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Adjacent Segment Pathology Following Anterior Decompression and Fusion Using Cage and Plate for the Treatment of Degenerative Cervical Spinal Diseases

Kyung-Jin Song[1], Byung-Wan Choi[2], Jong-Kil Kim[1]

[1]*Department of Orthopedic Surgery, Chonbuk National University Hospital, Chungbuk National University College of Medicine, Jeonju, Korea*
[2]*Department of Orthopedic Surgery, Haeundae Paik Hospital, Inje University College of Medicine, Busan, Korea*

Study Design: Retrospective study.
Purpose: To analyze the incidence and prevalence of clinical adjacent segment pathology (CASP) following anterior decompression and fusion with cage and plate augmentation for degenerative cervical diseases.
Overview of Literature: No long-term data on the use of cage and plate augmentation have been reported.
Methods: The study population consisted of 231 patients who underwent anterior cervical discectomy and fusion (ACDF) with cage and plate for degenerative cervical spinal disease. The incidence and prevalence of CASP was determined by using the Kaplan-Meier survival analysis. To analyze the factors that influence CASP, data on preoperative and postoperative sagittal alignment, spinal canal diameter, the distance between the plate and adjacent disc, extent of fusion level, and the presence or absence of adjacent segment degenerative changes by imaging studies were evaluated.
Results: CASP occurred in 15 of the cases, of which 9 required additional surgery. At 8-year follow-up, the average yearly incidence was 1.1%. The rate of disease-free survival based on Kaplan-Meier survival analysis was 93.6% at 5 years and 90.2% at 8 years. No statistically significant differences in CASP incidence based on radiological analysis were observed. Significantly high inci¬dence of CASP was observed in the presence of increased adjacent segment degenerative changes (p<0.001).
Conclusions: ACDF with cage and plate for the treatment of degenerative cervical disease is associated with a lower incidence in CSAP by 1.1% per year, and the extent of preoperative adjacent segment degenerative changes has been shown as a risk factor for CASP.

Keywords: Degenerative cervical spine disease; Anterior cervical discectomy and fusion; Adjacent segment pathology; Cage and plate

Introduction

Anterior cervical discectomy and fusion (ACDF) is a standard surgical treatment method for symptomatic radiculopathy of the cervical spine and myelopathy. Since its initial description and application by Robinson and Smith [1], this technique has shown excellent results based on long-term data, resulting in its extensive use to

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Corresponding author: Byung Wan Choi
Department of Orthopedic Surgery, Haeundae Paik Hospital, Inje University,
875 Haeun-daero, Haeundae-gu, Busan 612-030, Korea
Tel: +82-51-797-0240, Fax: +82-51-797-0249, E-male: alla1013@naver.com

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this day. However, it is believed that the arthrodesis of spinal segment scan leads to excessive stress at the unfused adjacent levels and it leads to the development of adjacent segment pathology (ASP). When discussing ASP, it is important to differentiate between radiographical ASP, which is radiographical evidence of degeneration at the levels adjacent to a previous fusion, and clinical ASP (CASP), which is the development of clinically relevant symptoms (i.e., radiculopathy and/ or myelopathy) that correlate with radiographical evidence of degeneration that is adjacent to a previous fusion [2]. The prevalence of CASP during the current follow up periods of 4.5 years and 21 years are 25%–89% [3-5] and 7%–15%, respectively [1,6-8]. Several factors have been associated with the development of ASP, such as the number and location of fusion segments, age, and pre-existing degenerative changes at adjacent segments [4,9,10].

Majority of the reports on post-surgical degenerative changes are associated with ACDF procedures that utilize autogenous iliac tricorticalgrafts. Nowadays, cervical interbody fusion cage or allograft with plate augmentation is widely used for lowering the donor site morbidity and enhancing the stability, but no long-term data on the use of cage and plate augmentation have been reported to date. This study therefore examined the incidence and prevalence of CASP after ACDF with cage and plate augmentation and evaluated the influence of various factors in the development of CASP, comparing these with existing published reports.

