



Anterior cervical X-shape-corpectomy and fusion vs. anterior cervical corpectomy and fusion for two-level cervical spondylosis

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Abstract

Purpose Anterior cervical X-shape-corpectomy and fusion (ACXF) is a novel cervical surgery, designed as partial alternative to the classic technique, anterior cervical corpectomy and fusion (ACCF). The aim of this study was to evaluate the early-stage outcomes of ACXF in treating two-level cervical spondylosis (CS) through comparisons with ACCF.

Methods A retrospectively comparative study was conducted in two cohorts of patients who underwent single-vertebral ACXF or ACCF to treat two-level CS during September 2019 and October 2021. Clinical and radiological data of all the patients were collected from pre-operation to 1 year after the surgery, following by intra- and intergroup analyses and comparisons.

Results Fifty-seven patients were included, with 24 undergoing ACXF and 33 undergoing ACCF. ACXF group had significantly shorter drainage duration (2.13 ± 0.61 days vs. 3.48 ± 1.30 days, $P < 0.001$) and less drainage volume (30.21 ± 26.88 ml vs. 69.30 ± 37.65 ml, $P < 0.001$) than ACCF group. Both techniques significantly improved all the clinical parameters ($P < 0.01$) with comparable effects ($P > 0.05$). Each complication rate in ACXF group was lower than that in ACCF group without significant difference ($P > 0.05$). ACXF showed a significantly smaller transverse decompression range than ACCF (11.93 ± 1.27 mm vs. 16.29 ± 1.88 mm, $P < 0.001$). Postoperatively, ACXF yielded a comparable fusion rate ($P > 0.05$) and a significantly lower subsidence rate ($P < 0.01$) than ACCF technique at all time points.

Conclusions ACXF is a potential surgical alternative for certain patients with two-level CS, as it provides both adequate decompression range and fewer adverse events than ACCF. The further modifications on ACXF worth exploration.

Keywords Cervical spondylosis · Anterior cervical X-shape-corpectomy and fusion · Anterior cervical corpectomy and fusion · Novel surgical technique · Surgical outcomes

Abbreviations

ACCF	Anterior cervical corpectomy and fusion
CS	Cervical spondylosis
ACDF	Anterior cervical discectomy and fusion
CSF	Cerebrospinal fluid
TMC	Titanium mesh cage
OPLL	Ossification of posterior longitudinal ligament
ACXF	Anterior X-shape-corpectomy and fusion
VASneck	Visual analogue scale score for the neck

NDI	Neck disability index
JOA	Japanese Orthopaedic Association
RR	Recovery rate
CT	Computed tomography
MRI	Magnetic resonance imaging
CL	Cervical lordosis
SVA	Sagittal vertical axis
T1S	T1 slope
FSU	Functional spinal unit
ROM	Range of motion
TDR	Transverse decompression range
APCD	Anteroposterior canal diameter
PSTT	Prevertebral soft tissue thickness
SCA	Spinal canal area
RASP	Radiological adjacent segment pathology

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Introduction

Anterior cervical corpectomy and fusion (ACCF) is a time-tested surgical intervention for patients with cervical spondylosis (CS) that was first described in the 1950s [1]. Multiple clinical trials have demonstrated favorable outcomes with ACCF. In contrast to the classic intervertebral approach, anterior cervical discectomy and fusion (ACDF), ACCF offers a more extensive operative exposure and a broader decompression range, making it applicable to a wider spectrum of indications, particularly in cases where compression extends to the vertebral level [1, 2].

Concomitant with the excellent decompressive effect, however, ACCF is reported to induce more intraoperative and postoperative adverse events. Several systematic reviews have consistently indicated a higher overall complication rate in ACCF compared to ACDF [3, 4]. The extensive corpectomy would inevitably lead to prominent structural disruption and damage, resulting in cerebrospinal fluid (CSF) leakage, haemorrhage and neurological deficit, etc. [5]. Additionally, the commonly used internal implants in ACCF have also been shown to be associated with adverse events. The anterior plate in ACCF may elevate the likelihood of postoperative dysphagia, adjacent segmental degeneration and instrumental failures [6]. And the titanium mesh cage (TMC) has been linked to a higher risk of subsidence [7]. For a subset of patients who present with extensive disc prolapses, localized retrovertebral osteophytes or segmental ossification of posterior longitudinal ligament (OPLL), their decompression requirements may not warrant a traditional corpectomy, while ACCF may expose them to unnecessary risks. To address this concern, we have introduced a novel surgical technique known as anterior X-shape-corpectomy and fusion (ACXF), which combines one-level ACCF and two-level ACDF, serving as a potential alternative for these patients to achieve adequate decompression with a reduced risk of adverse events.

The aim of this study was to assess the early-stage clinical and radiological outcomes of ACXF for treating two-level CS patients by conducting a retrospective comparison between ACXF and ACCF cohorts.

Materials and methods

Study design and participants

A retrospectively comparative study involved two cohorts of consecutive two-level CS patients who aged 40–70 years and had undergone single-level ACXF or

ACCF by the same orthopaedic surgeon at our institution between September 2019 and October 2021.

