

# Comparison of a zero-profile anchored spacer (ROI-C) and the polyetheretherketone (PEEK) cages with an anterior plate in anterior cervical discectomy and fusion for multilevel cervical spondylotic myelopathy

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## Abstract

**Purpose** We aimed to analyze the clinical and radiographic efficacy of a new zero-profile anchored spacer called the ROI-C in anterior discectomy and fusion (ACDF) for multilevel cervical spondylotic myelopathy (MCSM).

**Method** We retrospectively reviewed the clinical, radiological outcomes and complications of multilevel ACDF with the ROI-C or with the polyetheretherketone (PEEK) cages with an anterior plate. From April 2011 to April 2014, 60 patients with MCSM were operated on using ACDF, with the ROI-C in 28 patients and PEEK cages with an anterior plate in 32 patients. The operative time, intraoperative blood loss, and clinical and radiological results were compared between the ROI-C group and the cage-plate group.

**Results** The mean follow-up time was  $23.8 \pm 6.6$  months, ranging from 12 to 36 months. At the first month and the last follow-up, the neck disability index (NDI) scores were decreased, and the Japanese Orthopedic Association (JOA) scores were significantly increased, compared with the presurgical measurements in both groups. There were no significant differences in NDI scores or JOA scores between the two groups ( $P > 0.05$ ), but there were significant differences in the operation time, blood loss and the presence of dysphagia ( $P < 0.05$ ). In addition, the cervical Cobb angle and disk height showed significant corrections, compared to those measured before the operation. There was no

adjacent disc degeneration observed in the ROI-C group, and one patient with skip levels showed disc degeneration of the normal level between the skip levels in the cage-plate group. The degeneration rate of the cage-plate group was 3.1 %.

**Conclusions** The primary clinical and radiographic efficacies of both ROI-C and cages with plates in ACDF for MCSM were satisfactory; both approaches could improve and maintain cervical lordosis and disk height. However, the ROI-C was associated with a simpler operation, a shorter operation time, less blood loss, and a lower risk of postoperative dysphagia compared to the PEEK cage with an anterior plate.

**Keywords** Multilevel spondylotic myelopathy · Anterior discectomy and fusion · ROI-C · PEEK cage

## Introduction

Since its introduction in 1958 by Smith, Robinson [1] and Cloward [2], anterior cervical discectomy and fusion (ACDF) has been considered a safe and effective surgical treatment for cervical degenerative disk disease. Today, the procedure has become the gold-standard operation for single-level cervical spondylotic myelopathy [3, 4]. However, anterior decompression with multilevel bone grafting is not stable, with frequent instances of displacement and a low fusion rate. Although titanium plate fixation can ensure the stability of the cervical spine, enhance the fusion rate and correct the spinal curve to physiological lordosis for single-level fusion, the side effects of the anterior plate, such as screw or plate dislodgement, soft tissue injury, and esophageal perforation and dysphagia, remain unavoidable when multilevel fusion is performed for patients [5–7]. To

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reduce the potential complications, a zero-profile anchored spacer (ROI-C, LDR, Troyes, France) has been gradually clinically applied for multilevel cervical degenerative disc disease. In this system, a designed intervertebral fusion device is constructed of a polyetheretherketone (PEEK) cage with two integrated self-locking clips, which can enter the vertebral body through the endplate. The whole device can be implanted into the intervertebral space, providing adequate stability and avoiding implant contact with the anterior soft tissue. The ROI-C has been used in anterior discectomy and fusion for single-level or two-level cervical degenerative disc disease and has obtained satisfactory clinical outcomes [8]. However, there is little knowledge about the outcomes of this zero-profile device in multilevel fusion. We performed this retrospective study to compare the clinical and radiological results of the ROI-C and PEEK cages with titanium plates for treating multilevel cervical spondylotic myelopathy (MCSM).

## Materials and methods

### Patient population

This was a retrospective and comparative clinical study. The patients were selected based on the timing of presentation and were subsequently divided into two groups based on the surgical method applied. From April 2011 to April 2014, 28 patients with MCSM who underwent fusion using zero-profile anchored spacer (ROI-C, LDR, Troyes, France) implants were classified as the ROI-C group (Fig. 1). During the same period, 32 patients who underwent fusion using PEEK cages and anterior plates (Medtronic, Minneapolis, MN, USA) served as the cage-plate group (Fig. 2). Twenty-eight patients with a mean age of  $56.6 \pm 9.7$  years old (range 40–75 years) received ROI-C implants in the target segments. Among these patients, the levels to be treated included C<sub>3–6</sub> (six patients), C<sub>4–7</sub> (nine patients), C<sub>3–4</sub> + C<sub>4–5</sub> + C<sub>6–7</sub> (two patients), C<sub>3–4</sub> + C<sub>5–6</sub> + C<sub>6–7</sub> (three patients), and C<sub>3–7</sub> (eight patients). Another 32 patients, with a mean age of  $57.5 \pm 9.5$  years old (range 42–78 years), received PEEK cages implanted in the target segments with anterior plates, and the corresponding operative levels included C<sub>3–6</sub> (nine patients), C<sub>4–7</sub> (nine patients), C<sub>3–4</sub> + C<sub>4–5</sub> + C<sub>6–7</sub> (one patient), C<sub>3–4</sub> + C<sub>5–6</sub> + C<sub>6–7</sub> (three patients), and C<sub>3–7</sub> (ten patients).

