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Clinical Study

Is there an impact of cervical plating on the development of adjacent segment degeneration following Smith-Robinson procedure? A magnetic resonance imaging study of 84 patients with a 24-year follow-up

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Abstract

BACKGROUND CONTEXT: Anterior cervical discectomy and fusion (ACDF) without and with cervical plating (ACDF+CP) are accepted surgical techniques for the treatment of degenerative cervical disc disorders. The effect of CP on the development of adjacent segment degeneration (ASD) remains unclear.

PURPOSE: To assess whether CP accelerates the degeneration of the adjacent and adjoining segments.

STUDY DESIGN/SETTING: This is an imaging cohort study.

PATIENT SAMPLE: Retrospectively, a total of 84 patients who underwent ACDF or ACDF+CP were identified. At final follow-up, an MRI was performed and evaluated in this study.

MATERIALS AND METHODS: An MRI of 84 patients who underwent ACDF (46 patients) and ACDF+PS (38 patients) was performed. The mean follow-up was 24 years (17–45 years). None of the patients had a repeat procedure in the cervical spine. The grade of degeneration of the segments adjacent and adjoining to the fusion was assessed via a five-step grading system (segmental degeneration index, or SDI) that includes disc signal intensity, anterior and posterior disc protrusion, narrowing of the disc space, and foraminal stenosis. Furthermore, the disc height (DH) and sagittal segmental angle (SSA) of fused segments were measured.

RESULTS: A significantly ($p<.001$) greater SDI was identified at the caudal adjacent segment following ACDF compared to ACDF+CP. No other significant differences were identified in patients following ACDF and ACDF+CP. Between 50% and 96% of all segments showed severe degenerative changes according to SDI. There was no significant difference in DH between the patients following ACDF and ACDF+CP. The SSA in patients who underwent ACDF+CP was significantly greater than in the ACDF patients ($p=.002$).

FDA device/drug status: Caspar plate (Aesculap AG, Tuttlingen, Germany).

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CONCLUSIONS: In this cohort of patients, cervical plating had no significant impact on segmental degeneration and decrease of DH in the adjacent and adjoining segments. ACDF+CP seem to preserve the lordotic alignment more with respect to the SSA than ACDF.

Keywords: ACDF; Adjacent Segment Degeneration; Cervical Plate; Cervical Spine; Long-term follow-up; MRI

Introduction

Anterior cervical discectomy and fusion (ACDF) without and with a cervical plate (ACDF+CP) are both accepted surgical techniques for the treatment of degenerative cervical disc disorders (DCDD). Adjacent segment degeneration (ASD) has been observed following both procedures. However, some authors believe that the use of a CP might increase the stress on the adjacent segments and accelerate the degeneration of those levels [1–5].

The purpose of this study was to assess the effect of CP on the adjacent and adjoining segments in long-term follow-up. To the best of the authors' knowledge, no studies are available which assess and compare the grade of degeneration of the adjacent segments following ACDF and ACDF+CP using an MRI with follow-up more than 20 years. Further, this study assessed and compared the grade of degeneration of the segments which are located cranially and caudally to the adjacent segment (first and second cranial and caudal adjoining segments).

Materials and methods

We retrospectively reviewed all consecutive files of patients who had undergone a de novo one-, two- or three-level Smith-Robinson procedure without (ACDF) and with anterior cervical plating (ACDF+CP) at our neurosurgical department for a minimum of 18 years and a maximum of 45 years ago.

Inclusion criteria were patients who underwent ACDF or ACDF+CP with an autologous iliac bone graft for degenerative disorders with full documentation of preoperative neurologic status, a detailed operation report of the initial ACDF and repeat procedures, postoperative process during hospitalization, postoperative neurologic status, and contact details. All patients who did not fulfill the inclusion criteria were excluded. Patients with a repeated (second) procedure at the cervical spine were excluded from the analysis in order to maintain the chronological connection of ACDF and ACDF+CP to the initial adjacent and adjoining segments.

Three hundred thirteen out of 709 patients fulfilled the inclusion criteria. Three hundred ninety-six patients were excluded due to the initial diagnosis of trauma, infection or tumor, divergent surgical technique, incomplete clinical documents, or incomplete contact.

We were able to successfully contact 293 patients via the telephone (93.6%). One hundred sixty-one patients participated in the follow-up assessment (54.9%) and 107 patients agreed to visit our department for an in-person follow-up examination and MRI scan of the cervical spine (66.5%).

MRI scan of the cervical spine was performed in 102 participants. In five cases, an MRI scan could not be performed, in one case due to cochlea implant, in two cases due to cardiac pace maker, and in two cases due to claustrophobia. The study design was approved by local ethics committee and informed consent was obtained from all individual participants.