Materials and Methods

1. Materials

A retrospective study was conducted on 231 patients who received ACDF with cage and plate for degenerative cervical disease, from January 2002 to May 2010, and were available for follow-up for at least 2 years. Exclusion criteria for the subjects included trauma cases, other previous surgical history of the cervical spine such as concomitant posterior decompression or fusion or revision cases, and absence of clinical and radiological analysis during follow-up. From January 2002 to May 2010, 518 patients received ACDF by a single surgeon (K.J.S.). Among the 518 cases, 182 were trauma cases, 56 cases were done by using tricortical iliac autoboneand plate augmentation, 14 cases met the exclusion criteria due to revision surgery or combined posterior procedure, and 35 cases were lost during follow ups. The study population consisted of 137 men and 94 women. Average age of the patients at the time of surgery was 54.37 years, and the average follow-up duration was 63.85 months (range, 36.0–123.6 months).

From 231 patients, 86 underwent one-level fusion, 117 received two-level fusion, 26 received three-level fusion, and 2 received four-level fusion. 174 patients received surgery due to radiculopathy, whereas 57 patients received surgery for myelopathy. As for determining the extent of fusion level in the cases that showed multi-level lesions in the preoperative radiological images, we tried to operate on only the symptom-related levels through the precise physical examination and preoperative diagnostic electromyography if needed. However, with the presence of the radiological degenerative changes adjacent to the symptomatic level of more than grade III, we included this level for the fusion.

2. Operation methods

General anesthesia was used on all patients. First, cancellous bone for bone graft was obtained percutaneously with a trocar (diameter 7 mm; AO Synthes, Bettlach, Switzerland) by 1-cm mini-incision, from at least 2 cm on the lateral side of anterior superior iliac spine to prevent the injury of lateral femoral cutaneous nerve [11]. A standard Smith-Robinson method was used to expose the cervical spine. After a complete decompression by removing osteophyte and remnant disc materials, an end-plate cartilage was removed with high-speed burr and curette until bleeding occurred. Finally, a polyetheretherketone -cage filled with cancellous bone grafts was inserted into the intervertebral space and then the anterior plating was performed. The cage we used was Solis cage (Stryker, Kalamazoo, MI, USA). Also, Maxima Anterior Cervical Plate System (U&I Corporation, Uijeongbu, Korea) or Cervical Spine Locking Plate (AO North America, Paoli, PA, USA) was used for anterior stabilization. After the operation, a Philadelphia cervical orthosis was applied for 4 weeks and a soft collar was recommended for an additional 2 weeks.

3. Methods

Careful physical examinations and radiological examinations, including plain radiography and magnetic resonance imaging (MRI), were performed preoperatively in all patients. Radiographic data were evaluated postoperatively at 6 weeks, at 3, 6, 9, 12, and 18 months, and then annually, by using antero-posterior, lateral, and flexion/extension lateral plain radiographs. In the cases that developed additional radiculopathy or myelopathic symptoms during the follow-up, MRI was performed for the evaluation purposes. The development of CASP is defined as a newly developed nerve compression lesion in the adjacent segments to the fusion level, radiologically confirmed through MRI or computed tomography (CT)-myelogram, and a presentation of a new development of radiculopathic or myelopathic symptoms (Fig. 1). Clinical