Patients who met any of the following exclusion criterion were excluded: (1) had experienced cervical trauma, tumour, deformation, infection or other operations; (2) had comorbid diseases that would influence the surgical effect, such as severe immunological or metabolic disease; (3) were not follow-up for at least 1 year and (4) did not have adequate clinical and radiological data.

The study was approved by the ethics committee of our institution. Informed consents were obtained from all the patients.

Surgical procedure

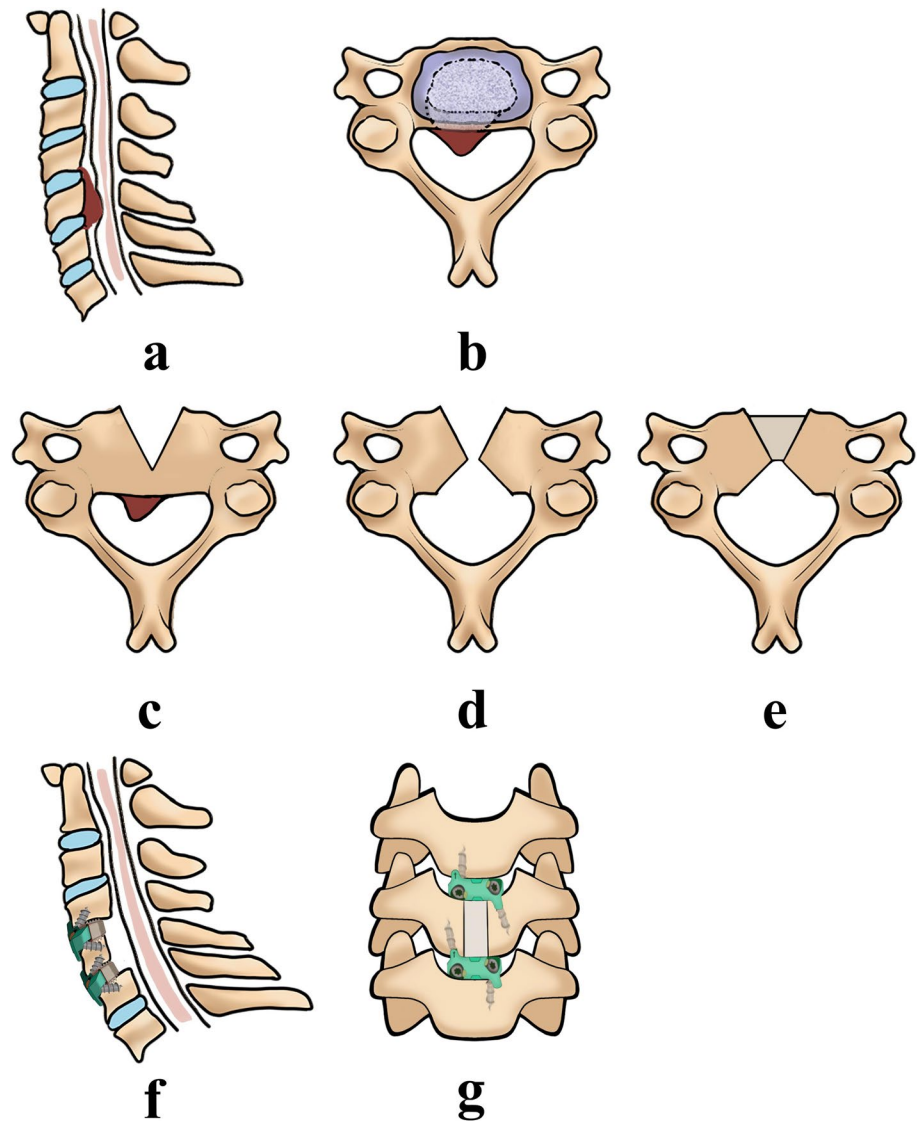
The specific procedure of ACXF was described in our previous article [8]. The major procedures included: (1) A standard Smith–Robinson approach was applied to expose the responsible vertebra under the guidance of C-arm fluoroscopy. (2) Conventional intervertebral decompressions were conducted to remove the adjacent discs. (3) A V-shaped corpectomy was implemented on the responsible vertebra using an ultrasonic bone scalpel, the width of which decreased anteriorly to posteriorly with the apex not breaking out the posterior wall of the vertebra. And the resected bone mass was preserved to be reused as a bone graft. (4) An inserted V-shaped corpectomy was performed by ultrasonic scalpel and rongeur to remove the remaining wall along with the compressions. (5) The excised bone mass was trimmed and grafted back into the anterior V-shaped groove. (6) Two appropriate Zero-P or Zero-P VA stand-alone spacers (DePuy Synthes, Massachusetts, USA) were placed into two adjacent intervertebral spaces with screws for fixation. (7) Lastly, the incision was routinely closed (Fig. 1).

ACCF was performed in the conventional procedure. The immediately postoperative images of both techniques are presented in Fig. 2.

Clinical evaluation

The perioperative data, including operation time, blood loss, drainage duration and volume, were recorded. Patient-reported outcomes, including visual analogue scale score for the neck (VAS_{neck}), neck disability index (NDI) and Japanese Orthopaedic Association (JOA) score, were utilized for clinical assessment [9]. The recovery rate (RR) was calculated as: $(\text{postoperative JOA} - \text{preoperative JOA}) / (17 - \text{preoperative JOA}) \times 100\%$. All the clinical parameters were investigated preoperatively and at routine intervals of 1 day, 3 months, 6 months and 1 year postoperatively. In addition, any intraoperative or postoperative complication was detected and recorded in detail.

