Original Article

Is posterior cervical imbalance after anterior cervical discectomy with fusion a determinant in the development of adjacent cervical degeneration? A retrospective study with an average of 8 years of follow-up

ABSTRACT

Aims: The primary objective of this study is to evaluate the hypotheses that postoperative sagittal imbalance influences the development of adjacent segment degeneration (ASDeg) in patients who have undergone an anterior cervical discectomy with fusion (ACDF).

Settings and Design: This was a retrospective cohort study.

Subjects and Methods: We analyzed 63 patients with ACDF with a minimum of 2 years of follow-up. In the imaging evaluation, sagittal balance parameters were included, as well as radiographic parameters that target the development of ASDeg. In addition, discrimination was made between arthrodesis techniques.

Statistical Analysis Used: Categorical variables were compared using the Chi-square test and Fisher's exact test. Continuous variables were compared using *t*-test when the data were normally distributed and Wilcoxon tests when the distribution was not normal.

Results: Patients with postoperative imbalance presented with radiographic ASDeg at a rate of 26% ($n = 5$) versus 22% ($n = 9$) in patients with postoperative balance, this difference was not significant ($P = 0.7$). In those who underwent surgery with plate, we found that 23% ($n = 4$) developed ASDeg versus 22% ($n = 1$) of patients with anterior cervical arthrodesis with cage-plate and 27% ($n = 10$) of patients who underwent interbody device surgery, with this difference being nonsignificant ($P = 0.7$).

Conclusion: We concluded that neither postoperative imbalance nor the type of arthrodesis in patients undergoing ACDF for degenerative pathology showed a positive correlation with the development of radiographic cervical ASDeg at an average follow-up of 8 years.

Keywords: Adjacent segment degeneration, anterior cervical discectomy with fusion, cervical imbalance, cervical spondylosis, proximal intervertebral disc angle, sagittal balance

INTRODUCTION

Cervical spondylosis (CD) refers to the natural aging process that includes a wide range of progressive degenerative changes that affect all components of the cervical spine, usually appearing after the fifth decade of life.[1] The vast majority of patients go through this process asymptomatically; however, if present, symptoms can manifest as mechanical neck pain, radiculopathy, myelopathy, or a combination of the same. Although most patients respond adequately to conservative treatment, surgical intervention should be considered in cases with severe or progressive cervical

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myelopathy as well as in those patients with axial neck pain or persistent radiculopathy following failure of nonsurgical measures.[2]

Introduced in 1940, anterior cervical discectomy with fusion (ACDF) is the standard of care for radiculopathy and cervical spondylotic myelopathy, particularly those with a loss of cervical lordosis and up to three levels affected, with satisfactory clinical outcomes.[3] However, ACDF is not without complications. A common consequence of long-term cervical fusion is adjacent segment degeneration (ASDeg). ASDeg describes the radiographic changes observed at the levels close to the previously fused segment or segments, without correlation with clinical symptoms. Its incidence ranges from 25% to 92% at 10 years.[4] ASDeg should be differentiated from the term adjacent segment disease (ASD), which represents the appearance of imaging but symptomatic changes, with a 10-year incidence between 22% and 38%.[5] Biomechanical studies suggest that the creation of rigid sectors influences the mechanical properties of adjacent mobile segments, generating hypermobility and increased stress on joint surfaces, leading to their premature degeneration.[6] The literature shows that 0.2% of cervical fusion may require additional intervention due to the development of ASDeg.[7]

Various risk factors have been identified for the development and progression of ASDeg, such as age, smoking, and length of arthrodesis, among others.[8] There is little evidence pointing to how surgical interventions that alter sagittal alignment, such as ACDF, may influence the development of ASDeg due to imbalance compensation mechanisms.[9] To answer this question, we proposed to develop a retrospective study of patients with anterior cervical arthrodesis of one to three levels with a minimum of 2 years of follow-up and to compare the incidence of ASDeg in those patients without preoperative sagittal imbalance and who suffered alteration of the same in the last postoperative follow-up with those who did not have alterations in cervical balance.

The primary objective of this study is to evaluate the hypothesis that postoperative sagittal imbalance influences the development/progression of ASDeg in patients over 18 years of age with an ACDF. The secondary objectives were to report the overall incidence of ASDeg and to discriminate whether there are differences according to the type of arthrodesis (plate vs. self-sustaining interbody device) in a group of patients treated in a high-complexity center in the long term after ACDF surgery.