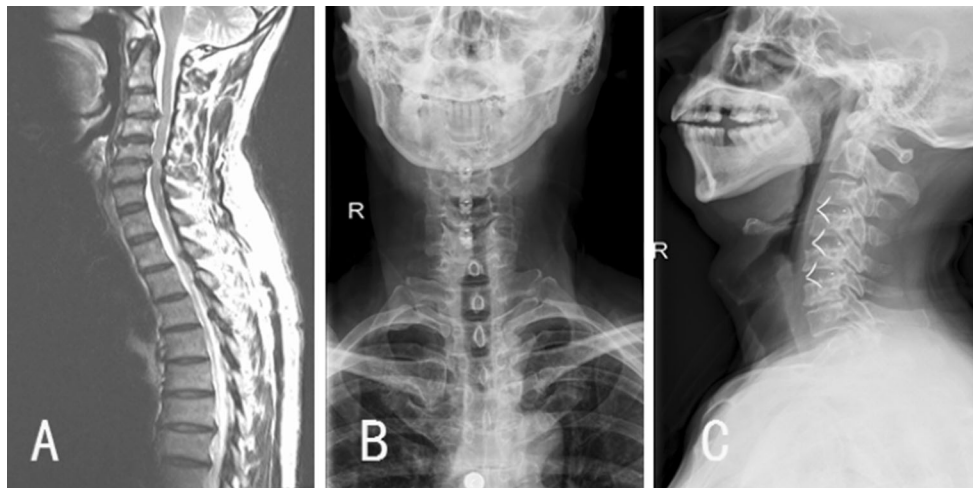
The inclusion criteria were as follows: (1) symptoms of cervical myelopathy and/or radiculopathy; (2) cervical spine radiography, computed tomography (CT), or magnetic resonance imaging (MRI) showing intervertebral disc degeneration, herniation, and posterior vertebral body osteophyte formation; and (3) cervical pathology level  $\geq 3$ .

The exclusion criteria included the following: (1) developmental stenosis and continuous or combined ossification of the posterior longitudinal ligament; and (2) history of previous cervical spine surgery, tumor, or any serious general illness. The patients' preoperative data and operative segments are shown in Table 1. There were no significant differences in patient age, sex, follow-up time, or operative level between the ROI-C group and the cage-plate group ( $P > 0.05$  Table 1). This study was approved by the Institutional Ethics Committee of Soochow University.

### Surgical procedure

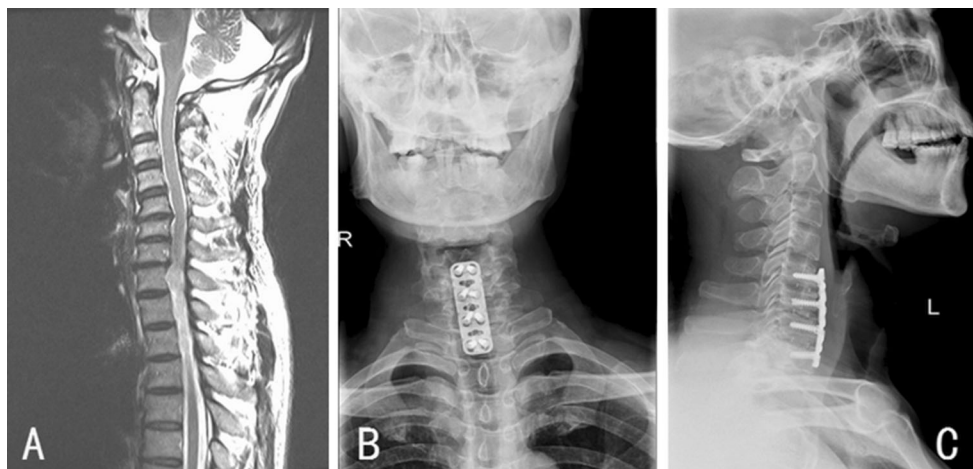
All of the surgeries were performed by the same surgeon. The patients were administered general anesthesia and were placed in the supine position. The surgical procedure was performed using a standard anterior Smith-Robinson approach [1]. After confirmation and exposure of the appropriate vertebral levels, the compressive materials, including the intervertebral disk and osteophyte, were removed. The posterior longitudinal ligament was opened, and other compressive elements were removed to ensure adequate dural and neural decompression. The endplate cartilage was scraped, and the bony endplate was preserved as much as possible to prevent cage subsidence.

In the ROI-C group, trial spacers were used to determine the appropriate size of the anchored intervertebral fusion cage. After 0.25 mg of recombinant human bone morphogenetic protein (rhBMP-2, Pharmaceutical Group Investment Limited Corporation, Hangzhou, China) was administered, the local osteophytes were excised and exclusively placed in the center of a PEEK cage. Then, the cage was inserted with an impactor. Correct positioning of the cage was controlled using C-arm fluoroscopy on lateral and anteroposterior views. After implantation of the cage, two cervical anchoring clips were placed into the lower and upper vertebrae through the anterior part of the cage to ensure primary stabilization by self-locking function of the anchoring clips. In the cage-plate group, the appropriate size for the PEEK cage was determined by both preoperative templating and intraoperative evaluation using a trial cage. The PEEK cage was placed with 0.25 mg of rhBMP-2 and excised local osteophytes, and the cage was inserted into the disc space as described above. After removal of the Caspar distractor, self-tapping screws were used to fix the anterior cervical plate. After the operations, the patients were asked to sit up 24 h later, and they walked on the second day with a neck collar. The clinical and radiographic data analyses were performed three separate times by an independent observer to ensure accuracy.