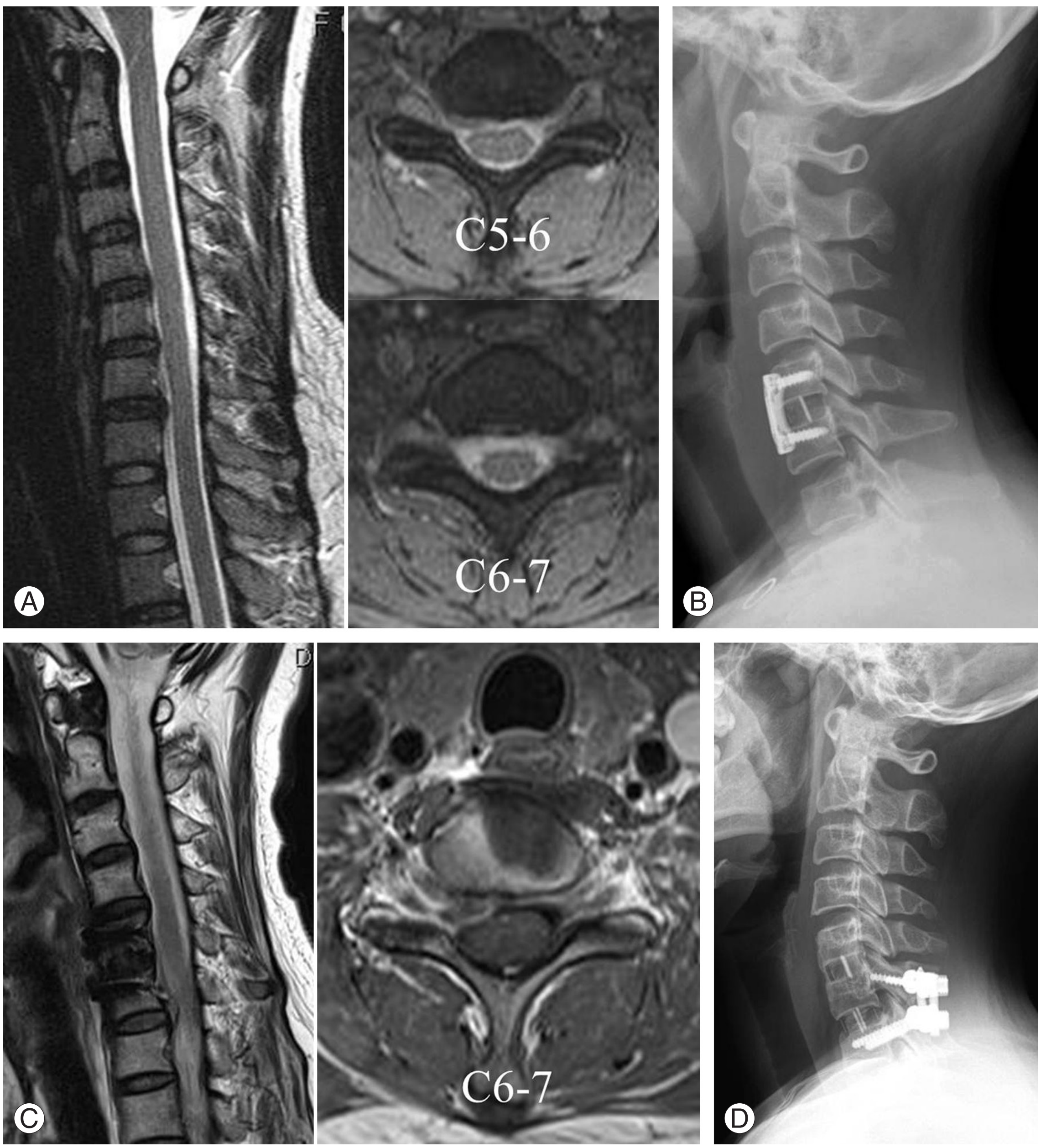

Fig. 1. A 38-year-old female complained of neck pain and severe right radiculopathy. **(A)** Preoperative magnetic resonance imaging (MRI) showing herniated nucleus pulposus on C5–6 with right C6 root compression. There also sowing herniated nucleus pulposus on C6–7 without root compression. **(B)** Single level anterior decompression and fusion was performed on C5–6 level. **(C)** On postoperative 4-year follow-up, she complained of recurred right radiating symptom. The MRI showing adjacent C6–7 level root compression. **(D)** She complained of chronic dysphagia after first operation. We performed anterior decompression and fusion combined with posterior fixation on C6–7.

data were gathered from all 231 patients on the development of new symptoms, time interval between the development of new symptoms and the initial surgery, treatment methods, and clinical results.

