ORIGINAL

# A comparison of reoperation rates after single-level anterior cervical discectomy and fusion (ACDF) between the procedures with and without anterior plate fixation

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**Abstract : Introduction : The plate fixation for anterior cervical discectomy and fusion (ACDF) has become increasingly widespread for facilitating early mobilization and improving fusion rate. However, apart from multilevel operations, there is still some controversy over its use for single-level ACDF. This retrospective study has compared the reoperation rates after single-level ACDFs performed at our institution between the procedures with and without plate fixation. Methods : This retrospective study included a total of 131 patients with ≥ 1-year of follow-up after a single-level ACDF, consisting of 100 patients without plating (conventional ACDF) and 31 patients with plate fixation (plated ACDF). Results : Eleven patients (8.4% of all patients) : four conventional ACDFs (4% of the conventional ACDFs) and seven plated ACDFs (22.6% of the plated ACDFs), had reoperation surgeries. The incidence of reoperation was significantly higher in the plated ACDFs than in the conventional ACDFs (P = 0.0037). The log-rank test revealed a significant difference (P = 0.00003) in 5-year reoperation-free survival rates between the conventional (96.9%) and the plated groups (68.3%). Conclusion : Anterior cervical plating may have a negative impact on the adjacent segment integrity, resulting in an increased reoperation rate after a single-level ACDF at relatively shorter postoperative time points. J. Med. Invest. 70 : 334-342, August, 2023**

***Keywords*** **:** *Anterior cervical discectomy and fusion, adjacent segment disease, reoperation, anterior cervical plate, interbody cage*

## INTRODUCTION

Anterior cervical discectomy and fusion (ACDF) represents an established surgical treatment for degenerative cervical spine diseases. The technique conventionally involved autologous bicortical or tricortical iliac crest bone graft (ICBG) without plating and postoperative external immobilization. A negative aspect of this procedure includes the possibility of graft-related complications such as subsidence, collapse, and extrusion as well as bone harvest site morbidity (1). To reduce these limitations and eliminate the need for postoperative external immobilization, spine surgeons have increasingly employed non-autologous bone materials such as allograft or various synthetic interbody cages in combination with an anterior cervical plate (2). According to the studies on multilevel ACDFs (3-5), the use of anterior cervical plate helped provide immediate stability and facilitate fusion. In contrast, another study (6) on single-level ACDFs showed that the plate fixation had no benefit in fusion rate or clinical outcome, but rather 9.7% of the patients with plated ACDF required reoperation. In addition, whether anterior cervical plate accelerates adjacent segment degeneration or not still remains a matter of controversy (7, 8). This, at times, results in clinically symptomatic neural compression. We wish to report our experience on a comparison of reoperation rates after single-level ACDFs between the procedures with and without anterior plate fixation.

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## MATERIALS & METHODS

### *1. Patients*

From January 2000 to December 2020, 168 patients underwent a single-level ACDF at our institution. Of these, we retrospectively studied 131 patients (74 men and 57 women) with mean (range) age 66 (27-91) years, who had a minimum one year of follow-up evaluations (mean, 70 months ; range, 12-199 months). All patients had radiographic evidence of a solid fusion. This study divided the 131 patients into those without and those with plate fixation : 100 patients who had undergone stand-alone autologous tricortical ICBG conducted before July 2010 (conventional group) and 31 patients who had had an ACDF with either an ICBG (3 patients) or an interbody cage packed with cancellous autograft (28 patients) followed by anterior plating (plated group) after July 2010. The clinical diagnoses included cervical spondylotic myelopathy (CSM) in 75 patients, cervical disc herniation (CDH) in 35, ossification of posterior longitudinal ligament (OPLL) in 9, cervical spondylotic radiculopathy in 7, cervical spondylotic amyotrophy in 4, and infection in 1. In the study period, any one of the eight experienced spine surgeons performed ACDF. This study was approved by the institutional review board (IRB) at the first author's institution (approval number : ERB-108570).

### *2. Single-Level ACDF Techniques*

#### *2.1. ACDF with a stand-alone autologous ICBG (conventional group)*

After surgical exposure of the anterior aspect of the vertebral bodies with a standard anterior cervical approach, patients with cervical myelopathy underwent ascending and/or descending evoked potential (EP) studies as described earlier (9-11). For this purpose, a series of recording needle electrodes (Dantec 13R23, Dantec Medical, Skovlunde, Denmark) was inserted into

the intervertebral discs in the midline. This electrodiagnostic technique carried out during surgery before decompression procedures served well as a measure for documenting the site of conduction block and excluding clinically silent cord compression seen on MRI, allowing for a surgical intervention at the appropriate level responsible for the main functional change. With EP confirmation of the lesion site (9, 11, 12), a discectomy at a single appropriate level followed by a partial removal of the adjacent vertebrae above and below with a high-speed carbide-tipped burr created a vertical trench of 10 to 15 mm long and at least 15 mm wide through the center of each vertebra. The trench was then deepened with a diamond-tipped burr under the operating microscope until the posterior vertebral cortex and osteophytes were completely removed. Finally, a piece of tricortical ICBG was tapped into the intervertebral space distracted by the Casper cervical distractor (Aesculap, Center Valley, PA).

