




Original Article

Corresponding Author

Dong Wuk Son

 <https://orcid.org/0000-0002-9154-1923>

Department of Neurosurgery, Pusan
National University Yangsan Hospital, 20
Geumo-ro, Mulgeum-eup, Yangsan 50612,
Korea

Tel: +82-55-360-2126

Fax: +82-55-360-2156

E-mail: md6576@naver.com

Received: April 2, 2017

Revised: January 23, 2018

Accepted: February 1, 2018



This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/4.0/>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

Copyright © 2018 by the Korean Spinal Neurosurgery Society

INTRODUCTION

Interest in cervical sagittal alignment has been recently increasing because the preoperative characteristics of these factors can predict postoperative cervical alignment and clinical outcomes.¹⁻³ Because these parameters are of significance in pre-

Differences in Cervical Sagittal Alignment Changes in Patients Undergoing Laminoplasty and Anterior Cervical Discectomy and Fusion

Su Hun Lee^{1,2}, Dong Wuk Son^{1,2}, Jun Seok Lee^{1,2}, Dong Ha Kim^{1,2}, Soon Ki Sung^{1,2}, Sang Weon Lee^{1,2}, Geun Sung Song^{1,2}

¹Department of Neurosurgery, Pusan National University Yangsan Hospital, Pusan National University School of Medicine, Yangsan, Korea

²Research Institute for Convergence of Biomedical Science and Technology, Pusan National University Yangsan Hospital, Yangsan, Korea

Objective: Anterior cervical discectomy and fusion (ACDF) and laminoplasty (LP) are the most commonly performed procedures for degenerative cervical spondylosis. Cervical sagittal alignment (CSA) has recently been studied as an important predictor of clinical and radiological outcomes. The data from previous studies are insufficient for analysis using the recently designed CSA parameters, T1 slope (T1s), and T1s minus cervical angle (T1sCA).

Methods: We retrospectively collected data from patients who underwent ACDF and LP from January 2013 to May 2016. The CSA parameters included CA, sagittal vertical axis, T1s, and T1sCA. T1sCA values were used to evaluate the preoperative cervical balance (T1sCA > 20°: imbalance). Clinical results were evaluated using the neck disability index (NDI) and recovery rate (RR) according to the Japanese Orthopedic Association scoring system.

Results: We analyzed the data of 72 patients (ACDF, n = 39; LP, n = 33). Imbalance on ACDF was associated with an increase in CA (balance: preoperative [PRE], 15.64° → follow-up [F/U], 15.74°, p = 0.953; imbalance: PRE, -1.14° → F/U, 8.045°, p = 0.008), whereas balance on LP was associated with a significant decrease in CA (balance: PRE, 16.26° → F/U, 11.59°, p = 0.009; imbalance: PRE, 5.36° → F/U, 2.38°, p = 0.249). No significant difference was found in the RR and NDI changes in the ACDF group based on balance, but a significant difference was found in RR in the LP group (balance: 61.65% ± 19.88%, imbalance: 46.90% ± 15.71%, p = 0.046).

Conclusion: We found a significant difference in postoperative alignment in cases of ACDF and LP according to preoperative cervical sagittal balance. The postoperative clinical results of the LP group were more affected by F/U alignment than by the degree of alignment change.

Keywords: Cervical vertebrae, Laminoplasty, Spinal fusion

dicting the changes that occur when the balance between gravity and force of extension from the posterior neck muscle is disturbed, these factors have been predominantly studied in laminoplasty (LP), a procedure that severely invades the posterior neck muscular-ligament complex.⁴⁻⁸ Because anterior cervical discectomy and fusion (ACDF) does not damage the posterior

neck muscular-ligament complex, studies regarding the influence of preoperative parameters are limited; however, several studies have focused on preoperative C2–7 cervical angle (CA).⁹⁻¹² Recently, Kwon et al.¹³ approached post-ACDF cervical alignment using T1 slope (T1s) and sagittal vertical axis (SVA). Further studies using preoperative parameters are expected to increase. The effect of the preoperative parameters of ACDF and LP on postoperative alignment and clinical outcome has been studied, focusing on the same disease group or similar levels.¹⁴⁻²⁰ However, these studies do not contain much of the new alignment parameters and concepts of cervical sagittal balance. In addition, the results of typical surgery (short level ACDF and multilevel LP) that are most commonly performed are rather unknown.

In this study, to evaluate the effect of preoperative sagittal parameters on typical cervical surgery, we aimed to evaluate the effect of preoperative sagittal parameters through comparison of radiologic clinical results of each operation, not a comparison of the 2 surgeries.

MATERIALS AND METHODS

1. Patient Population

1) ACDF group

Between January 2013 and May 2016, data from 76 patients who underwent ACDF for cervical spondylosis at a single institution were collected. The inclusion criteria were as follows: (1) patients who required surgery because of uncontrolled symptoms even after 6 weeks of treatment; and (2) 1- or 2-level ACDF using a stand-alone cage (n = 54). The exclusion criteria were as follows: (1) patients whose T1S could not be measured (short neck, unable to maintain a routine standing position) (n = 5); (2) patients with a history of previous cervical surgery (n = 8); and (3) patients who underwent follow-up less than 1 year (n = 2). Ultimately, we enrolled 39 patients and 53 segments for analysis. The ACDF was performed as follows. All patients underwent surgery using the standard Smith-Robinson anteromedial left-sided approach. We performed bilateral uncinated process resection, even in patients with unilateral symptoms, to eliminate remnant osteophyte regrowth. After complete decompression, a stand-alone PEEK cage (CORNERSTONE-PSR, Medtronic Sofamor-Danek, Memphis, TN, USA) was filled with demineralized bone matrix and applied under fluoroscopy. We attempted to position the cage in the anterior edge of the upper vertebra to prevent subsidence. After Caspar distractor release, a manual pullout test confirmed the stability

of the segments. All patients were instructed to wear a soft collar for 2 months postoperatively.