Fig. 1 Schematic diagram for ACXF surgery. The osteophyte posterior to the C5 body and C4/5, C5/6 disc herniations (a–b); V-shaped corpectomy after C4/5 and C5/6 discectomies (c); inverted V-shaped corpectomy and decompression (d); insertion of the excised and trimmed bone mass (e) and installation of double Zero-P VA systems (f, g)

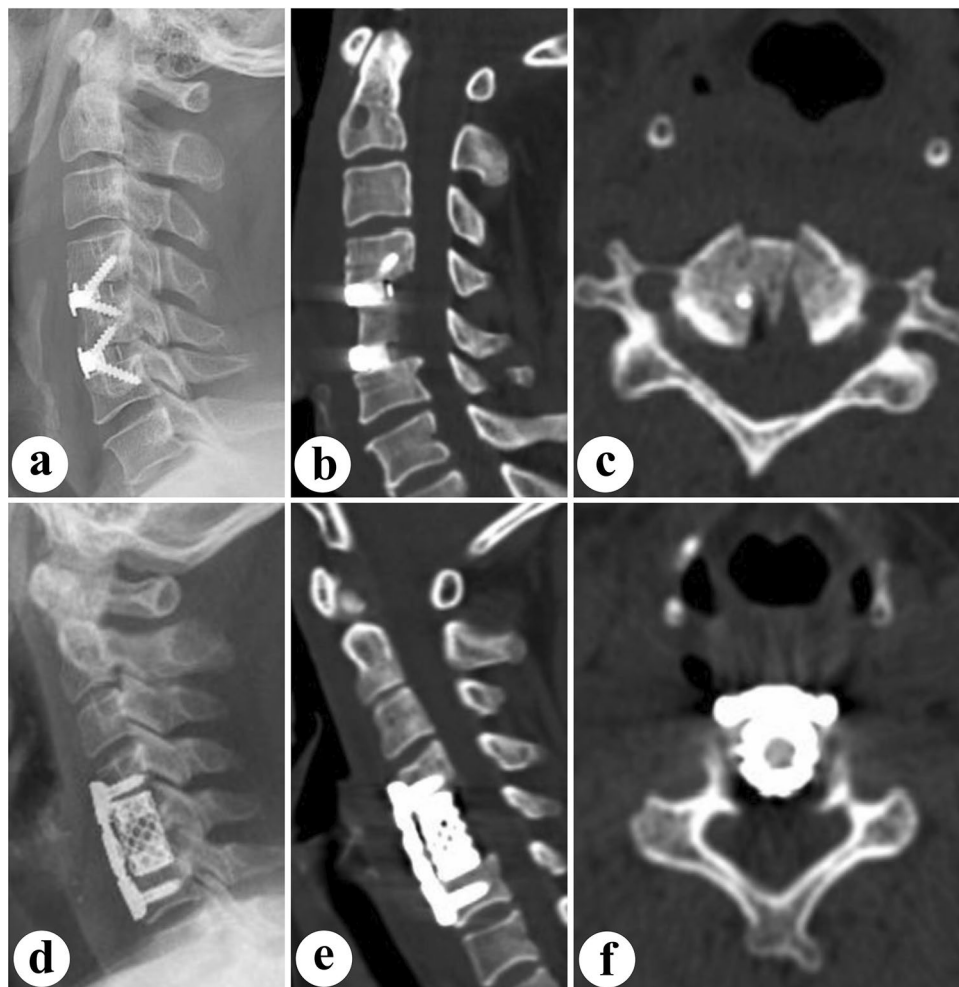


Radiological evaluation

All patients had taken radiological examinations of X-ray, computed tomography (CT) and magnetic resonance imaging (MRI) preoperatively and at routine intervals of 1 day, 3 months, 6 months and 1 year postoperatively. The images were collected to evaluate the radiological parameters, including cervical lordosis (CL), sagittal vertical axis (SVA), T1 slope (T1S), functional spinal unit (FSU) height, FSU range of motion (ROM), C2–C7 ROM, prevertebral soft tissue thickness (PSTT), fusion rate, subsidence rate, radiological adjacent segment pathology (RASP), transverse decompression range (TDR), anteroposterior canal diameter (APCD) of the spinal canal and spinal canal area (SCA). On lateral radiographs, CL, SVA, T1S, FSU height, FSU ROM and C2–C7 ROM were assessed according to conventional definitions. PSTT was

determined as the length of a line from posterior aspect of the trachea to the centre of the anterior vertebral cortex, which was paralleled to the upper endplate [10]. In each case, the average PSTT of two vertebral levels adjacent to the responsible vertebra was taken into analysis. And Δ PSTT was the difference of PSTT before and after the surgery. Solid bony fusion was defined as the presence of a new trabecular bony bridge or FSU ROM observed from dynamic lateral radiographs was less than 2° [11]. Subsidence was defined as over 2-mm loss of FSU height compared with that of the 1 day postoperative radiograph [12]. The RASP was assessed preoperatively and 1 year postoperatively according to the criteria established by Kellgren et al., which involves at least one of the following signs on radiographs: (1) anterior osteophytosis or ossification of anterior longitudinal ligament, (2) loss of disc height and (3) sclerosis of vertebral endplate [13]. The

Fig. 2 Immediately postoperative X-ray and CT images of ACXF (a–c) and ACCF (d–f)



newly onset or progression of RASP from pre-operation to 1 year post-operation was recorded. TDR, APCD and SCA were measured on cross-sectional CT. Measurements concerning part of parameters are illustrated in Fig. 3.

