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# Correlation analysis between preoperative odontoid incidence and clinical outcomes 2 years after anterior cervical discectomy and fusion

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## Abstract

**Objective** This study presents a novel odontoid parameter, the odontoid incidence (OI), to examine the correlation between OI on preoperative cervical sagittal radiographs and 2-year clinical outcomes following short-segment anterior cervical discectomy and fusion (ACDF) in patients with cervical spondylotic myelopathy (CSM).

**Methods** A retrospective analysis of the clinical data of 87 patients with CSM who underwent ACDF surgery from January 2018 to December 2023 was conducted. The patients were categorized into a larger OI group (44 patients, OI > 12.62°) and a smaller OI group (43 patients, OI ≤ 12.62°) on the basis of the median cervical sagittal OI prior to surgery. The postoperative follow-up duration was 2 years. Cervical sagittal parameters were assessed on lateral cervical spine radiographs both preoperatively and postoperatively. Additionally, the Japanese Orthopedic Association (JOA), neck disability index (NDI), and visual analog scale (VAS) scores were documented for each patient before surgery and at the final 2-year postoperative follow-up.

**Results** Compared with those in the preoperative period, the T1 slope, C2–C7 Cobb angle, sagittal segmental angle (SSA), and C0–C2 Cobb angle significantly improved in 87 patients with cervical spondylosis ( $P < 0.05$ ). At the 2-year postoperative follow-up, all patients exhibited significant improvements in JOA, NDI, and VAS scores compared with the preoperative values ( $P < 0.05$ ). No statistically significant difference was observed in the preoperative or baseline data between the larger OI group and the smaller OI group ( $P > 0.05$ ); however, a statistically significant difference was noted in the postoperative SSA between the two groups ( $P < 0.05$ ). A statistically significant difference was observed in the VAS score and NDI score at the final follow-up between the two groups ( $P < 0.05$ ), as well as in the improvement in the JOA score and VAS score (preoperative score minus the final follow-up score), between the two groups ( $P < 0.05$ ). The results of the Pearson correlation analysis indicated a negative correlation between the preoperative OI score and the VAS and NDI scores at the final postoperative follow-up ( $P = 0.012$ ,  $r = -0.268$ ) ( $P = 0.028$ ,  $r = -0.236$ ).

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**Conclusion** In ACDF, the preoperative OI of patients with CSM was negatively correlated with the VAS and NDI scores at the final postoperative follow-up; Larger preoperative OI corresponded to lower VAS and NDI scores at the final follow-up, leading to comparatively improved 2-year clinical outcomes.

**Keywords** Odontoid incidence, Anterior cervical discectomy and fusion, Cervical spondylotic myelopathy, Sagittal parameters

## Introduction

The prevalence of cervical spondylosis is increasing annually due to population aging and lifestyle alterations [1]. The pathogenesis primarily results from compression of the spinal cord, blood vessels, and nerves by degenerated cervical intervertebral discs, hyperplastic bone, and the ligamentum flavum, leading to various symptoms and signs [2]. Cervical spondylotic myelopathy (CSM) is a prevalent and severe variant of cervical spondylosis and represents the most frequent form of spinal cord injury in adults [3]. It frequently manifests as cervical pain, paresthesia, limb weakness, diminished hand dexterity, and a sensation of cotton in the feet. It may subsequently result in urinary and fecal incontinence, potentially leading to chronic disability, pain, financial strain, and a decline in quality of life [4].

Anterior cervical discectomy and fusion (ACDF) is the standard minimally invasive technique for addressing cervical spondylosis. ACDF has demonstrated substantial improvements in pain and dysfunction in patients with cervical spondylosis, as indicated by improvements in the neck disability index (NDI), Japanese Orthopedic Association (JOA) score, and visual analog scale (VAS) score for pain [5, 6]. Recently, interest in the influence of cervical sagittal alignment on postoperative clinical outcomes in patients undergoing cervical spine surgery has increased [7, 8]. The significance of cervical sagittal balance has been increasingly acknowledged since a study indicated a substantial correlation between sagittal balance and patients' quality of life scores [9]. Cervical sagittal imbalance is a primary contributor to degenerative cervical diseases [10]. Cervical spine parameters are essential for analyzing cervical sagittal alignment, assisting spine specialists in evaluating the clinical symptoms of cervical spondylosis, developing diagnostic and treatment strategies, choosing suitable surgical protocols, and forecasting postoperative clinical outcomes [11, 12]. The cervical sagittal balance parameters that are extensively analyzed include the C0–2 angle (C0–2), C2–C7 cervical lordosis (CL), C2 slope (C2S), T1 slope (T1S), and T1 slope minus cervical lordosis (T1S-CL) [13]. Nonetheless, these parameters are deficient because they are not invariant anatomical metrics, and the measurements may contain substantial inaccuracies. Consequently,

identifying new, relatively stable anatomical parameters of the cervical spine is essential for a comprehensive evaluation of cervical alignment [14].