Radiological data for the following were gathered: sagittal alignment before and after surgery, spinal canal diameter, range of motion (ROM), number of fusion segments, ROM of the adjacent segment and the percentage it represented in overall ROM, presence or absence of degenerative changes on radiological exams before and after surgery, and distance between the metal plate and disc after surgery (Fig. 2).

Cervical sagittal alignment and ROM were measured by using the Cobb angle formed by the posterior margin of the vertebral segments C2 and C7. The angle formed by the posterior vertebral body margin of the fusion segment and the posterior vertebral body margin of the adjacent segment was taken to measure the ROM of the adjacent segment, and the proportion of the segment's involvement in the range of flexion–extension motion was calculated.

The distance from the upper and lower end of the metal plate to the intervertebral disc after surgery was also measured [12,13].

Preoperative radiological degenerative change in adjacent segment was evaluated by using preoperative plain radiographs and MRI. The degenerative changes were determined by using Hilibrand definitions (Table 1).

Two blinded physicians, as observers, independently interpreted each of the radiological findings, and the average findings were used in the analysis. When there was a difference in the interpretation, the two observers drew a mutual conclusion, and this was used for analysis. To evaluate the reliability of findings, we used standardized confidence analysis to determine inter-observer correlation coefficienct values (Cronbach's a), and these were categorized as poor (a\0.4), fair to good (0.4–0.7), and excellent (a\0.7) [14].

The cases were divided into two groups of CASP group, for those with development of CASP, and the disease-free (DF) group. The clinical and radiological parameters between the two groups was evaluated and compared.

4. Statistical analysis

The annual incidence of CASP was defined as the percentage of previously DF patients that developed new symptoms. Prevalence was defined as the percentage of

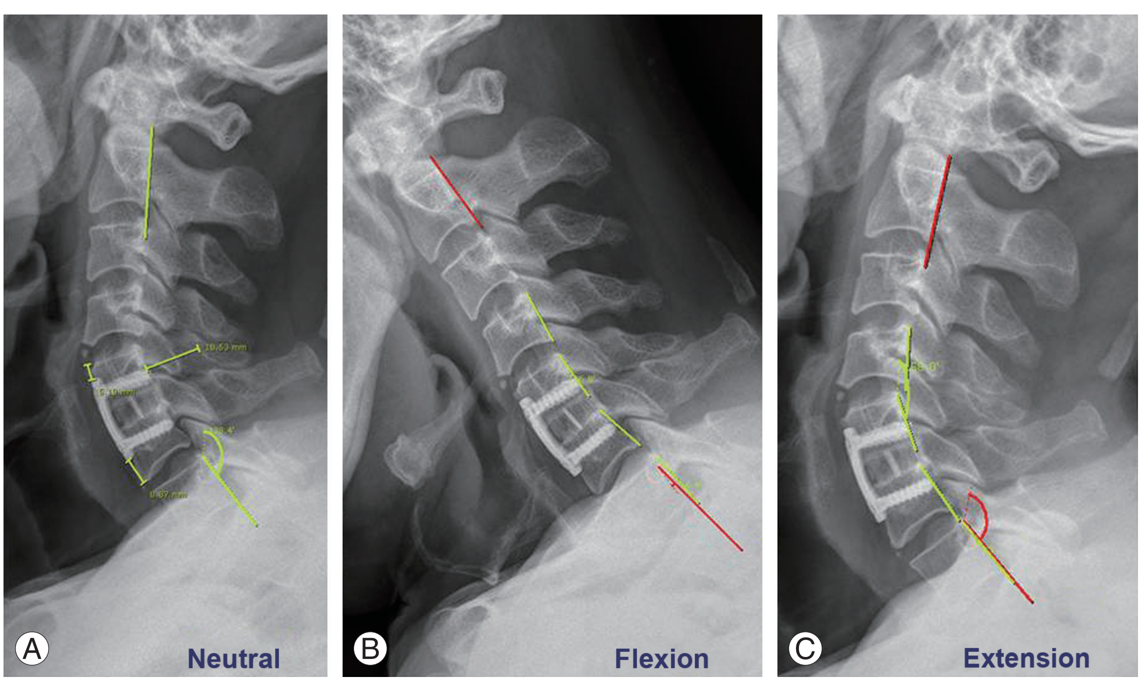

Fig. 2. (A–C) Radiological analysis. Sagittal alignment before and after surgery, spinal canal diameter, range of motion (ROM), number of fusion segments, ROM of the adjacent segment and the percentage it represented in overall ROM, presence or absence of degenerative changes on radiological exams before and after surgery, and distance between the metal plate and disc after surgery was measured.