Statistical analysis

The quantitative data were shown as mean \pm standard deviation (normally distributed) or median (interquartile range) (not normally distributed), while the qualitative data were expressed as fractions. For quantitative data, paired *t*-test or Wilcoxon signed-rank test was used for intragroup comparisons at different time points, and an independent *t*-test or Mann–Whitney *U*-test was utilized for intergroup comparisons. The Pearson χ^2 test or Fisher precision probability test was adopted for the analysis of qualitative data. All the data were analysed using IBM SPSS Statistics, version 26.0 (IBM Corp., Armonk, New York, USA). All reported *P* values were two-sided, and the difference was considered to be statistically significant when the *P* value < 0.05 .

Results

Baseline data

A total of 57 patients were enrolled in the study, among whom 24 underwent ACXF and 33 underwent ACCF. The specific values of the baseline data of two groups are displayed in Table 1. There were no significant differences detected in any baseline data between two groups ($P > 0.05$), except in follow-up time (13.92 ± 2.59 months vs. 15.64 ± 3.39 months, $P = 0.042$).

Clinical results

In average, ACXF group had shorter operation time (143.75 ± 29.31 mins vs. 155.45 ± 27.51 mins, $P = 0.129$) and less blood loss (106.67 ± 47.24 ml vs. 127.88 ± 48.59 ml, $P = 0.105$) than ACCF group without significances. Drainage duration (2.13 ± 0.61 days vs. 3.48 ± 1.30 days, $P < 0.001$) and drainage volume (30.21 ± 26.88 ml vs. 69.30 ± 37.65 ml, $P < 0.001$) were significantly less in ACXF group than

Fig. 3 Illustration of measurements for CL, SVA, T1S, FSU, PSTT, TDR, APCD and SCA on radiographs