Lee et al. introduced a novel cervical sagittal parameter, the odontoid incidence (OI), an autonomous anatomical metric unaffected by external influences [15]. The OI can be distinctly demonstrated on cervical sagittal X-ray. Moreover, OI is a clinically relevant parameter, which significantly correlated with postoperative health-related quality of life (HRQOL) [16]. This study aimed to determine the correlation between preoperative OI and clinical outcomes in patients with CSM who underwent short-segment ACDF to facilitate the preoperative prediction of postoperative functional recovery.

## Materials and methods

### Participants

This study included eighty-seven patients with short-segment CSM who underwent ACDF surgery at the First Affiliated Hospital of Guangzhou University of Chinese Medicine from January 2018 to December 2023. The mean postoperative follow-up duration was 2 years. The inclusion criteria were as follows: (1) definitive diagnosis of cervical spondylosis in two or fewer segments; (2) inadequate conservative treatment significantly impairing daily activities; and (3) all participants underwent ACDF surgery, utilizing endoprostheses such as the Zero-P, Skyline, and ZEVO anterior cervical spine endoprosthesis systems. The exclusion criteria were as follows: (1) congenital cervical spine deformities; (2) neck trauma or injury; (3) prolonged use of aspirin, polivir, or similar medications; (4) severe comorbidities (e.g cardiovascular, cerebrovascular, pulmonary, or renal diseases) who could not endure surgery; and (5) prior history of cervical spine surgery. The study protocol received approval from the Clinical Trial Review Committee of the First Affiliated Hospital of Guangzhou University of Chinese Medicine (NO. K[2020] 104), and written informed consent was obtained from all participants prior to the study. The participants in this study provided consent for the publication of their images.

### Surgical procedure

The identical surgeon and their team conducted the operations. The patients were directed to perform tracheal tube pushing training for 1 to 2 d prior to the operation. Following tracheal intubation under general anesthesia, the patients were positioned supine, the head was stabilized, the shoulders were retracted inferiorly, and a transverse incision was executed on the right side of the neck. The skin was incised and subcutaneously excised, bluntly dissected to the anterior intervertebral space with the trachea and esophagus retracted to the left side, while the longissimus cervical muscle and anterior vertebral fascia were separated to expose the anterior longitudinal ligament. The designated intervertebral space was identified with a locator pin and verified with a C-arm machine. The intervertebral space was accessed using a Caspar spreader, the intervertebral disc was excised, the dural sac was explored and decompressed until it resumed its bulging form, the cartilage from the upper and lower endplates was abraded, and bone fragments were implanted into the intervertebral space. The remaining intervertebral gaps were addressed similarly, and the plates were secured with screws. The C-arm machine apparatus was utilized once more for fluoroscopy to verify the proper positioning of the plates and screws, followed by washing. Hemostasis was achieved with an electrocautery knife, a drainage tube was inserted, and the site was sutured, cleaned, and wrapped with sterile gauze. Postoperatively, patients were monitored, antibiotics were administered consistently for 24 h, the drainage tube was withdrawn after 1 to 2 d, a neck brace was utilized for 8 to 12 weeks, and functional exercises were conducted based on the patient's condition.

### Radiographic analyses and data collection

All patients were categorized into two groups according to the median preoperative OI, which served as the critical threshold [17]. Data regarding age, sex, surgical duration and intraoperative hemorrhage were gathered for both cohorts; preoperative and postoperative lateral, hyperextension and hyperflexion X-rays of the cervical spine were obtained. OI was defined as the angle formed between the line that is exactly perpendicular to the midpoint of the C2 endplate and the line that runs from this very point to the center of the odontoid process [15]. The C2–C7 Cobb's angle is defined as the angle between two lines perpendicular to the lower endplates of C2 and C7. The C0–C2 Cobb angle represents the intersection angle between the McGregor line and the parallel line of the C2 lower endplate. The C2–C7 sagittal vertical axis measures the horizontal distance from the perpendicular line passing through the geometric center of the C2

(or the odontoid process) to the perpendicular line passing through the posterior superior angle of the C7. The T1 slope is the angle between a horizontal line and a line parallel to the upper endplate of the T1. The C2 slope is the angle between the C2 lower endplate and the horizontal line. The specific measurements of these indices are illustrated in Fig. 1. The anterior convexity angle of the surgical segment was defined as the angle formed between the upper endplate of the superior vertebra and the lower endplate of the inferior vertebra of the surgical segment (SSA), whereas the curvatures of the superior and inferior vertebrae of the surgical segment were recorded in the power position film (upper and lower-SSA-ROMs). The JOA, VAS, and NDI scores were used to evaluate the patients' postoperative results. The JOA, NDI, and VAS scores were assessed preoperatively and at the final follow-up, and the results were evaluated by two senior physicians. Figure 2 depicts a quintessential case follow-up.

