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Is It Meaningful and Necessary to Avoid the Seventh Cervical Vertebra in Long Level Cervical Fusion?

Jung Jae LEE[1], Hong Kyung SHIN[2], Sang Ku JUNG[3], Su Bum LEE[4], Tae Kyu LEE[1], Jin Hoon PARK[2]

[1]The Catholic University of Korea, Uijeongbu St. Mary's Hospital, Department of Neurological Surgery, Uijeongbu, Republic of Korea
[2]Asan Medical Center, University of Ulsan College of Medicine, Department of Neurosurgery, Seoul, South Korea
[3]University of Ulsan College of Medicine, Gangneung Asan Hospital, Department of Emergency Medicine,Gangneung, Korea
[4]Korea University Medicine, Department of Neurosurgery, Seoul, South Korea

Corresponding author: Jin Hoon PARK ✉ jhpark@amc.seoul.kr

ABSTRACT

AIM: To compare the clinical and radiological results of patients who underwent multilevel posterior cervical fusion (PCF) with different end levels (C6 or C7).

MATERIAL and METHODS: We collected radiographs and clinical results of all subjects who underwent 3 level or more PCF for degenerative disease from May 2012 to December 2020. Based on the location of the end of fusion during surgery, patients were divided into C6 (group 1) and C7 patients (group 2). The clinical and radiological results of both groups were compared over two years.

RESULTS: A total of 52 patients met the inclusion criteria of this study (21 in group 1 and 31 in group 2). The clinical results demonstrated a statistically significant difference with respect to a lower neck visual analog scale score in group 1 than in group 2 at the last follow-up (p=0.03). With regard to the radiological results, the C2–C7 sagittal vertical axis showed significantly greater values in group 2 than in group 1 at the final follow-up (p=0.02). For thoracic kyphosis (TK), group 2 had lower TK values than group 1 (p=0.03), and the T9 spinopelvic inclination was significantly greater in group 2 than in group 1 (p=0.01).

CONCLUSION: In this study, aggravation of cervical kyphosis and neck pain was observed when C7 was included in multilevel PCF surgery. The inclusion of C7 also affected the thoracolumbar parameters and global spine alignment.

KEYWORDS: Cervical spine, Extended fusion, C7, C6, Spinal curvatures, Spinal fusion

ABBREVIATIONS: PCF: Posterior cervical fusion, **BMD:** Bone marrow density, **CL:** Cervical lordosis, **SA:** Segmental angle, **SVA:** Sagittal vertical axis, **TK:** Thoracic kyphosis, **LL:** Lumbar lordosis, **PL:** Plumb line, **SPI:** Spinopelvic inclination, **IRB:** Institutional review board, **NDI:** Neck disability index, **VAS:** Visual analog scale

INTRODUCTION

Multilevel degenerative cervical pathologies or deformities can be attributed to posterior cervical fusion (PCF) and decompression procedures, which are increasingly performed at advanced ages (5,19,22,34). However, considering the surgical extent of multilevel PCF, inclusion of the C7 vertebra can be risky. Furthermore, some surgeons have noted that multilevel instruments ending at C7 can be associated with an elevated risk of adjacent segmental degeneration (7,8,14,24,32). The C7 vertebra is anatomically unique: it not only marks the transition from the dynamic cervical segment to a relatively rigid thoracic segment of the spine but also represents the point at which cervical lordosis (CL) reverses into thoracic kyphosis (TK) (2,11). The C7 spinous

Jung Jae LEE : 0000-0002-1887-0069
Hong Kyung SHIN : 0000-0001-8182-3321
Sang Ku JUNG : 0000-0002-9606-0440
Su Bum LEE : 0000-0003-4732-8137
Tae Kyu LEE : 0000-0003-0784-3740
Jin Hoon PARK : 0000-0002-0903-3146

process is unique compared with superior spinous processes including the C6 spinous process because it is associated with a very important anatomical function, namely, the attachement of the trapezius and rhomboid muscles, which are connected to the scapula (28). Some studies have reported that axial pain can be prevented by excluding C7 during laminoplasty (12,13). However, to date, few studies that deal with avoiding C7 in multistage PCF surgery are available; hence, the issue remains unclear.

In this study, clinical and radiological results were compared among patients who underwent multilevel PCF with different end levels (at the C6 or C7 vertebra).