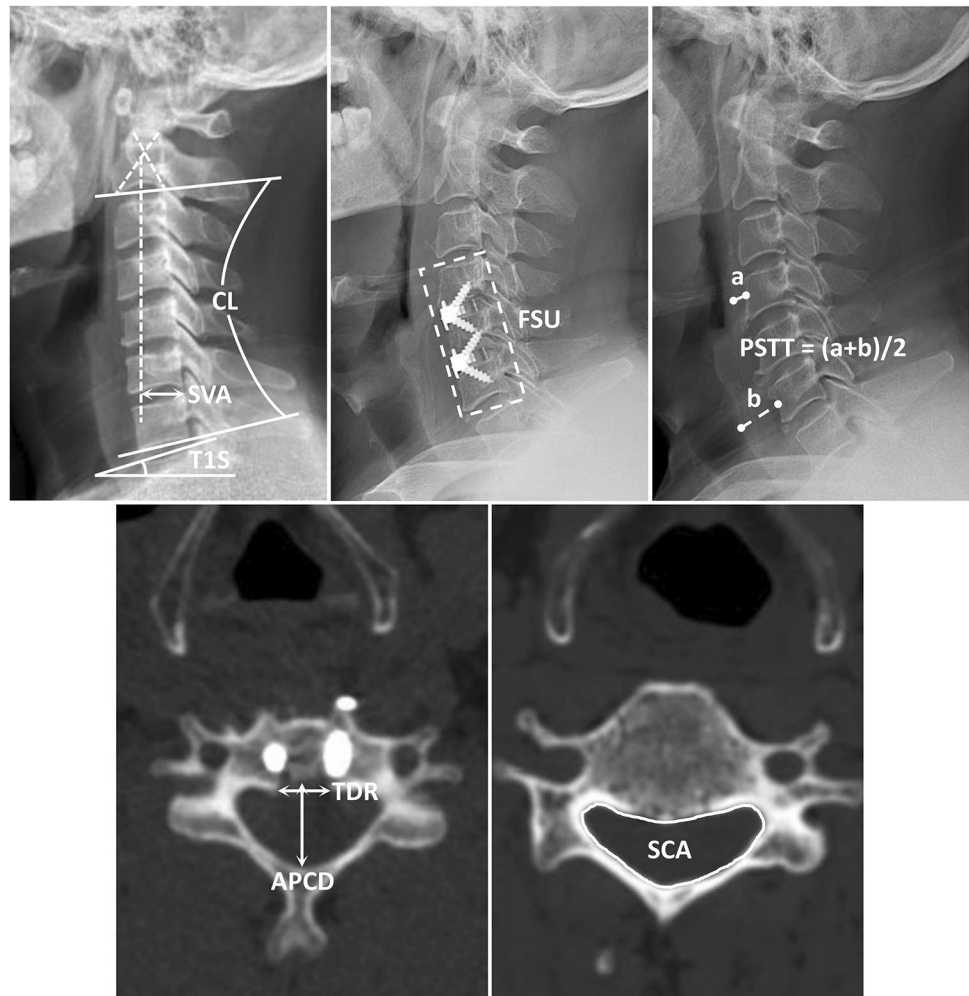


Table 1 Comparison of the baseline data between ACXF and ACCF groups

	ACXF group	ACCF group	<i>P</i> value
Cases, <i>n</i>	24	33	
Age, yrs	53.08 ± 6.92	54.82 ± 5.76	0.307 ^a
Gender (M/F)	14/10	21/12	0.685 ^b
BMI, kg/m ²	22.95 ± 2.66	22.93 ± 2.56	0.980 ^a
Follow-up time, months	13.92 ± 2.59	15.64 ± 3.39	0.042 ^a
Smoking status (Y/N)	8/16	10/23	0.808 ^b
Alcohol consumption (Y/N)	11/13	14/19	0.798 ^b
Corpectomy segment, <i>n</i>			> 0.999 ^c
C3	0	1	
C4	5	6	
C5	16	21	
C6	3	4	
C7	0	1	

BMI, body mass index

^aindependent samples *t*-test; ^bPearson χ^2 test and ^cFisher's exact test

that in ACCF group. JOA, NDI and VAS_{neck} scores significantly improved in both groups compared to those before the operation ($P < 0.01$). No significant intergroup differences were observed in these clinical parameters and RR rate at almost all time points ($P > 0.05$). In ACXF group, there were two cases of dysphagia and one case of hoarseness, who were alleviated after several days of appropriate treatment. While in ACCF group, there were six cases of dysphagia, four cases of CSF leakage, three cases of hoarseness and one case of haematoma. Compared to ACCF group, ACXF group yielded relatively lower incidences for each complication, but the intergroup differences were not significant ($P > 0.05$). None of other complications were observed in either group (Table 2).

Radiological results

CL improved after both surgeries, with no significant intergroup differences observed in CL, SVA and T1S at any time point ($P > 0.05$). FSU height for both groups peaked immediately after the surgery, but gradually decreased

Table 2 Comparison of the perioperative data, clinical parameters and complications between ACXF and ACCF groups

	ACXF group	ACCF group	P value
Operation time, mins	143.75 ± 29.31	155.45 ± 27.51	0.129 ^a
Blood loss, ml	106.67 ± 47.24	127.88 ± 48.59	0.105 ^a
Drainage durations, days	2.13 ± 0.61	3.48 ± 1.30	< 0.001 ^a
Drainage volumes, ml	30.21 ± 26.88	69.30 ± 37.65	< 0.001 ^a
JOA score			
Pre-op	8.00(1.75)	8.00(2.00)	0.626 ^b
Post-op	10.00(1.75) ^{c**}	10.00(1.00) ^{c**}	0.304 ^b
3 mo	15.00(1.75) ^{c**}	15.00(0.00) ^{c**}	0.339 ^b
6 mo	16.00(1.00) ^{c**}	15.00(1.00) ^{c**}	0.454 ^b
1 yr	16.00(0.75) ^{c**}	16.00(1.00) ^{c**}	0.698 ^b
RR rate, %			
Post-op	21.38 ± 13.15	14.39 ± 16.65	0.094 ^a
3 mo	78.52 ± 8.28	75.81 ± 7.75	0.212 ^a
6 mo	84.48 ± 5.74	82.82 ± 7.40	0.365 ^a
1 yr	89.47 ± 7.98	90.42 ± 7.06	0.638 ^a
NDI score			
Pre-op	55.58 ± 7.73	57.33 ± 8.56	0.431 ^a
3 mo	22.21 ± 4.73 ^{d**}	21.97 ± 4.33 ^{d**}	0.844 ^a
6 mo	15.29 ± 2.94 ^{d**}	16.18 ± 2.73 ^{d**}	0.245 ^a
1 yr	7.92 ± 1.59 ^{d**}	8.33 ± 1.38 ^{d**}	0.296 ^a
VAS _{neck} score			
Pre-op	7.50(1.00)	7.00(1.00)	0.787 ^b
Post-op	2.00(2.00) ^{c**}	2.00(1.00) ^{c**}	0.717 ^b
3 mo	1.00(0.75) ^{c**}	2.00(1.00) ^{c**}	0.008 ^b
6 mo	1.00(0.00) ^{c**}	1.00(0.75) ^{c**}	0.272 ^b
1 yr	1.00(0.00) ^{c**}	1.00(0.00) ^{c**}	0.299 ^b
Complications (Y/N)			
Dysphagia	2/22	6/27	0.446 ^e
CSF leakage	0/24	4/29	0.130 ^e
Hoarseness	1/23	3/30	0.631 ^e
Haematoma	0/24	1/32	> 0.999 ^e

JOA, Japanese Orthopaedic Association; RR, recovery rate; NDI, neck disability index and VAS, visual analogue scale

^aindependent samples *t*-test; ^bMann–Whitney *U*-test; ^cWilcoxon signed-rank test; ^dpaired samples *t*-test; ^eFisher's exact test