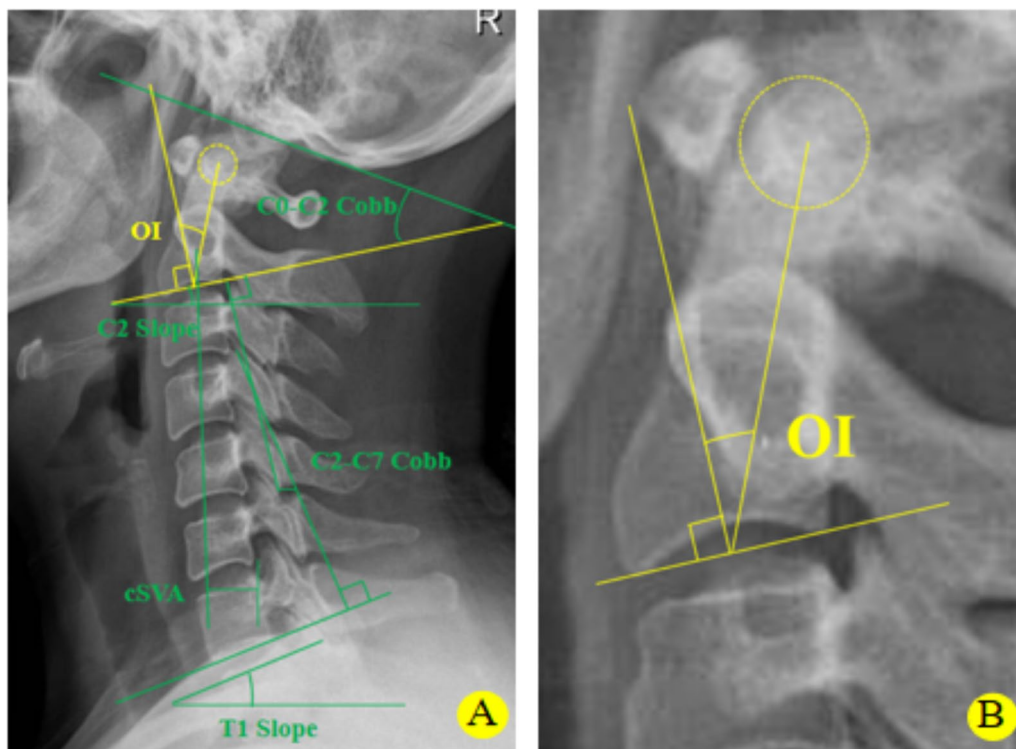
### Statistical analysis

We conducted the data analysis via SPSS version 21.0. Continuous variables are presented as the means  $\pm$  standard deviations. Qualitative data were analyzed via the chi-square test. Paired samples t-tests were employed to assess significant differences between preoperative and postoperative parameters. Statistical comparisons of the cervical sagittal parameters and different score types between the two groups were conducted via the independent samples t test. Pearson correlation analysis was used to examine the relationships between preoperative OI and postoperative follow-up scores. *P* values less than 0.05 were considered statistically significant.

## Results

### Patient demographics

This study enrolled 87 patients with CSM who underwent ACDF and categorized them into two groups on the basis of the median preoperative OI (12.62°): the larger OI group and the smaller OI group (Table 1). The larger OI group comprised 44 patients with a mean age of  $50.68 \pm 12.35$  years, whereas the smaller OI group included 43 patients with a mean age of  $54.88 \pm 9.84$  years. No statistically significant differences ( $P > 0.05$ ) were detected between the larger OI group and the smaller OI group in terms of age, sex, duration of surgery, intraoperative bleeding, Range of motion (ROM), mobility of the upper segment of the operated segment (Upper-SSA-ROM), or mobility of the lower segment of the operated segment (Lower-SSA-ROM) (Table 2).



