Review Article

Anterior cervical plating technique to prevent adjacent-level ossification development

Dong-Ho Lee, MD, PhD, Jung-Sub Lee, MD, PhD, Jin-Seok Yi, MD, Woojin Cho, MD, PhD, Lukas P. Zebala, MD, K. Daniel Riew, MD,*

a Department of Orthopaedic Surgery, Asan Medical Center, University of Ulsan College of Medicine, 388-1, Pungnap2-dong, Songpa-gu, Seoul, 138-736, Korea
b Department of Orthopaedic Surgery, Pusan National University, 179, Gudeok-Ro, Seo-Gu, Busan, 602-739 Korea
c Department of Neurosurgery, Daejeon Catholic Hospital, Catholic University, 64, Daheung-Ro, Jung-Gu, Daejeon, 301-012, Korea
d Department of Orthopaedic Surgery, Washington University Medical Center, 660 S. Euclid Ave., Campus Box 8233, St. Louis, MO 63110, USA

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Abstract

BACKGROUND CONTEXT: The proximity (<5 mm) of the plate to the adjacent disc space is known to be a critical risk factor for adjacent-level ossification development (ALOD). As plates provide many advantages including higher fusion rates and improved alignment, their use will continue. Instead, it is necessary to modify the plating techniques to minimize this complication.

PURPOSE: To determine if our newer plating technique decreases the incidence of ALOD after anterior cervical plating.

STUDY DESIGN: Retrospective matched cohort analysis of preoperative and postoperative radiographic data.

PATIENT SAMPLE: One hundred patients were classified into two groups; conventional (C) and new (N) plating techniques. The control group (Group C) was matched to the study group (Group N) in a 1:1 fashion using matching criteria of age (within 5 years), gender, number of fusion levels, and comorbidities, including diabetes and tobacco use.

OUTCOME MEASURES: The lateral plain X-rays of cervical spine taken at postoperative 6 months and 2 years were used for analysis.

METHODS: In Group N, the cranial and caudal screws were started at the anterior end plate corners and angled away from the end plates so as to use the shortest possible plate and maximize the distance to the adjacent end plates. Group C was the historical control using a longer plate with more orthogonal screw angulation. On postoperative 6-week lateral films, the distances from the tip of the plate to both cranial and caudal adjacent discs (plate-to-disc distances) were measured. Based on the postoperative 2-year radiographs, the incidence of ALOD was determined, and the severity of ossification was classified on a scale ranging from Grade 0 (no ossification) to Grade 3 (complete bridging).

RESULTS: Mean plate-to-disc distances in Group N were significantly longer at both cranial and caudal adjacent levels than those in Group C (p<.001). The incidence of ALOD was significantly lower in Group N than in Group C, both at the cranial adjacent disc spaces (42% vs. 72%) and caudal adjacent disc spaces (20% vs. 42%) (p<.05). Severe ossification (Grade 2 or greater) also developed less frequently in Group N at cranial and caudal levels (6% vs. 20%, respectively; p<.05).

FDA device/drug status: Not applicable.

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The disclosure key can be found on the Table of Contents and at www.TheSpineJournalOnline.com.

* Corresponding author. Department of Orthopaedic Surgery, Washington University Medical Center, 660 S. Euclid Ave., Campus Box 8233, St. Louis, MO 63110, USA. Tel.: 314-747-2565; fax: 314-747-2599.

E-mail address: riewd@wudosis.wustl.edu (K.D. Riew)

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Introduction

Anterior adjacent-level ossification development (ALOD) is thought to be a type of heterotopic ossification, rather than a secondary degeneration developing at the disc adjacent to a fused level. This assumption is based on several studies showing that the ossification occurs in soft tissues that do not form bone under normal conditions. More importantly, this bone matures within the first 2 years after surgery, in contrast to adjacent segment degeneration, in which osteo- phytic bone and disc degeneration gradually increase over time [1–3]. Adjacent-level ossification development occurs commonly after anterior cervical arthrodesis with plating [4–7], and its low incidence in unplated fusions indicates that plating techniques contribute to its development [2]. Previously, we demonstrated that the proximity (<5 mm) of the plate to the adjacent disc space is a critical risk factor of ALOD [1,8]. Because plates do provide many advantages, including higher fusion rates and improved alignment [9–13], it will be important to develop better plating techniques to minimize this complication. In this study, we sought to determine if keeping the plate as short as possible decreases ALOD.