**Fig. 1** The preoperative sagittal T2-weighted magnetic resonance image (a) of 53-year-old male patient showed cervical spondylotic myelopathy at C4–C7 levels. The postoperative anteroposterior

(b) and lateral (c) radiographs showed anterior cervical discectomy and fusion with the zero-profile anchored spacers (ROI-C)



**Fig. 2** The preoperative sagittal T2-weighted magnetic resonance image (a) of 59-year-old male patient with cervical spondylotic myelopathy at C5–T1 levels. The postoperative anteroposterior

(b) and lateral (c) radiographs showed anterior cervical discectomy and fusion with PEEK cage with an anterior plate

### Data collection and outcome evaluation

All of the patients were routinely examined at 1, 3, and 6 months after surgery and every year thereafter. The follow-up clinical examinations were performed by a physician from our team.

### Clinical evaluation

The clinical outcomes were evaluated using the neck disability index (NDI) score and the Japanese Orthopaedic Association (JOA) score preoperatively and at each follow-

up. The JOA recovery rate (RR) was also calculated, which was defined according to the method of Hirabayashi et al. [9] as follows:  $RR = (\text{postoperative JOA score} - \text{preoperative JOA score}) / (17 - \text{preoperative JOA score}) \times 100\%$ . The RR results were grouped as 75 % or more (excellent), 50–74 % (good), 25–49 % (fair), and less than 25 % (poor). The incidence of dysphagia was recorded using the system defined by Bazaz [10]. The severity of dysphagia was graded as none, mild, moderate, or severe (Table 2). The Odom criteria [11] were used to evaluate the surgical effects in each patient after 1 year of follow-up (Table 3).

**Table 1** Preoperative patient data and operative details in the two groups undergoing different methods of anterior cervical discectomy and fusion

	ROI-C group	Cage-plate group	<i>P</i> value
Sex (male/female)	10/18	12/20	0.886
Age (years)	56.6 ± 9.7	57.5 ± 9.5	0.731
Follow-up time (months)	23.3 ± 6.9	24.2 ± 6.4	0.603
Operated levels			
C <sub>3–6</sub>	6	9	0.926
C <sub>4–7</sub>	9	9	
C <sub>3–4</sub> + C <sub>4–5</sub> + C <sub>6–7</sub>	2	1	
C <sub>3–4</sub> + C <sub>5–6</sub> + C <sub>6–7</sub>	3	3	
C <sub>3–7</sub>	8	10	
Operative time (min)			
Three-level	136.9 ± 14.6	153.5 ± 19.4	0.003
Four-level	150.6 ± 22.3	176.6 ± 25.2	0.037
Blood loss (ml)			
Three-level	89.6 ± 17.6	110.0 ± 22.0	0.002
Four-level	108.6 ± 21.5	137.6 ± 31.0	0.039

**Table 2** Bazaz grading system for dysphagia

Symptom severity	Liquid food	Solid food
None	None	None
Mild	None	Rare
Moderate	None or rare	Occasionally (only with specific food)
Severe	None or rare	Frequent (majority of solids)

**Table 3** Odom criteria

Grade	Definition
Excellent	All preoperative symptoms relieved, able to carry out daily occupations without impairment
Good	Minimum persistence of preoperative symptoms, able to carry out daily occupations without significant interference
Fair	Relief of some preoperative symptoms, but whose physical activities were significantly limited
Poor	Symptom and signs unchanged or worse

### Radiologic evaluation

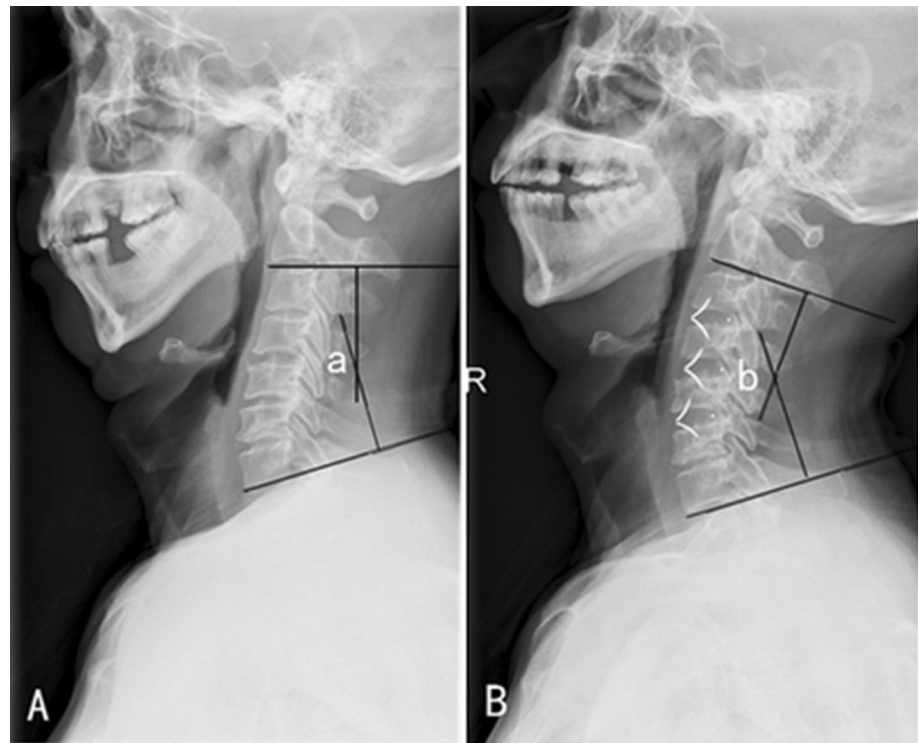
(1) According to X-ray and CT scan reconstructions, fusion was considered when the following conditions were satisfied [12]: (1) absence of motion between the spinous processes; (2) absence of a radiolucent gap between the graft and the endplate; and (3) the presence of continuous bridging bony trabeculae at the graftendplate interface. (2) Cervical lordosis was assessed using the Cobb angle of C2–C7 with the method described by Borden [13]; this angle was formed by the lines along the inferior endplate of C2 to the inferior endplate of C7 in the neutral position (Fig. 3a, b). (3) The disk height was the distance from the inferior endplate of the cephalad vertebral body to the superior

endplate of the caudal vertebral body of the fused segment, which was calculated as the mean value of the height of the anterior border and posterior border [14]. (4) New osteophyte formation or enlargement, new narrowing of the intervertebral disc space, or increase of the anterior longitudinal ligament was regarded as adjacent segment degeneration.