**Fig. 1** Measurement of odontoid parameters and cervical spine parameters on cervical spine X-ray sagittal images. **A** Measurement of the OI and other cervical spine parameters on an X-ray image; **B** High-resolution view of the OI shown on an X-ray image

#### Pre- and postoperative imaging results and scores at follow-up for all patients

A comparison of the preoperative and postoperative cervical sagittal parameters of all patients in this study revealed that all the cervical sagittal parameters, with the exception of the cSVA ( $P=0.563$ ), significantly improved postoperatively relative to preoperatively ( $P<0.05$ ) (Table 3). Additionally, the JOA, VAS, and NDI scores of all patients at the final follow-up were significantly greater ( $P<0.05$ ) than those at the preoperative (Table 4). These findings suggest that ACDF surgery effectively improves the physiological curvature of the cervical spine, restores sagittal balance, and significantly alleviates followed-up clinical symptoms in patients.

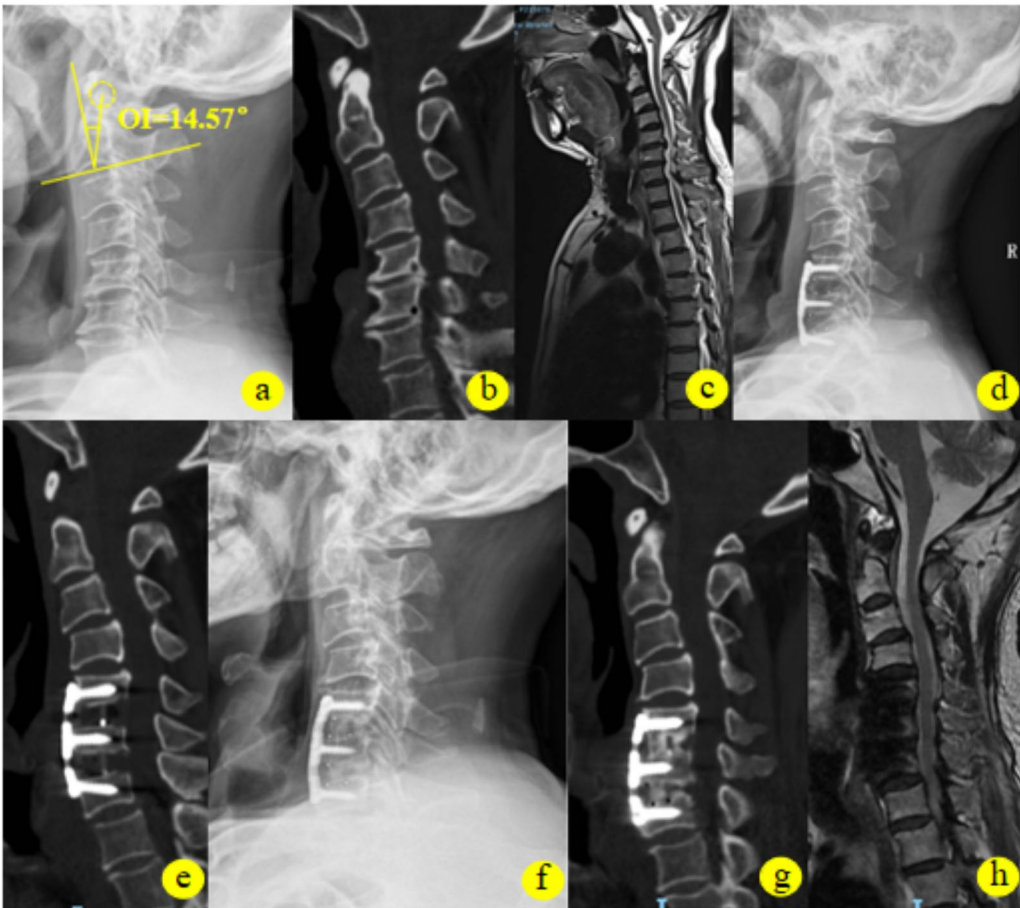
#### Imaging parameters in the larger OI group and the smaller OI group

Aside from the C2 slope ( $P<0.01$ ), no statistically significant differences were observed in the preoperative baseline indicators between the larger OI group and the smaller OI group ( $P>0.05$ ). Given that  $OI=OT+C2$  slope, it can be inferred that the preoperative C2 slope of the larger OI group exceeded that of the smaller OI group. A statistically significant difference in postoperative segmental curvature was observed between the two

groups ( $P<0.05$ ), whereas the remaining postoperative parameters were not statistically significantly different ( $P>0.05$ ). Patients exhibiting reduced preoperative OI demonstrated increased postoperative surgical segmental curvature ( $P=0.027$ ), indicating that those with lower preoperative OI possess a greater capacity to rectify the physiological curvature of the surgically affected segment (Table 5).