Materials and methods

Study design

Since 2003, we have been using an anterior cervical plating technique to prevent ALOD on the basis of our own clinical experiences and preceding studies. We selected 50 consecutive patients who underwent surgery by the senior (last) author (KDR) using a conventional plating technique between January 2000 and August 2001 and met the inclusion/exclusion criteria as the control group (Group C). The inclusion criteria were the following: (1) anterior cervical discectomy/corpectomy of three or less levels and fusion with plating, (2) age 20 years or older, (3) solid fusion, and (4) minimum 2-year follow-up. Exclusion criteria were the following: (1) previous anterior or posterior cervical spine surgery, (2) fusion extending proximally to C2 or distally to T1, (3) additional cervical spine surgery within 2 years, (4) preexisting anterior osteophytes adjacent to the index level, or (5) nondegenerative disease (trauma, infection, tumor, and inflammatory diseases).

Group C was matched to a study group (Group N) in a 1:1 fashion using matching criteria of age (within 5 years), gender, number of fusion levels, and comorbidities, including diabetes and tobacco use. Patient selection and all the analyses were performed independently by two experienced spine surgeons who were not involved in the care of the patients.

Plating technique

The basic concept of the new plating technique is to keep the cranial and caudal ends of the plate away from the adjacent discs as much as possible. To accomplish this, the most cranial and caudal screw holes are made at the corners immediately adjacent to their respective operative-level end plate, and the shortest plate that fits these pilot holes is selected. The screw insertion angles are directed away from the end plates, allowing for longer screws than the previous conventional technique (Fig. 1, Left). We used fixed angle screws cranially and variable angle screws caudally to limit subsidence to the caudal vertebra as the caudal vertebra is taller than the cranial.

The conventional plating technique consisted of drilling pilot holes on the anterior surface of the vertebral bodies with screws placed parallel to the end plates. Although we tried to place the screws as close to the end plate as possible, this technique required wider dissection of the anterior longitudinal ligament and longus colli muscles around the operative disc level compared with our new technique (Fig. 1, Right). Regardless of the technique, we preoperatively measured the anteroposterior diameter of each vertebra and strived to place the longest possible screws.

Radiological parameters for comparison between Group N and Group C

The distances between the tips of the plate and the caudal and cranial adjacent discs (plate-to-disc distance) were measured on the postoperative 6-week lateral radiograph of the cervical spine. We also measured the screw-to-end plate angle at the most cranial and caudal vertebral bodies of the fused segments. We gauged the height of vertebral body that remained after end plate carpentry. The anteroposterior diameter of the cranial/caudal end vertebrae and the real length of the screws placed in those vertebrae were measured. Screw-to-body ratio was calculated by dividing the screw length by vertebral diameter (Fig. 2).

The ALOD severity on postoperative 2-year lateral films was classified into four grades using the previously described grading system: Grade 0 (no ALOD formation), Grade 1 (ALOD extends across less than 50% of the disc space), Grade 2 (ALOD extends greater than or equal to
50% of the disc space), and Grade 3 (complete bridging of the adjacent disc space) (Fig. 3) [8]. Each independent observer determined the grade of the adjacent-level ossification twice on two separate occasions, and the average of the four measurements was used as the final grade. All the radiological parameters and incidence/degree of ALOD investigated were compared between Group N and Group C.

**Statistical analysis**

Statistical analysis was conducted using the independent sample *t* test for continuous variables, chi-square test to compare proportions, and Spearman correlation test to determine intraobserver and interobserver variability using SPSS statistical package (version 12.0; SPSS, Inc., Chicago, IL, USA). The level of significance was set at *p* < .05.

**Results**

The age at the time of surgery was not significantly different between both groups (*p* = .73). As the patients were matched, the gender, number of fusion levels, and comorbidities were same in both groups (*p* = 1.00 each). Among the 50 patients in each group, 20 patients underwent arthrodesis at one level; 23 at two levels; and 7 at three levels (Table 1).