2) LP group

We retrospectively reviewed the medical records of 64 patients who underwent open-door LP for cervical spondylotic myelopathy and ossification of the posterior longitudinal ligament between January 2013 and May 2016. The exclusion criteria were as follows: (1) less than three levels of LP (n = 3); (2) with trauma, tumor, and infection (n = 15); (3) patients whose T1S could not be measured (short neck, unable to stand) (n = 6); and (4) patients who underwent follow-up less than 1 year (n = 7). Finally, we enrolled 33 patients for analysis. The LP was performed as follows. All patients underwent expansive open-door LP with a plate fixation system (CENTERPIECE, Medtronic Sofamor-Danek). If the stenotic lesion invaded the C2 or C7 level of the cervical spine, we carefully performed partial hemilaminectomy at C2 or C7 level. Postoperatively, all patients were instructed to wear a soft neck collar for 2 months, with the aim of preventing postoperative kyphosis.

3) Compliance With Ethical Standards

All procedures performed in studies involving human participants were in accordance with the ethical standards of Institutional Review Board (IRB) of the Pusan National University Yangsan Hospital (approval number: 05-2018-013). The study protocol was approved by the IRB of Pusan National University Yangsan Hospital, which waived the requirement for informed consent due to the retrospective nature of this study.

2. Radiological Evaluation

All radiological assessments were performed at 1-month intervals by an independent observer who was experienced in spinal diseases. The mean values were calculated and used for statistical analysis. Lateral standing plain radiographs were obtained in patients in a neutral standing position facing forward at the following time points: preoperative (PRE), immediately after surgery, 7 days postoperatively (POST), every 3 months after surgery, and at the latest follow-up (F/U) examination. Lateral standing flexion/extension plain radiographs were obtained PRE and every 3 months starting at 6 months after surgery. We measured CA, SVA, and T1S using commercial software (Marosis 5.0, INFINITT Healthcare, Seoul, Korea) (Fig. 1), and described the measurement method applied in Table 1. Range of motion (ROM) was defined as the extension angle minus the flexion angle. Alignment of C2–7 CA ≥ 0 was de-

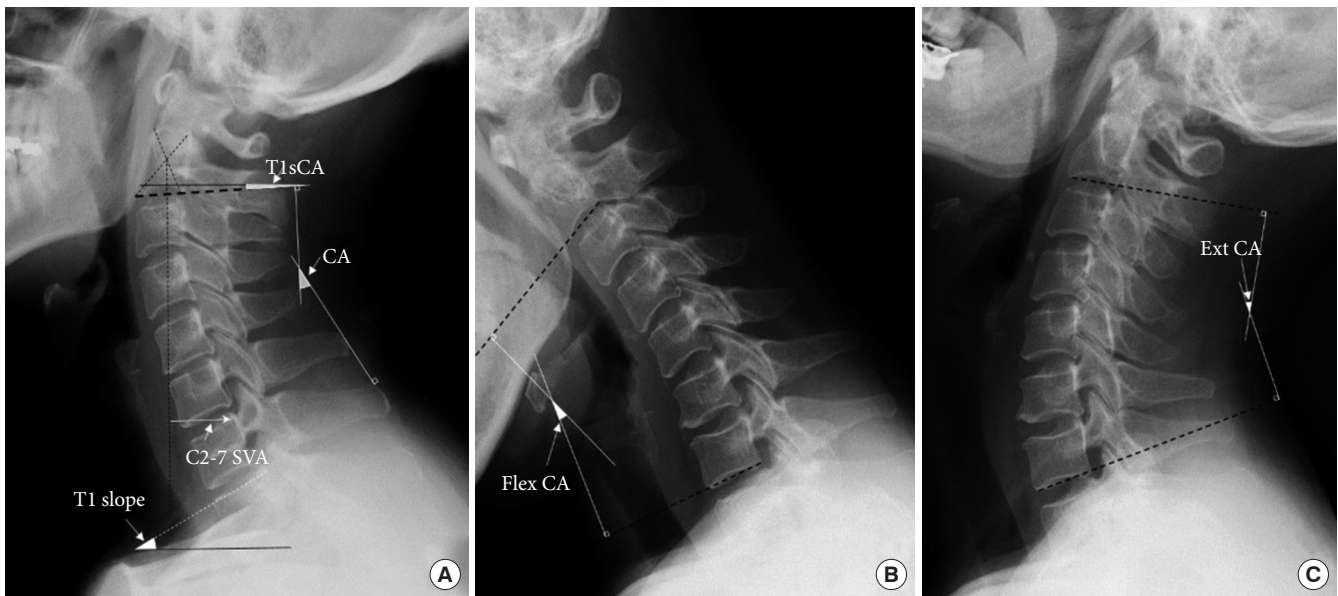


Fig. 1. Measurements of radiological parameters, including neutral lateral image (A), flexion lateral image (B), and extension lateral image (C). SVA, sagittal vertical axis; CA, C2–7 cervical angle; T1sCA, T1s minus CA; Flex, flexion.

Table 1. Parameters of plain radiograph

Parameter	Measurement tool	Reference of measurement
Lateral standing		
C2–7 CA (°)	Spine Cobb angle	From LE of C2 V to LE of C7 V
C2–7 SVA (mm)	Spine balance	From C2 plumb line to posterior margin of UE of C7
T1 slope (°)	Cobb angle	From UE of T1 to horizontal line
T1sCA		T1 slope minus C2–7 CA
Lateral standing dynamic		
C2–7 ROM (°)	Spine Cobb angle	Extension CA–flexion CA

CA, cervical angle; SVA, sagittal vertical axis; T1sCA, T1 slope minus cervical angle; ROM, range of motion; UE, upper endplate; LE, lower endplate; V, vertebra.

defined as lordosis. After the cervical spine compensated for the T1S by cervical lordosis, the additional angle required to restore the cervical sagittal angle to the horizontal line was defined as T1s minus CA (T1sCA) ($T1sCA = T1s - CA$) (Fig. 1). T1sCA values were used to evaluate the PRE cervical sagittal balance ($T1sCA \leq 20^\circ$, balance; $> 20^\circ$, imbalance).²¹

3. Clinical Evaluation

Clinical evaluations included neck disability index (NDI) and modified Japanese Orthopedic Association (JOA) score.²² The evaluations were performed PRE and POST and at follow-up. The recovery rate was calculated based on the following formula (Hirabayashi method): recovery rate (RR JOA) (%) = $(POST\ JOA - PRE\ JOA) / (full\ score - PRE\ JOA) \times 100$.²³

4. Statistical Analysis

The Shapiro-Wilk test was used to confirm normality of the data ($p > 0.05$). Data were presented as the number of subjects in each group or mean \pm standard deviation. Each independent variable was compared between the 2 groups using the independent-sample Student t-test, and by 1-way analysis of variance (ANOVA) for continuous variables. The Chi-square test and Fisher exact test were used for categorical variables. Pearson correlation analysis was used to investigate for relationships among CA, T1S, SVA, and T1SCA. We describe the strength of the correlation using the absolute value of r, as recommended by Evans.²⁴ Repeated-measures (RMs) ANOVAs were performed to investigate longitudinal trends. Multiple linear regression analysis was performed by stepwise method. Values of

p < 0.05 denoted a significant difference. All analyses were performed using IBM SPSS Statistics ver. 21.0 (IBM Co., Armonk, NY, USA).