*2.2. ACDF with a plate (plated group)*

Unlike the conventional group, the ACDF for this group required preserving the vertebral bodies and their bony endplates adjacent to the disc space to be decompressed as much as possible for preventing less-than-ideal plate fixation and cage subsidence. We managed to thoroughly remove the disc materials and the offending posterior osteophytes through a narrow working corridor with the help of the operating microscope. For the safe, adequate decompression, the intervertebral space must be kept distracted either by spreader forceps or Casper distractor system during the decompression procedures. Usually, the decompression was completed with incision of the posterior longitudinal ligament, which allowed the dura to bulge anteriorly. An interbody cage packed with the cancellous bone, which was harvested through a small cortical window made on top of the anterior iliac crest, was inserted into the intervertebral space distracted by the Casper distractor. We used either one of the two interbody cages made of titanium-coated polyetheretherketone (PEEK) : the CeSpace cage (Aesculap, Center Valley, PA) for 20 patients and Anatomic PEEK PTC (Medtronic, Sofamor Danek, Memphis, TN) for 8 patients. In the remaining 3 patients, we placed an ICBG instead of a cage. All plated group patients underwent single-segment fixation with one of the two dynamic anterior plates with locking screw mechanisms : 23 patients with an ABC plate (Aesculap, Center Valley, PA), which allows screw translation and rotation within the plate and 8 patients with a Zevo plate (Medtronic, Sofamor Danek, Memphis, TN), which only allows screw rotation within the plate. As we had been concerned about the initial stability of stand-alone PEEK cage use, we also decided to use an anterior plate to provide supplementary support.

The wound closure in both groups consisted of meticulous hemostasis, thorough irrigation with saline, repositioning the subperiosteally dissected flaps of bilateral longus colli muscles and the anterior longitudinal ligament with a few sutures, the closed suction drain tube placement, and closing in layers over the drain.

*2.3. Postoperative management*

All patients were allowed to ambulate as soon as clinically possible with a semirigid cervical collar for additional stability. We encouraged the patients to continue bracing for at least 3 months for the conventional group and at least 6 weeks for the plated group.

*3. Statistical Analysis*

We conducted the Fisher's exact t-test for nominal variables and Mann Whitney U-test for continuous variables to elucidate the factors associated with the reoperation between the conventional and plated ACDFs. Log-rank test was used to compare the reoperation-free survival rates between the two groups. Because computed radiography (CR) supplanted film radiography in 2010 at our institution, we could access CR data of plated ACDF patients when we conducted this study. On the other hand, it was difficult to access radiographic films of conventional ACDF patients. CRs taken after the initial surgery and before the reoperation or at the last follow-up were evaluated using the following items : cervical alignment (C2-7 angle), intervertebral disc height (DH), plate to disc distance (PDD), and range of motion (ROM). Adjacent cranial and caudal segments of the operated segment were evaluated for the abovementioned items except for the C2-7 angle. Wilcoxon signed-rank test was used for paired comparisons to evaluate degenerative changes after plated ACDFs. Reoperation cases due to symptomatic adjacent segment disease (ASD) were also assessed. The Torg-Pavlov ratio at the C5 vertebral body level, calculated by the sagittal diameter of the midpoint of the posterior surface of the C5 vertebral body to the closest point of the C5 lamina / sagittal diameter of C5 vertebral body measured between the midpoints of anterior and posterior surfaces, was also measured in 31 plated patients after the initial surgery to evaluate the bony spinal canal stenosis.

All statistical analyses were performed with EZR (13) (Saitama Medical Center, Jichi Medical University, Saitama, Japan), which is a graphical user interface for R (The R Foundation for Statistical Computing, Vienna, Austria) . $P < 0.05$ was considered statistically significant.

## RESULTS

Table 1 summarizes a comparison between the data of conventional and plated groups at initial ACDF. The two groups showed no significant differences in age (averaged 65.5 vs 67.6 years ; $p = 0.39$) and gender ratio (M/F) (57/43 vs 17/14 ; $p = 0.84$), but the conventional group had a significantly longer follow-up evaluation than the plated group (averaged 78 vs 44 months ; $p = 0.00029$). Compared with the conventional group, the plated group included CSM patients at a lower rate (63.0% vs 38.7%) and CDH patients at a higher rate (21.0% vs 45.2%), resulting in a significantly different frequency distribution ($p = 0.026$) of the diagnoses at initial surgery between the two groups. In contrast, the frequency distribution of the ACDF levels showed no significant difference between the groups ($p = 0.38$). As mentioned in the Methods section above, we used different types of interbody graft between the two groups ($P < 0.00001$) : the ICBG for all conventional group patients and the PEEK cage for all except 3 plated group patients (Table 1).

