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DEVELOPMENT OF ADJACENT-LEVEL OSSIFICATION IN PATIENTS WITH AN ANTERIOR CERVICAL PLATE

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Background: It has been our experience that ossification occurs adjacent to anterior cervical plates. Our hypothesis was that the closer the plate is to the adjacent disc space, the greater the ossification.

Methods: We retrospectively reviewed the lateral radiographs of the cervical spine of 118 patients who had a solid fusion following an anterior cervical arthrodesis with a plate for the treatment of a degenerative cervical condition; none of the patients had had cervical spine surgery prior to the index arthrodesis. The plate-to-disc distance was measured on the postoperative lateral radiograph and was used to divide the patients into two groups for each of the two adjacent disc spaces. In group A the plate-to-disc distance was <5 mm, and in group B it was ≥5 mm. The mean duration of follow-up was 25.7 months. The severity of the ossification at the two adjacent disc spaces was classified on a scale ranging from grade 0 (no ossification) to grade 3 (complete bridging). Eighteen patients were excluded from the measurement of the severity of the caudal ossification because overlapping by the bone of the shoulder precluded adequate visualization of the caudal level.

Results: Ossification developed in seventy (59%) of the 118 cephalad adjacent disc spaces and twenty-nine (29%) of the 100 caudal adjacent disc spaces ($p < 0.001$). The mean cephalad plate-to-disc distance was shorter than the mean caudal plate-to-disc distance ($p < 0.001$). The rate of ossification was higher in group A than in group B, both at the cephalad adjacent disc spaces (67% compared with 24%) and at the caudal adjacent disc spaces (45% compared with 5%) (both $p < 0.001$). In addition, 93% (twenty-six) of the twenty-eight cases of moderate-to-severe ossification developed in group A.

Conclusions: We found a positive association between adjacent-level ossification following anterior cervical plate procedures and the plate-to-disc distance. We now strive to place anterior cervical plates at least 5 mm away from the adjacent disc spaces in order to decrease the likelihood of moderate-to-severe adjacent-level ossification.

Level of Evidence: Therapeutic Level III. See Instructions to Authors for a complete description of levels of evidence.

Anterior cervical plates are effective in achieving immediate stability, restoring the normal lordotic curve, and increasing fusion rates¹⁻⁴. However, the development of late adjacent-level degenerative changes, such as anterior osteophyte formation or ossification of the anterior longitudinal ligament, has been reported following anterior cervical arthrodesis⁵⁻¹¹. Furthermore, there have been few studies concerning the association of anterior cervical plates and late degenerative changes. Goffin et al. found late degenerative changes at the disc levels adjacent to the fused area in fifteen of twenty-five patients with fractures and/or dislocations of the cervical spine, and they recommended the use of the shortest plate possible to avoid extending the plate into adjacent discs¹². Mähring described two types of anterior spondylophyte formation—"noses" and "bridges"—at segments adjacent to

the fusion and stressed that careful operative technique can decrease postoperative spondylophyte formation at segments adjacent to a fusion¹³.

It has been the experience of the senior author (K.D.R.) that ossification commonly occurs at the motion segments adjacent to anterior cervical plates used to treat degenerative cervical disc conditions, especially when the plates were placed close to an adjacent disc space. To our knowledge, however, no one has previously examined the relationship between plate-to-disc distance and peri-plate ossification. We therefore undertook the current study to analyze that relationship.

Materials and Methods

One hundred and eighteen patients who had a solid fusion following an anterior cervical arthrodesis with a plate for

the management of a degenerative cervical condition, who had had no previous cervical spine surgery, and who had been followed for a minimum of one year were identified from a database for inclusion in this study. Patients who had had preoperative anterior osteophytes cephalad or caudad to the level subsequently treated with the anterior cervical plate were excluded from the study. All of the surgical procedures were performed by the senior author (K.D.R.). The criteria used to define fusion were no radiolucency between the graft and the

vertebral body, bridging osseous trabeculae, and <1 mm of motion between the tips of the posterior spinous processes of the fused segments on flexion and extension lateral radiographs of the cervical spine. Sixty-four of the patients were men, and fifty-four were women. The mean age at the time of surgery was 51.8 years (range, thirty-two to seventy-six years). The mean duration of postoperative follow-up was 25.7 months (range, twelve to seventy-six months). The diagnosis was cervical spondylotic radiculopathy in forty-eight patients,



Fig. 1-A

The plate-to-disc distances were measured from the tips of the plate to the cephalad (Fig. 1-A) and caudal (Fig. 1-B) adjacent disc spaces on the postoperative lateral radiograph of the cervical spine.