MATERIAL and METHODS

Demographic Data

Data from all patients who underwent PCF for degenerative disease, corresponding to level 3 or more, including at least two years of postoperative follow-up data from May 2012 to December 2020 were collected from a consolidated radiographic and clinical database. The inclusion criteria were as follows: 1) Screw fixation including multilevel (≥3) PCF without the addition of C1 screws or the occiput; 2) preoperative degenerative cervical disease warranting cervical fusion; 3) minimum follow-up period of two years with complete clinical and radiologic data; 4) no prior cervical spinal surgery; and 5) no history of combined surgery (e.g., anterior cervical discectomy fusion). The exclusion criteria were as follows 1) cervical spine trauma; 2) spine tumours (primary or metastasis); 3) spinal infections; 4) prior cervical spinal surgery; and 5) an ossified posterior longitudinal ligament.

Patients were divided into two groups: group 1 (fusions ending at C6) and group 2 (fusions ending at C7).

Differences in the PCF levels, number of laminectomies, and demographic variables such as age, gender, past smoking history, body mass index (BMI), underlying diseases (hypertension and diabetes), and bone mineral density (BMD, T-score) were examined and compared between the two groups to determine risk.

Clinical conditions before surgery and surgery outcomes (immediately after surgery and 24 months postoperatively) were compared among all patients in the two groups. The factors used to assess clinical outcomes were the visual analog scale (VAS) score for neck and arm pain and the Neck Disability Index (NDI) to evaluate the patient's quality of life. If the patients had difficulty completing written questionnaires during outpatient visits, investigations were conducted orally or over the phone.

Surgical Procedure

Cervical pedicle screw (CPS) implantation was performed in all patients who underwent PCF. The safety and efficacy of CPS implantation, even with a free-hand technique for several challenging spinal diseases, including cervical spinal degenerative disease, have been demonstrated in several studies (6,10,15,21,29,30). Moreover, the safety and efficacy of subaxial CPS implantation have also been validated in several occasions (20,27,29). Most CPS insertions have been performed using the free-hand technique; however, in cases of difficult insertions, a lateral mass screw or skip screw technique has been performed (16,35). Following surgery, the patient's head position was changed by moving the remote-controlled table head segment to create the ideal curvature before rod fixation (1).

Radiologic Evaluation

Radiographic measurements were performed using lateral cervical and whole spine radiography. The Cobb method was used to evaluate kyphosis following measurement of cervical lordosis (CL), thoracic kyphosis (TK), lumbar lordosis (LL), and segmental lordosis (SL) in the surgical area (9). To confirm the cervical spine parameters, the T1 slope, CL, and SL, we measured the CL (the angle of the sagittal Cobb between the C2 and C7 vertebrae) and SL (the angle between two of the cranial endplates of a superior vertebra and caudal endplates of an inferior vertebra in the surgical segment) using the Cobb angle and the T1 slope (the angle between the upper extension of T1 and the horizontal baseline).

The cervical spine alignment was measured along the C2–C7 sagittal vertical axis (SVA). The distance between C2 and C7 was used to measure the C2–C7 SVA (Figure 1A). The thoracolumbar parameters including TK (Cobb angle measurement between T5–12), LL (Cobb angle measurement between L1–S1), and mismatch between pelvic incidence and LI were also measured (Figure 1B).

The C7 plumb line (PL) and T9 spinopelvic inclination (SPI) were determined to evaluate global alignment. The distance between the C7 body line and the upper posterior edge of the sacrum was measured to determine the C7 PL, and the angle between the vertical line and the line connecting the T9 vertebral center and the femoral head axis depicted the T9 SPI (Figure 1C) (26).

Assessment of all spine parameters was conducted preoperatively, immediately postoperatively, six months postoperatively, and two years postoperatively. The probability of the development of distal junctional kyphosis (DJK) in all groups was also compared and analyzed. DJK was defined as an angular change of less than 10° at the distal disk level from the end of the fusion construct between the baseline level and the last follow-up (31).

Statistical Analysis

Continuous variables are reported using the mean±standard deviation, and categorical variables are reported using frequencies or percentages. The statistical significance of the difference between radiological and clinical results was confirmed using unpaired Student's t-tests or the Mann–Whitney U test to compare continuous variables and the Chi-square test or Fisher's exact test for categorical variables. The relationship between various parameters and the changes with respect to these parameters are described using linear regression. The SPSS Statistics for Windows, version 17.0 (IBM Corp., Armonk, NY, USA) was used for the statistical

analyses. A p-value<0.05 was considered to indicate statistical significance.