A total of 11 patients (8.4% of all patients) had reoperations either earlier than 1 month (early reoperation) (4 patients) or later than 1 year (late reoperation) (7 patients) postoperatively (Table. 2). Of the 4 patients (3.1% of all patients) with an "early reoperation", 2 patients each initially had undergone the conventional and the plated ACDFs. Their "early reoperation" resulted from neurological worsening secondary to epidural hematoma needing revision : reoperation for the same site of primary surgery (3 patients) or cage subsidence due to host bone osteoporosis (1 patient). The 3 patients with epidural hematoma underwent evacuation of the hematoma within three days after initial surgery. Another patient with cage subsidence and cervical sagittal alignment change required an additional laminoplasty for recurrent cord compression. Of the 7 patients (5.3% of all patients) with "late reoperation", 2 patients initially had undergone conventional ACDFs and 5, plated ACDFs. The late reoperation resulted from ASD in 6 patients (4.6% of all patients) and a cervical spine infection at the level different from the initial surgical intervention in 1 patient. All ASD patients underwent

Table 1. Patient demographic data

| | Conventional ACDF | Plated ACDF | P-value |
|---|---|---|---|
| Number of patients | 100 | 31 | |
| Age (years old), mean [range] | 65.5 [29-90] | 67.6 [28-91] | 0.39 |
| Gender ratio : male / female | 57/43 | 17/14 | 0.84 |
| Length of follow-up (months), mean [range] | 78 [12-199] | 44.4 [12-113] | 0.00029 |
| Diagnosis | | | 0.026 |
| CSM | 63 | 12 | |
| CDH | 21 | 14 | |
| C-OPLL | 9 | 0 | |
| CSR | 4 | 3 | |
| CSA | 3 | 1 | |
| Infection | 1 | 0 | |
| Surgical level | | | 0.38 |
| C3-4 | 31 | 6 | |
| C4-5 | 34 | 12 | |
| C5-6 | 28 | 7 | |
| C6-7 | 5 | 4 | |
| C7-Th1 | 2 | 1 | |
| interbody graft | | | <0.00001 |
| auto iliac bone | 100 | 3 | |
| PEEK cage | 0 | 28 | |

CSM : Cervical Spondylotic Myelopathy, CDH : Cervical Disc Herniation, C-OPLL : Cervical Ossification of Posterior Longitudinal Ligament, CSR : Cervical Spondylotic Radiculopathy, CSA : Cervical Spondylotic Amyotrophy
Fisher's exact t-test and Mann-Whitney U-test were used for the nominal and continuous variables, respectively. $P < 0.05$ was considered to be significant.

Table 2. Demographic data of patients who underwent reoperation

| Patient no. | Age | Gender | Diagnosis | Surgical level | Plate | Cage | Early/late | Time after initial surgery | Reason for reoperation |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 46 | male | CSM | C3-4 | no | no | early | 0 day (12 hours) | hematoma |
| 2 | 37 | female | CDH | C5-6 | no | no | early | 1 day | hematoma |
| 3 | 67 | female | CDH | C4-5 | no | no | late | 25 months | ASD |
| 4 | 49 | female | CDH | C5-6 | no | no | late | 175 months | ASD |
| 5 | 85 | male | CSM | C4-5 | yes | yes | early | 3 days | hematoma |
| 6 | 69 | female | CSM | C4-5 | yes | yes | early | 3 weeks | cage subsidence |
| 7 | 71 | male | CDH | C5-6 | yes | yes | late | 12 months | ASD |
| 8 | 76 | female | CSM | C3-4 | yes | yes | late | 22 months | ASD |
| 9 | 75 | male | CSR | C4-5 | yes | yes | late | 54 months | ASD |
| 10 | 69 | male | CDH | C4-5 | yes | no | late | 58 months | ASD |
| 11 | 65 | male | CSM | C4-5 | yes | yes | late | 99 months | infection |

CSM : Cervical Spondylotic Myelopathy, CDH : Cervical Disc Herniation, CSR : Cervical Spondylotic Radiculopathy, ASD : adjacent segment disease
early : reoperation within a month after the initial surgery, late : reoperation over a year after the initial surgery

a reoperation of laminoplasty and/or laminectomy for recurrent myelopathy.

The incidence of "overall reoperation" surgery was significantly higher in the plated ACDFs than in the conventional ACDFs (P = 0.0037). The PEEK cage, which was used together with the anterior plate, was also associated with a higher incidence of "overall reoperation" surgery than the ICBG (P = 0.012). Other risk factors were excluded from the reoperation-related factors (P > 0.05) (Table 3).

For all 11 reoperations, the intervals between initial and reoperations averaged 50.0 months in the conventional group and 35.1 months in the plated group. The corresponding values for 6 reoperations as a result of new myelopathy averaged 100 and 36.5 months, respectively (Table 2). The log-rank test revealed a significant difference (P = 0.00003) in reoperation-free survival rates at 5 years after initial surgery between the two groups ; 96.9% (95%CI, 90.6-99.0) for the conventional group vs 68.3% (95%CI, 37.3-86.3) for the plated group (Figure 1).

Table 4 showed changes of C2-7 angle, DH, PDD, ROM from after the initial surgery to last follow-up or before the reoperation. PDDs at adjacent cranial and caudal segment had significantly reduced at the final follow-up or before reoperation compared to after the initial operation (P = 0.0008 and 0.0004). ROM at both cranio-caudal segments increased during two time points (P = 0.005 and 0.049). C2-7 angle and DH showed no significant changes (P > 0.05).