P* < 0.05 when compared to pre-op; *P* < 0.01 when compared to pre-op

during the follow-up period. Postoperative FSU height loss was greater in ACCF group compared to ACXF group (Fig. 4). ACXF yielded a significantly smaller TDR than ACCF (11.93 ± 1.27 mm vs. 16.29 ± 1.88 mm, *P* < 0.001). APCD and SCA were significantly enlarged after both techniques (*P* < 0.01), while postoperative SCA for ACXF group was significantly smaller than that for ACCF group (*P* ≤ 0.001). PSTT also increased significantly (*P* < 0.01) after both surgeries. There were significant differences between ACXF and ACCF groups in postoperative PSTT (18.02 ± 3.27 mm vs. 20.80 ± 3.79 mm, *P* = 0.005) and

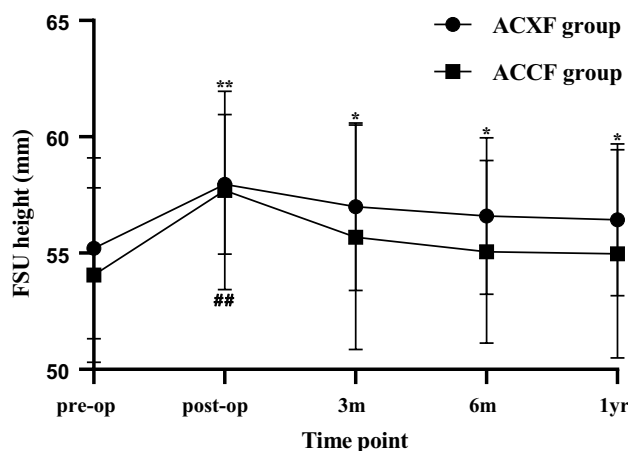


Fig. 4 Change of FSU height in ACXF and ACCF groups along the timeline. (**p* < 0.05; ***p* < 0.01 compared with preoperative value in ACXF group; #*p* < 0.05; ##*p* < 0.01 compared with preoperative value in ACCF group)

ΔPSTT (6.38 ± 2.59 mm vs. 10.15 ± 2.91 mm, *P* < 0.001). Fusion rate was consistently comparable between two groups (*P* > 0.05), while subsidence rate was significantly lower in ACXF group than that in ACCF group at all postoperative time points (*P* < 0.01). None of significant differences were detected in general, newly-onset or progressive RASP between two groups 1 year after the surgery (*P* > 0.05) (Table 3). A typical case is shown in Fig. 5.

Discussion

This study evaluated the clinical and radiological outcomes of a novel surgical technique, ACXF, and compared them with those of ACCF in the management of patients with two-level CS. ACXF was originally designed for CS patients with extensive disc prolapses, localized retrovertebral osteophytes or segmental OPLL, who required an intermediate decompression range between that provided by ACCF and ACDF. As ACXF is considered as partial alternative to ACCF, it is important to determine its optimal indications. The current research indicated a gratifying clinical efficacy of ACXF for cases involving compression with a transverse dimension less than 12 mm. All patients exhibited a significant increase in APCD and SCA, rendering sufficient room to release the spinal cord. Correspondingly, their clinical parameters improved as the neurological symptoms were relieved, which was comparable to the outcomes observed after ACCF. However, for patients presenting with extremely lateral disc prolapses, osteophytes or wide-based OPLL, the priority of ACXF may diminish.

ACXF showed superiority in minimize the surgical trauma. The foundation of ACXF lies in the two-step