Statement of Ethics

This study was approved by the institutional review board of our institution: Samsung Medical Center Institutional Review Board (IRB No.2022-10-009; Date: November 08, 2022)

RESULTS

Demographics and Clinical Outcomes

Fifty-two patients met the inclusion criteria and were included in the study; group 1 and group 2 included 21 and 31 patients, respectively. Serious complications such as neuromuscular and spinal cord injury, hematoma formation, instrument-related complications (e.g., screw misplacement and a broken screw and rod), and wound infections were uncommon in all the patients. Group 1 and group 2 did not differ significantly with respect to the differences in the PCF level, number of laminectomies, patient age or sex, underlying disease, BMD, BMI, or smoking history (Table I).

Clinical outcomes indicated that the preoperative and immediately postoperative neck VAS and NDI scores in group 2 were lower than those group 1. However, the differences were not significant. During the final follow-up, the neck VAS scores in group 1 were statistically significantly lower than those in group 2 (p=0.03, Table II).

Radiologic Outcomes

The two groups did not differ significantly with respect to the preoperative cervical, thoracic, and global spinal alignment parameters. With respect to the cervical spine parameters,

Table I: Patient Demographics in the Two Study Groups

Group (caudal fixation)	1 (C6 fusion end, n=21)	2 (C7 fusion end, n=31)	p-value
Mean age (years) ± †SD	62.15 ± 9.50	60.52 ± 10.41	0.61
Sex (M/F)	18/3	25/6	0.86
Fusion level (n) ± SD	4.00 ± 0.80	3.85 ± 0.97	0.51
Number of laminectomies (n) ± SD	2.66 ± 0.65	2.83 ± 0.77	0.41
Hypertension (%)	23.8	41.9	0.18
Diabetes mellitus (%)	14.2	32.2	0.14
Smoking (%)	47.6	41.9	0.69
Body mass index	23.84 ± 3.69	24.75 ± 3.19	0.48
Bone marrow density	-1.38 ± 1.69	-1.49 ± 1.72	0.81
§DJK development, n (%)	1 (4.76)	8 (25.8)	**0.04**

***†SD:** standard deviation; **§DJK:** distal junctional kyphosis.*

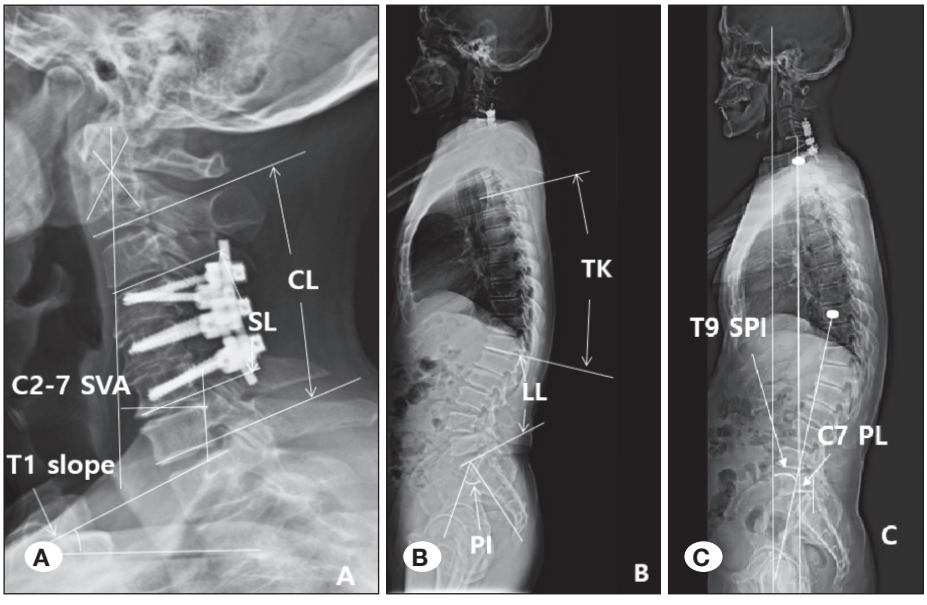

Figure 1: Measurement of cervical **(A)** and thoracolumbar parameters **(B)** and global spine alignment **(C)** on standard lateral cervical and whole spine radiographs. **CL,** C2 to C7 cervical lordosis (C2–C7); **SL,** segment lordosis; **SVA,** sagittal vertical axis; **TK,** thoracic kyphosis; **LL,** lumbar lordosis; **PI,** pelvic incidence; **SPI,** spinopelvic inclination.

group 2 had smaller C2–C7 SVA values than group 1 immediately postoperatively; however, at the final follow-up, group 1 showed significantly lower values than those in group 2 (p=0.02; Table III, Figure 2A).