There was a similar trend of PDD and ROM changes in four reoperation cases due to ASD, with the abovementioned overall change. We did not conduct statistical analysis due to the small sample number. PDD changes at adjacent cranial and caudal segments between two time points were -0.7{-1.9 to 0.0} and -1.0{-2.6 to 0.0}, respectively. Similarly, ROM changes at two segments were 8.8{2 to 19} and 1.8{-1 to 7}. The Torg-Pavlov ratio of four reoperation cases was 0.7{0.6 to 0.8} and that of all 31 plated patients was 0.7{0.5 to 1.2}.

Table 3. P-values in univariate analysis of potential risk factors for reoperation

| | Overall reoperation |
|---|---|
| conventional or anterior cervical plate use | 0.0037* |
| auto iliac bone or PEEK cage | 0.012* |
| surgical level | 0.69 |
| diagnosis | 0.52 |
| gender ratio : male/female | 1 |
| surgery year | 0.32 |
| age of patients | 0.6 |
| follow-up period | 0.19 |

Fisher's exact t-test and Mann-Whitney U-test were used for the nominal and continuous variables, respectively. P<0.05, marked as *, was considered to be significant.

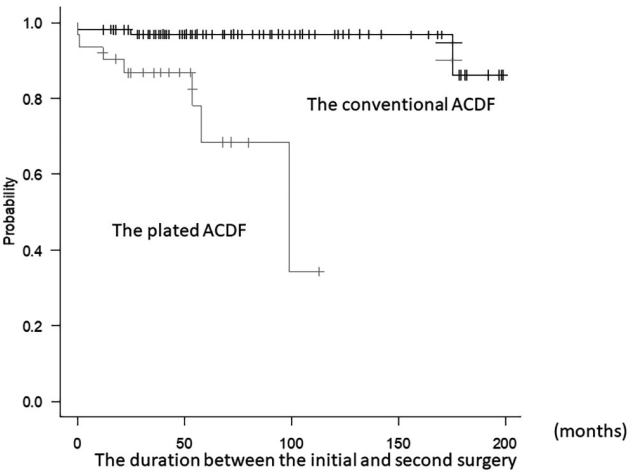


Figure 1. Two Kaplan-Meier survival curves comparing the reoperation-free survival probabilities of conventional (non-plated) versus plated ACDF group patients.
The log-rank test revealed a significant difference (p = 0.00003) in 5-year reoperation-free survival probabilities between the conventional (96.9%) and the plated group patients (68.3%).

Table 4. Radiographic data of plated ACDF patients : all plated ACDF patients and reoperation cases due to ASD

| | | All plated ACDF patients (N=31) | | P-value | Reoperation cases due to ASD (N=4) | | P-value |
|---|---|---|---|---|---|---|---|
| | | After initial operation | Final follow-up / before reoperation | | After initial operation | Final follow-up / before reoperation | |
| C2-7 angle | | 12.3 [-24 to 35] | 9.6 [-19 to 35] | 0.3 | 17.3 [3 to 28] | 16.8 [4 to 23] | NA |
| DH | at adjacent cranial segment | 6.4 [4.1 to 8.8] | 6.5 [4.4 to 8.7] | 0.8 | 6.9 [5.4 to 8.7] | 6.6 [5.3 to 8.7] | NA |
| | at adjacent caudal segment | 5.5 [2.2 to 9.2] | 5.5 [2.2 to 9.2] | 0.1 | 4.6 [2.2 to 7.3] | 4.6 [2.2 to 7.3] | NA |
| PDD | at adjacent cranial segment | 3.3 [-2.3 to 6.7] | 2.6 [-2.7 to 6.1] | 0.0008* | 3.8 [1.0 to 5.3] | 3.1 [1 to 5] | NA |
| | at adjacent caudal segment | 4.6 [0 to 9.2] | 3.9 [0 to 9.4] | 0.0004* | 4.4 [1.4 to 7.8] | 3.4 [1.4 to 5.2] | NA |
| ROM | at adjacent cranial segment | 6.7 [0 to 22] | 9.8 [0 to 21] | 0.005* | 3.5 [1 to 7] | 9.8 [7 to 13] | NA |
| | at adjacent caudal segment | 4.2 [0 to 15] | 6.6 [0 to 16] | 0.049* | 4.5 [1 to 12] | 6.3 [0 to 12] | NA |
| Torg-Pavlov ratio at C5 vertebral body level | | 0.7 [0.5 to 1.2] | | NA | 0.7 [0.6 to 0.8] | | NA |

Data were expressed as mean[range]. Wilcoxon's signed rank-test was used for paired continuous variables. P < 0.05, marked as *, was considered to be significant.
ACDF : anterior discectomy and fusion, ASD : adjacent segment disease, DH : intervertebral disc height, PDD : plate to disc distance, ROM : range of motion, NA : not applicable

Case Presentation 1. (patient no. 4 in Table 2)

A 49-year-old woman suffered from progressive spastic limb paresis with disc herniation at C5-6, where the intraoperative EP studies uncovered conduction block with normal conduction at the other levels. She underwent the conventional C5-6 ACDF (Figure 2a and 2b), resulting in a good functional outcome. However, she experienced a recurrence of spastic limb paresis 14 years after the initial surgery with radiographic evidence of C6-7 degenerative changes, anterior osteophyte formation and disc space narrowing, and MRI evidence of mild to moderate spinal cord compression at C4-5 and C6-7 (Figure 2c and 2d). She underwent a reoperation with combined laminectomies and laminoplasties, which yielded clinical improvement to the point where she was ambulatory on her own.