SUBJECTS AND METHODS

After obtaining approval from our institution's research ethics committee (IRB00012779, protocol #7103), we retrospectively analyzed a consecutive series of patients with cervical fusion (ACDF) operated on between May 2001 and May 2021. Table 1 shows the inclusion and exclusion criteria.

Demographic data

Preoperative demographic data including sex, age, body mass index (BMI), smoking, American Society of Anesthesiologists score, and modified five-item frailty index (mFI-5) were collected.[10,11] The mFI-5 includes five clinical variables: heart failure, diabetes, Chronic obstructive pulmonary disease or pneumonia, hypertension, and the degree of functional dependence.

Imaging evaluation

In the imaging evaluation, the number of levels and the location of the arthrodesis segments were included. The type of arthrodesis was categorized as cervical arthrodesis plate, cage-plate, or self-sustaining interbody device.

Sagittal balance was assessed on profile cervical spine radiographs using lordosis of segment C2–C7 and sagittal vertical axis C2–C7. Lordosis of segment C2–C7 was defined as the angle between a line parallel to the lower saucer of C2 and a line parallel to the lower saucer of C7, normal value = The slope T1°–17° [Figure 1a].[12] Sagittal vertical axis C2–C7 was defined as the horizontal distance between a vertical line from the midpoint of the C2 vertebra and the posterosuperior angle of the upper saucer of C7, normal value <40 mm [Figure 1b].[13]

The development or progression of ASDeg was assessed by radiographic parameters that included proximal narrowing of the intervertebral disc (NID), proximal intervertebral disc angle (IDA), listhesis, and anterior osteophyte. We

Table 1: Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Patients ≥18 years old	Patients ≤18 years old
Patients with preoperative cervical sagittal balance	Patients with preoperative cervical sagittal imbalance
Undergoing ACDF	Posterior cervical approach
Degenerative pathology	All patients diagnosed with infection or fracture
Complete cervical radiographic evaluation before and postoperatively	Incomplete cervical radiographic evaluation
Follow-up ≥of 2 years	Follow-up ≤of 2 years
Patients ≥18 years old	Patients ≤18 years old
Patients with preoperative cervical sagittal balance	Patients with preoperative cervical sagittal imbalance

ACDF - Anterior cervical discectomy with fusion

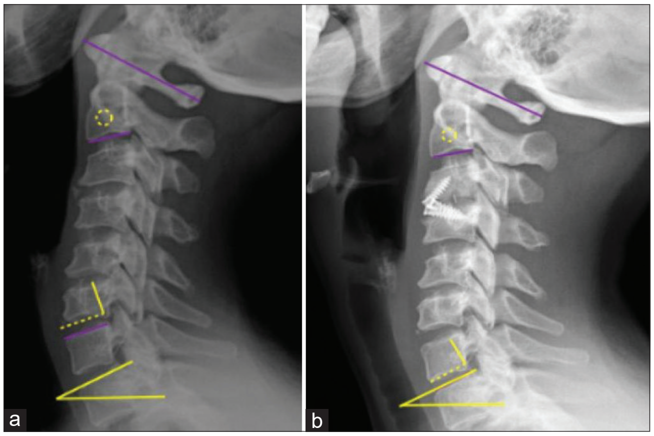

Figure 1: (a) Preoperative cervical spine X-ray profile showing the measurement of lordosis of the C2–C7 segment (−5° in this case), the T1 slope (26° in this case), and the C2–C7 sagittal vertical axis (−5 mm in this case). (b) Postoperative cervical spine X-ray profile at 5 years of follow-up from a C3–C4 anterior cervical discectomy with fusion showing the measurement of lordosis of the C2–C7 segment (−19° in this case), the T1 slope (27° in this case), and the C2–C7 sagittal vertical axis (0 mm in this case)

define ASDeg as: an exacerbation of two categories on the Kellgren–Lawrence scale in NID conditions [Figure 2a],[14] a change greater than 10° in the angle of proximal kyphosis IDA [Figures 2b and c],[15] any change exceeding 2 mm in listhesis [Figures 2d and e],[16] or any change in the Park prescription [Figures 3a-d].[17]

Sagittal imbalance was defined as the alteration of at least one of the two values mentioned above (lordosis of the C2–C7 segment and sagittal vertical axis C2–C7). To assess the relationship between sagittal imbalance in the development/progression of ASDeg in patients over 18 years of age with an ACDF, two groups were divided: patients without preoperative sagittal imbalance and who suffered alteration in the same at the last postoperative follow-up and patients without preoperative sagittal imbalance and without alteration of the same at the last postoperative follow-up.