Mean (± standard deviation) cranial and caudal vertebral body heights in Group N were 13.0 ± 1.5 and 15.8 ± 2.4 mm, respectively, which were not significantly different from those in Group C (13.0 ± 1.4 and 15.4 ± 2.4 mm, respectively, *p* > .05). In contrast, mean plate-to-disc distances were significantly longer in Group N than in Group C both at the cranial (5.2 ± 1.7 vs. 2.3 ± 1.8 mm, *p* < .001) and caudal end vertebrae (6.7 ± 1.9 vs. 4.3 ± 2.2 mm, *p* < .001) (Fig. 4). In Group N, 30 (60%) of 50 patients had a plate-to-disc distance of 5 mm or greater at cranial and 44 (88%) at caudal adjacent disc. These proportions were significantly higher than three (6%) of 50 patients at cranial and 14 (28%) at caudal adjacent disc in Group C (*p* < .001 each).

The correlation coefficients for intraobserver and interobserver variabilities of the technique for grading the severity of the ALOD were *r* = 0.91 (*p* < .05) and *r* = 0.89 (*p* < .05), respectively. Ossification developed in 42% (21) of 50 cranial and 20% (10) of 50 caudal adjacent disc spaces in Group N. These incidences of ALOD in Group N were significantly lower than those in Group C, which were 72% (36) of 50 cranial and 42% (21) of 50 caudal adjacent disc.
spaces (p<.05). Ten patients (20%) showed a severe ALOD (Grade 2 or 3) at cranial and three patients (6%) at caudal adjacent disc in Group N. The incidence of severe ALOD in Group C was significantly higher at both end plates (23 patients [46%] at cranial and 10 patients [20%] at caudal adjacent disc spaces, p<.05 each) (Table 2) (Fig. 5).

In Group N, screws were inserted with a larger angulation both cranially (13.3±4.9°) and caudally (10.1±5.1°) than in Group C (2.5±4.3° cranially and 2.8±6.2° caudally; p<.001). Mean screw-to-body ratios (a proxy of cranial and caudal vertebral body screw lengths) were significantly higher in Group N than in Group C (92.2% vs. 76.8% at cranial, p<.001; 83.6% vs. 75.4% at caudal end vertebra, p<.001) (Table 3).

**Discussion**

Periplate ossification has been previously discussed as an incidental finding after anterior cervical arthrodesis with plating. Mähring [7] interpreted this phenomenon as secondary to excessive dissection along the anterior longitudinal ligament or the improper placement of the plates. Goffin et al. [5] recommended the use of the shortest possible plate to avoid undesirable changes that can be caused by excessive extension of the plate into adjacent healthy discs. Park et al. [8] demonstrated that the ossification occurred at a significantly higher rate and was more severe in patients with plates within 5 mm of an adjacent disc space. It had been our experience that using only a shorter plate was not sufficient to afford proper plate-to-disc distances with our previous conventional plating technique.

![Fig. 3. Grading of adjacent level ossification. Grade 0: no ossification at adjacent disc space, Grade 1: ossification extending across <50% of adjacent disc space, Grade 2: ossification extending across ≥50% of the adjacent disc space, and Grade 3: complete bridging of the adjacent regardless of presence of complete fusion.](image)

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Patient demographics in Groups N and C</th>
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<tr>
<td></td>
<td>Group N (new technique)</td>
</tr>
<tr>
<td>Age*</td>
<td>48.2±7.7 y</td>
</tr>
<tr>
<td>Gender, n (%)</td>
<td>1.00</td>
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<tr>
<td>Male</td>
<td>23 (46)</td>
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<tr>
<td>Female</td>
<td>27 (54)</td>
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<tr>
<td>Number of fusion level, n (%)</td>
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<tr>
<td>1</td>
<td>20 (40)</td>
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<tr>
<td>2</td>
<td>23 (46)</td>
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<tr>
<td>3</td>
<td>7 (14)</td>
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</table>

* The values are given as the mean±standard deviation.

![Fig. 4. Comparison of vertebral body height (VH) and plate-to-disc distance (PDD) between the two groups. Mean cranial and caudal vertebral body heights were not significantly different (p>0.05). In contrast, mean plate-to-disc distances were significantly longer in group N than in group C both at the cranial and caudal vertebrae (p<0.001 each) * p<0.05.](image)
All plates extend beyond their screw holes both cranially and caudally by a few millimeters. Although we placed the parallel screws very close to the operative-level end plates, these extensions tended to protrude toward the adjacent-level discs and reduce the plate-to-disc distance as a result. Therefore, we used a modified plating technique to place the plate as far away from the adjacent disc spaces as possible. Our study hypothesis was that this modified plating technique would reduce the incidence and severity of ALOD compared with our previous conventional technique. Considering that we tried to place the screws as close to the operative-level end plate as possible when using the conventional technique, even meticulous plate positioning could not eliminate ALOD. This finding suggested that it is also necessary to modify the location and direction of screws, which prompted our technique modification.