Case Presentation 2 (Patient no. 9 in Table 2)

A 75-year-old man presented with intractable right arm pain with weakness of the deltoid and the biceps muscles. Temporary pain relief after selective right C5 nerve root block together with the electromyographic (EMG) evidence of denervation in the deltoid and the biceps on the right confirmed the diagnosis of right C5 radiculopathy. He underwent C4-5 ACDF with a PEEK cage and a dynamic anterior cervical plate, resulting in a successful outcome. MRIs 6 months after the initial surgery demonstrated, although clinically silent, mild to moderate cord compressions at C3-4 and C6-7 adjacent to the initial ACDF level (Figure 3a and 3b). MRIs 4 years after the initial surgery, when he developed difficulty walking, showed increased segmental motion at C3-4 with kyphotic alignment change at the lower cervical spine and increased spinal cord compressions both at C3-4 and C6-7 levels (Figure. 3c and 3d). As a result, he underwent a reoperation with selective laminectomies at C3-4 and C6-7, which improved myelopathy, restoring ambulation.

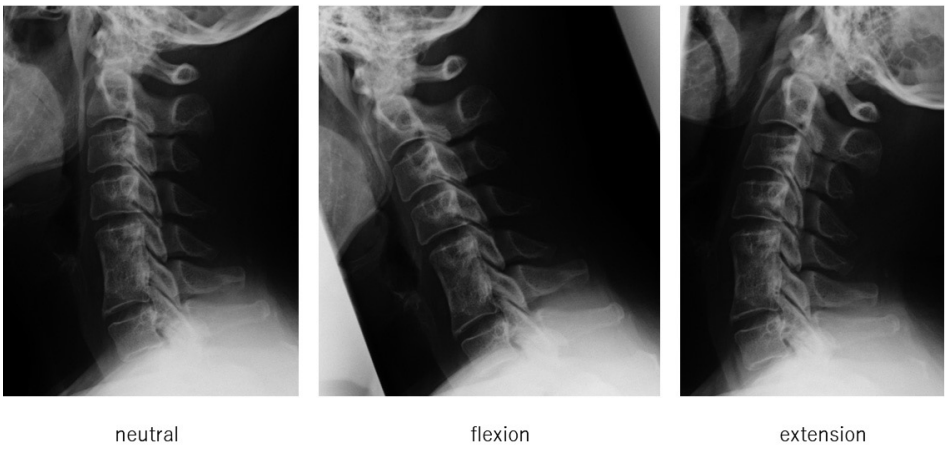


Figure 2a. Follow-up computed radiograph (CR) studies at 4 years after initial ACDF without plate fixation. CRs showed cervical lordotic alignment with preserved cervical motion without instability.

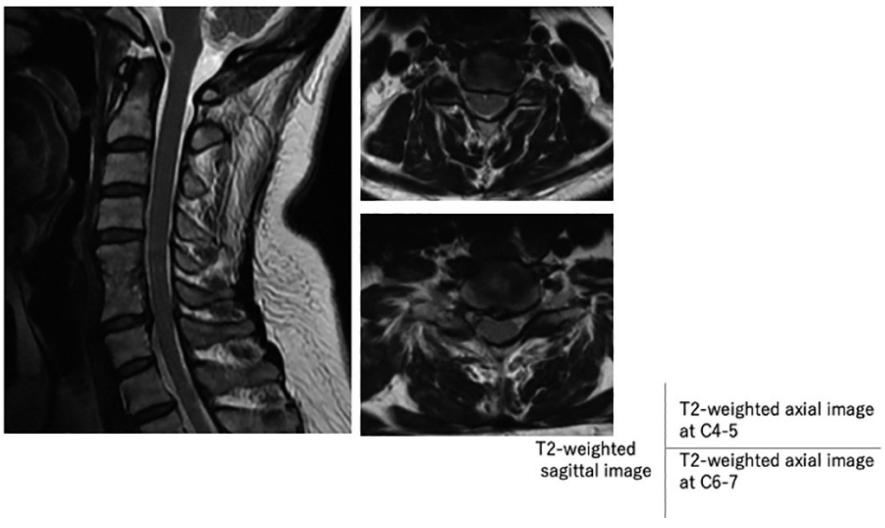


Figure 2b. Follow-up MRI studies at 4 years after initial ACDF without plate fixation. The T2-weighted images showed an adequate decompression and solid fusion at C5-6 with only a mild asymptomatic ASD at C6-7.