#### Comparison of scores in the larger OI group and the smaller OI group

No statistically significant differences in preoperative JOA, VAS, or NDI scores were observed between the two groups ( $P>0.05$ ). Except for the JOA score ( $P=0.149$ ), a statistically significant difference ( $P<0.05$ ) was observed in the NDI and VAS scores at the final follow-up between the two groups (Table 6). Compared with the smaller OI group, the larger OI group presented lower NDI and VAS scores at the final follow-up ( $P<0.05$ ). A greater preoperative OI was correlated with reduced NDI and VAS scores during final postoperative follow-up and was more likely to enhance final postoperative pain status and axial symptoms. To facilitate a precise comparison and assessment of the clinical efficacy between the two groups during final



**Fig. 2** Patient presentation: This is a 72-year-old male patient with cervical spondylosis. **a–c** Preoperative imaging data suggest C5–7 disc herniation with corresponding spinal stenosis. The preoperative OI value was 14.57°, and the patient’s main symptom was unsteady walking with numbness in both hands. **d, e** Immediate postoperative review revealed that the patient underwent C5–7 ACDF surgery, which presented postoperative changes in the cervical spine. **f–h** Postoperative review 2 years after surgery revealed that C5–7 had been fused, and the corresponding spinal canal did not show any significant narrowing. Walking instability, neck pain and hand numbness significantly improved

follow-up, we evaluated the difference between the preoperative and final follow-up scores. The results indicated that the ΔJOA and ΔVAS scores were significantly greater in the larger OI group than in the smaller OI group ( $P<0.05$ ) (Table 7), implying that the larger OI group exhibited superior improvement rates in the JOA score and VAS score, thereby enhancing final

postoperative spinal cord function and alleviating pain conditions.

**Table 1** Grouping is based on the median OI

Parameters (n = 87)	OI
Median OI	12.62
Larger OI (OI > 12.62°)	16.93 ± 4.13
Smaller OI (OI ≤ 12.62°)	10.24 ± 1.67
Larger OI (OI > 12.62°), smaller OI (OI ≤ 12.62°), larger OI (16.93 ± 4.13), and smaller OI (10.24 ± 1.67°)	

**Table 2** Demographic and clinical data for both the larger OI group and the smaller OI group

Parameters	Larger OI (n = 44)	Smaller OI (n = 43)	P value
Age	50.68 ± 12.35	54.88 ± 9.84	0.083
Sex (male/female)	14/30	20/23	0.160
Operation time (min)	124.66 ± 32.13	130.65 ± 32.76	0.392
Blood loss (mL)	35.00 ± 33.38	39.30 ± 34.67	0.557
ROM (°)	33.48 ± 14.64	32.41 ± 18.19	0.764
Upper-SSA-ROM (°)	7.74 ± 5.55	8.92 ± 5.76	0.332
Lower-SSA-ROM (°)	8.45 ± 4.24	9.12 ± 5.34	0.514

ROM, cervical spine mobility; ROM, Range of motion; SSA, sagittal segmental angle

**Table 3** Comparison of preoperative and postoperative parameters for all patients

Parameters (n = 87)	Preoperation	Postoperation	P value
T1 slope (°)	21.51 ± 7.64	25.48 ± 7.18	0.000
C2–C7 Cobb (°)	7.42 ± 7.35	13.03 ± 8.15	0.000
SSA (°)	5.64 ± 5.25	8.75 ± 5.32	0.000
C0–C2 Cobb (°)	31.26 ± 6.92	23.84 ± 8.16	0.000
cSVA (mm)	21.33 ± 11.02	20.63 ± 10.81	0.563
C2 slope (°)	7.92 ± 4.71	10.45 ± 6.07	0.001

cSVA, cervical sagittal vertical axis; SSA, sagittal segmental angle

**Table 4** Efficacy scores at the final follow-up and preoperative follow-up for all patients

Parameters (n = 87)	Preoperation	Final follow-up	P value
JOA	13.25 ± 2.70	15.25 ± 1.46	0.000
NDI	21.90 ± 8.02	3.86 ± 1.95	0.000
VAS	5.08 ± 1.56	1.14 ± 1.11	0.000