### Statistical analysis

All of the analyses were performed using the Statistical Package for the Social Sciences (version 18.0 SPSS, Chicago, IL, USA). Differences between the two treatment groups were assessed using Student's *t* tests. The paired-samples *t* test was used for paired data and the independent-samples *t* test for unpaired data. Differences in categorical variables were assessed using the Chi-square test. The results of two-tailed tests were considered significant when *P* was less than 0.05. The intraobserver reliability was calculated using the reliability statistics by intraclass correlation (ICC) for cervical lordosis and disk height. The values of the ICC may range from 0 to 1, with a higher value indicating better reliability. Intraclass correlation values less than 0.40 were considered as poor, 0.40–0.59 as fair, 0.60–0.74 as good, and 0.75–1.00 as excellent.

**Fig. 3** **a** Preoperative cervical lordosis (Cobb angle of C2–C7, *a*). **b** Postoperative cervical lordosis (Cobb angle of C2–C7, *b*)



## Results

The surgeries were performed successfully in all cases. The mean follow-up time was  $23.8 \pm 6.6$  months, ranging from 12 to 36 months. No complications, such as bolt loosening, or ruptures of the anchoring clips, screws or titanium plates were observed in the two groups during the follow-up period. The operation times for three levels in the ROI-C group and cage-plate group were  $136.9 \pm 14.6$  and  $153.5 \pm 19.4$  min, respectively. The blood loss volumes in the corresponding groups were  $89.6 \pm 17.6$  and  $110.0 \pm 22.0$  ml, respectively. The operative times for four levels in the ROI-C group and cage-plate group were  $150.6 \pm 22.3$  and  $176.6 \pm 25.2$  min, respectively. The corresponding blood loss volumes were  $108.6 \pm 21.5$  and  $137.6 \pm 31.0$  ml, respectively. The differences in operative time and intraoperative blood loss between the ROI-C group and the cage-plate group were significant ( $P < 0.05$ , Table 1). The ROI-C group had a shorter operation time and less blood loss compared than the cage-plate group.

## Clinical outcomes

The mean JOA scores increased significantly from the preoperative evaluation to the last follow-up, with an increase from  $10.4 \pm 2.1$  preoperatively to  $14.6 \pm 1.7$  postoperatively in the ROI-C group and from  $10.6 \pm 1.9$  preoperatively to  $14.4 \pm 1.8$  postoperatively in the cage-

plate group. The corresponding NDI scores decreased significantly from  $35.3 \pm 2.8$  preoperatively to  $13.1 \pm 3.1$  postoperatively in the ROI-C group and from  $34.7 \pm 2.7$  to  $13.5 \pm 3.2$  in the cage-plate group. The JOA recovery rates were  $61.2 \pm 19.0$  and  $58.8 \pm 19.9$  % for the ROI-C and cage-plate groups, respectively. There was no significant difference in the JOA recovery rate between the two groups. According to the Odom criteria, the percentages of patients with excellent and good clinical outcomes were 85.7 % in the ROI-C group and 84.3 % in the cage-plate group. Although the postoperative JOA scores and NDI scores in both groups differed significantly from those measured preoperatively ( $P < 0.001$ , Table 4), there were no significant differences in the JOA scores or NDI scores between the two groups ( $P > 0.05$  Table 4).

## Radiologic outcomes

The results of the ICC analysis for radiologic measurements between three separate times of an independent observer indicated good reliability. The intraobserver reliability statistics by ICC was 0.937 for cervical lordosis and 0.917 for disk height. The postoperative disk height and cervical lordosis were significantly improved in both groups. In the ROI-C group, the disk height increased from  $4.6 \pm 0.7$  mm preoperatively to  $6.3 \pm 0.8$  mm postoperatively, and cervical lordosis increased from  $11.4^\circ \pm 7.2^\circ$  preoperatively to  $19.0^\circ \pm 7.8^\circ$  at the final follow-up

**Table 4** The mean outcomes of clinical and radiological parameters measured before operation and during follow-up (mean  $\pm$  SD)

Parameters	ROI-C group	Cage-plate group
JOA scores		
Preoperative	10.4 $\pm$ 2.1	10.6 $\pm$ 1.9
Postoperative 1 month	14.3 $\pm$ 1.8 <sup>#</sup>	14.1 $\pm$ 1.7 <sup>#</sup>
Final follow-up	14.6 $\pm$ 1.7 <sup>#</sup>	14.4 $\pm$ 1.8 <sup>#</sup>
NDI scores		
Preoperative	35.3 $\pm$ 2.8	34.7 $\pm$ 2.7
Postoperative 1 month	13.5 $\pm$ 3.4 <sup>#</sup>	14.0 $\pm$ 3.0 <sup>#</sup>
Final follow-up	13.1 $\pm$ 3.1 <sup>#</sup>	13.5 $\pm$ 3.2 <sup>#</sup>
Disk height (mm)		
Preoperative	4.6 $\pm$ 0.7	4.5 $\pm$ 0.6
Postoperative 1 month	6.5 $\pm$ 0.9 <sup>#</sup>	6.0 $\pm$ 0.7 <sup>#</sup>
Final follow-up	6.3 $\pm$ 0.8 <sup>#</sup>	5.9 $\pm$ 0.9 <sup>#</sup>
Cervical lordosis (°)		
Preoperative	11.4 $\pm$ 7.2	11.7 $\pm$ 7.5
Postoperative 1 month	19.5 $\pm$ 7.5 <sup>#</sup>	18.9 $\pm$ 7.9 <sup>#</sup>
Final follow-up	19.0 $\pm$ 7.8 <sup>#</sup>	18.7 $\pm$ 7.8 <sup>#</sup>
Clinical outcomes according to Odom criteria	Excellent: 10; good: 14; fair: 3; bad: 1	Excellent: 12; good: 15; fair: 4; bad: 1