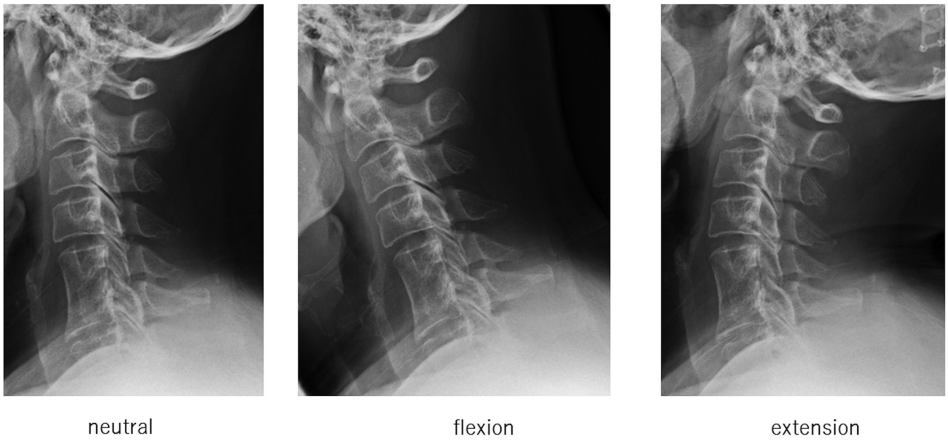


Figure 2c. CR studies at 14 years postoperatively.
Anterior osteophyte formation and disc space narrowing at C6-7 were observed. Decreased cervical lordosis with preserved cervical ROM were also noted.

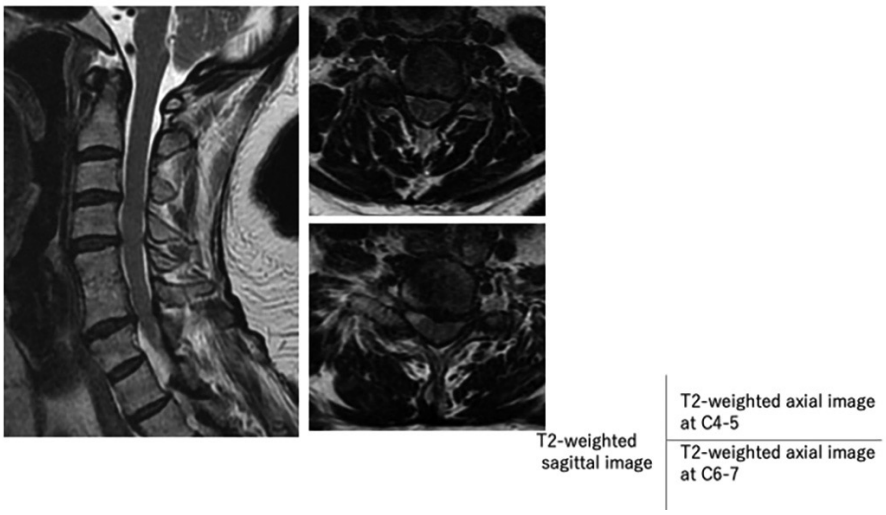


Figure 2d. MRI studies at 14 years postoperatively.
Reflecting the recurrence of spastic limb paresis, the T2-weighted images showed an increase in cord compression at C6-7 adjacent to the level of initial ACDF.

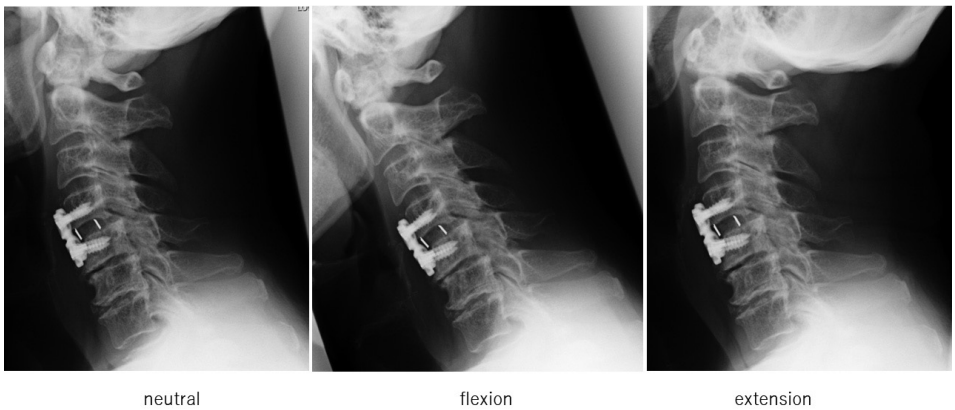


Figure 3a. Follow-up CR studies at 6 months after initial ACDF at C4-5.
CRs showed intervertebral disc height reduction at the lower cervical spine with C3-4 disc height sparing. C3-4 segmental motion was three degrees.