RESULTS

1. Patient Characteristics and Surgical Techniques

The LP group was significantly older than the ACDF group (LP, 60.94 ± 11.66; ACDF, 51.08 ± 9.40; p < 0.001). Other variable, such as sex, body mass index (BMI), and F/U loss rates were not statistically significant. Operative levels and disease entity for each group are shown in Table 2.

2. Radiological Outcomes

1) Preoperative radiologic parameters for all patients

The distribution of CA, T1s, SVA, and ROM in all patients were 11.42° ± 9.96°, 27.07° ± 5.89°, 21.87 ± 10.96 mm, and 38.37° ± 11.80°, which met the normal distribution by Kolmogorov-Smirnov test (p > 0.05). The correlation analysis of cervical sagittal parameters with age was not statistically significant, except

Table 2. Patients' characteristic

Characteristic	ACDF (n = 39)	LP (n = 33)	p-value
Age (yr)	51.08 ± 9.40	60.94 ± 11.66	< 0.001
Sex, male:female	21:18	19:14	0.814
BMI (kg/m ²)	24.63 ± 7.78	25.78 ± 2.62	0.076
Operation segments			
1 Level	25	-	
2 Level	24	-	
C3-4	3	-	
C4-5	13	-	
C5-6	26	-	
C6-7	11	-	
3 Level	-	7	
4 Level	-	21	
5 Level	-	5	
Disease entity			0.009
Disc or bony spur	34	20	
OPLL	5	13	
F/U loss (enrolled/total)	2/41	7/40	0.088
F/U duration (mo)	17.52 ± 4.82	16.04 ± 4.19	0.173

Values are presented as mean ± standard deviation or number. ACDF, anterior cervical discectomy and fusion; LP, laminoplasty; BMI, body mass index; OPLL, ossified posterior longitudinal ligament; F/U, follow-up.

for the weak negative correlation of ROM (r = -0.286, p = 0.02).

2) Comparative analysis of radiologic parameter between the ACDF and LP groups

The measured values of the cervical sagittal parameters of the 2 groups are summarized in Table 3. Independent t-test was performed for comparison between the 2 groups at each PRE, POST, and F/U time points. PRE: All parameters between the 2 groups were not statistically different. POST: CA, T1s showed a statistically significant difference (CA, p = 0.011; T1s, p = 0.049). FU: CA and T1sCA were close to statistical significance (CA, p = 0.059; T1sCA, p = 0.082), and CA ROM was significantly different (p = 0.002). The result of RM-ANOVA is shown in Fig. 2. The longitudinal trend in all parameters were significantly different between the groups (CA, p = 0.002; T1s, p =

Table 3. Radiological outcomes and comparative analysis

Variable	PRE	POST	F/U	p-value ^d
C2-7 CA (°)				
ACDF	10.91 ± 11.00	13.23 ± 8.53	13.57 ± 9.09	0.002* ^a
LP	12.96 ± 8.27	7.40 ± 10.40	8.80 ± 11.95	
p-value ^c	0.371 ^b	0.011*	0.059	
T1s (°)				
ACDF	26.90 ± 6.08	27.57 ± 5.84	26.91 ± 6.65	0.001*
LP	27.19 ± 5.74	24.83 ± 5.73	25.92 ± 6.79	
p-value	0.832	0.049*	0.539	
SVA (mm)				
ACDF	21.72 ± 11.51	27.57 ± 5.84	22.35 ± 9.87	0.042*
LP	20.58 ± 10.81	24.58 ± 11.87	25.14 ± 14.49	
p-value	0.670	0.404	0.354 ^b	
CA ROM (°)				
ACDF	40.69 ± 12.56	N/A	31.83 ± 9.67	< 0.001
LP	34.55 ± 10.62	N/A	21.29 ± 13.69	< 0.001
p-value	0.072		0.002*	
T1sCA (°)				
ACDF	15.99 ± 10.28	14.34 ± 7.83	13.34 ± 8.76	0.025* ^a
LP	14.23 ± 7.84	17.44 ± 9.12	17.12 ± 9.42	
p-value	0.426	0.125	0.082	

Values are presented as mean ± standard deviation. ACDF, anterior cervical discectomy and fusion; LP, laminoplasty; PRE, preoperative; POST, postoperative day 7; F/U, last follow-up; CA, cervical angle; T1s, T1 slope; SVA, sagittal vertical axis; ROM, range of motion; N/A, not available; T1sCA, T1s minus CA. ^aIndicates the p-value of Mauchly test of sphericity < 0.05. ^bIndicates the p-value of Levene test for equality of variances < 0.05. ^cIndependent t-test. ^dRepeated-measured analysis of variance test (CA ROM was calculated by paired t-test). *p < 0.05, statistical significance.