Table 3 Comparison of the radiological parameters between ACXF and ACCF groups

	ACXF group	ACCF group	P value
CL, °			
Pre-op	14.00 ± 9.87	13.58 ± 6.80	0.867 ^a
Post-op	18.57 ± 8.84 ^{b*}	17.88 ± 9.50 ^{b*}	0.752 ^a
3 mo	15.74 ± 12.10	14.61 ± 8.53	0.715 ^a
6 mo	16.90 ± 9.33	15.70 ± 8.69	0.637 ^a
1 yr	17.99 ± 8.90 ^{b*}	16.97 ± 7.08	0.647 ^a
SVA, cm			
Pre-op	2.15 ± 0.80	2.23 ± 0.92	0.805 ^a
Post-op	2.55 ± 0.74	2.70 ± 0.99	0.637 ^a
3 mo	2.43 ± 0.83	2.55 ± 1.18	0.743 ^a
6 mo	2.31 ± 0.85	2.47 ± 1.00	0.626 ^a
1 yr	2.23 ± 0.87	2.41 ± 0.80	0.566 ^a
T1S, cm			
Pre-op	28.02 ± 11.08	29.49 ± 9.97	0.691 ^a
Post-op	31.48 ± 8.59	31.78 ± 7.47	0.914 ^a
3 mo	28.36 ± 8.44	29.14 ± 10.37	0.804 ^a
6 mo	29.59 ± 7.61	29.67 ± 10.66	0.979 ^a
1 yr	30.65 ± 10.27	31.37 ± 8.81	0.832 ^a
FSU height, mm			
Pre-op	55.21 ± 3.89	54.06 ± 3.76	0.264 ^a
Post-op	57.96 ± 3.00 ^{b**}	57.69 ± 4.27 ^{b**}	0.790 ^a
3 mo	56.99 ± 3.60 ^{b*}	55.68 ± 4.82	0.268 ^a
6 mo	56.59 ± 3.36 ^{b*}	55.06 ± 3.93	0.130 ^a
1 yr	56.43 ± 3.26 ^{b*}	54.97 ± 4.48	0.180 ^a
FSU ROM, °			
Pre-op	12.68 ± 6.23	13.00 ± 6.97	0.863 ^a
3 mo	2.71 ± 3.66 ^{b**}	2.82 ± 2.55 ^{b**}	0.890 ^a
6 mo	2.27 ± 1.59 ^{b**}	2.05 ± 1.73 ^{b**}	0.622 ^a
1 yr	1.38 ± 0.88 ^{b**}	1.32 ± 0.86 ^{b**}	0.809 ^a
C2–C7 ROM, °			
Pre-op	40.93 ± 8.37	42.93 ± 9.44	0.411 ^a
3 mo	19.88 ± 6.83 ^{b**}	18.66 ± 4.89 ^{b**}	0.433 ^a
6 mo	23.67 ± 7.48 ^{b**}	23.91 ± 7.03 ^{b**}	0.964 ^a
1 yr	27.57 ± 10.83 ^{b**}	27.97 ± 9.91 ^{b**}	0.887 ^a
TDR, mm	11.93 ± 1.27	16.29 ± 1.88	<0.001 ^a
APCD, mm			
Pre-op	9.33 ± 1.87	7.96 ± 1.42	0.003 ^a
Post-op	16.02 ± 1.87 ^{b**}	16.35 ± 3.08 ^{b**}	0.650 ^a
3 mo	15.54 ± 1.96 ^{b**}	16.31 ± 2.56 ^{b**}	0.225 ^a
6 mo	15.22 ± 1.38 ^{b**}	16.20 ± 3.01 ^{b**}	0.105 ^a
1 yr	15.11 ± 1.64 ^{b**}	16.08 ± 2.69 ^{b**}	0.120 ^a
SCA, mm ²			
Pre-op	176.97 ± 31.87	170.06 ± 40.82	0.493 ^a
Post-op	255.29 ± 28.13 ^{b**}	291.72 ± 31.62 ^{b**}	<0.001 ^a
3 mo	260.75 ± 24.00 ^{b**}	294.43 ± 39.83 ^{b**}	0.001 ^a
6 mo	263.32 ± 18.15 ^{b**}	289.65 ± 35.58 ^{b**}	0.001 ^a
1 yr	258.38 ± 24.21 ^{b**}	283.26 ± 26.58 ^{b**}	0.001 ^a
PSTT, mm			
Pre-op	11.64 ± 3.16	10.65 ± 2.68	0.208 ^a

Table 3 (continued)

	ACXF group	ACCF group	P value
Post-op	18.02 ± 3.27 ^{b**}	20.80 ± 3.79 ^{b**}	0.005 ^a
Δ	6.38 ± 2.59	10.15 ± 2.91	<0.001 ^a
Fusion rate (Y/N)			
3 mo	14/10	20/13	0.863 ^c
6 mo	18/6	26/7	0.736 ^c
1 yr	21/3	30/3	0.689 ^d
Subsidence rate (Y/N)			
3 mo	4/20	17/16	0.007 ^c
6 mo	6/18	22/11	0.002 ^c
1 yr	6/18	23/10	0.001 ^c
RASP (Y/N)			
1 yr	13/11	14/19	0.381 ^c
Δ [†]	1/23	3/30	0.631 ^d

CL, cervical lordosis; SVA, sagittal vertical axis; T1S, T1 slope; FSU, functional spinal unit; ROM, range of motion; TDR, transverse decompression range; APCD, anteroposterior canal diameter; SCA, spinal canal area; PSTT, prevertebral soft tissue thickness and RASP, radiological adjacent segment pathology

^aindependent samples *t*-test; ^bpaired samples *t*-test; ^cPearson χ^2 test; ^dFisher’s exact test

P* < 0.05 when compared to pre-op; *P* < 0.01 when compared to pre-op

[†]Newly onset or progression from pre-operation to 1 year post-operation

corpectomy, comprising an initial V-shaped corpectomy followed by an inverted V-shaped corpectomy, combinedly forming an X-shaped profile in the transverse view of the vertebra. The first “V” groove facilitates the exposure of the operative field, while the second “inverted V” groove enhances direct anterior decompression. This two-step corpectomy contributes to the preservation of the responsible vertebra, in stark contrast to conventional corpectomy which covers majority of the vertebral body and exposes nearby anatomical structures to potential injuries, increasing the risks of haemorrhage, CSF leakage, infection and neurological deficit [14, 15]. In ACXF, guided by preoperative and intraoperative imaging, we limited the bone resection within the X-shaped groove, reducing disruption and damage to surrounding tissues, especially to the nerves and dura mater. In this study, ACXF resulted in relatively less blood loss, significantly shorter drainage durations and less volumes. There were no cases of CSF leakage, haematoma or neurological deficit, and only one case of hoarseness detected among the ACXF cohort, indicating the satisfactory safety of ACXF.