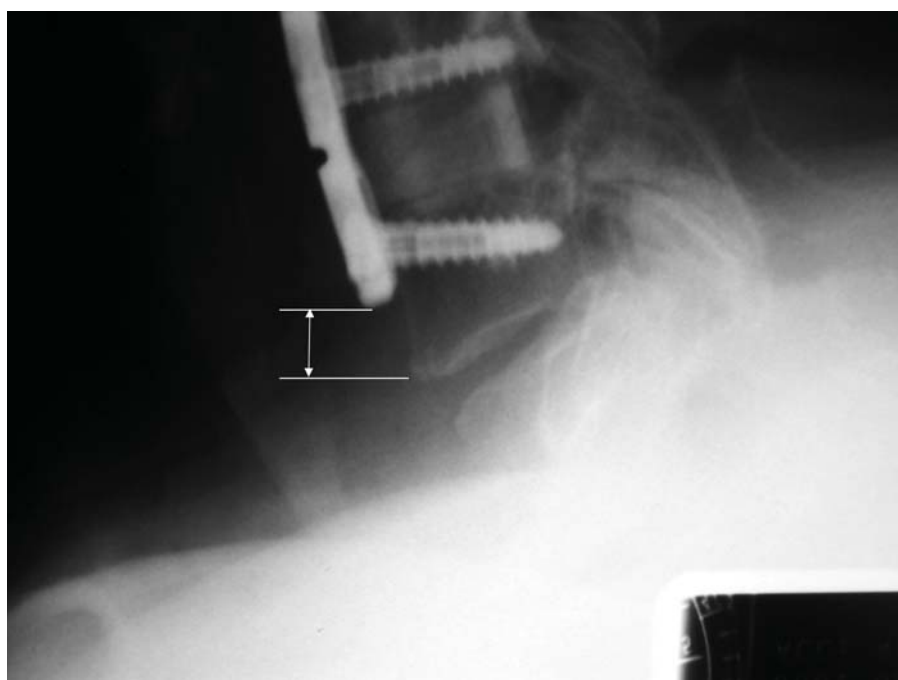


Fig. 1-B



Fig. 2-A

Figs. 2-A through 2-D Lateral radiographs of the cervical spine, made at the time of final follow-up, showing the different grades of adjacent-level ossification. **Fig. 2-A** Grade 0: no adjacent-level ossification.



Fig. 2-B

Grade 1: ossification extending across <50% of the adjacent disc space.

cervical disc herniation in twenty-two, a combination of cervical spondylotic radiculopathy and cervical disc herniation in twenty-eight, and cervical spondylotic myeloradiculopathy in twenty. Thirty-six patients underwent the arthrodesis at one level; forty-seven, at two levels; thirty-two, at three levels; and three, at four levels.

The radiographs of the cervical spine were made with the standard tube-to-film distance (1.8 m) for all patients. All of the radiographic analyses were performed independently

by two experienced spine surgeons who were not involved in the patients' care. The distances between the tips of the plate and the caudal as well as the cephalad adjacent disc (plate-to-disc distance) were measured on the immediate postoperative lateral radiograph of the cervical spine (Figs. 1-A and 1-B). The distances were used to divide the patients into two groups for each of the cephalad and caudal adjacent disc spaces. In group A the plate-to-disc distance was <5 mm, and in group B it was ≥ 5 mm. The severity of the ossification at