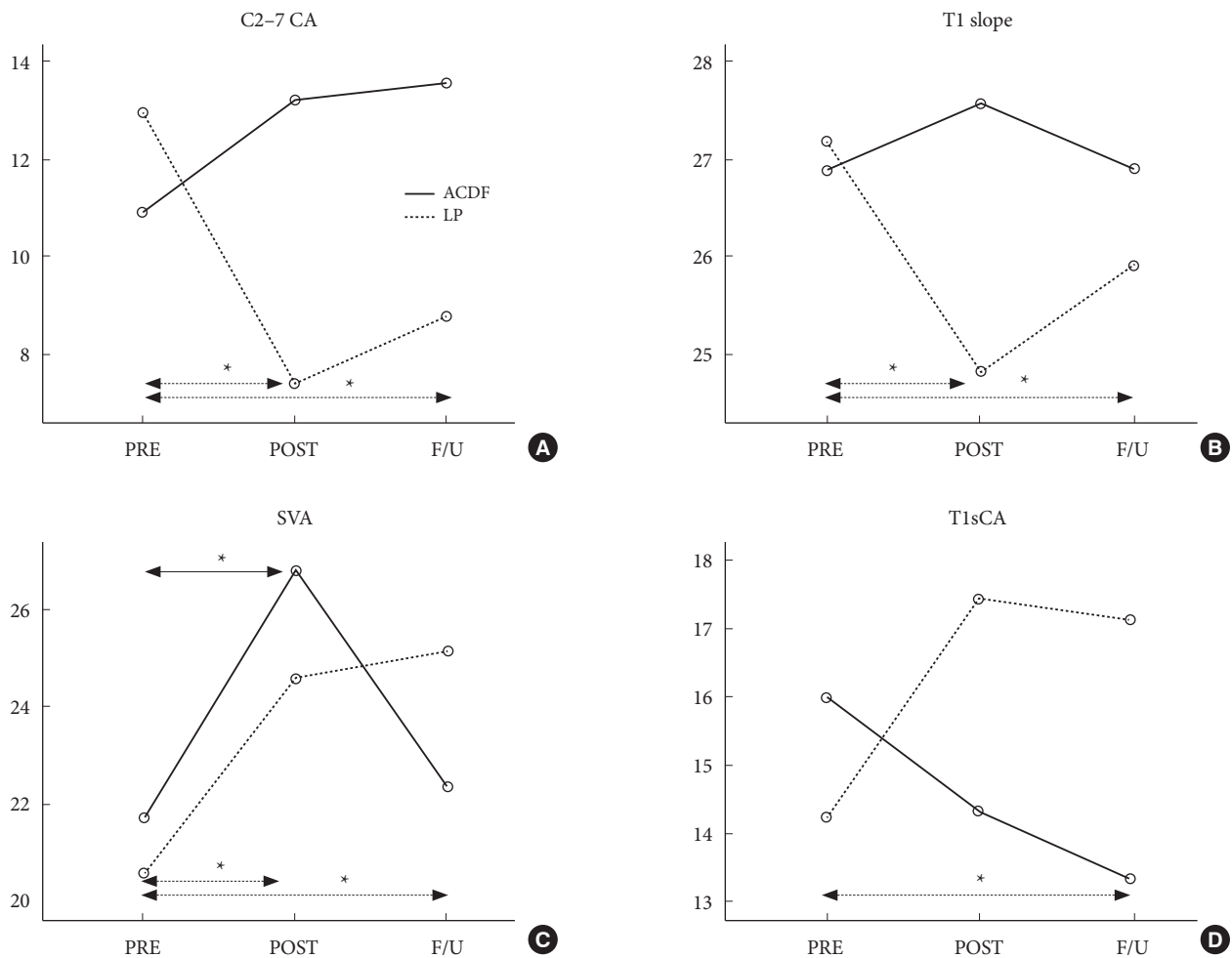


Fig. 2. The mean value of cervical sagittal alignment parameters (A, C2-7 CA; B, T1 slope; C, SVA; D, T1sCA) according to ACDF and LP. ACDF, anterior cervical discectomy and fusion; LP, laminoplasty; C2-7 CA, C2-7 cervical angle; SVA, C2-7 sagittal vertical axis; T1sCA, T1 slope minus CA; PRE, preoperative; POST, postoperative day 7; F/U, last follow-up image. * $p < 0.05$, statistical significance according to time point.

0.001; SVA, $p = 0.042$; T1sCA, $p = 0.025$). A paired t-test was performed to evaluate the difference between PRE-POST, and PRE-FU. For ACDF, PRE-POST SVA and PRE-FU ROM showed significant differences. In the case of LP, all measurements, except for PRE-POST T1sCA, showed statistical significance (Fig. 2). Paired t-test was performed based on cervical balance (PRE T1s-CA $\leq 20^\circ$, balance; $> 20^\circ$, imbalance) for each group to evaluate the alignment change based on cervical balance (Figs. 3, 4).

(1) Balance ACDF group: A significant increase was found in SVA POST, but decreased at FU. No statistical significance was found between PRE-FU SVA. (2) Imbalance ACDF group: CA and T1sCA significantly changed in POST, and these changes persisted in F/U. (3) Balance LP group: CA, SVA, and T1sCA significantly changed in POST, and these changes persisted in F/U.

(4) Imbalance LP group: T1s decreased significantly in POST, but in FU, and no significant difference was found with PRE.

3) Correlation analysis for loss of cervical lordosis

We evaluated a correlation analysis for continuous variables to analyze factors affecting loss of cervical lordosis (PRE-CA minus F/U-CA). In the ACDF group, loss of cervical lordosis was related to PRE-CA, PRE-SVA, PRE-T1sCA, and PRE-ROM, and was unrelated to age and T1s. In the LP group, T1s has a significant correlation with loss of cervical lordosis ($r = -0.419$, $p = 0.015$), but all other factors were not significant (Table 4).

3. Clinical Outcomes

In the ACDF group, the PRE-JOA and PRE-NDI were 14.28 ± 2.04 and 35.79 ± 7.94 , respectively, and were improved to