Regarding the analysis between arthrodesis techniques related to the development/progression of ASDeg in patients over 18 years of age with an ACDF, three groups were divided: patients with anterior cervical arthrodesis with plate, patients with anterior cervical arthrodesis with cage-plate, and patients with anterior cervical arthrodesis with self-sustaining interbody device.

ASDeg was defined as the presence of the following radiographic changes: Δ NID of two categories on the Kellgren–Lawrence scale, Δ of 10° at the angle of proximal kyphosis, Δ > to two mm in listhesis, Δ ≥ two categories in the Park Ossification Graduation.

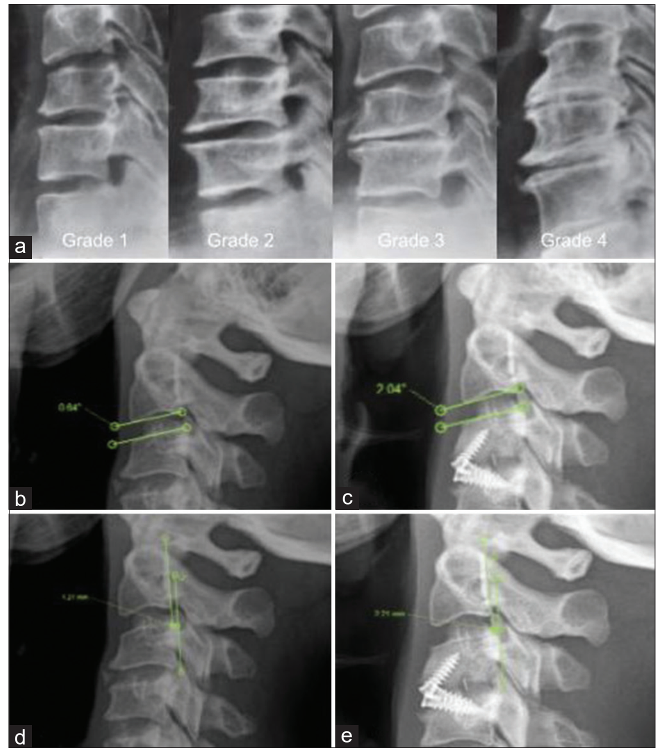

Figure 2: (a) Kellgren–Lawrence classification for grading disc degeneration. (b) Preoperative cervical spine X-ray profile showing the measurement of the angle of the proximal intervertebral disc (0.64°). (c) Postoperative cervical spine X-ray profile showing the measurement of the angle of the proximal intervertebral disc (2.04°). (d) Preoperative cervical spine X-ray profile showing vertebral listhesis (1.21 mm). (e) Postoperative cervical spine X-ray profile showing vertebral listhesis (2.21 mm)

Surgical treatment

All surgeries were performed by one of three spine surgeons in the division (CS, MG, and MP). Postoperative check-ups were routinely established at 15 and 45 days, 3 months, 1 year, 2 years, and every 2 years thereafter.

Reliability

Before performing the radiographic measurements, a training session was carried out including visualization of ten radiographs of cases not belonging to the included cohort. After this stage, 20 cases were randomly selected to measure proximal NID, proximal IDA, listhesis, and ossification. Agreement between measurements was assessed using the intraclass correlation coefficient to evaluate quantitative variables and weighted kappa to evaluate categorical variables.[18] Intraclass correlation coefficients between raters were 0.705 (confidence interval [CI]: 0.18–0.92) for listhesis and 0.956 (CI: 0.83–0.99) for proximal IDA. Weighted kappa was 0.8041 (CI 0.2046–1.0000) for ossification and 0.9243 (0.7163–1.0000) for proximal NID.