Surgical technique of initial ACDF and ACDF+CP

In all cases, a transverse skin incision was performed and a combination of sharp and blunt dissection was used to identify the prevertebral fascia. The presumptive segment was identified using either a needle or a dissector with a blunt tip. A complete discectomy and decompression of both nerve roots were performed. An autologous iliac crest

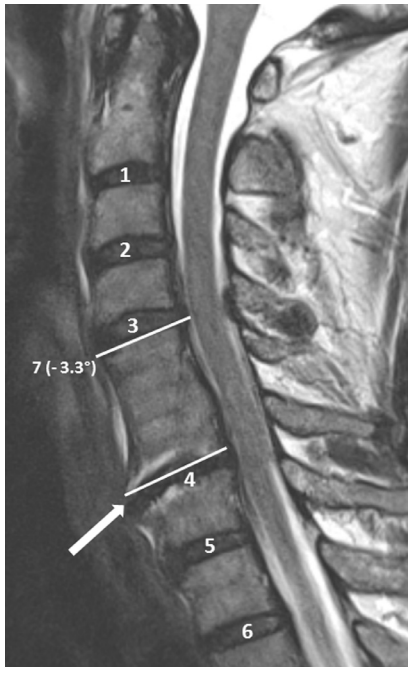

Fig. 1. Adjacent and adjoining segments and SDI-measurements, 1: second cranial adjoining segment, 2: first cranial adjoining segment, 3: cranial adjacent segment, 4: caudal adjacent segment, 5: first caudal adjoining segment, 6: second caudal adjoining segment, 7: Cobb angle of the SSA (−3.3°), white arrow: anterior disc protrusion (disc material protruding beyond the anterior margin of the vertebral body—1 point).

Table 1
Five-step grading system for segmental degeneration

Category	Grade of degeneration	Points
Disc signal intensity	Bright as or slightly less bright than CSF	0
	Dark and/or speckled	1
	Almost black	2
Posterior disc protrusion	Disc material confined within the posterior margin of the VB	0
	Disc material protruding beyond the posterior margin of the VB without compression	1
	Beyond the VB with cord compression	2
Anterior disc protrusion	Disc material confined within the anterior margin of the VB	0
	Disc material protruding beyond the anterior margin of the VB	1
Narrowing of disc space	0%–25% difference of disc height narrowing between the adjacent segment compared to the median disc height of nonadjacent segment	0
	25%–50% difference of disc height narrowing between the adjacent segment compared to the median disc height of nonadjacent segment	1
	>50% difference of disc height narrowing between the adjacent segment compared to the median disc height of the nonadjacent segment	2
Foraminal stenosis	Axial foraminal diameter >4.0 mm	0
	Axial foraminal diameter <4.0 mm	1

graft was harvested and tapped gently into position in each disc space. In cases of ACDF+CP, a Caspar plate (Aesculap AG, Tuttlingen, Germany) was implanted to obtain additional stabilization. Before closure of the wound, the position of the graft was confirmed fluoroscopically.

MRI protocol

A 3.0 Tesla MRI was used for all participants (Siemens Magnetom Skyra, Erlangen, Germany). The protocol for each scan consisted of a T1 sagittal images (TR 833 ms; TE 12 ms; flip angle 150˚), T2 sagittal images (TR 5,110 ms; TE 96 ms; flip angle 150˚), T1 axial images (TR 530 ms; TE 9 ms; flip angle 150˚), T2 axial images (TR 5,740 ms; TE 92 ms; flip angle 150˚), and a sagittal T2-SPACE images (TE 1,600 ms; TR 232 ms; flip angle 100˚).

Evaluation of MRI

Each MRI imaging was independently reviewed only once using the Centricity PACS-system (General Electric Healthcare, Chalfont St Giles, Great Britain) by an experienced neurosurgeon (BWB) and a neuroradiologist (AS). No information about the patient's history was given. For assessment, a T2-weighted sagittal and axial sequence was used. The reviewers were allowed to amplify the image up to 200%. The reviewers assessed the two segments which were located cranial and caudal to the fused level. These two segments were defined as cranial and caudal adjacent segment (see Fig. 1).

Further, the reviewers assessed the two segments which were located cranial to the cranial adjacent segment and caudal to the caudal adjacent segment. These segments were defined as first and second cranial and caudal adjoining segment (see Fig. 1). Depending on the location of the initial fusion, two adjacent segments (one cranial and one caudal) and four adjoining segments (two cranial and two caudal) were assessed.