In terms of the thoracolumbar parameters, group 2 demonstrated significantly greater TK angles than group 1 immediately postoperatively (p=0.04); however, the angles became similar in both groups at six months, and by the last follow-up, group 2 demonstrated significantly smaller TK angles (p=0.03, Table IV, Figure 2B).

With respect to global spine alignment, group 1 had larger values for the T9 SPI than group 2 immediately postoperatively; however, at six months, the values became similar, and during the last follow-up, group 2 demonstrated statistically significantly higher values (p=0.01, Figure 2C, Table IV).

In addition, there were significantly more patients with DJK in group 2 than in group 1 (4.76% vs. 25.8%, p=0.04; Table I).

DISCUSSION

In this study, the clinical radiographic results at two years with and without the inclusion of C7 in PCF were compared. The C7 vertebra represents an anatomical transition point from the dynamic cervical spine to the relatively rigid thoracic spine and the reversal of CL to TK (11). Thus, to ensure biomechanical stability, familiarity with different instrumental modalities in the transitional cervicothoracic junction is warranted (23).

Table II: Comparison of Clinical Results for Each Period in the Two Study Groups

Group (caudal fixation)	1 (C6 fusion end, n=21)	2 (C7 fusion end, n=31)	p-value
§**VAS score (neck)**			
Pre-surgery	7.69 ± 1.31	7.11 ± 2.02	0.60
Immediately post-surgery	3.52 ± 2.31	2.35 ± 1.72	**0.06**
2 years post-surgery	1.80 ± 1.74	2.94 ± 1.63	**0.03**
VAS score (arm)			
Pre-surgery	7.04 ± 2.17	7.45 ± 1.74	0.46
Immediately post-surgery	3.00 ± 2.32	3.12 ± 2.32	0.84
2 years post-surgery	2.52 ± 1.69	3.45 ± 2.32	0.12
‡**NDI score**			
Pre-surgery	29.12 ± 10.82	26.48 ± 11.20	0.33
Immediately post-surgery	14.40 ± 9.92	11.74 ± 8.30	0.23
2 years post-surgery	9.90 ± 7.30	12.37 ± 8.35	0.19

§VAS: *visual analog scale;* ***‡NDI:*** *neck disability index.*

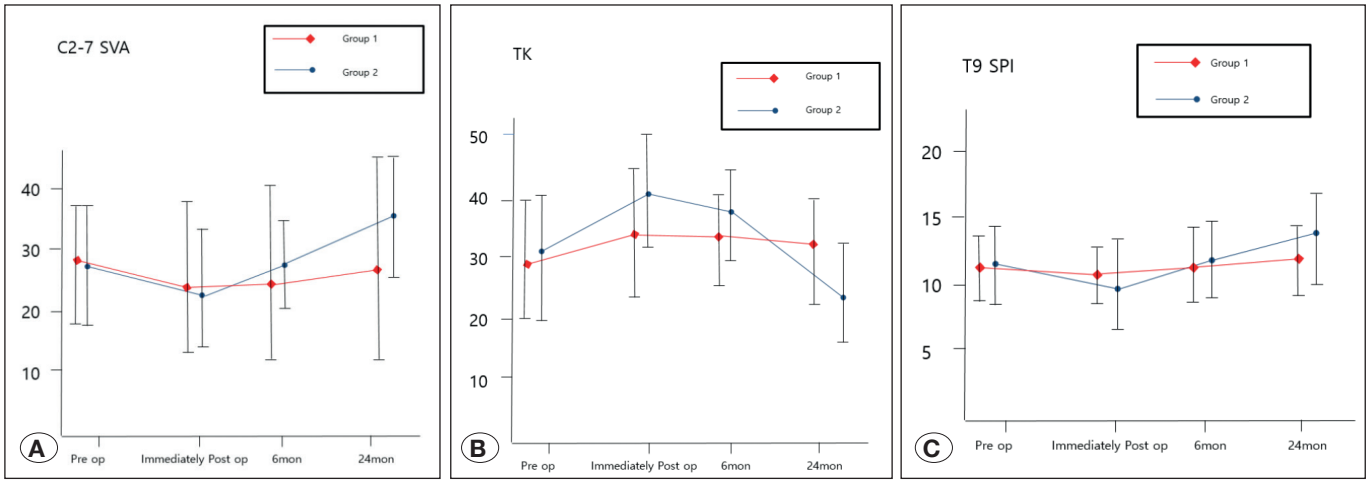

Figure 2: Graph showing the C2–C7 SVA (mm) **(A)**, TK (degree) **(B)**, and T9 SPI (degree) **(C)** preoperatively, immediately postoperatively, and 6 and 24 months postoperatively in each group. **SVA:** sagittal vertical axis; **TK:** thoracic kyphosis; **SPI:** spinopelvic inclination.