Statistical data analysis

Continuous variables were expressed as means and

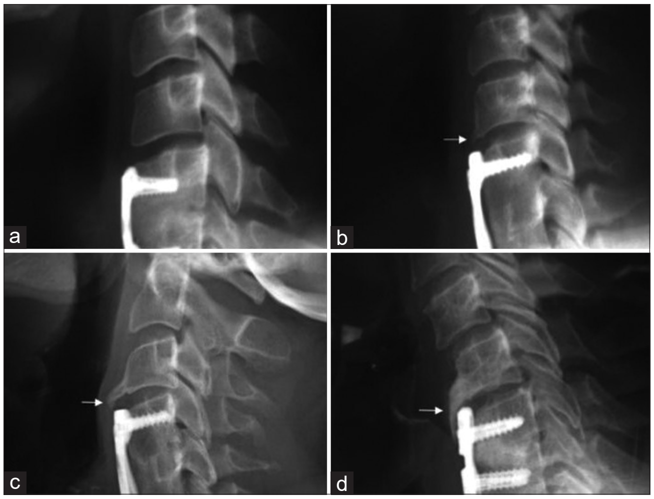

Figure 3: Ossification rating of adjacent park level. (a) Grade 0: No ossification present at the adjacent level. (b) Grade 1: Ossification that extends less than 50% of the disc space (arrow highlights the region of minimal ossification). (c) Grade 2: Ossification that extends more than 50% of the disc space (arrow emphasizes the area of significant ossification). (d) Grade 3: Complete bridging of the adjacent disc space (arrow indicates complete ossification with no visible disc space)

standard deviations, or medians and interquartile ranges, depending on whether they had a normal distribution or not. Categorical variables were reported as frequencies and percentages. Categorical variables were compared using the Chi-square test and Fisher's exact test. Continuous variables were compared using *t*-test when the data were normally distributed and Wilcoxon tests when the distribution was not normal. The variables were considered statistically significant with $P < 0.05$. The analyses were performed with Stata v15.0 software (STATA Corporation, California) and Surgimap software (Nemaris, Inc. Product).

RESULTS

After applying the inclusion and exclusion criteria in the institutional database, the final study population consisted of 63 patients ≥18 years old [Figure 4]. The mean age of the cohort was 66 ± 16 years (range: 31–82 years), 34 (54%) were female, and the mean BMI was 27.6 ± 3.2 (range: 17.9–41). The mean clinical follow-up was 8 ± 3.3 years (range: 2–18 years). Imaging follow-up with radiographs was 6.5 ± 2.4 years (range: 2–16 years) [Table 2].

A total of 37 one-level arthrodesis procedures (58.73%), 22 two-level arthrodesis procedures (34.92%), and 4 three-level arthrodesis procedures (6.35%) were performed and subsequently reviewed. In the analysis of the type of arthrodesis, 20 patients were treated with a plate (21.5%), 6 with cage-plate (8.7%), while 37 patients underwent fixation with an interbody device (58.8%) [Table 3].

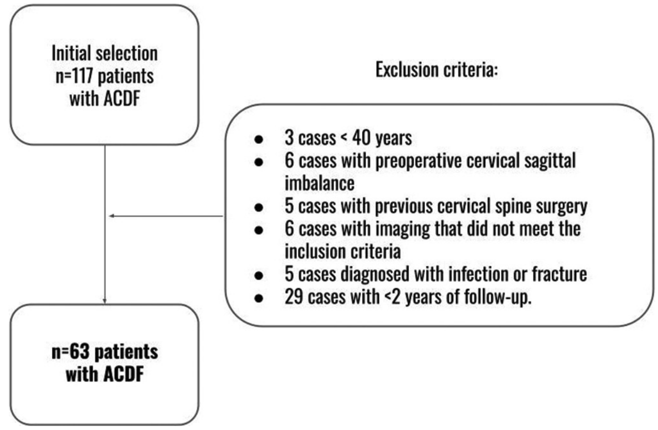

Figure 4: Flowchart of the study cohort. ACDF - Anterior cervical discectomy with fusion

Regarding the parameters related to sagittal imbalance, the average preoperative C2–C7 segment lordosis was −11°±10° (−42°–24°), while in the postoperative period, it was −8°±10° (−35°–23°). The preoperative mean C2–C7 sagittal vertical axis values were 9 mm ± 9.10 mm (−8 mm–36 mm), while postoperatively, it was 17 mm ± 11.70 mm (2 mm–53 mm). Table 4 reports the values of the pre- and postoperative imaging parameters as well as the variation between them in 8 years of average follow-up.

Of the 63 patients included in the cohort, 22 (35%) presented postoperative imbalance, 14 (22.3%) due to loss of lordosis, and 8 (12.7%) due to sagittal vertical axis displacement. The remaining 41 (55%) patients maintained sagittal balance during the postoperative follow-up. In the analysis of our first objective, where we evaluated whether the presence of postoperative imbalance would be a predisposing factor for ASDeg, we found that patients with preserved postoperative balance had an ASDeg rate of 26% ($n = 5$) versus 22% ($n = 9$) in patients without postoperative balance, with the difference between both groups being nonsignificant ($P = 0.7$) [Table 5].

n the analysis of our second objective, we compared the proportion of patients with degeneration in those who underwent surgery with plate versus those who underwent surgery with a self-sustaining interbody device. We found that 23% ($n = 4$) of patients who underwent plate surgery developed ASDeg versus 22% ($n = 1$) of patients with anterior cervical arthrodesis with cage-plate and 27% ($n = 10$) of patients who underwent interbody device surgery, with this difference being nonsignificant ($P = 0.7$) [Table 6].