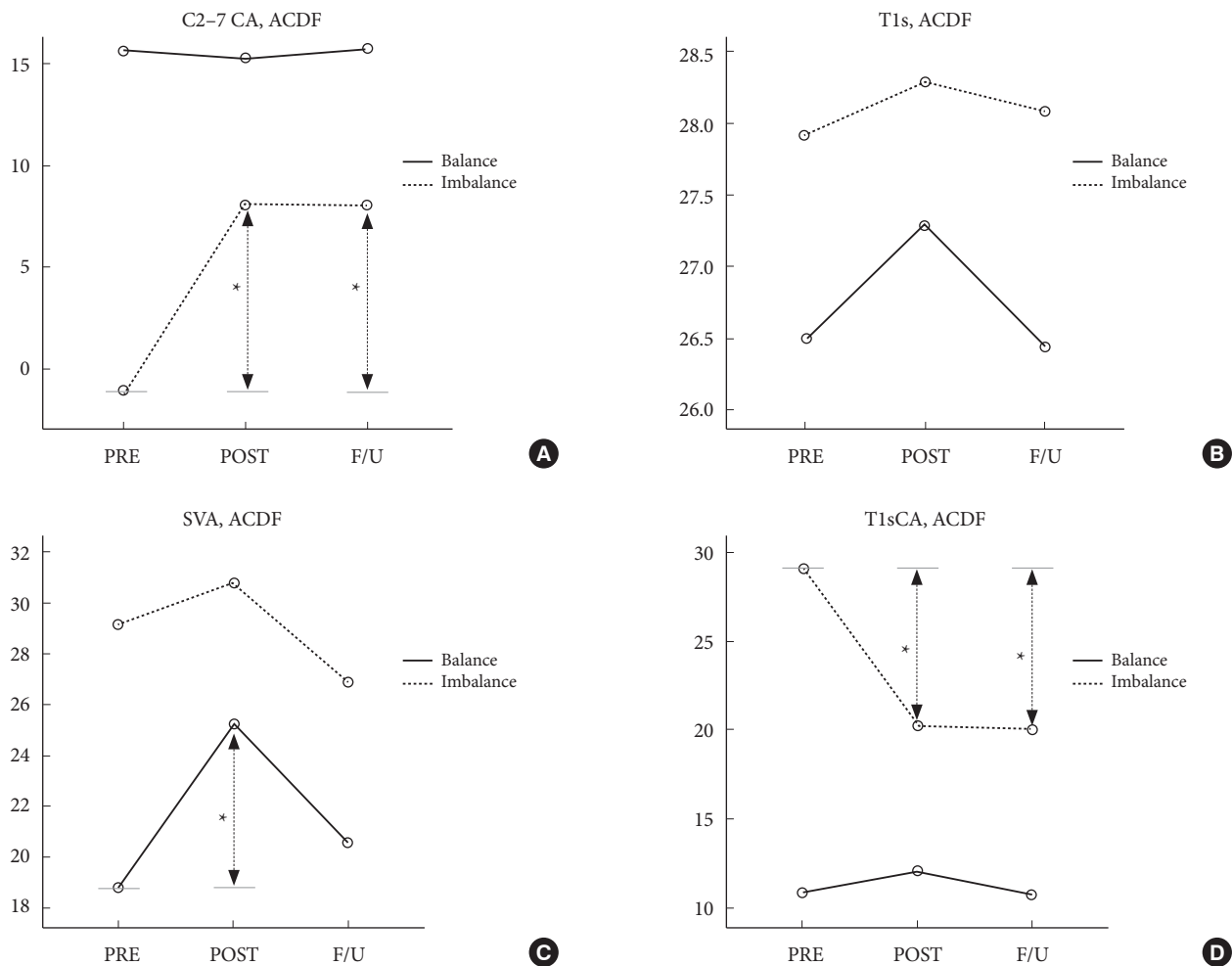


Fig. 3. The mean value of cervical sagittal alignment parameters (A, C2-7 CA; B, T1 slope; C, SVA; D, T1sCA) of ACDF according to balance (T1sCA ≤ 20°, balance; T1sCA > 20°, imbalance). ACDF, anterior cervical discectomy and fusion; C2-7 CA, C2-7 cervical angle; T1s, T1 slope; SVA, C2-7 sagittal vertical axis; T1sCA, T1 slope minus CA; PRE, preoperative; POST, postoperative day 7; F/U, last follow up image. *p < 0.05, statistical significance according to time point.

Table 4. Correlation analysis for loss of cervical lordosis

Variable	ACDF		LP	
	r	p-value	r	p-value
Loss of cervical lordosis (°)	-2.66 ± 9.52		4.16 ± 7.68	
Preoperative				
Age	0.041	0.806	0.303	0.087
C2-7 CA	0.616	< 0.001*	-0.120	0.504
T1s	0.147	0.371	-0.419	0.015*
SVA	-0.351	0.028*	-0.238	0.183
T1sCA	-0.571	< 0.001*	-0.180	0.317
ROM	0.408	0.012*	-0.009	0.964

ACDF, anterior cervical discectomy and fusion; LP, laminoplasty; CA, cervical angle; T1s, T1 slope; SVA, sagittal vertical axis; ROM, range of motion; T1sCA, T1s minus CA.

*p < 0.05, statistical significance.

15.72 ± 2.15 and 15.03 ± 9.91 after surgery, respectively. No statistical significance was found in the Spearman correlation analysis between clinical improvement and preoperative radiologic parameters and postoperative parameter changes. We assessed the effect of cervical balance on clinical outcome, and no difference was found in RR JOA and NDI change between the 2 groups (Table 5).

In the LP group, PRE-JOA and PRE-NDI were 10.91 ± 2.38 and 36.15 ± 5.63, respectively, and were improved to 14.73 ± 2.07 and 25.21 ± 5.06 after surgery, respectively. Spearman correlation showed that RR JOA was significantly correlated with PRE-CA (r = 0.362, p = 0.038), F/U-CA (r = 0.473, p = 0.005), and F/U-T1sCA (r = -0.509, p = 0.002). The cervical balance showed a significant difference in the clinical outcome in the LP group. RR JOA in the balance group (61.65% ± 19.88%) was