Table III: Comparison of Cervical Parameters Between Each Group

Group (caudal fixation)	1 (C6 fusion end, n = 21)	2 (C7 fusion end, n = 31)	p-value
T1 slope			
Pre-surgery	26.04 ± 8.92	23.14 ± 8.24	0.17
Immediately post-surgery	29.07 ± 8.00	31.92 ± 7.89	0.20
6 months post-surgery	28.96 ± 6.78	29.12 ± 7.04	0.92
2 years (last follow-up)	26.41 ± 8.55	24.68 ± 7.34	0.37
***CL**			
Pre-surgery	9.31 ± 8.04	7.80 ± 7.22	0.42
Immediately post-surgery	16.96 ± 8.67	18.25 ± 9.79	0.57
6 months post-surgery	15.00 ± 9.70	15.96 ± 8.32	0.70
2 years (last follow-up)	11.81 ± 8.77	8.37 ± 7.24	**0.08**
§SL			
Pre-surgery	7.56 ± 8.11	5.65 ± 7.05	0.30
Immediately post-surgery	12.18 ± 6.63	13.05 ± 8.97	0.65
6 months post-surgery	11.52 ± 7.31	11.74 ± 8.25	0.92
2 years (last follow-up)	9.37 ± 6.29	9.08 ± 8.21	0.87
C2-7 II SVA			
Pre-surgery	27.83 ± 10.10	27.52 ± 10.55	0.90
Immediately post-surgery	26.11 ± 12.19	25.05 ± 9.20	0.72
6 months post-surgery	26.16 ± 14.16	28.78 ± 8.70	0.41
2 years (last follow-up)	27.05 ± 17.23	34.84 ± 10.46	**0.02**

***CL:** Cervical lordosis; **§SL:** Segmental lordosis, **IISVA:** Sagittal vertical axis.*

Table IV: Comparison of Thoracolumbar and Global Spine Parameters Between Each Group

Group (caudal fixation)	1 (C6 fusion end, n = 21)	2 (C7 fusion end, n = 31)	p-value
C7 plumb line			
Pre-surgery	41.93 ± 26.51	38.79 ± 18.80	0.62
Immediately post-surgery	13.76 ± 13.00	8.71 ± 14.12	0.19
6 months post-surgery	14.76 ± 13.02	17.71 ± 24.01	0.60
2 years (last follow-up)	29.99 ± 31.60	43.65 ± 26.06	**0.07**
***TK**			
Pre-surgery	29.42 ± 9.48	30.90 ± 9.73	0.59
Immediately post-surgery	34.52 ± 9.67	40.06 ± 9.04	**0.04**
6 months post-surgery	33.42 ± 9.45	36.87 ± 9.75	0.21
2 years (last follow-up)	30.52 ± 9.28	24.87 ± 9.24	**0.03**

Table IV: Cont.

Group (caudal fixation)	1 (C6 fusion end, n = 21)	2 (C7 fusion end, n = 31)	p-value
§LL			
Pre-surgery	49.04 ± 13.13	52.74 ± 7.00	0.19
Immediately post-surgery	45.18 ± 11.73	48.51 ± 4.71	0.15
6 months post-surgery	46.00 ± 10.29	49.45 ± 5.51	0.22
2 years (last follow-up)	48.66 ± 12.93	53.16 ± 7.83	0.12
T9 †SPI			
Pre-surgery	11.31 ± 2.33	11.57 ± 2.74	0.72
Immediately post-surgery	10.53 ± 2.32	9.93 ± 2.95	0.42
6 months post-surgery	11.19 ± 2.23	11.68 ± 2.88	0.51
2 years (last follow-up)	11.27 ± 2.40	12.78 ± 3.32	**0.01**
II PI-LL mismatch			
Pre-surgery	2.68 ± 15.34	0.00 ± 9.23	0.39
Immediately post-surgery	6.59 ± 13.98	4.15 ± 7.84	0.52
6 months post-surgery	5.78 ± 12.83	3.28 ± 8.64	0.41
2 years (last follow-up)	3.06 ± 15.27	-0.36 ± 9.46	0.28

***TK:** Thoracic kyphosis; **§LL:** Lumbar lordosis; **†SPI:** Spinopelvic inclination; **II PI:** Pelvic incidence.*

Although laminectomy and multilevel PCF are known as the standard techniques, the outcomes of posterior fusion including C7 remain controversial.