For each segment, the segmental degeneration index (SDI) and the intervertebral disc height (DH) were assessed. Furthermore, the sagittal segmental angle (SSA) of the fused segments was assessed. Agreement between the reviewers and the intraclass correlation (ICC) were assessed. An ICC of more than 0.8 is considered to indicate very good interrater reliability.

Segmental degeneration index

The SDI is a modified version of the five-step grading system which was designed by Matsumoto et al. (see Figs. 1–3) [6,7].

For each category, points were given depending on the grade of degeneration (see Table 1). The total score for each segment ranged from 0 to 8 points. If one category could not be evaluated with absolute certainty, the authors did not assess this specific category and the maximum of possible points were downgraded according to the maximum points of this specific category.

The SDI was assessed as follows: the total of determined points according to the five-step grading system divided by the maximum of possible points. Therefore, the SDI might range from 0.0 to 1.0.

A SDI of 0.0 describes a segment without signs of degeneration, whereas a SDI of 1.0 describes a segment that shows the most distinct signs of degeneration.

The authors defined a SDI of <0.333 as mild, a SDI of 0.334–0.667 as moderate, and a SDI of >0.667 as severe.

If there was a disagreement between the raters concerning the grade of the assessed SDI consensus was reached by evaluating the grade together again.

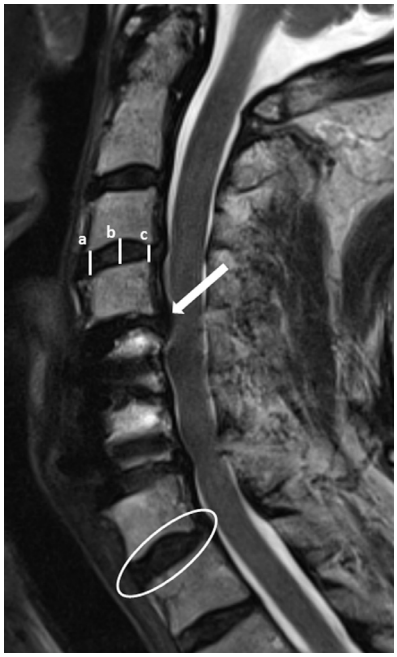

Fig. 2. SDI and DH measurements, white ring: disc signal intensity (dark and/or speckled—1 point), white arrow: posterior disc protrusion (disc material protruding beyond the posterior margin of the vertebral body with compression—2 points), a: anterior disc height, b: middle disc height, c: posterior disc height.

Intervertebral disc height

The intervertebral DH of each segment was defined as the mean of anterior, middle, and posterior DH (see Fig. 2). The mean value was assigned in cases of disagreement between the radiographic data.

Sagittal segmental angle (SSA)

The SSA of the fused segments was via the Cobb angle formed by the superior end plate of the uppermost vertebral body and a line to the inferior end plate of the lowermost vertebral body involved in the fusion (see Fig. 1). The mean value was assigned in cases of disagreement between the radiographic data.

Data analysis

SPSS software version 23 was used for statistical analysis (Armonk, NY). A p value $<.05$ was considered to be statistically significant. A t test and Mann-Whitney U test were used to compare the SDI, DH, and SSA of each segment.

Results

Patient demographics

A compilation of patient demographics is shown on Table 2. The result of the in-person examination of the individuals who participated in the study has been reported previously [8–10].

Identification of the affected segment

The following data are based on the operative reports which were reviewed thoroughly. In 52 cases, the affected segment was identified using lateral fluoroscopy and a dissector or retractor with a blunt tip, the disc was not punctured via the dissector or retractor.

In 32 cases, the presumptive segment was identified using lateral fluoroscopy and a needle. The correct disc was