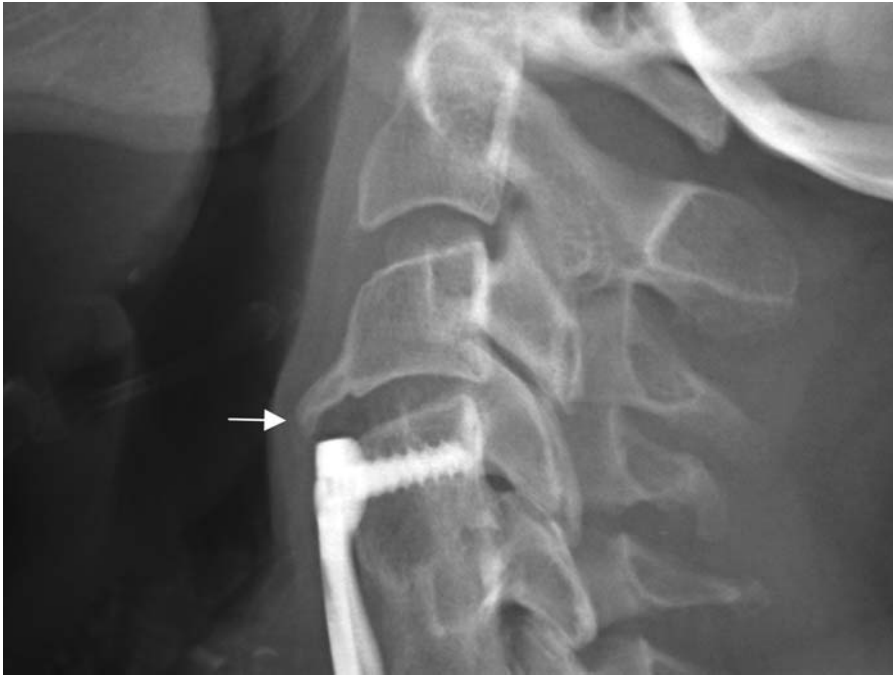


Fig. 2-C
Grade 2: ossification extending across $\geq 50\%$ of the adjacent disc space.



Fig. 2-D
Grade 3: complete bridging of the adjacent disc space.

the cephalad and caudal adjacent disc spaces was classified, on the last follow-up lateral radiograph, as grade 0 (none) (Fig. 2-A), grade 1 (mild) if the ossification extended across $< 50\%$ of the disc space (Fig. 2-B), grade 2 (moderate) if the ossification extended across $\geq 50\%$ of the disc space (Fig. 2-C), or grade 3 (severe) if there was complete bridging of the adjacent disc space (Fig. 2-D). Eighteen patients were excluded from the grading of the ossification at the caudal adjacent level because overlapping by the bone of the shoulder precluded ade-

quate visualization of that level. Each independent observer determined the grade of the adjacent-level ossification twice, and the average of the four measurements was used as the final grade.

Five different types of anterior cervical plates were used: forty-four C-TEK Anterior Cervical Plate Systems (Interpore Cross, Irvine, California), twenty-seven Cervical Spine Locking Plates (Synthes Spine, Paoli, Pennsylvania), twenty-three Atlantis and fourteen Orion Anterior Cervical Plating Systems

(Medtronic Sofamor-Danek, Memphis, Tennessee), and ten Caspar Bicortical Anterior Cervical Plates (ABC Aesculap, Tuttlingen, Germany).

Statistical analyses were performed with use of the chi-square test, independent sample t test, and Spearman correlation test. A p value of <0.05 was considered to be significant.

Results

The correlation coefficients for intraobserver and interobserver variabilities of the technique for grading the severity of the adjacent-level ossification were $r = 0.98$ ($p < 0.001$) and $r = 0.96$ ($p < 0.001$), respectively. These findings validate the capacity of the grading system to measure the severity of adjacent-level ossification on a lateral radiograph of the cervical spine.

Ossification developed in 59% (seventy) of the 118 cephalad adjacent disc spaces and 29% (twenty-nine) of the 100 caudal adjacent disc spaces ($p < 0.001$). The severity of the ossification was grade 0 in forty-eight cephalad adjacent disc spaces, grade 1 in fifty-three, grade 2 in eight, and grade 3 in nine. The severity was grade 0 in seventy-one caudal adjacent disc spaces, grade 1 in eighteen, grade 2 in seven, and grade 3 in four. The mean cephalad plate-to-disc distance (and standard deviation) was 2.86 ± 1.78 mm, and the mean caudal plate-to-disc distance was 4.02 ± 1.89 mm ($p < 0.001$).