**Table 5** Comparison of preoperative and postoperative parameters between the larger OI group and the smaller OI group

Parameters	Larger OI (n = 44)	Smaller OI (n = 43)	P value
C2–C7cobb (°)			
Preoperation	6.29 ± 7.96	8.58 ± 6.56	0.148
Postoperation	13.26 ± 8.75	12.80 ± 7.58	0.795
C0–C2cobb (°)			
Preoperation	32.28 ± 6.31	30.21 ± 7.41	0.164
Postoperation	23.99 ± 8.14	23.68 ± 8.27	0.858
cSVA (mm)			
Preoperation	22.34 ± 12.55	20.29 ± 9.22	0.390
Postoperation	20.38 ± 11.82	20.89 ± 9.80	0.827
T1 slope (°)			
Preoperation	21.70 ± 7.83	21.32 ± 7.51	0.820
Postoperation	24.87 ± 8.30	26.10 ± 5.85	0.425
C2 slope (°)			
Preoperation	9.73 ± 5.45	6.07 ± 2.84	0.000
Postoperation	9.95 ± 6.14	10.96 ± 6.02	0.441
SSA (°)			
Preoperation	5.53 ± 5.92	5.75 ± 4.54	0.850
Postoperation	7.51 ± 4.55	10.02 ± 5.78	0.027

cSVA, cervical sagittal vertical axis; SSA, sagittal segmental angle

**Correlation between preoperative OI and scores**

Pearson correlation analysis was performed between the preoperative OI score and the VAS, NDI, and JOA

**Table 6** Comparison of efficacy scores preoperatively and at the final follow-up between the larger OI group and the smaller OI group

Score	Larger OI (n = 44)	Smaller OI (n = 43)	P value
JOA			
Preoperation	12.91 ± 3.14	13.60 ± 2.14	0.232
Final follow-up	15.48 ± 1.42	15.02 ± 1.49	0.149
NDI			
Preoperation	21.70 ± 8.03	22.09 ± 8.10	0.823
Final follow-up	3.25 ± 0.81	4.49 ± 2.52	0.003
VAS			
Preoperation	5.25 ± 1.18	4.91 ± 1.88	0.309
Final follow-up	0.75 ± 0.92	1.53 ± 1.16	0.001

**Table 7** Comparison of efficacy score improvement values between the larger and smaller OI groups (Preop minus final follow-up)

Parameters	Larger OI (n = 44)	Smaller OI (n = 43)	P value
ΔJOA	− 2.57 ± 2.95	− 1.42 ± 2.22	0.043
ΔNDI	18.45 ± 7.91	17.60 ± 8.44	0.629
ΔVAS	4.50 ± 1.52	3.56 ± 2.28	0.026

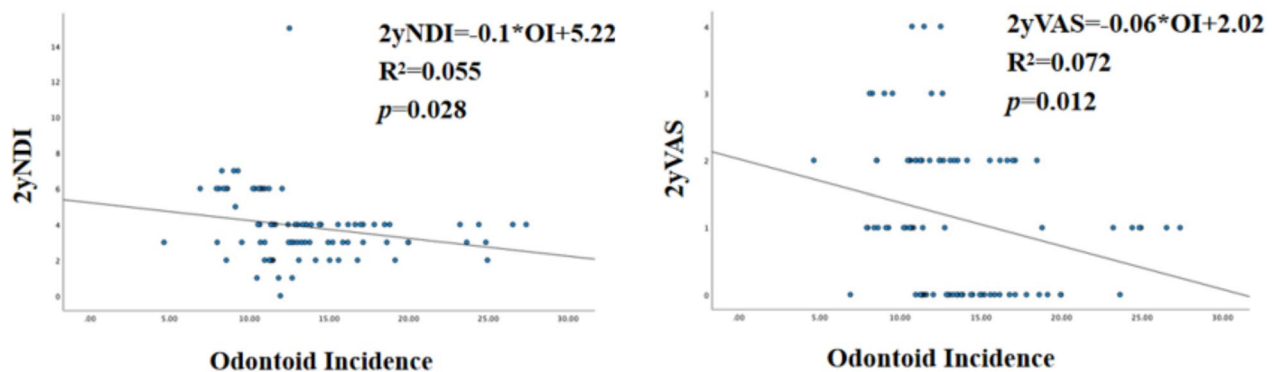
**Table 8** Correlation analysis between preoperative OI and final follow-up scores

Parameters (n = 87)	Final follow-up		
	JOA	NDI	VAS
Pre-OI			
r	0.119	− 0.236	− 0.268
p value	0.274	0.028	0.012

scores at the final follow-up for all patients. The results revealed a negative correlation between preoperative OI and the NDI and VAS scores at the final follow-up ( $P=0.012$ ,  $r= - 0.268$ ), ( $P=0.028$ ,  $r= - 0.236$ ). There was no correlation between the preoperative OI and any other parameter. The above results indicated that the larger the preoperative OI was (Table 8), the smaller the NDI and VAS scores were during 2-year postoperative follow-up. Linear regression analysis also revealed that preoperative OI was correlated with postoperative NDI and VAS scores (Fig. 3).