Table 1. Radiographic grading of degenerative changes at adjacent levels

Garde	Disease	Findings		
		Plain radiography	Magnetic resonance imaging	Computed tomography or myelography, or both
I	None	Normal	Normal	Normal
II	Mild	Narrowing of disc space, no posterior osteophytes	Signal change in intervertebral disc	Normal
III	Moderate	<50% of normal disc height, posterior osteophytes	Herniated nucleus pulposus without neural compression	Herniated nucleus pulposus; no nerve-root cutoff or spinal cord compression
IV	Severe	Same as for grade III	Spinal cord compression with or without nerve-root compression	Nerve-root cutoff with or without spinal cord compression

Table 2. Data from the Kaplan-Meier survivorship analysis

Follow–up (yr)	Entered	Lost to follow-up	New disease	Incidence of new disease (%)	Disease-free survival
1	231	0	2	0.9	99.1±0.6
2	229	0	4	1.7	97.4±1.0
3	225	44	2	0.9	96.5±1.2
4	179	38	1	0.6	95.8±1.4
5	140	15	3	2.1	93.6±1.8
6	122	27	2	1.6	91.9±2.2
7	93	46	1	1.1	90.2±2.7
8	46	16	0	0	90.2±2.7

Values are presented as number of patients.

patients that developed CASP during the follow-up period. The incidence and prevalence of CASP were determined, and its etiology and progression were examined by using the Kaplan-Meier survival analysis. The relationship between each factor and the development of CASP was examined by using the student's *t* test and the chi-square test, by comparing between CASP group and DF group. PASW ver. 18.0 (SPSS Inc., Chicago, IL, USA) was used for statistical analysis, with a significance level of $p<0.05$.

Results

1. CASP incidence and prevalence

CASP occurred in 15 patients (6.8%) of the study population. Twelve patients were male and 3 were female. At the time of their first surgery, the average age was 57.7 years (range, 39–79 years) and the average time until the incidence of CASP was 37.8 months (range, 8.6–60.3 months) after the first surgery. At the 8-year follow-up, the average annual incidence of CASP was 1.1% (0–2.1%/year). DF survival based on the Kaplan-Meier survival analysis was 93.6% at 5 years and 90.2% at 8 years (Table 2).

2. Radiological factors related to development of CASP (Table 3)

Inter-observer correlation coefficient (Cronbach's a) showed that intraobserver (0.73) and interobserver (0.71) correlations are excellent.

A high incidence of lordosis was observed in the DF group, although this difference was not statistically significant ($p=0.648$). Postoperatively, an increase in lordosis was observed in both groups compared to preoperative sagittal alignment, although this observation was not statistically significant between the two groups ($p=0.869$). The cervical ROM, spinal canal diameter before surgery,

Table 3. Clinical and radiological parameters between CASP group and DF group

Parameter	CASP group	DF group	*p*-value
Age at operation (yr)	57.73±9.34	54.09±11.19	0.716
Sex (male:female)	12:3	125:91	0.092
Diagnosis (radiculopathy:myelopathy)	10:5	164:52	0.421
No. of the levels fused (1 level:2 levels:3 levels:4 levels)	3:11:0:1	83:106:26:1	0.301
Preoperative alignment (degree), (+) lordosis, (–) kyphosis	15.04±10.45	17.88±13.39	0.648
Preoperative range of motion (degree)	42.96±12.28	41.91±14.15	0.424
Spinal canal diameter (mm)	15.34±1.33	15.07±1.59	0.993
Postoperative range of motion ration			
Upper adjacent level (%)	28.46±15.42	35.36±32.06	0.384
Lower adjacent level (%)	16.37±14.40	12.18±14.26	0.376
Fusion alignment (degree) (+) lordosis, (–) kyphosis	23.76±13.16	24.79±11.23	0.869
Plate to disc (cephalad) (mm)	3.15±1.93	2.57±1.54	0.153
Plate to disc (caudal) (mm)	3.76±2.51	3.65±2.08	0.951

CASP, clinical adjacent segment pathology; DF, disease-free.