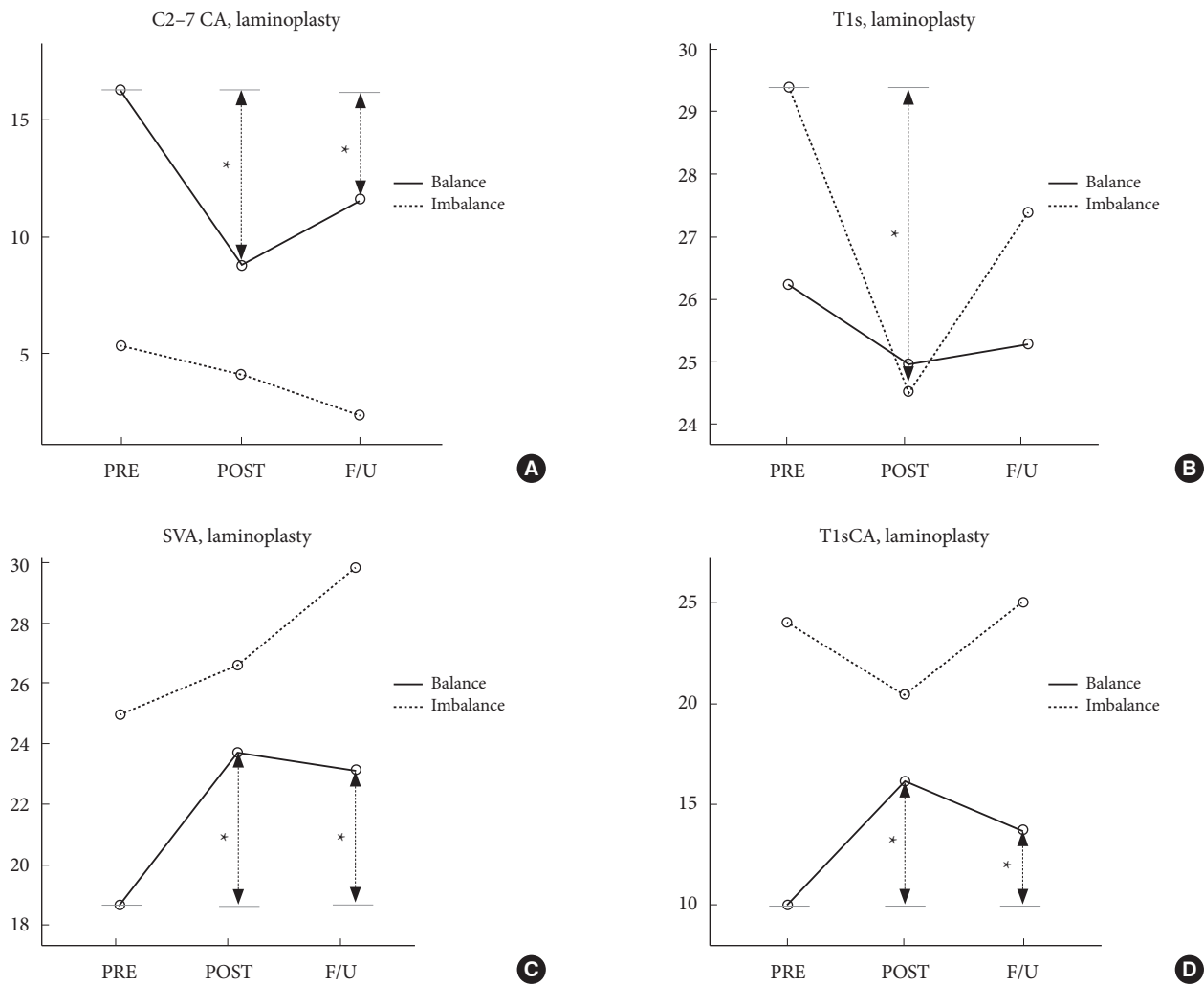


Fig. 4. The mean value of cervical sagittal alignment parameters (A, C2-7 CA; B, T1 slope; C, SVA; D, T1sCA) of laminoplasty according to balance (T1sCA $\leq 20^\circ$, balance; T1sCA $> 20^\circ$, imbalance). C2-7 CA, C2-7 cervical angle; T1s, T1 slope; SVA, C2-7 sagittal vertical axis; T1s-CA, T1 slope minus CA; PRE, preoperative; POST, postoperative day 7; F/U, last follow up image. * $p < 0.05$, statistical significance according to time point.

Table 5. Comparative analysis of clinical outcome according to cervical balance

Variable	ACDF			LP		
	Balance (n = 28)	Imbalance (n = 11)	p-value	Balance (n = 23)	Imbalance (n = 10)	p-value
PRE-JOA	14.50 \pm 1.93	13.73 \pm 2.28	0.293	11.30 \pm 2.57	10.00 \pm 1.63	0.150
PRE-NDI	35.00 \pm 8.12	37.82 \pm 7.45	0.325	35.17 \pm 5.95	38.40 \pm 4.25	0.132
RR-JOA	42.50 \pm 44.68	23.00 \pm 58.40	0.203	61.65 \pm 19.88	46.90 \pm 15.71	0.046*
NDI change	21.29 \pm 9.42	20.00 \pm 11.97	0.754	10.83 \pm 4.14	10.30 \pm 3.65	0.731

Balance group: T1sCA $\leq 20^\circ$, Imbalance, $> 20^\circ$.

ACDF, anterior cervical discectomy and fusion; LP, laminoplasty; PRE-JOA, preoperative JOA score; PRE-NDI, preoperative neck disability index (NDI) score; RR-JOA, recovery rate of JOA; NDI change, preoperative NDI minus postoperative NDI.

* $p < 0.05$, statistical significance.

significantly higher than that in the imbalance group (46.90% \pm 15.71%) ($p = 0.046$). NDI change did not show a significant

difference (balance group, 10.83 \pm 4.14; imbalance group, 10.30 \pm 3.65) (Table 5).

DISCUSSION

ACDF and LP are the most common surgical methods for degenerative cervical spondylosis. The effect of LP is due to indirect decompression by posterior migration of the spinal cord from the anterior compression lesions.^{25,26} In this respect, several studies found poor outcome in patients with preoperative kyphotic alignment.²⁷⁻²⁹ Furthermore, postoperative kyphotic changes are also associated with poor outcome.^{4,30,31} This postoperative kyphotic changes have also been reported in patients without preoperative kyphotic alignment,⁴ and recent studies focused on their association with T1s.^{2,5,7,8,32} In patients with high T1s, the posterior neck muscular-ligament complex injury is associated with postoperative kyphotic changes, leading less posterior migration of the spinal cord.⁶

The ACDF directly removes the anterior compression lesion and increases the height of the neural foramen, which also results in the indirect decompression.³³ However, graft failures, such as subsidence and pseudarthrosis have been reported frequently,^{12,34,35} which may diminish the effectiveness of indirect decompression and resulted in the recurrence of symptoms.³⁵ Our recent study reported that subsidence was associated with PRE T1s.³⁶ In addition, preoperative cervical alignment has also been reported to be associated with the clinical outcome of ACDF.³⁷⁻³⁹ Kwon et al.¹³ recently evaluated the relationship of preoperative radiologic parameters to postoperative SVA, which was known to be associated with clinical outcome.^{2,32} With regard to the recognition of the importance of preoperative parameters in ACDF, we analyzed the effects of preoperative parameters on radiological and clinical outcomes in ACDF compared with LP.

