-plate interface. Further prospective and randomized study will be needed to further elucidate if these radiographic differences have significant implications for clinical differences between the two plate systems.

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