JOA Japanese Orthopedic Association, NDI Neck Disability Index

<sup>#</sup>  $P < 0.05$  comparing with preoperative value

**Table 5** Complications after operations in the two groups

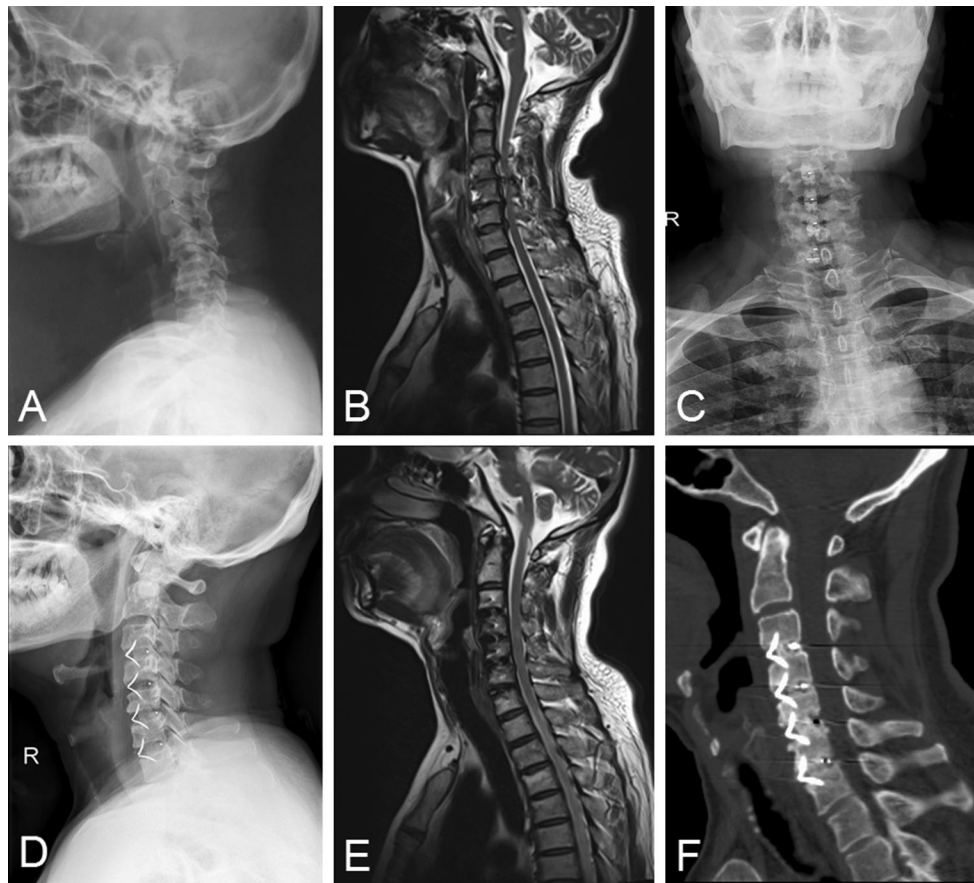
Groups	ROI-C group	Cage-plate group	<i>P</i> value
Dysphagia rate			
Postoperative 1 month	6/28 (21.4 %)	13/32 (40.6 %)	0.111
Postoperative 3 months	1/28 (3.6 %)	8/32 (25 %)	0.020
Final follow-up	1/28 (3.6 %)	7/32 (21.9 %)	0.037
Adjacent segment degeneration	0/28 (0 %)	1/32 (3.1 %)	0.346

( $P < 0.01$ , Table 4). In the cage-plate group, the corresponding parameters significantly increased from  $4.5 \pm 0.6$  mm preoperatively to  $5.9 \pm 0.9$  mm postoperatively and from  $11.7^\circ \pm 7.5^\circ$  preoperatively to  $18.7^\circ \pm 7.8^\circ$  at the final follow-up ( $P < 0.01$ , Table 4). There were no significant differences in these parameters between the two groups ( $P > 0.05$ ), but at the last follow-up, the cervical Cobb angle and disk height showed significant corrections when compared to those measured before the operations.

### Complications

Six patients (21.4 %) complained of mild dysphagia 1 month after surgery in the ROI-C group; the dysphagia of five patients disappeared after 3 months. Only one patient had no apparent relief at the last follow-up, and the incidence of dysphagia in the ROI-C group was approximately 3.6 %. There were 13 (40.6 %) patients who complained of

dysphagia in the cage-plate group. Of these, seven patients complained of mild dysphagia, and six patients complained of moderate dysphagia 1 month after surgery. After conservative treatment, five patients recovered after 3 months, and one patient recovered after 6 months. However, seven patients had no apparent relief at the last follow-up, and the incidence of dysphagia in the cage-plate group was approximately 21.9 %. The difference in dysphagia rate between the two groups was statistically significant ( $P = 0.037$ , Table 5). There was no adjacent disc degeneration observed in the ROI-C group, and one patient with skip levels had disc degeneration of the normal level between the skip levels in the cage-plate group. The degeneration rate in the cage-plate group was 3.1 %, and there was no significant difference in the incidence of adjacent segment degeneration between the two groups ( $P > 0.05$ , Table 5). Solid fusion was achieved in all patients of two groups at 3–6 months postoperatively (Fig. 4).