In this study, the group that underwent PCF surgery with the inclusion of C7 showed an increase in C2–C7 SVA and complained of neck pain two years postoperatively. Kato *et al*. reported that the proportion of patients experiencing axial pain after surgery was similar in a group of patients with muscle attachments to C7 and a group of patients in whom the muscle attachments to C7 were not preserved (17). Furthermore, other studies have reported that groups with preserved muscle attachements to C7 showed higher incidences of initial axial neck pain, ranging from 15–56% compared with 49–86% in group without perserved muscle attachements to C7 (4,12,13). According to the findings of Kennamer et al., poor cervical spine alignment can predict poor clinical outcomes as well as the need for revision surgery (18).

With regard to the thoracolumbar parameters and global spine alignment, at the last follow-up, smaller TK and a larger T9 SPI, LL, and C7 plumb lines were observed in group 2, and statistically significant values were found only in TK and the T9 SPI in this study. Many studies have demonstrated a close resemblance between cervical and thoracic spine alignment (3,25). This study demonstrated a statistically significant correlation between the T9 SPI and C2–C7 SVA values between six months and two years (last follow-up) postoperatively (r=0.39, p=0.04, Figure 3).

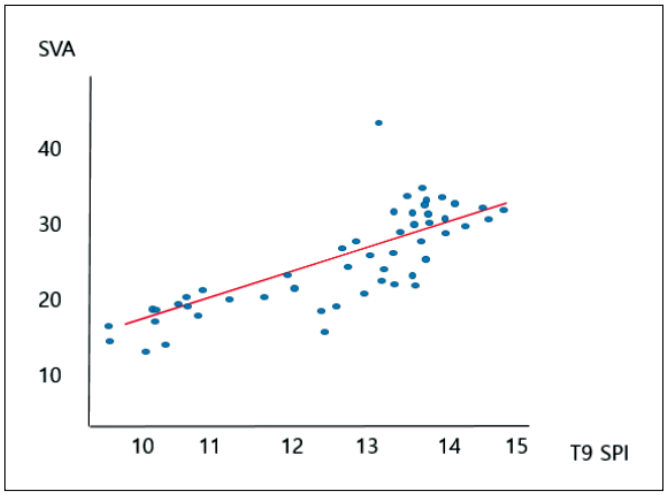

Figure 3: Correlation between changes in the C2–C7 SVA and T9 SPI between 6 months and 2 years after surgery in 52 patients who underwent PCF. **SVA:** sagittal vertical axis; **SPI:** spinopelvic inclination; **PCF:** posterior cervical fusion.

Although larger values were observed in group 2 in the LL and C7 plumb lines, no statistically significant differences were observed. However, group 2 demonstrated higher T9 SPI values. The overall balance and trunk tilt of the sagittal spine were assessed using the T9 SPI (33). Only 52 patients with three or more fusion levels were included in this study. Further studies using more patients and more levels are warranted.

There are several limitations to this study. First, few patients were included. Second, this study was conducted retrospectively. Third, owing to the improvement in their clinical status, some patients did not comply with the outpatient follow-up visits, which could have led to selection bias.

CONCLUSION

In this study, aggravation of cervical kyphosis (C2–7 SVA) and neck pain was confirmed following the inclusion of C7 in multisegmental PCF surgery, which also affected TK and global spine alignment (T9 SPI). Thus, the findings of this study suggest that the inclusion of C7 during PCF surgery should be avoided.

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Conflicts of Interest: The authors declare no conflict of interest with respect to the materials or methods used in this study or the findings specified in this paper.

AUTHORSHIP CONTRIBUTION

Study conception and design: JHP
Data collection: JHP, JJL
Analysis and interpretation of results: JHP, JJL, TKL
Draft manuscript preparation: SBL, SKJ, HKS
Critical revision of the article: JHP, JJL, HKS
Other (study supervision, fundings, materials, etc...): JJL, HKS, TKL
All authors (JJL, HKS, SKJ, SBL, TKL, JHP) reviewed the results and approved the final version of the manuscript.

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