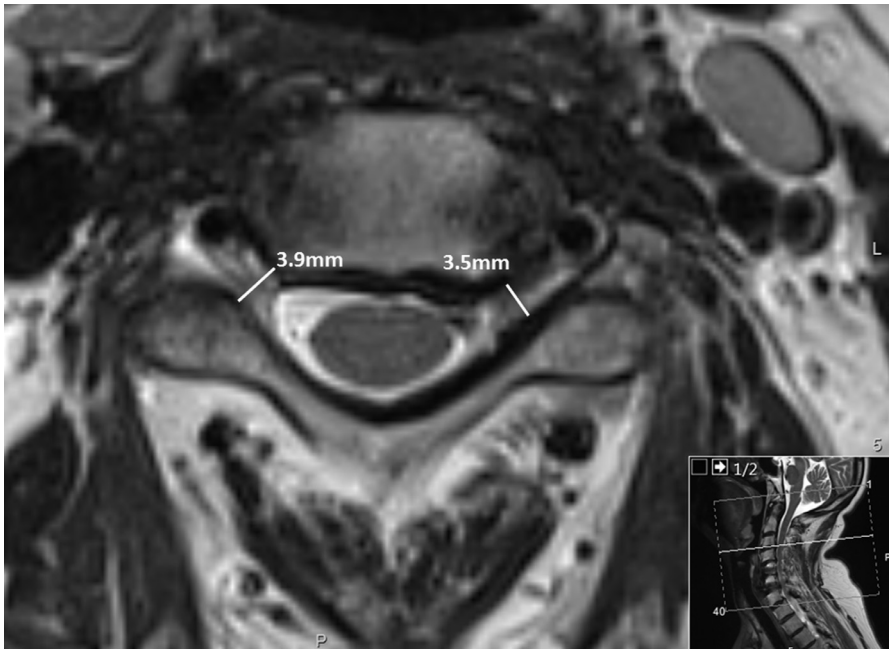

Fig. 3. SDI measurement (foraminal stenosis), T2-weighted axial image with bilateral foraminal stenosis (1 point).

Table 2
Patient demographics

	ACDF	ACDF+CP	
Mean age at initial procedure	42 (range: 26–56 years)	43 (range: 28–55 years)	
Mean follow-up (years)	27 (range: 18–45 years)	21 (range:17–27 years)	
Gender (male/female)	27/19	23/15	
Mean age at follow-up	70 (range: 52–80 years)	64 (range: 46–82 years)	
≤59 years	4	10	
60–69 years	13	15	
70–79 years	28	12	
≥80 years	1	1	
Diagnosis			
Soft disc herniation	39	23	
Cervical spondylotic myelopathy	3	10	
Cervical spondylosis	4	5	
Fused levels prior to follow-up MRI			
1 level	C4-5	2	1
	C5-6	13	6
	C6-7	18	8
	C7-Th1	1	n.a.
2 level	C4-5 & C6-7	1	n.a.
	C4-6	1	5
	C5-7	10	13
3 level	C3-6	n.a.	3
	C4-7		2

punctured in 28 cases and the wrong disc was punctured in 4 cases. In two cases, the cranial adjacent disc, in one case the caudal disc, and in one case of a two-level noncontinuous ACDF, the intermediate disc was falsely punctured. According to the SDI of falsely punctured disc, a severe generation was noted in three cases (ie, 0.75, 0.75, and 0.88) and moderate degeneration in one case (ie, 0.50).

Five-step grading system, segmental degeneration index (SDI), and disc height (DH) measurement

The assessment of all segments according to the five-step grading system revealed that 0, 1, and 2 points were given in 1%, 97%, and 2% for disc signal intensity in both groups (ACDF and ACDF+CP). For posterior disc protrusion, 0, 1, and 2 points were given in 1%, 72%, and 27% in the ACDF group, and in 2%, 79%, and 18% in the ACDF +CP group, respectively. For narrowing of the disc space, 0, 1, and 2 points were given in 81%, 14%, and 4% in the ACDF group and in 82%, 15%, and 3% in the ACDF+CP group, respectively. For foraminal stenosis, 0 and 1 points were given in 23% and 77% in the ACDF group, and in 22% and 78% in the ACDF+CP group, respectively. For anterior disc protrusion, 0 and 1 points were given in 54% and 46% in the ACDF group, and in 72% and 28% in the ACDF+CP group, respectively.

A detailed compilation of given points and frequencies of the five-step grading system with respect to the segment and surgical technique is shown on Table 3.

The SDI of all cranial adjoining segments following ACDF was mild in 26%, moderate in 67%, and severe in 7% of all cases. Following ACDF+CP, the SDI was mild in 32%, moderate in 63%, and severe in 5% of cases.

The SDI of all adjacent segments following ACDF was mild in 9%, moderate in 68%, and severe in 23% of all cases. Following ACDF+CP, the SDI was mild in 43%, moderate in 39%, and severe in 17% of cases.

The SDI of all caudal adjoining segments following ACDF was mild in 43%, moderate in 47%, and severe in 10% of all cases. Following ACDF+CP, the SDI was mild in 42%, moderate in 42%, and severe in 16% of cases.

A detailed compilation of frequency of all SDI with respect to the segment and the surgical technique is shown on Table 4.

In the ACDF group, the DH of all cranial adjoining segments ranged between 1.9 and 3.0 mm in 11%, between 3.1 and 5.0 mm in 56%, and it was over 5.1 mm in 33% of cases. In the ACDF+CP group, the DH of all cranial adjoining segments ranged between 1.0 and 3.0 mm in 10%, between 3.1 and 5.0 mm in 71%, and it was over 5.1 mm in 19% of cases.