Compared with our conventional plating technique, the new plating technique significantly increased the plate-to-disc distance, with significantly more patients having a plate-to-disc distance of 5 mm or greater at the cranial and caudal end vertebrae. In Group C, only 3 (6%) and 14 (28%) patients had a plate-to-disc distance of 5 mm or greater at cranial and caudal end vertebra, respectively. In contrast, Group N had 30 (60%) of 50 patients with a plate-to-disc distance of 5 mm or greater at the cranial

<table>
<thead>
<tr>
<th>ALOD grade</th>
<th>Cranial adjacent segment, n (%)</th>
<th>Caudal adjacent segment, n (%)</th>
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<tbody>
<tr>
<td></td>
<td>Group N</td>
<td>Group C</td>
</tr>
<tr>
<td>Grade 0</td>
<td>29 (58)</td>
<td>14 (28)</td>
</tr>
<tr>
<td>Grade 1</td>
<td>11 (22)</td>
<td>13 (26)</td>
</tr>
<tr>
<td>Grade 2</td>
<td>7 (14)</td>
<td>13 (26)</td>
</tr>
<tr>
<td>Grade 3</td>
<td>3 (6)</td>
<td>10 (20)</td>
</tr>
<tr>
<td>Total</td>
<td>50 (100)</td>
<td>50 (100)</td>
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ALOD, adjacent-level ossification development.

and 44 (88%) at the caudal adjacent disc. In Group N, the increased plate-to-disc distance resulted in a reduction in ALOD incidence (42% of cranial and 20% caudal disc spaces) compared with matched conventional plating patients (72% of cranial and 42% of caudal). Perhaps more importantly, the incidence of severe ALOD (Grade 2 or 3) was significantly reduced in Group N versus C: 6% versus 20%, respectively, at the caudal disc and 20% versus 46% at the cranial disc (p<.05 each) (Fig. 6).

It is common that the amount of vertebral body remaining for a plate and screws will be less at the cranial than caudal vertebra because end plate carpentry typically requires greater bone resection of the cranial than caudal end plate. In addition, the cranial vertebral body is typically shorter than the caudal one. These factors make it more difficult to maintain adequate plate-to-disc distance (≥5 mm) at the cranial compared with the caudal vertebra. Furthermore, the incidence and severity of ALOD are known to be much higher at the cranial adjacent disc regardless of the plate-to-disc distance [8]. Therefore, we suggest that our modified technique be preferentially applied to the cranial vertebra, which is at higher risk of ALOD. In addition, this technique would be more helpful in cases that require more vertebral body resection (ie, large posterior osteophytes, ossification of the posterior longitudinal ligament) to achieve adequate decompression. Another advantage of our technique is that dissection along the anterior longitudinal ligament, a risk factor for ALOD [2,5,7], is minimized because less visible vertebral body is required to place the shorter plate and with more angulated screws. Unfortunately, even with a concerted effort to minimize the plate length, we were not able to keep the plate-to-disc distance greater than 5 mm in every case. There were cases where osteophytes or other compressive pathology required a more extensive end plate resection, shortening the cranial vertebral height. Even in cases where the plate-to-disc distance was 5 mm or longer, the incidence of ALOD was still higher compared with unplated patients in a previous study [2]. This finding suggests that it may not be possible to achieve ALOD levels comparable to unplated cases, regardless of the technique. We hypothesize that there is something about placing a plate that appears to induce the formation of ALOD. Potential contributing factors for ALOD that may be postulated include the mismatch of modulus of elasticity between the bone and metallic implants, wider

Table 2
Distribution of adjacent-level ossification grades at cranial and caudal adjacent segments

<table>
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<tr>
<th></th>
<th>Cranial adjacent segment, n (%)</th>
<th>Caudal adjacent segment, n (%)</th>
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<tbody>
<tr>
<td>Grade</td>
<td>Group N</td>
<td>Group C</td>
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<td></td>
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<td>7 (14)</td>
<td>13 (26)</td>
</tr>
<tr>
<td>Grade 3</td>
<td>3 (6)</td>
<td>10 (20)</td>
</tr>
<tr>
<td>Total</td>
<td>50 (100)</td>
<td>50 (100)</td>
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Table 3
Summary statistics for screw-to-end plate angle and screw-to-body ratio in Groups N and C