The concept of preoperative cervical sagittal balance is evaluated by various factors. In existing literature, cervical sagittal imbalance was defined as T1s > 40°, SVA > 40 mm, and T1s-CA > 20°.²¹ In our study, no T1s > 40° in both groups, and SVA > 40 mm was also too small to obtain statistical significance (ACDF SVA > 40 mm, 4 patients; LP SVA > 40 mm, 2 patients). We compared the postoperative alignment differences based on each operation based on T1sCA > 20°, and ACDF showed a significant improvement in alignment of the imbalance group and no significant change in the balance group (Fig. 3). In the LP balance group, alignment deterioration was prominent, whereas in the imbalance group, it was not significant (Fig. 4). However, these results do not mean that LP in the balance group results in worse outcomes. The loss of cervical lordosis (Δ CA) of the balance group is much larger than the imbalance group, but

F/U CA of balance group still maintains a higher value than the F/U CA of the imbalance group (F/U CA: balance, 11.59° ± 10.67°; imbalance, 2.38° ± 12.79°; p = 0.040). This result is similarly present in T1sCA (F/U T1sCA: balance, 13.70° ± 7.75°; imbalance, 25.01° ± 8.33°; p = 0.001). Similarly, in the ACDF, the improvement of cervical sagittal alignment parameters in the imbalance group was significantly higher than that in the balance group, but the F/U values of these parameters were still higher in the balance group (F/U CA: balance, 17.74° ± 8.96°; imbalance, 8.05° ± 7.09°; p = 0.015). This result shows that the cervical sagittal balance, which is a comprehensive result of preoperative factors, has different effects on the radiological results of 2 different surgical procedures.

What is interesting at POST is that T1s was significantly decreased in the imbalance LP group, and this change was slightly recovered in the F/U period (Fig. 4B). The imbalance group has high T1s and low CA. When LP was performed in these patients, additional decrease in CA occurred. We speculated that the additional decline of CA caused gaze disturbance. The patient attempted to recover gaze by changing the T1s (as a proxy of thoracolumbar curvature) to compensate the disturbance. Surely, to explain these changes, a large-scale study of whole spine images would be needed. We note, however, that our study suggests that the change in T1s is also an important parameter in the study of LP, and that T1sCA is a better representative of LP alignment than T1s alone.

Because our study is not based on the similar disease entities, we did not compare the clinical outcomes between the 2 surgical procedures. We analyzed the effect of preoperative sagittal balance and postoperative radiologic change on the clinical outcome for each surgical procedure. In the clinical results of the LP group, the RR JOA in the balance group was higher than that in the imbalance groups, despite a significant decline of CA occurring in the balance group. Based on the Spearman correlation analysis, RR JOA was correlated with PRE-CA, F/U-CA, F/U-T1sCA, but not with SVA and T1S. All delta values of CA, T1s, SVA, and T1sCA were also not correlated with RR JOA. In addition, our study demonstrated that F/U-T1sCA can better reflect the RR JOA than F/U CA. We assumed that the reason of F/U-T1sCA being more correlated with RR JOA than F/U-CA is because T1s also affected by the surgical procedure. In the case of ACDF, balance did not affect postoperative clinical outcomes.

This study has several limitations. First, this study is a retrospective small sized, non/-controlled study. Second, we did not limit the inclusion criteria to the same disease entity in compar-

ing the two surgical procedures. Third, we did not include the various methods of ACDF and LP.

CONCLUSION

We found a significant difference in the postoperative alignment of ACDF and LP based on the preoperative cervical sagittal balance. Particularly, the imbalance ACDF group showed postoperative alignment improvement, but the balance LP group showed alignment deterioration. The postoperative clinical results of the LP group were more affected by F/U alignment than the change of alignment. Because T1s in LP is also a variable element based on surgery, we suggest that T1sCA is a more appropriate alignment evaluation factor.

CONFLICT OF INTEREST

The authors have nothing to disclose.

REFERENCES

- Ames CP, Blondel B, Scheer JK, et al. Cervical radiographical alignment: comprehensive assessment techniques and potential importance in cervical myelopathy. *Spine (Phila Pa 1976)* 2013;38 (22 Suppl 1):S149-60.
- Tang JA, Scheer JK, Smith JS, et al. The impact of standing regional cervical sagittal alignment on outcomes in posterior cervical fusion surgery. *Neurosurgery* 2012;71:662-9.
- Knott PT, Mardjetko SM, Tschy F. The use of the T1 sagittal angle in predicting overall sagittal balance of the spine. *Spine J* 2010;10:994-8.
- Sakai K, Yoshii T, Hirai T, et al. Cervical sagittal imbalance is a predictor of kyphotic deformity after laminoplasty in cervical spondylotic myelopathy patients without preoperative kyphotic alignment. *Spine (Phila Pa 1976)* 2016;41:299-305.
- Kim B, Yoon DH, Ha Y, et al. Relationship between T1 slope and loss of lordosis after laminoplasty in patients with cervical ossification of the posterior longitudinal ligament. *Spine J* 2016;16:219-25.
- Lin S, Zhou F, Sun Y, et al. The severity of operative invasion to the posterior muscular-ligament complex influences cervical sagittal balance after open-door laminoplasty. *Eur Spine J* 2015;24:127-35.
- Cho JH, Ha JK, Kim DG, et al. Does preoperative T1 slope affect radiological and functional outcomes after cervical laminoplasty? *Spine (Phila Pa 1976)* 2014;39:E1575-81.
- Kim TH, Lee SY, Kim YC, et al. T1 slope as a predictor of kyphotic alignment change after laminoplasty in patients with cervical myelopathy. *Spine (Phila Pa 1976)* 2013;38: E992-7.
- Gillis CC, Kaszuba MC, Traynelis VC. Cervical radiographic parameters in 1- and 2-level anterior cervical discectomy and fusion. *J Neurosurg Spine* 2016;25:421-9.
- Gum JL, Glassman SD, Douglas LR, et al. Correlation between cervical spine sagittal alignment and clinical outcome after anterior cervical discectomy and fusion. *Am J Orthop (Belle Mead NJ)* 2012;41:E81-4.
- Huang DN, Yu M, Xu NF, et al. The relationship between changes of cervical sagittal alignment after anterior cervical discectomy and fusion and spino-pelvic sagittal alignment under rousouly classification: a four-year follow-up study. *BMC Musculoskelet Disord* 2017;18:87.
- Tomé-Bermejo F, Morales-Valencia JA, Moreno-Pérez J, et al. Degenerative cervical disc disease: long-term changes in sagittal alignment and their clinical implications after cervical interbody fusion cage subsidence: a prospective study with standalone lordotic tantalum cages. *Clin Spine Surg* 2017;30:E648-55.
- Kwon WK, Kim PS, Ahn SY, et al. Analysis of associating factors with C2-7 sagittal vertical axis after two-level anterior cervical fusion: comparison between plate augmentation and stand-alone cages. *Spine (Phila Pa 1976)* 2017;42:318-25.
- Fang Z, Tian R, Sun TW, et al. Expansion open-door laminoplasty with foraminotomy versus anterior cervical discectomy and fusion for coexisting multilevel cervical myelopathy and unilateral radiculopathy. *Clin Spine Surg* 2016;29: E21-7.
- Hou Y, Liang L, Shi GD, et al. Comparing effects of cervical anterior approach and laminoplasty in surgical management of cervical ossification of posterior longitudinal ligament by a prospective nonrandomized controlled study. *Orthop Traumatol Surg Res* 2017;103:733-40.
- Jiang YQ, Li XL, Zhou XG, et al. A prospective randomized trial comparing anterior cervical discectomy and fusion versus plate-only open-door laminoplasty for the treatment of spinal stenosis in degenerative diseases. *Eur Spine J* 2017;26: 1162-72.
- Macagno A, Liu S, Marascalchi BJ, et al. Perioperative risks associated with cervical spondylotic myelopathy based on surgical treatment strategies. *Int J Spine Surg* 2015;9:24.
- Seng C, Tow BP, Siddiqui MA, et al. Surgically treated cervi-