In the ACDF group, the DH of all adjacent segments ranged between 1.0 and 3.0 mm in 30%, it ranged between 3.1 and 5.0 mm in 57%, and it was over 5.1 mm in 13% of cases. In the ACDF+CP group, the DH of all adjacent segments ranged between 1.0 and 3.0 mm in 47%, between 3.1 and 5.0 mm in 42%, and it was over 5.1 mm in 12% of cases.

In the ACDF group, the DH of all caudal adjoining segments ranged between 1.9 and 3.0 mm in 12%, it ranged between 3.1 and 5.0 mm in 67%, and it was over 5.1 mm in 22% of cases. In the ACDF+CP group, the DH of all caudal adjoining segments ranged between 2.3 and 3.0 mm in

Table 3
Compilation of positive findings according to the five-step grading system

Category	Points	2. cranial adjoining segment		1. cranial adjoining segment		Cranial adjacent segment		Caudal adjacent segment		1. caudal adjoining segment		2. caudal adjoining segment	
		ACDF	ACDF+CP	ACDF	ACDF+CP	ACDF	ACDF+CP	ACDF	ACDF+CP	ACDF	ACDF+CP	ACDF	ACDF+CP
Disc signal intensity	0/2 points	2.4%	0.0%	0.0%	3.2%	2.1%	3.2%	2.1%	0.0%	0.0%	0.0%	0.0%	0.0%
	1/2 points	95.2%	100.0%	97.8%	93.5%	95.7%	93.5%	95.7%	100.0%	100.0%	97.0%	100.0%	100.0%
	2/2 points	2.4%	0.0%	2.2%	3.2%	2.1%	3.2%	2.1%	0.0%	0.0%	3.0%	0.0%	0.0%
Posterior disc protrusion	0/2 points	0.0%	0.0%	0.0%	0.0%	2.2%	0.0%	2.2%	0.0%	0.0%	6.7%	0.0%	12.5%
	1/2 points	80.5%	92.3%	65.2%	77.8%	41.3%	42.9%	41.3%	89.5%	94.1%	86.7%	100.0%	87.5%
	2/2 points	19.5%	7.7%	34.8%	22.2%	56.3%	57.1%	56.3%	10.5%	5.9%	6.7%	0.0%	0.0%
Narrowing of the disc space	0/2 points	97.6%	100.0%	89.1%	95.8%	53.3%	38.1%	70.5%	72.7%	93.3%	96.0%	93.3%	100.0%
	1/2 points	0.0%	0.0%	8.7%	4.2%	33.3%	52.4%	25.0%	22.7%	6.7%	4.0%	6.7%	0.0%
	2/2 points	2.4%	0.0%	2.2%	0.0%	13.3%	9.5%	4.5%	4.5%	0.0%	0.0%	0.0%	0.0%
Foraminal stenosis	0/2 points	30.8%	35.0%	7.7%	13.3%	8.7%	3.8%	8.7%	23.5%	53.1%	30.0%	36.4%	33.3%
	1/2 points	69.2%	65.0%	92.3%	86.7%	91.3%	96.2%	91.3%	76.5%	46.9%	70.0%	63.6%	66.7%
Anterior disc protru sion	0/2 points	78.6%	89.3%	52.2%	71.4%	44.7%	50.0%	44.7%	97.3%	37.0%	71.1%	71.1%	58.3%
	1/2 points	21.4%	10.7%	47.8%	28.6%	53.3%	50.0%	53.3%	2.7%	63.0%	28.9%	28.9%	41.7%

Table 4
Compilation of frequency of mild, moderate, and severe SDI

	2. cranial adjoining segment		1. cranial adjoining segment		Cranial adjacent segment		Caudal adjacent segment		1. caudal adjoining segment		2. caudal adjoining segment	
SDI	ACDF	ACDF+CP	ACDF	ACDF+CP	ACDF	ACDF+CP	ACDF	ACDF+CP	ACDF	ACDF+CP	ACDF	ACDF+CP
0.000−0.333 (mild degeneration)	45.2%	40.7%	5.3%	17.4%	4.3%	26.3%	12.8%	60.5%	30.4%	39.5%	55.6%	44.7%
0.334−0.666 (moderate degeneration)	52.4%	59.3%	81.6%	78.3%	59.6%	39.5%	72.3%	15.8%	67.4%	57.9%	26.7%	26.3%
0.667−1.000 (severe degeneration)	2.4%	0.0%	13.2%	4.3%	36.2%	34.2%	14.9%	23.7%	2.2%	2.6%	17.8%	28.9%