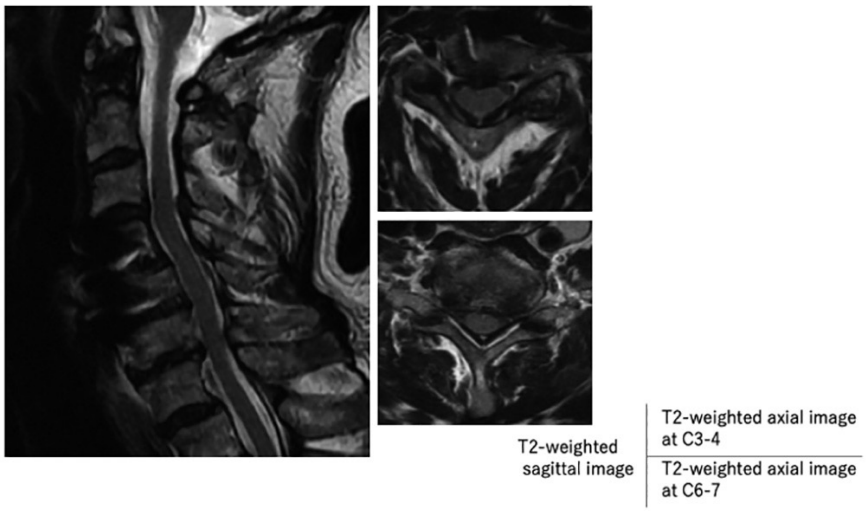


Figure 3b. Follow-up MRI studies at 6 months after initial ACDF at C4-5.
Although the initial operation at C4-5 improved C5 radiculopathy, a clinically silent, mild cord compression had developed at the adjacent C3-4 level.

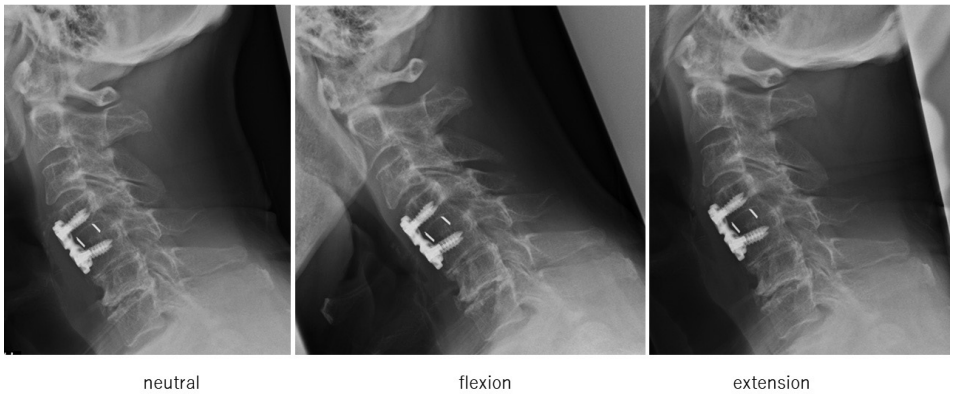


Figure 3c. CR studies at 4 years after the initial ACDF at C4-5.
CRs showed C3-4 disc height reduction and advanced degeneration at the lower cervical spine. C3-4 compensatory increased motion (10 degrees) and kyphotic alignment changes at the lower cervical spine due to severe disc degeneration were also noted.

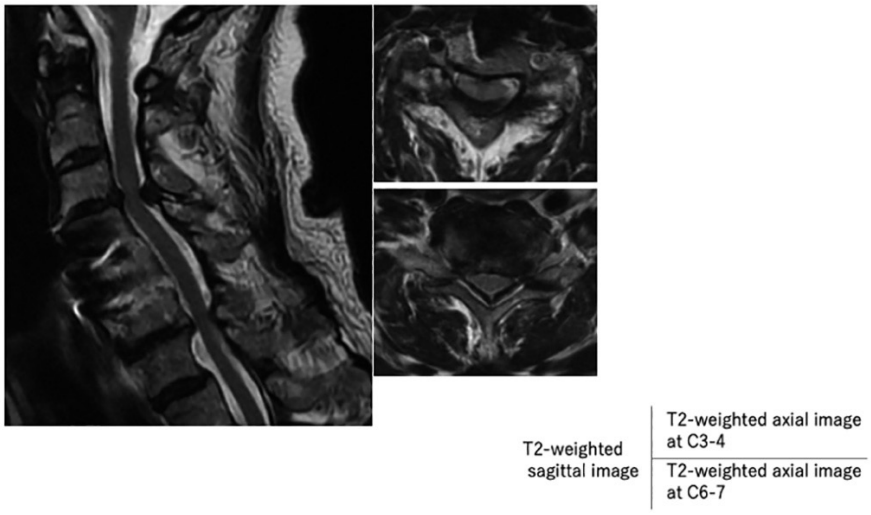


Figure 3d. MRI studies at 4 years after the initial ACDF at C4-5.
Reflecting the development of spastic limb paresis, the MRIs showed marked cord compression with high-intensity T2 signals within the cord at C3-4 adjacent to the previous ACDF level.

## DISCUSSION

While this area still remains controversial, this single-center, retrospective cohort study has suggested that plate fixation for single-level ACDFs increased the rate of reoperation, although the instrumentation provides immediate stability at the fusion level and eliminates the bone harvest site morbidity.

Consistent with a previous large database study (14), which reported a reoperation rate within 90 days after a single-level ACDF of 3.4%, our early reoperation rate was similar at 3.1% (4 out of 131 patients). As with another previous report (15), the early reoperations in our study most commonly resulted from postoperative epidural hematoma with nearly the same incidence in both the conventional group (two cases, 2%) and the plated group (one case, 3%).