Table 4. Number of cases of preoperative radiological degenerative change in adjacent segment

Value	CASP group	DF group
Grade I	1	145
Grade II	4	38
Grade III	5	20
Grade IV	5	13

CASP, clinical adjacent segment pathology; DF, disease-free.

and the number of fusion segments showed no significant differences.

Neither of the percentages for the upper nor the lower adjacent segment involvements in the total cervical range of motion was statistically significant (p=0.384; p=0.376).

No statistically significant differences were found for the two groups, in the distance between the intervertebral disc and the metal plate (p=0.153; p= 0.951).

3. Preoperative radiological degenerative change and development of CASP

In the CASP group, 10 cases (66%) showed disc herniation of more than grade III at the adjacent segment in preoperative radiographs, whereas 33 cases (15.3%) in the DF group showed disc herniation (p=0.002) (Table 4). Radiological degenerative changes occurred in 119 cases (54.1%), of which 15 (12.6%) developed adjacent segment disease (ASDz). The incidence of CASP based on the preoperative extent of radiological degenerative change was 1 in 141 (0.7%) of the grade 1 patients, 4 in 43 (9.3%) of the grade 2 patients, 5 in 24 of the grade 3 (20.8%) patients, and 5 in 18 (27.7%) of the grade 4 patients; the incidence of ASDz showed a significant increase in relation to the extent of degenerative changes before surgery (p<0.001).

Discussion

ACDF is regarded as a gold standard treatment for degenerative cervical spine disease, but the fusion may increase mechanical stress at the adjacent disc levels, accelerate degenerative changes, and eventually lead to 'adjacent segment pathology'. Sufficient evidence is available to prove the occurrence of ASP. Hilibrand et al. [8] reported that at 10-year follow-up after anterior decompression and fusion using autograft only, the incidence of ASDz was 14.2% and the average annual incidence was 2.9% (range 1.6%–4.2%) [7]. Ishihara et al. [15] reported that utilization of the same procedure resulted in 19% incidence of CASP, and that the DF survival rates were 89% for 5 years, 84% for 10 years, and 67% for 17 years. However, no reports of CASP have been reported after ACDF using cage and plate.

In this study, 15 cases (6.8%) of CASP following ACDF with cage and plate were observed, which is lower than those of other existing surgical procedures. DF survival was 93.6% at 5 years and 90.2% at 8 years, which were also superior to other current surgical approaches. A possible reason for this discrepancy may be attributable to the fact that when autograft or a cage alone is used in the fusion process, more instability occurs in the fusion segment, thus accelerating degenerative changes in the adjacent segments. The use of an additional metal plate may result in the increased stability and lordosis and decreased biomechanical pressure on the adjacent segments. Agarwal et al. [1] compared the incidence of CASP in the patients that underwent ACDF with autograft without plating or allograft, to those patients with plating. He showed that while 22.3% of the no-plating group required additional surgery, only 10.4% of patients in the plating group required surgery, indicating a decrease in the incidence of CASP when using an additional plate [1]. Another possible reason for the low incidence in CASP involves the ease of ACDF with cage and plate in facilitating multi-level fusion, thus, enabling the surgical inclusion of the adjacent segments with degenerative changes before surgery. The number of two level procedures was high in a series of our patients predominantly treated for radiculopathy. We had a low threshold for extending fusions of adjacent segment degeneration in accordance to the recommendation of Hilibrand et al. [8], and this might have resulted in a lower incidence of CASP. This can be a limitation of this study.