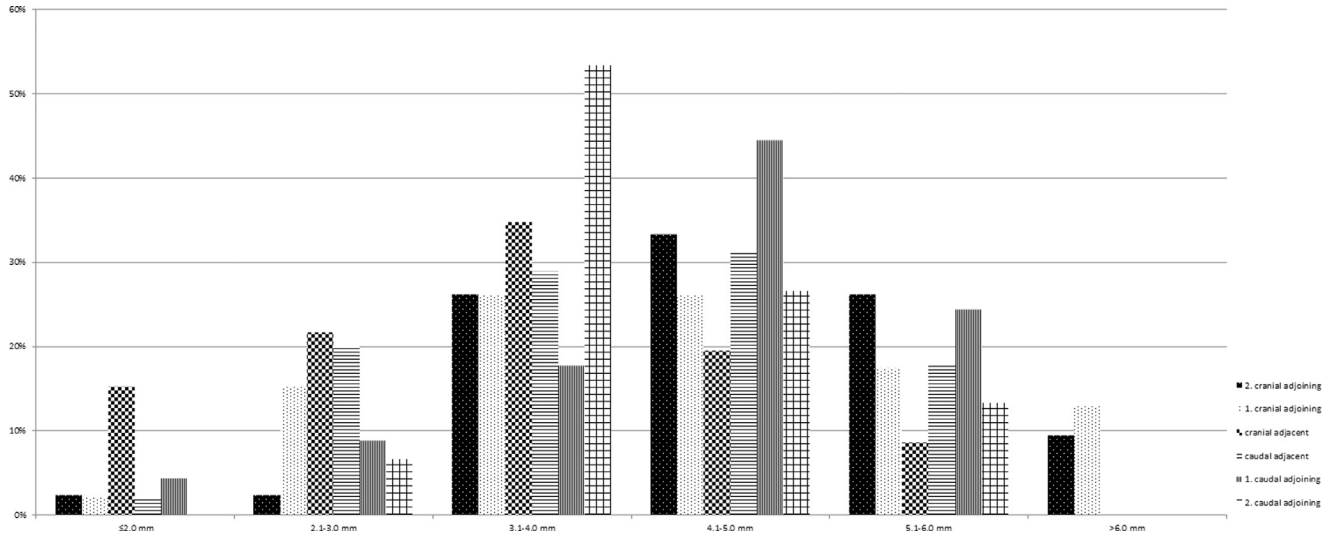

Fig. 4. Frequency of DH following ACDF.

10%, between 3.1 and 5.0 mm in 75%, and it was over 5.1 mm in 15% of cases.

A detailed complication of all DH frequencies with respect to the segment and surgical techniques (ACDF and ACDF+CP) are shown in Figs. 4 and 5. The reviewers had agreement in 46.1% for DH, in 7.7% for SSA, and in 82.4% for SDI.

The ICC showed very good reliability. ICC was 0.942 for DH, 0.986 for SSA, and 0.977 for SDI.

Comparison of SDI, DH, and SSA

The SDI, the DH, and the SSA of cranial and caudal adjacent segments, of first and second cranial and of caudal adjoining segments of one to three-level ACDF and ACDF+CP procedures as well as for one- and two-level procedures were compared. The SDI of the caudal adjacent segment was significantly lower (less signs of degeneration) in the ACDF+PS group in overall as well as the one- and two-level comparison. Furthermore, the SSA was significantly higher (more lordotic) following ACDF +PS procedures in the overall as well as the one- and two-level comparison. A compilation of the all comparison is shown in Table 5.

Discussion

Aging of the cervical spine is a physiological process which is associated with the occurrence and progress of degenerative changes. The most sensitive technique to assess the grade of disc degeneration is a magnetic resonance imaging (MRI) [11,12].