**Fig. 4** The preoperative lateral view (a) and sagittal T2-weighted magnetic resonance image (b) of 53-year-old male patient showed cervical spondylotic myelopathy at C3–C7 levels, in whom the 4-level anterior cervical discectomy and fusion (ACDF) was performed with the zero-profile anchored spacers (ROI-C). The postoperative anteroposterior (c) and lateral (d) radiographs showed a

satisfactory improvement of the cervical lordosis. The postoperative sagittal T2-weighted magnetic resonance image (e) showed efficient decompression of the spinal canal. The computed tomography (CT) scan reconstructions (f) of 3-month follow-up showed excellent fusion

## Discussion

Multilevel cervical spondylotic myelopathy is a leading cause of spinal cord dysfunction and can substantially decrease quality of life. Thus far, surgical treatment has been advocated for MCSM by many authors; however, the choice of surgical approach for MCSM remains a controversial subject. Anterior, posterior and combined anterior and posterior surgical approaches for patients with MCSM have all been advocated [15, 16].

Multilevel cervical spondylotic myelopathy typically occurs in elderly patients, specifically those whose MRI scans show anterior compressive pathology, such as disc herniation and osteophyte and ligament hyperplasia. An anterior approach not only allows for direct decompression, but also can help to restore the height of the interbody space and to reconstruct cervical lordosis. The most commonly used anterior approaches for MCSM are anterior cervical discectomy and fusion (ACDF) and anterior

cervical corpectomy with fusion (ACCF). The long corpectomy in the treatment of MCSM usually results in more bleeding, graft dislodgment, and kyphotic deformity and a higher incidence of postoperative complications [17–19]. ACDF can increase the height of the ventral column and restore lordosis by allowing the intervening vertebral body segments to be pulled toward the lordotic ventral plate, which compensates for the aforementioned shortcomings. Burkardt et al. [20] performed a comparative study of 118 consecutive patients who underwent ACDF or ACCF, and the results showed that ACDF resulted in less blood loss, greater improvements in cervical lordosis and better segmental height than with ACCF. In addition, multilevel ACDF can provide multiple distraction points and therefore can increase the solid fusion rate than better ACCF procedures. Vanichkachorn et al. [21] concluded that patients undergoing ACDF with trinity evolution (TE) in combination with a PEEK interbody spacer and anterior fixation had a high rate of fusion success. However, the

application of an anterior titanium plate in multilevel ACDF is also accompanied by various complications, such as increased risks of hardware failure and postoperative dysphagia. To avoid the potential complications caused by titanium plates, a zero-profile anchored spacer (ROI-C, LDR, Troyes, France) has attracted attention as a treatment for cervical degenerative disc disease.

The new zero-profile anchored spacer (ROI-C) can be totally implanted into the intervertebral space so that it avoids implant contact with the front soft tissue. Moreover, the zero-profile anchored spacer, consisting of a cage and two anchoring clips, can combine interbody support and supplemental fixation into a single device. These unique structures offer a fixation mechanism that is similar to the function of a plate and screws, thereby ensuring excellent primary stability of the implant. Furthermore, the elastic modulus of the anchored cage is a PEEK-Optima material, which is similar to bone and can help to decrease stress shielding and increase bony fusion. Scholz et al. [22] analyzed different multilevel cervical fixation techniques, and the results showed that the locking plate and cage construct was stiffer than the anchored devices in multilevel constructs. However, it remains unclear what the clinical significance may be. Mattei et al. [23] reported a case of vertebral body fracture after ACDF with zero-profile anchored cages in adjacent levels. They considered future biomechanical and clinical studies are warranted to evaluate the safety of employing such devices for treatment of multilevel cervical degenerative disc disease. In our study, all of the patients obtained excellent fusion and good stability at the final follow-up assessment.

Surgery for MCSM aims to decompress the spinal cord and nerve roots, to restore the height, to reconstruct lordosis, and to stabilize the spinal column to prevent further degeneration at the affected levels [24]. Normal lordotic alignment is one of the most important factors related to good motion and function of the cervical spine. Sagittal malalignment after anterior cervical discectomy and fusion may cause postoperative axial pain and worsening of neurologic deficits, influencing functional recovery [25]. Moreover, sagittal malalignment has been shown to be associated with accelerated degenerative changes in adjacent segments during long-term follow-up [26]. In our study, the postoperative disk height and cervical lordosis were significantly improved in both groups and were also maintained at the last follow-up. There were no significant differences in these parameters between the two groups, but the ROI-C group was found to be superior to the cage with plate group in terms of operation time and blood loss. In addition, the ROI-C was associated with a significant benefit in treating skip compressive pathology in MCSM. When patients with the presence of the skip compressive pathology in MCSM were operated on using ACDF with

plating, the plate could constrain the activity of the normal level between skip levels, reducing the number of vertebrae with active function and causing biomechanical changes. However, the application of the ROI-C in skip levels could maintain activity at a normal level between skip levels, thus not sacrificing any normal motion segments.