**Complications**

Three patients exhibited dysphagia during the immediate postoperative period: one from the larger OI group



**Fig. 3** Linear regression analysis between preoperative OI and NDI and VAS scores at the 2-year postoperative follow-up

and two from the smaller OI group, with no statistically significant difference observed between the groups ( $\chi^2 = 3.357$ ,  $P = 0.325$ ). Their severity was moderate, and none of the patients experienced dysphagia at the final follow-up. No instances of adjacent spondylosis, implant failure, cage subsidence, plate or screw loosening, or dislocation were observed in any patient.

## Discussion

In recent years, clinical studies concerning cervical sagittal balance have garnered significant attention [18], and research has established a close association between the onset of cervical spondylosis and imbalance in the cervical sagittal sequence. Prior biomechanical research has indicated that the cervical spine exhibits the most extensive sagittal range of motion. The head's center of gravity progressively shifts forward as the cervical curvature develops from normal physiological anterior convexity to the loss of this convexity or even cervical retroversion. Consequently, the moment that the arm in the cervical spine activities relative to the neck's center of rotation increases, leading to heightened compensatory work by the muscles, ligaments, and intervertebral joints in the posterior cervical region. This, in turn, exacerbates degeneration in the cervical spine, particularly in intervertebral joints affected by hyperplasia and other degenerative conditions [19]. ACDF has emerged as a standard procedure for addressing cervical spondylosis, effectively excising the affected disc and adequately decompressing the spinal cord. Various interbody fusion devices, including titanium plates combined with cage internal fixation and the Zero-P fusion system, have been employed in ACDF. These devices can restore the height of the intervertebral space and enhance the physiological curvature of the cervical spine, thereby effectively reinstating the cervical spine's localization and sagittal balance, and their efficacy is widely acknowledged

[20]. The findings of this study align with the previous results, indicating that the T1 slope, C2–C7 Cobb angle, SSA, and C0–C2 Cobb angle of 87 patients were significantly improved compared with those in the preoperative period ( $P < 0.05$ ). Additionally, the JOA, VAS, and NDI scores at the 2-year postoperative follow-up were significantly greater than those at the preoperative follow-up ( $P < 0.05$ ).

Surgical intervention for cervical spondylosis should prioritize not only effective decompression of the spinal nerves in the affected segment but also reconstruction of the local sagittal balance [21]. The frequently utilized clinical parameters for evaluating cervical sagittal balance include the C0–C2 Cobb angle, C2–C7 Cobb angle, cSVA, T1S and T1S–CL, which serve as critical references in the selection of surgical interventions and the evaluation of postoperative cervical sagittal balance [14, 22], however, these parameters have certain limitations. The anatomical alignment parameters of the cervical spine are not assessed in a fixed position. Furthermore, when assessing cervical spine sagittal parameters on radiographs, the cervicothoracic junction is frequently inadequately delineated, and the obscured T1 and C7 vertebrae are difficult to identify, complicating the measurement of conventional sagittal position parameters [23]. Furthermore, T1S and C2S are assessed solely along horizontal lines, which may consequently result in measurement inaccuracies [24]. The identification of novel, independent, and consistent anatomical parameters of the cervical spine is essential for a comprehensive evaluation of cervical alignment and sagittal balance.

Lee et al. studied cervical spine sagittal radiographs from 42 subjects and proposed a new cervical spine sagittal parameter, the OI. The OI adds measurements in the vertical axis direction to those in the horizontal axis direction to analyze the degree of cervical spine alignment in both directions. Unlike C7 and T1, which are

sometimes not visible in some patients, the OI is easy to measure on plain cervical radiographs [15]. Notably, the data in the above study were based only on healthy asymptomatic adults, which limits the clinical relevance and utility of the study in patients with cervical spondylosis. In addition, few studies related to odontoid parameters. Many previous studies have reported the relationships between other cervical balance parameters and health-related quality of life (HRQOL) [25]. Nevertheless, these studies have focused mainly on patient prognosis and postoperative cervical alignment, and few studies have systematically evaluated the relationships between preoperative cervical sagittal parameters and cervical symptoms in patients with degenerative cervical spine disease. Therefore, this study investigated the relationships between preoperative cervical sagittal OI parameters and clinical scores at 2-year postoperative follow-up.