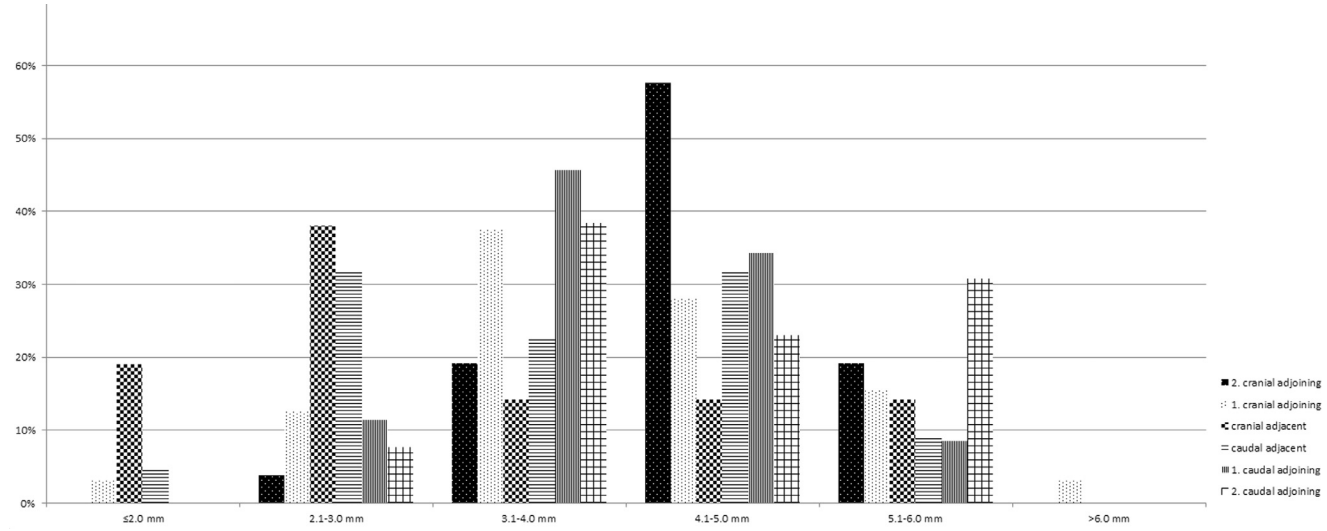

Fig. 5. Frequency of DH following ACDF+CP.

Table 5
Comparison of SDI, DH, and SSA

		One to three-level procedures			One-level procedures			Two-level procedures		
		ACDF	ACDF+CP	p Value	ACDF	ACDF+CP	p Value	ACDF	ACDF+CP	p Value
S D I	Cranial adjacent segment (mean)	0.63	0.57	.136	0.60	0.63	.331	0.64	0.50	.051
	Caudal adjacent segment (mean)	0.50	0.33	**<.001**	0.48	0.35	**.033**	0.49	0.28	**<.001**
	1. cranial adjoining segment (mean)	0.43	0.38	.234	0.47	0.43	.503	0.47	0.43	.723
	2. cranial adjoining segment (mean)	0.38	0.38	.744	0.37	0.37	.651	0.34	0.35	1.000
	1. caudal adjoining segment (mean)	0.38	0.38	.312	0.42	0.39	.519	0.33	0.31	.851
	2. caudal adjoining segment (mean)	0.25	0.38	.360	0.36	0.35	.846	0.23	0.43	.267
Disc height (mm)	Cranial adjacent segment (mean)	3.5	2.9	.289	3.40	3.24	.550	3.28	3.54	.910
	Caudal adjacent segment (mean)	4.0	3.6	.139	4.12	3.79	.447	3.71	3.64	.855
	1. cranial adjoining segment (mean)	4.5	3.9	.328	4.47	4.24	.576	4.07	3.91	.754
	2. cranial adjoining segment (mean)	4.5	4.3	.402	4.58	4.32	.359	4.71	4.47	.879
	1. caudal adjoining segment (mean)	4.4	4.0	**.026**	4.28	3.94	.144	4.45	4.16	.348
	2. caudal adjoining segment (mean)	4.0	4.2	.821	4.19	3.96	.488	5.00	4.65	1.000
SSA (°)	Sagittal segmental alignment of fused segment (mean)	**−3.73**	3.43	**.002**	**−3.10**	**2.79**	.079	**−4.32**	5.56	**.005**

Significances are marked in bold numbers.

Based on MRI imaging, asymptomatic volunteers over the age of 40 years will have significantly more degenerative findings than volunteers who are younger than 40 years of age [13]. The frequency of these degenerative changes will increase over the time. About 85% of volunteers over the age of 60 years have loss of disc signal intensity (Grade 1 and Grade 2) and 25% have posterior disc protrusion according to Matsumoto et al. [6].

Although there is no consensus whether ASD is a natural course of degeneration or due to ACDF previous studies have reported that the age at surgery, the number of fused segments, the location of the fused segment, the previous degeneration of the adjacent segment, and the excessive distraction of the disc space are causative factors [1,2,14–18].

Furthermore, accelerated adjacent of disc degeneration might be caused by false puncture while disc identification. The rate of falsely punctured disc has been reported to be up to 17.8% and the associated risk of ASD is three times higher in these cases [19]. In the present study, the rate of falsely punctured discs was 12.5%. But only 4 out of 170 adjacent discs which were assessed in these sturdy were falsely punctured. This small number does not allow for a profound conclusion regarding the process of degeneration. However, three out of four falsely punctured adjacent discs showed severe degeneration, whereas the overall rate of severe SDI was 23% in ACDF and 17% in ACDF+CP cases.