We evaluated the various causative factors of CASP by analyzing diverse clinical and radiological factors. Our result showed only the preoperative radiological degenerative change related with the development of CASP. Lawrence et al. [16] performed a systemic review to determine the risk factors for the development of ASP after cervical fusion surgery. They concluded that the factors contributing to the development of CASP include age of less than 60 years, fusing adjacent to the C5–C6 and/or C6–C7 levels, a pre-existing disc herniation, and/or dural compression secondary to spinal stenosis.

Katsuura et al. [9] presented a direct relationship between the incidence of CASP and lordosis of the sagittal cervical spine, in which the loss of lordotic curvature could lead to the development of CASP. However, similar to the findings of Elsawaf et al. [5], our study also did not find any significantly direct relationship between sagittal alignment and development of CASP, despite of the increased lordosis in the DF group.

The occurrence of CASP following ACDF has generally been thought to arise due to the increase in biomechanical pressure of the adjacent segment. Chow et al. [3] reported about the increased pressure within the intervertebral disc of the adjacent segments by using a biomechanical model. Conversely, Rao et al. [17] showed by using biomechanical models that the pressure on intervertebral disc of the adjacent segments and the movement between vertebrae do not change after fusion. Clinical studies showed that the complementary increase in the sagittal ROM after fusion promotes CASP [5]. Our study estimated the increase in pressure to the adjacent segments after fusion by measuring the proportion of the fused adjacent segments in the total ROM. We found that the proportion of adjacent segment involvement in the total ROM following fusion increased in the upper adjacent segments in the DF group and in the lower adjacent segments in the disease group. However, no statistical relationship between the incidence of ASDz and the range of motion was observed. We did not find a significant difference in the incidence rate of CASP based on the number of fusion segments.

Several opinions exist regarding the incidence of CASP and fusion level. Hilibrand et al. [8] reported that the incidence of CASP increased in the single-level fusions involving segments C5–6 or C6–7 [7]. However, some data showed that there was no relation between the number of fusion segments and the incidence of CASP [15,18]. The overall strength of evidence is “low” supporting that the multiple levels of fusion reduced the risk of CASP [16], and our result was concurrent.

Park et al. [12] identified an association between the adjacent-level ossification and the distance between intervetebral disc and metal plate in ACDF with plate fixation. However, whether the anterior ossification that formed adjacent to the fused segments is a degenerative change induced by fusion, is yet to be confirmed. In our study, no significant relationship between CASP and the distance between the intervertebral disc and the metal plate was observed. Additional research on the anterior ossification formation and the clinical symptoms, as well as the associated degenerative changes of adjacent segments, is therefore warranted.

Ishihara et al. [15] reported that the incidence of CASP is high when degenerative changes are observable on the preoperative CT-myelogram or MRI. In addition, Teramoto et al. [19] observed radiologic degenerative changes in 51.1% of the cases after an average follow-up of 10 years, and reported that only 6.7% of these cases required surgical intervention. In our study, radiologic follow-ups revealed degenerative changes in 54.1% of the cases, similar to existing treatments. Furthermore, we confirmed on a high incidence in CASP when radiologic evaluations showed increased degenerative changes in the adjacent segment before surgery. Thus, it is necessary to preoperatively verify whether degenerative changes in the segment, including all adjacent segments, are causing the symptoms of CASP.

The limitations of this study include a short follow-up period of 8 years, which may be insufficient to fully examine the incidence of CASP. In addition, a direct comparison could not be made with other cases that did not use a cage and plate. However, this study deserves the merit of being the first intermediate- to long-term study on cervical ACDF conducted by a single operator, from which the clinical, radiological, and follow-up data were collected for a relatively large number of patients. We believe a prospective, multi-centered study involving a large population and long-term follow-up will be needed to gather extensive clinical data regarding the incidence of CASP following ACDF in degenerative cervical diseases.

Conclusions

ACDF with cage and metal plate augmentation for degenerative cervical disease is a surgical procedure that can reduce the incidence of ASDz by 1.1% per year. The incidence of ASDz was high in the cases with preoperative radiological degenerative disc changes in the adjacent segments.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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