Ossification occurred in 67% (sixty-five) of the ninety-seven cephalad adjacent-level disc spaces in group A (cephalad plate-to-disc distance of <5 mm) and 24% (five) of the twenty-one cephalad disc spaces in group B (cephalad plate-to-disc distance of ≥ 5 mm) ($p < 0.001$). Of note is the fact that all nine cases of grade-3 cephalad adjacent-level ossification and all eight cases of grade-2 cephalad ossification developed in group A.

Ossification occurred in 45% (twenty-seven) of the sixty caudal adjacent-level disc spaces in group A and 5% (two) of the forty in group B ($p < 0.001$). All four cases of grade-3 caudal adjacent-level ossification developed in group A. Of the seven cases of grade-2 caudal ossification, five were in group A and two were in group B.

Discussion

Peri-plate ossification has been previously discussed as an incidental finding following arthrodesis with an anterior cervical plate and has been thought to be secondary to oversizing or improper placement of the plate^{12,13}. Our findings demonstrate that, if an anterior cervical plate is placed <5 mm from the cephalad or caudal adjacent disc space, there is an increased risk of moderate-to-severe cephalad or caudal adjacent-level ossification ($p < 0.001$). While twenty-six cases of grade-2 or 3 adjacent-level ossification developed in the patients with a plate-to-disc distance of <5 mm, only two cases of grade-2 ossification and no cases of grade-3 ossification developed in the patients with a plate-to-disc distance of ≥ 5 mm. Those results indicate that a plate-to-disc distance of <5 mm is strongly associated with the development of moderate-to-severe adjacent-level ossification.

The ossification occurred at a significantly higher rate and was more severe at the cephalad adjacent levels than at the caudal adjacent levels ($p < 0.001$). Because the mean cephalad plate-to-disc distance was shorter than the mean caudal plate-to-disc distance ($p < 0.001$), we attributed the higher rate and more severe extent of the cephalad adjacent-level ossification to the shorter cephalad plate-to-disc distance.

Mähring¹³ suggested that excessive dissection along the anterior longitudinal ligament can affect the development of late degenerative changes. However, in our series, all of the operative procedures were performed by the senior author (K.D.R.) using the same microscope-visualized surgical technique with minimum stripping of the anterior longitudinal ligament.

The exact mechanism of adjacent-level ossification was not identified in this study. Although it is our opinion that the association between the plate position and the extent of the adjacent-level ossification may be due to irritation of the anterior aspect of the adjacent disc space, we have no evidence to support that hypothesis at this time. In addition, we cannot exclude the possibility that adjacent-level ossification may develop as the result of the healing of a stripped anterior longitudinal ligament or anterior fibers of the annulus fibrosus.

In this paper, we use the term *adjacent-level ossification* to describe ossification that was observed at the disc spaces adjacent to an anterior cervical plate. In previous studies, this observation was referred to as *late degenerative changes*^{12,13}. While it is likely that many of those cases were simple degenerative changes, at least some may have been due to the plate irritating the anterior longitudinal ligament or the anterior annulus during flexion-extension movements. We are currently comparing adjacent-level ossification following arthrodeses performed with a plate with that following arthrodeses performed without a plate to determine if the plate itself is responsible for the increased rate and severity of adjacent-level ossification.

There is some controversy concerning the influence of adjacent-level ossification on clinical outcome. Goffin et al.¹² reported that late degenerative changes at adjacent levels were not associated with signs or symptoms of radiculopathy, myelopathy, or cervical instability. In their series, there were no reoperations due to these degenerative changes, but the duration of their follow-up was short. In contrast, Gore et al.⁸ found that patients with recurrent pain were more likely to have progression of spondylosis cephalad and caudad to the fused segments than were those without recurrent pain. Because we did not examine this issue in the current study, we believe that the association between adjacent-level ossification and clinical outcomes needs to be investigated in future studies.

As a result of this study, we now routinely attempt to use the shortest plate possible. We drill fixation holes as close to the fused disc space as possible and angle the trajectory of the drill away from the fused disc both cranially and caudally. This allows the placement of the shortest possible plate, and

we strive to insert the plate ≥ 5 mm away from the adjacent disc spaces. ■

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