Chronic dysphagia is a well-known phenomenon after ACDF and plating, with variability ranging from 3 to 21 % [5, 6, 10, 27]. The rate of dysphagia in the cage with plate group in our study was similar to that in the current literature [10, 28, 29]. We did not find a significant difference in the incidence of dysphagia 1 month after surgery, but we confirmed that the incidence of chronic dysphagia was lower in the ROI-C group (3.6 %), compared to 25 % in the cage with plate group, after 3 months of follow-up. Although the exact pathophysiologic mechanism of dysphagia remains unknown, postoperative soft tissue edema, esophageal injury, postoperative hematoma, and adhesive formations around implanted cervical plates might be possible explanations for dysphagia [10, 29]. According to Lee et al. [29], dysphagia was related to the thickness of the titanium plate at the level of fusion. Similar findings were also observed in a prospective study by Barbagallo et al. [30] which compared a series of patients treated with single- or multilevel ACDF with a zero-profile device or with the polyetheretherketone (PEEK) cages with an anterior plate. In such study, the zero-profile device is safe, efficient and the dysphagia is minimal. Nioku et al. [31] also demonstrated chronic dysphagia rates in patients submitted to zero-profile anchored cages are better than those for nonintegrated plate and spacer constructs. The new zero-profile anchored spacer could be completely contained in the intervertebral space, avoiding implant contact with the soft tissue in front of the cervical spine. This spacing might avoid any mechanical irritation of the esophagus and might explain the low dysphagia rate in the ROI-C group. In addition, the ROI-C has a smaller volume than the PEEK cage with plate device, allowing for a smaller incision. Furthermore, this smaller incision allows for less exposure and avoids mechanical stimulus of the related structures. Thus, we conclude that application of the ROI-C assures mild postoperative prevertebral soft tissue injury and a low incidence of dysphagia after ACDF in MCSM.

One concern with multilevel ACDF is the potential for accelerated adjacent segment degeneration related to increased rigidity. Earlier studies have shown that the presence of a plate is likely to accelerate degenerative changes in adjacent segments [32, 33]. The widely quoted rate for symptomatic degeneration after ACDF is 2.9 % [34]. Although the exact pathophysiologic mechanism remains unknown, it is believed that more motion is transferred to fewer remaining motion segments, which hastens the onset of disc degeneration, chondroosseous



spur formation, and new disease at adjacent levels. In our study, there was no adjacent disc degeneration observed in the ROI-C group. One patient with the skip compressive pathology in MCSM after ACDF with plating showed disc degeneration of the normal level between the skip levels; however, no symptoms due to these radiographical changes were observed, and no repeat operations were needed secondary to the degenerative level.

## Conclusions

The results of our study showed that both ROI-C and PEEK cage with anterior plate fixation were effective for MCSM and could restore and maintain the cervical lordosis and disk height. However, the ROI-C was associated with a simpler operation, shorter operation time, less blood loss, and a lower risk of postoperative dysphagia than the PEEK cage with anterior plate. Because of the relatively short follow-up period and small number of patients in this study, more patients and longer follow-ups are needed to confirm the results we obtained in this study.

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**Compliance with ethical standards**