The OI, a critical parameter in cervical sagittal balance, is defined as the sum of the angle of inclination of the odontoid process (OT) and the C2 slope ( $OI = OT + C2S$ ) [15]. The OI is intricately connected to the CL via C2S, significantly influencing various cervical spine disorders and the pathomechanisms underlying cervical spine degeneration [15]. It is essential to investigate the impact of OI on cervical sagittal balance and select surgical approaches to rectify cervical kyphosis. The OT denotes the spatial orientation of the odontoid process, which may rely on the equilibrium of cranial and horizontal vision and aid in assessing cervical alignment and sagittal balance [26]. The use of odontoid parameters facilitates a comprehensive examination of cervical alignment and the compensatory condition of the patient. A biomechanical study confirmed that the extension potential of the upper cervical spine is related to the anatomical characteristics of the odontoid process and that an odontoid process with a greater posterior inclination or a larger OI results in an increased ROM of C1 relative to C2 [27]. The OI, akin to the pelvic angle of incidence (PI), pertains to the compensatory reserve of cervical extension, thereby facilitating an evaluation of the patient's compensatory status and meticulous planning for optimal cervical alignment correction. The OI pertains to the cervical spine anatomy and remains unaffected by external factors [15], whereas additional benefits of the odontoid parameter are continually being investigated and revealed. Lee et al. reported that patients with a higher OI were significantly correlated with enhanced NDI scores ( $r = -0.40$ ,  $P < 0.05$ ) [16]. The findings of the present study revealed a negative correlation between preoperative OI and VAS and NDI scores at the final postoperative follow-up ( $P = 0.012$ ,  $r = -0.268$ ), ( $P = 0.028$ ,  $r = -0.236$ ), indicating that patients with greater preoperative odontoid

incidence angles presented lower VAS and NDI scores at the final follow-up. We also discovered that patients with a reduced preoperative OI exhibited, conversely, enhanced postoperative mobility of the operated segment. Our analysis suggested a correlation between the morphology of the odontoid process, which varies among individuals, and the observed cervical alignment inconsistencies. Specifically, when the odontoid axis—defined as the line extending from the midpoint of the inferior endplate of C2 to the center of the odontoid process—tilts anteriorly beyond the vertical axis, it indicates a misalignment in the cervical spine. Furthermore, the spatial orientation of the odontoid process significantly influences the overall alignment of the cervical spine [16], subsequently impacting postoperative segmental mobility.

This study has certain limitations. This was a retrospective study, and minor variations in the positioning of radiographs obtained from the patients may have resulted in selection bias. Second, the sample size was limited, and we could not conduct a retrospective analysis of the imaging parameters at the final follow-up. Our study revealed that the internal fixation devices utilized for patients who underwent ACDF surgery were inconsistent and included both Zero-P plates and conventional plates. Potential confounders may have influenced the correlation between preoperative OI and postoperative follow-up scores, undermining the validity of the results. Consequently, the findings of this study must be regarded with prudence.

## Conclusion

In summary, ACDF is a traditional minimally invasive cervical spine procedure that effectively alleviates symptoms of spinal cord compression and preserves the sagittal alignment of the cervical spine in patients with CSM. The preoperative OI of patients with spinal cervical spondylosis was negatively correlated with the VAS and NDI scores at the final postoperative follow-up. These findings indicate that a larger preoperative OI is correlated with smaller VAS and NDI scores at the final follow-up, leading to improved final clinical outcomes while also serving as an effective preoperative predictor of postoperative functional recovery.

## Abbreviations

OI	Odontoid incidence
ACDF	Anterior cervical discectomy and fusion
JOA	Japanese Orthopedic Association
NDI	Neck Disability Index
VAS	Visual Analogue Scale
SSA	Sagittal Segmental Angle
SVA	Sagittal Vertical Axis
CSM	Cervical spondylotic myelopathy
HRQOL	Health-related quality of life
OT	Odontoid tilt

T1S T1 slope  
C2S C2 slope  
PI Pelvic angle of incidence  
ROM Range of motion

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### Author contributions

All the authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by YG, HL, YG, JH, ZZ, HZ, and YL, and the research design was performed by ZC, DL, HR and XJ. The first draft of the manuscript was written by YG, and all the authors commented on previous versions of the manuscript. All the authors read and approved the final manuscript.

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Not applicable.

### Availability of data and materials

The data used to support the findings of this study are included within the article.

### Declarations

#### Ethics approval and consent to participate

The study protocol was approved by the Clinical Trial Review Committee of the First Affiliated Hospital of Guangzhou University of Chinese Medicine (No. K [2020] 104).

#### Consent for publication

The authors affirm that the human research participants provided informed consent for the publication of the images in Figs. 1 and 2.

#### Competing interests

The authors declare that they have no competing interests.

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