Based on plain radiographs, the prevalence of ASD has been reported to vary from 18% to 92% [20–23]. However, wide range of prevalence might be caused by the fact that degeneration was poorly defined. Radiographs are preferred to assess changes of osseous structures whereas they are limited in the assessment of the disc itself.

Additionally, it has been reported that distance of the cervical plate to the adjacent disc space has an influence on the development of adjacent segment ossification [24,25]. However, it remains unclear whether the distance of the cervical plate to the adjacent disc space has an influence on the development of ASD [26]. The present study was not designed to assess the cervical plate to the adjacent disc space distance. Therefore, no reliable predictions can be made about the effect of this variable on the development of ASD.

There is a paucity of studies that compared the incidence of ASD between ACDF and ACDF+CP. Ji et al. compared radiographs of two-level ACDF to ACDF+CP and reported a significant disc space narrowing in patients who underwent ACDF+CP. No significant differences were reported concerning the development of new anterior osteophyte formation and of calcification of the anterior longitudinal ligament. In contrast to Ji's study, the subgroups' analysis of the present study showed no negative influence on the CP, on the DH, and on the SDI in two-level procedures [15]. Recently, Ahn et al. reported lower rates of ASD following ACDF compared to ACDF+CP based on CT and MRI imaging. However, the follow-up of both aforementioned studies was considerably low (ie, 2 years) compared to the present study.

To the best of the authors' knowledge, the present study is the first which compares the degeneration of adjacent and adjoining segments on MRI following ACDF and ACDF +CP in a long-term follow-up setting. The main purpose of the present study was to assess whether anterior cervical plating has an influence on ASD.

The data of the present study demonstrate that the ACDF and ACDF+CP are both followed by ASD. Based on the MRI scan, the signal intensity and the occurrence of foraminal stenosis of the adjacent and adjoining segments showed a consistent distribution. Whereas the frequency of narrowing of the disc space and posterior disc protrusion were more severe at the adjacent segments compared to the

adjoining segments. As a consequence, more severe degeneration according to the SDI was observed at the adjacent compared to the adjoining segments. These findings are in accordance with previous reports [7].

The data of the present study further demonstrate that the SDI of the cranial adjacent segment and the cranial and caudal adjoining segment were not significantly different in the ACDF and ACDF+CP groups. Based on this comparison, the adding of a cervical plate had no influence in the process of segmental degeneration in the present series of patients. Additionally, the mean DH of the adjacent segments and all but the 1. caudal adjoining segment were not statistical significantly different. Although there was a trend that the mean DH of segments following ACDF+CP was smaller compared to ACDF.

Interestingly, the only comparison with a significant difference according to SDI was of the caudal adjacent segment. The authors have no profound explanation why the caudal adjacent segment following ACDF was significantly higher compared to ACDF+CP. One reason might be that the SSA following ACDF+CP was significantly higher compared to ACDF. Therefore, the sagittal alignment of the cervical spine tends to be more lordotic after ACDF+CP.

It is well known that kyphotic alignment of the cervical spine following ACDF is a factor that accelerates the degenerative process of the adjacent segments [27]. Even though the sagittal alignment of the cervical spine (C2-7) was not measured via MRI, the SSA might have the same effect and especially on the caudal adjacent segment.

The authors made any effort to obtain preoperative imaging but at the time of the initial ACDF and ACDF+CP an MRI scan was not used frequently and furthermore in Germany by law imaging data has to be filed for a maximum of 10 years. Therefore, no comparison of preoperative and follow-up imaging was possible. The present study is limited due to its retrospective design to thoroughly understand and assess the influence of cervical plating on the process on ASD. Prospective long-term follow-up studies using radiograph and MRI are necessary. In the authors' opinion, the adding of a cervical plate is associated with more advantages than disadvantages. Currently, there is no evidence that cervical plating accelerates ASD. The data of this long-term follow-up study demonstrate that the rate of severe adjacent segment disc degeneration was lower compared to ACDF and the SSA was more lordotic. This finding strengthens the authors' opinion to perform cervical plating in any ACDF procedure.

Conclusion

No significant differences were seen in DH of adjacent and adjoining segment in patients following ACDF and ACDF+CP. Besides the caudal adjacent segment, the grade of degeneration at adjacent and adjoining segments was not significantly different. The SSA in patients following ACDF+CP was significantly greater.

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