**Conflict of interest** None.

## References

- Smith GW, Robinson RA (1958) The treatment of certain cervical-spine disorders by anterior removal of the intervertebral disc and interbody fusion. *J Bone Joint Surg Am* 40-A(3):607–624
- Cloward RB (1958) The anterior approach for removal of ruptured cervical disks. *J Neurosurg* 15(6):602–617
- Mummaneni PV, Kaiser MG, Matz PG et al (2009) Cervical surgical techniques for the treatment of cervical spondylotic myelopathy. *J Neurosurg Spine* 11(2):130–141
- Kim SW, Limson MA, Kim SB, Arbatin JJ, Chang KY, Park MS, Shin JH, Ju YS (2009) Comparison of radiographic changes after ACDF versus Bryan disc arthroplasty in single and bi-level cases. *Eur Spine J* 18(2):218–231
- Fountas KN, Kapsalaki EZ, Nikolakakos LG, Smisson HF, Johnston KW, Grigorian AA, Lee GP, Robinson JS Jr (2007) Anterior cervical discectomy and fusion associated complications. *Spine (Phila Pa 1976)* 32(21):2310–2317
- Kalb S, Reis MT, Cowperthwaite MC, Fox DJ, Lefevre R, Theodore N, Papadopoulos SM, Sonntag VK (2012) Dysphagia after anterior cervical spine surgery: incidence and risk factors. *World Neurosurg* 77(1):183–187
- Lowery GL, McDonough RF (1998) The significance of hardware failure in anterior cervical plate fixation. Patients with 2- to 7-year follow-up. *Spine (Phila Pa 1976)* 23(2):181–186
- Wang Z, Jiang W, Li X, Wang H, Shi J, Chen J, Meng B, Yang H (2015) The application of zero-profile anchored spacer in anterior cervical discectomy and fusion. *Eur Spine J* 24(1):148–154
- Hirabayashi K, Miyakawa J, Satomi K, Maruyama T, Wakano K (1981) Operative results and postoperative progression of ossification among patients with ossification of cervical posterior longitudinal ligament. *Spine (Phila Pa 1976)* 6(4):354–364
- Bazaz R, Lee MJ, Yoo JU (2002) Incidence of dysphagia after anterior cervical spine surgery: a prospective study. *Spine (Phila Pa 1976)* 27(22):2453–2458
- Odom GL, Finney W, Woodhall B (1958) Cervical disk lesions. *J Am Med Assoc* 166(1):23–28
- Vaccaro AR, Carrino JA, Venger BH, Albert T, Kelleher PM, Hilibrand A, Singh K (2002) Use of a bioabsorbable anterior cervical plate in the treatment of cervical degenerative and traumatic disc disruption. *J Neurosurg* 97(4 Suppl):473–480
- Borden AG, Rechtman AM, Gershon-Cohen J (1960) The normal cervical lordosis. *Radiology* 74:806–809
- Chen Y, Wang X, Lu X, Yang L, Yang H, Yuan W, Chen D (2013) Comparison of titanium and polyetheretherketone (PEEK) cages in the surgical treatment of multilevel cervical spondylotic myelopathy: a prospective, randomized, control study with over 7-year follow-up. *Eur Spine J* 22(7):1539–1546
- Ghogawala Z, Coumans JV, Benzel EC, Stabile LM, Barker FG (2007) Ventral versus dorsal decompression for cervical spondylotic myelopathy: surgeons' assessment of eligibility for randomization in a proposed randomized controlled trial: results of a survey of the Cervical Spine Research Society. *Spine (Phila Pa 1976)* 32(4):429–436
- Konya D, Ozgen S, Gercek A, Pamir MN (2009) Outcomes for combined anterior and posterior surgical approaches for patients with multisegmental cervical spondylotic myelopathy. *J Clin Neurosci* 16(3):404–409
- Hee HT, Majd ME, Holt RT, Whitecloud TS, Pienkowski D (2003) Complications of multilevel cervical corpectomies and reconstruction with titanium cages and anterior plating. *J Spinal Disord Tech* 16(1):1–8
- Vaccaro AR, Falatyn SP, Scuderi GJ, Eismont FJ, McGuire RA, Singh K, Garfin SR (1998) Early failure of long segment anterior cervical plate fixation. *J Spinal Disord* 11(5):410–415
- Wang JC, Hart RA, Emery SE, Bohlman HH (2003) Graft migration or displacement after multilevel cervical corpectomy and strut grafting. *Spine (Phila Pa 1976)* 28(10):1016–1021
- Burkhardt JK, Mannion AF, Marbacher S, Dolp PA, Fekete TF, Jezzenszky D, Porchet F (2013) A comparative effectiveness study of patient-rated and radiographic outcome after 2 types of decompression with fusion for spondylotic myelopathy: anterior cervical discectomy versus corpectomy. *Neurosurg Focus* 35(1):E4
- Vanichkachorn J, Peppers T, Bullard D, Stanley SK, Linovitz RJ, Ryaby JT (2016) A prospective clinical and radiographic 12-month outcome study of patients undergoing single-level anterior cervical discectomy and fusion for symptomatic cervical degenerative disc disease utilizing a novel viable allogeneic, cancellous, bone matrix (trinity evolution™) with a comparison to historical controls. *Eur Spine J*. doi:10.1007/s00586-016-4414-7
- Scholz M, Schleicher P, Pabst S, Kandziora F (2015) A zero-profile anchored spacer in multilevel cervical anterior interbody fusion: biomechanical comparison to established fixation techniques. *Spine (Phila Pa 1976)* 40(7):E375–E380
- Mattei TA, Teles AR, Dinh DH (2016) Vertebral body fracture after anterior cervical discectomy and fusion with zero-profile anchored cages in adjacent levels: a cautionary tale. *Eur Spine J*. doi:10.1007/s00586-015-4358-3

24. Hillard VH, Apfelbaum RI (2006) Surgical management of cervical myelopathy: indications and techniques for multilevel cervical discectomy. *Spine J* 6(6 Suppl):242S–251S
25. Song KJ, Taghavi CE, Lee KB, Song JH, Eun JP (2009) The efficacy of plate construct augmentation versus cage alone in anterior cervical fusion. *Spine (Phila Pa 1976)* 34(26):2886–2892
26. Park MS, Kelly MP, Lee DH, Min WK, Rahman RK, Riew KD (2014) Sagittal alignment as a predictor of clinical adjacent segment pathology requiring surgery after anterior cervical arthrodesis. *Spine J* 14(7):1228–1234
27. Riley LH, Skolasky RL, Albert TJ, Vaccaro AR, Heller JG (2005) Dysphagia after anterior cervical decompression and fusion: prevalence and risk factors from a longitudinal cohort study. *Spine (Phila Pa 1976)* 30(22):2564–2569
28. Yue WM, Brodner W, Highland TR (2005) Persistent swallowing and voice problems after anterior cervical discectomy and fusion with allograft and plating: a 5- to 11-year follow-up study. *Eur Spine J* 14(7):677–682
29. Lee MJ, Bazaz R, Furey CG, Yoo J (2005) Influence of anterior cervical plate design on Dysphagia: a 2-year prospective longitudinal follow-up study. *J Spinal Disord Tech* 18(5):406–409
30. Barbagallo GM, Romano D, Certo F, Milone P, Albanese V (2013) Zero-P: a new zero-profile cage-plate device for single and multilevel ACDF. A single institution series with four years maximum follow-up and review of the literature on zero-profile devices. *Eur Spine J* 22(Suppl 6):S868–S878
31. Njoku I Jr, Alimi M, Leng LZ, Shin BJ, James AR, Bhangoo S, Tsiouris AJ (2014) Anterior cervical discectomy and fusion with a zero-profile integrated plate and spacer device: a clinical and radiological study: clinical article. *J Neurosurg Spine* 21(4):529–537
32. Park JB, Cho YS, Riew KD (2005) Development of adjacent-level ossification in patients with an anterior cervical plate. *J Bone Joint Surg Am* 87(3):558–563
33. Kao FC, Niu CC, Chen LH, Lai PL, Chen WJ (2005) Maintenance of interbody space in one- and two-level anterior cervical interbody fusion: comparison of the effectiveness of autograft, allograft, and cage. *Clin Orthop Relat Res* 430:108–116
34. Hilibrand AS, Carlson GD, Palumbo MA, Jones PK, Bohlman HH (1999) Radiculopathy and myelopathy at segments adjacent to the site of a previous anterior cervical arthrodesis. *J Bone Joint Surg Am* 81(4):519–528