DISCUSSION

ACDF has proven to be the gold standard, with good clinical results, in cases of CS where conservative treatment fails.[19] However, ACDF can accelerate adjacent degenerative processes, which in the long term may lead to ASDeg after cervical spine surgery. Pathological changes of ASDeg mainly include CS, formation of cervical osteophytes around the vertebral body, narrowing of the disc space, vertebral slippage, herniated disc, and ligament hypertrophy. These degenerative changes can lead to cervical stenosis and involvement of adjacent segments, resulting in spinal cord injury and neurological symptoms.[20] ASDeg has a direct impact on the long-term outcome of patients with previous cervical surgery.

Table 2: Demographic characteristics of the study cohort

Variable	*n* (%)	Average	SD	Rank
Demographic parameters				
Age (years)		66	16	40–82
BMI		27.6	3.2	17.9–41
Sex (%)				
Female	34 (54)			
Male	29 (46)			
Clinical follow-up (years)		8	3.3	2–18
Radiographic follow-up (years)		6.5	2.4	2–16
mFI-5				
0	27 (42)			
0.2	29 (46)			
0.4	7 (12)			

BMI - Body mass index; mFI-5 - Modified 5-item fragility index; SD - Standard deviation

Table 3: Anterior cervical discectomy with fusion characteristics of the study cohort

Variable	Specification	
	N(%)	*N* and arthrodesis segment
Levels of arthrodesis		
1 level		15 C4–C5 12 C5–C6 5 C3–C4 4 C6–C7 1 C7–T1
2 levels		12 C5–C7 10 C4–C6
3 levels		2 C3–C6 1 C4–C7 1 C5–T1
Type of arthrodesis, *n* (%)		
Plate	20 (21.5)	
Cage-plate	6 (8.7)	
Interbody device	37 (58.8)	

It is unclear whether ASDeg after ACDF occurs due to segmental fusion or normal physiologic degeneration of the spine. Some researchers believe that biomechanical changes cannot fully explain cervical ASDeg. Goffin *et al*. found that among patients undergoing ACDF, patients suffering from CS had a higher incidence of ASDeg compared to patients with cervical trauma or tumors.[21] Consequently, they believe that fusion surgery only played a promoting role in ASDeg and was not the primary reason. There is no consensus in the literature yet on the most important question: Is DSA after ACDF due to segmental fusion or is it due to normal physiological degeneration of the spine? Kwok *et al*. found in a meta-analysis including 3563 participants limited evidence showed that multi-level fusion, greater asymmetry in cross-sectional area of the cervical paraspinal muscle, and preoperative degeneration in a greater number of segments were associated with a higher ASDeg incidence <4 years after ACDF with plate fixation. At ≥4 years after ACDF with plate, limited evidence supported that both cephalad and caudal plate-to-disc distances of <5 mm were associated with a higher ASDeg incidence.[22]

Table 4: Imaging characteristics of the study cohort

Variable	*n* (%)	Average	SD	Rank
Sagittal imbalance parameters				
Preoperative lordosis C2–C7		−11°	10°	−42°–24°
Postoperative lordosis C2–C7		−8°	10°	−35°–23°
Preoperative vertical axis C2–C7		9 mm	9.1 mm	−8–36 mm
Postoperative vertical axis C2–C7		17 mm	11.7 mm	2–53 mm
Delta ASDeg radiographic parameters				
Δ NID (Kellgren-Lawrence)				
Doubtful	41 (65)			
Minimal	27 (27)			
Moderate	5 (8)			
Severe	0			
Δ IDA proximal (%)		4.0	3.05	0.0–13.5
Δ listhesis (%)		8.0	9.7	0.0–35.7
Δ ossification (park)				
Grade 0	31 (59.6)			
Grade 1	20 (38.4)			
Grade 2	1 (1.9)			
Grade 3	0			

NID - Narrowing of the intervertebral disc; IDA - Intervertebral disc angle; ASDeg - Adjacent segment degeneration; SD - Standard deviation

Table 5: Postoperative imbalance and adjacent segment degeneration distribution of the study cohort