<table>
<thead>
<tr>
<th></th>
<th>Group N (new technique)</th>
<th>Group C (conventional technique)</th>
<th>p Value</th>
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<tbody>
<tr>
<td>Screw-to-end plate angle, cranial</td>
<td>13.3±4.9°</td>
<td>2.5±4.3°</td>
<td>&lt;.001</td>
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<tr>
<td>Screw-to-end plate angle, caudal</td>
<td>10.1±5.1°</td>
<td>2.8±6.2°</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Screw-to-body ratio, cranial</td>
<td>92.2±13.6%</td>
<td>76.8±6.2%</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Screw-to-body ratio, caudal</td>
<td>83.6±6.5%</td>
<td>75.4±6.5%</td>
<td>&lt;.001</td>
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</tbody>
</table>
dissection for the plate and screws, bone debris from the screw holes, or irritation of the anterior longitudinal ligament by titanium.

Placing angled screws from the corner of end plate may pose the risks that some screws could breach the operative-level end plates, end up in the graft, and consequently hinder the fusion at the interface between graft and host bone. To minimize this risk, we recommend that the graft be recessed a few millimeters such that it is not in contact with the screws. In addition, we recommend using fixed angle screws cranially and variable angle screws caudally to allow subsidence into the caudal vertebra. Moreover, the angled screws have the potential to loosen or pullout as they might not be surrounded by cortical bone. Although we had never experienced any such complications with our technique, it is certainly a possibility. To prevent this, we size the screw by placing it into the disc space and use a screw that we can bury into the space completely while just grazing the posterior longitudinal ligament. Because the screw is then angled upward, it turns out to be just short of being a bicortical screw. Cautious determination of screw entry and trajectory is surely mandatory not only for our plating technique but also for the conventional technique.

Our study has several limitations. First, Group C patients were operated on several years before Group N patients. Although we thought that there was no obvious change in the anterior cervical disectomy and fusion technique other than with the plates, there may have been a subtle change that the senior author was not aware of. This technical change and further experience could present an unquantifiable variable. This is obviously a flaw in all longitudinal studies. Second, we did not match the types of plates in Groups N and C. It may be possible that different plates are associated with different ALOD rates although it is difficult to imagine how this might happen. Some older plates only had fixed-angle screws that would not allow for our new technique, whereas all manufacturers that we are aware of make plates with the option for variable angle screws. With screws that are fixed at 90° to the plate, it would not be possible to use our modified technique. Another limitation is that ALOD was evaluated only on the 2-year postoperative films, which might reflect relatively short-term results. The purpose of this was to keep the follow-up periods for the two groups uniform. As we initiated the newer technique more recently, the mean follow-up period in Group C would be longer than that in Group N if we analyzed the radiological data at the time of the final follow-up. To keep the follow-up period uniform, we chose the 2-year period. It is known that ALOD progresses mainly within 24 months after surgery [1]; therefore, we felt that the two-year follow-up would be sufficient to observe this phenomenon.

Another criticism that has been directed at ALOD is that there is no evidence that it is clinically relevant. We agree that there is no evidence to date that patients with ALOD have increased pain or any other clinical symptoms. Nevertheless, we believe that if the surgeon and the patient agree to fuse a fixed number of levels and additional levels become unintentionally fused because of the plating technique, it is an undesirable complication. Given that 6% and 20% of the cranial levels in the modified and control cases, respectively, developed complete ankylosis, with attendant decrease in motion, this is not an uncommon result.

In conclusion, our new plating technique consists of minimizing dissection of anterior longitudinal ligament
by making the screw holes at the corner of the operative-level end plate, selecting the shortest possible plate, inserting screws with a cranial/caudal angle away from the corresponding end plate, and selecting the longest possible screws. Our modified technique was effective at increasing the plate-to-disc distance. We see no negatives to our newer technique, whereas it does appear to significantly reduce the incidence and severity of ALOD. We therefore recommend that, whenever it is feasible, one minimize the plate length by angling the screws away from the end plates.

References