- cal myelopathy: a functional outcome comparison study between multilevel anterior cervical decompression fusion with instrumentation and posterior laminoplasty. *Spine J* 2013;13:723-31.
19. Tamai K, Terai H, Suzuki A, et al. anterior cervical discectomy and fusion provides better surgical outcomes than posterior laminoplasty in elderly patients with C3-4 level myelopathy. *Spine (Phila Pa 1976)* 2017;42:548-55.
 20. Xu L, Sun H, Li Z, et al. Anterior cervical discectomy and fusion versus posterior laminoplasty for multilevel cervical myelopathy: A meta-analysis. *Int J Surg* 2017;48:247-53.
 21. Ames CP, Smith JS, Eastlack R, et al. Reliability assessment of a novel cervical spine deformity classification system. *J Neurosurg Spine* 2015;23:673-83.
 22. Benzel EC, Lancon J, Kesterson L, et al. Cervical laminectomy and dentate ligament section for cervical spondylotic myelopathy. *J Spinal Disord* 1991;4:286-95.
 23. Hirabayashi K, Miyakawa J, Satomi K, et al. Operative results and postoperative progression of ossification among patients with ossification of cervical posterior longitudinal ligament. *Spine (Phila Pa 1976)* 1981;6:354-64.
 24. Evans JD. Straightforward statistics for the behavioral sciences. Pacific Grove: Brooks/Cole Pub Co.; 1996.
 25. Baba H, Uchida K, Maezawa Y, et al. Lordotic alignment and posterior migration of the spinal cord following en bloc open-door laminoplasty for cervical myelopathy: a magnetic resonance imaging study. *J Neurol* 1996;243:626-32.
 26. Sodeyama T, Goto S, Mochizuki M, et al. Effect of decompression enlargement laminoplasty for posterior shifting of the spinal cord. *Spine (Phila Pa 1976)* 1999;24:1527-31.
 27. Miyamoto H, Maeno K, Uno K, et al. Outcomes of surgical intervention for cervical spondylotic myelopathy accompanying local kyphosis (comparison between laminoplasty alone and posterior reconstruction surgery using the screw-rod system). *Eur Spine J* 2014;23:341-6.
 28. Shamji MF, Mohanty C, Massicotte EM, et al. The association of cervical spine alignment with neurologic recovery in a prospective cohort of patients with surgical myelopathy: analysis of a series of 124 cases. *World Neurosurg* 2016;86:112-9.
 29. Suk KS, Kim KT, Lee JH, et al. Sagittal alignment of the cervical spine after the laminoplasty. *Spine (Phila Pa 1976)* 2007;32:E656-60.
 30. Kawaguchi Y, Kanamori M, Ishihara H, et al. Minimum 10-year followup after en bloc cervical laminoplasty. *Clin Orthop Relat Res* 2003;411:129-39.
 31. Kimura I, Shingu H, Nasu Y. Long-term follow-up of cervical spondylotic myelopathy treated by canal-expansive laminoplasty. *J Bone Joint Surg Br* 1995;77:956-61.
 32. Hyun SJ, Kim KJ, Jahng TA, et al. Relationship between T1 slope and cervical alignment following multilevel posterior cervical fusion surgery: impact of T1 slope minus cervical lordosis. *Spine (Phila Pa 1976)* 2016;41:E396-402.
 33. Suk KS, Lee SH, Park SY, et al. Clinical outcome and changes of foraminal dimension in patients with foraminal stenosis after ACDF. *J Spinal Disord Tech* 2015;28:E449-53.
 34. Kersten RF, van Gaalen SM, de Gast A, et al. Polyetheretherketone (PEEK) cages in cervical applications: a systematic review. *Spine J* 2015;15:1446-60.
 35. Kim WB, Hyun SJ, Choi H, et al. Long-term follow-up results of anterior cervical inter-body fusion with stand-alone cages. *J Korean Neurosurg Soc* 2016;59:385-91.
 36. Lee SH, Lee JS, Sung SK, et al. A lower T1 slope as a predictor of subsidence in anterior cervical discectomy and fusion with stand-alone cages. *J Korean Neurosurg Soc* 2017;60:567-76.
 37. Lee YS, Kim YB, Park SW. Risk factors for postoperative subsidence of single-level anterior cervical discectomy and fusion: the significance of the preoperative cervical alignment. *Spine (Phila Pa 1976)* 2014;39:1280-7.
 38. Wu WJ, Jiang LS, Liang Y, et al. Cage subsidence does not, but cervical lordosis improvement does affect the long-term results of anterior cervical fusion with stand-alone cage for degenerative cervical disc disease: a retrospective study. *Eur Spine J* 2012;21:1374-82.
 39. Gum JL, Glassman SD, Douglas LR, et al. Correlation between cervical spine sagittal alignment and clinical outcome after anterior cervical discectomy and fusion. *Am J Orthop (Belle Mead NJ)* 2012;41:E81-4.