Variable	Global (%)	ASDeg (%)	No ASDeg (%)
Postoperative imbalance patients	22 (25)	26	74
Lordosis	14	28	72
Sagittal vertical axis	8	24	76
Postoperative balance patients	41 (65)	22	78

ASDeg - Adjacent segment degeneration

Table 6: Arthrodesis techniques and adjacent segment degeneration distribution of the study cohort

Variable	Global (%)	ASDeg (%)	No ASDeg (%)
Plate	20 (21.5)	23	77
Cage-plate	6 (8.7)	22	78
Interbody device	37 (58.8)	27	73

ASDeg - Adjacent segment degeneration

There is a disparity in the literature as to whether loss of cervical lordosis is related to ASDeg progression. Recently, Yu *et al*. found that age and plate-disc distance were risk factors for ASDeg after ACDF due to increased stress on adjacent segments but clarified that if ACDF preserves or improves lordosis, it will reduce the incidence of ASDeg.[23] Katsuura *et al*. followed 42 patients with ACDF for 9.8 years after surgery; 13 patients developed progression of local kyphosis, of which 10 cases had ASDeg ($P < 0.05$).[24] However, other authors reported that they did not obtain an association between postoperative kyphosis and ASDeg, so they minimized the prioritization of maintaining and reconstructing cervical lordosis.[25] We chose two variables to analyze sagittal balance in our study, because many patients may maintain a falsely preserved balance due to compensatory mechanisms. To discuss cervical balance/imbalance in isolation without discussing where the cervical spine is sitting relative to the remaining spine is really missing a critical component of the concept of spinal balance. That's why lordosis of segment C2–C7 is measured in relation to T1 slope.[12] We did not obtain a correlation between sagittal imbalance and the development of ASDeg. These results could be explained by the variable behavior of the radiographic parameters of ASDeg. For example, ASDeg might manifest with compensatory retrolisthesis rather than anterolisthesis in the proximal segment of an arthrodesis. Similarly, not all degenerate segments tend to clamp into a standing X-ray; sometimes, the discs undergo hyperlordosis in an attempt to compensate for the underlying hypolordosis. This variability in both directions, without following a consistent trend, could explain the lack of statistical significance of our radiographic results. We believe that despite radiographs being a simple imaging study accessible to almost all clinical institutions, magnetic resonance imaging (MRI) parameters are more sensitive and specific when predicting cervical ASDeg.[23,24]

The literature indicates that the incidence of ossification is significantly higher in plates when they are located <5 mm to the adjacent disc space (51.3% ASDeg [$P = 0.010$]),[26] but we did not find literature in which ASDeg rates are compared according to the type of arthrodesis (plate vs. self-sustaining interbody device). In our study, we did not obtain significant differences between the two types of arthrodesis, although clarifying that the factor of plate position was not evaluated at the time of analysis. The rate of ASDeg was lower (although not statistically significant, $P = 0.7$) with the use of a plate compared to the patients with anterior cervical arthrodesis with cage-plate and self-sustaining interbody device, with values of 23% ($n = 4$) versus 22% ($n = 1$) and 27% ($n = 10$) of degeneration, respectively.

Finally, this study has numerous limitations. The cohort evaluated is relatively small and the retrospective nature could introduce bias in patient selection. In addition, our ASDeg analysis could fall on an overestimation of this rate, since we do not consider those patients who were excluded because they did not have follow-up radiographs, who may have had good clinical evolution, constituting a selection bias. In this study, we only performed radiographic analysis, which has the advantage of being easily accessible in any center, but we know that preoperative abnormal discs that can only show changes on MRI are a well-known risk factor for ASDeg, and their lack of analysis represents an important limitation for this study. Lastly, ASDeg has a complex definition that we are still working to understand and prevent. Its development and progression are influenced by multiple factors, including the number of fused levels, the specific region of arthrodesis, the sagittal alignment before and after surgery, the condition of the proximal disc prior to surgery, the orientation and potential injury to the facets during the procedure, as well as the patient's age, sex, and BMI, among other variables. Isolating these variables from the full spectrum of factors involved in this event is challenging.

As strengths, we highlight a long average follow-up period of 8 years in a single-center study in which surgical indication remained uniform over time and in which the inclusion and exclusion criteria have achieved a remarkable homogenization of the sample.

CONCLUSION

We conclude that neither the postoperative imbalance nor the type of arthrodesis in patients undergoing ACDF for degenerative pathology showed a positive correlation with the development of cervical radiographic ASDeg at an average follow-up of 8 years.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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