Any single-level ACDF carries the inherent risk of developing late ASD generally known as postoperative ASD (16). The current study has shown that ASD requiring reoperation developed earlier in the plated group than in the conventional group, as evidenced by a significantly lower reoperation-free rate at 5 years (68.3% vs 96.9%). Consistent with our data, one long-term follow-up study after Robinson ACDF for radiculopathy reported a reoperation rate of 7% (9 out of 122 patients) (17), while another two studies on single-level ACDFs with plate fixation showed higher reoperation rates ; one study at 15% (18) and the other at 28% (19). Although the PEEK cage was associated with a higher incidence of "overall reoperation" surgery than the ICBG ($P = 0.012$), this statistically significant difference was explained by the fact that all PEEK cages were concomitantly used with anterior plates due to concerns over the stability of stand-alone PEEK cage use. The current study, therefore, has provided further evidence on the adverse effect of the use of anterior plate for single-level ACDFs based on a comparison between the conventional and the plated ACDFs conducted at the same institution.

One previous study showed that the plate-to-disc distance (PDD) of < 5 mm at the time of surgery adversely affected the development of adjacent-level ossification (20). Our plated group patients who required reoperation, in fact, showed that all ends of the anterior plates except one end lay in close proximity to the adjacent discs with PDD ≤ 5 mm at the time of reoperation. In our series, however, many plated group patients who did not require reoperation also showed PDD < 5 mm at the final follow-up evaluations. Therefore, the need for a reoperation after plated ACDF depends, in addition to plate fixation with a short PDD, on other factors such as developmentally-narrowed canal (the normal Torg-Pavlov ratio is about 0.8 (21) and reoperation cases were 0.8 or less) and compensatory hypermobility after the initial surgery.

Widely used dynamic anterior cervical plates, developed in an attempt to improve the biomechanical deficiencies of static plates, allow themselves to settle through longitudinal translation by screw translation or screw rotation within the plate over time. This longitudinal settling of the plate-screw construct renders the ends of the plate closer to the adjacent disc spaces. Thus, one must bear in mind this possibility in attempting to employ dynamic anterior cervical plate fixation. The countermeasures to be taken include the following : (1) preservation of the subchondral bone of the vertebral endplates adjacent to the disc space(s) to be decompressed, which minimizes the cage subsidence, thereby limiting longitudinal translation of the plate-screw construct ; (2) the use of the widest possible cage to maximize the support at the endplate-cage interface ; (3) the use of the shortest possible plate positioned as far as possible from the adjacent disc spaces, which, at times, may require lateral fluoroscopic control. These technical considerations would help minimize the ASD-related reoperation rate not only in single-level ACDFs, as suggested by the current study, but also possibly in multilevel ACDFs.

## STUDY LIMITATIONS

The current study has several limitations. Firstly, we analyzed a small number of patients who required "reoperation" (n = 11) after single-level ACDFs to identify the potential risk factors for the reoperations. The limited number of events prevented the further multivariate analysis to adjust confounding factors including the PEEK cage use and the detailed analysis about the association between the timing of the reoperation : either "early" or "late," and anterior plate use. It was also difficult to compare ICBG or PEEK cage with or without anterior plate due to the small sample size. Secondly, the current series was not randomized, but all the conventional ACDFs were conducted prior to July 2010 during a 21-year study period from January 2000 to December 2020. Thirdly, any one of the 8 experienced spine surgeons, but not a single surgeon, performed conventional and/or plated ACDFs in the study period, which may have affected the consistency in surgeons' familiarity with ACDFs and the treatment decision-making trends. A senior spine surgeon and younger spine surgeon thus operated together (as surgeon and assistant) for better clinical outcomes and improved patient safety. Fourthly, some missing imaging data from past decades prevented us from further assessing the additional factors that might be found in the initial radiographs and MRIs. Fifthly, the current retrospective study relied on 131 patients who had had a single-level ACDF and a minimum of 1-year of postoperative follow-up. The follow-up rate was 78% (131 of 168 patients), in which 22% loss to follow-up may have led biased effects in the cohort study. Racial difference should be considered because only Japanese patients were enrolled in this study. This study nonetheless contributes to the documentation of further evidence that a single-level ACDF with plate fixation may increase the reoperation rate possibly resulting from an earlier development of adjacent segment diseases as compared to conventional ACDFs.

## CONCLUSIONS

A reoperation rate comparison between single-level ACDFs with and without anterior plate fixation has shown that the plate fixation may adversely affect the adjacent segment integrity. The incidence of "reoperation" was significantly higher in the plated ACDFs than in the conventional ACDFs ($P = 0.0037$). The log-rank test revealed a significantly lower ($p = 0.00003$) reoperation-free survival rate at 5 years in the plated group (68.3%) than in the conventional group (96.9%).

## CONFLICTS OF INTEREST

The authors report no conflict of interest in this study.

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## AUTHOR CONTRIBUTION

N.T. designed the study ; N.T. analyzed the date ; K.K, N.A., S.M., M.I, K.K., T.T., and Y.K. revised the manuscript ; K.K.,

K.K., and T.T supervised the study ; N.T. wrote the manuscript.

## ETHICAL APPROVAL

This study has been approved by the institutional review board (IRB) at the first author's institution (approval number : ERB-108570).

## INFORMED CONSENT

Informed consent for publication was obtained by all participants in this study.

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