The implants used in ACXF differed from those in conventional ACCF, which typically incorporates anterior plate and TMC. While anterior platerender robust fixation, it could elevate the risk of dysphagia [16]. In ACXF, two Zero-P (VA) spacers are employed in lieu of the plate to maintain

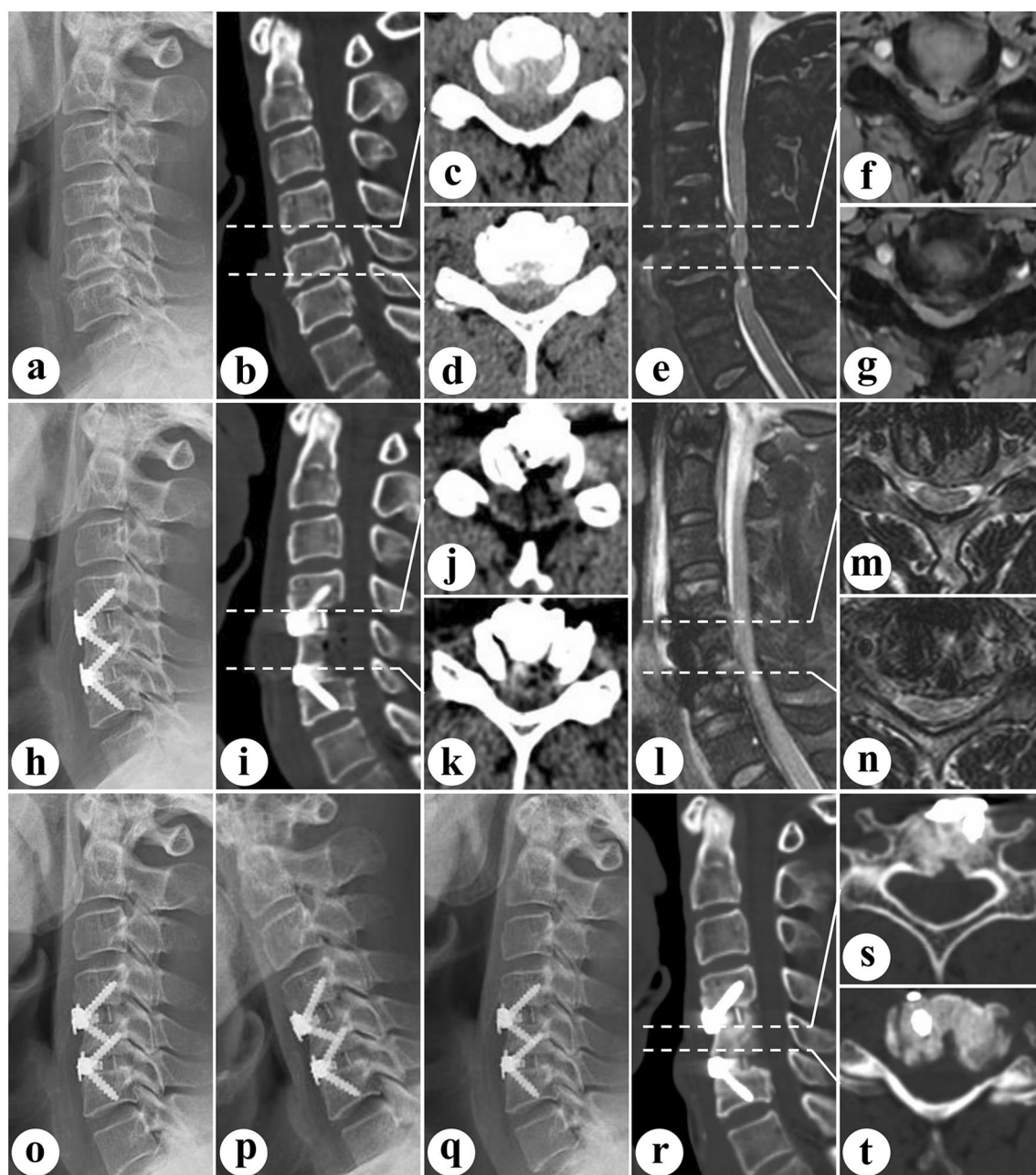


Fig. 5 A 48-year-old male who complained about muscle weakness of both upper extremities for 2 years with aggravation and difficulty walking for 3 months was diagnosed with cervical spondylotic myelopathy. The patient received ACXF on C5 vertebra, whose symptoms were alleviated immediately after the surgery. He recovered smoothly without any complication occurred and was discharged 8 days after admission. Preoperative images a–g showed OPLL at C5 level (a, b), disc prolapses at C4/5 and C5/6 levels (c, d), leading to compressions on spinal cord (e–g); immediately postoperative

images h–n showed that the bony graft and Zero-P VA spacers were in appropriate positions (h). The compressions were totally removed, and spinal canal was enlarged (i–k), providing adequate space for spinal cord with continuous CSF signal emerging (l–n); 6-month postoperative images o–t showed that the internal fixations stayed steady in neutral, flexion and extension positions (o–q). Bridging trabecular bone at adjacent intervertebral levels was detected on sagittal sections (r). Transverse sections showed apparent fusion between bony graft and bilateral residual vertebral walls (s, t)

the intervertebral height and provide internal fixation. Previous articles had compared the both implants and concluded that Zero-P had better performance than the plate in mitigating dysphagia [17, 18]. Theoretically, dysphagia following

anterior cervical surgery is mainly attributed to the impact on prevertebral structures, which leads to soft tissue swelling and irritation of the oesophagus [19]. Δ PSTT was adopted to quantify the influence on the prevertebral tissues through the

surgery, which had shown a significantly positive correlation with dysphagia [20]. The data that ACXF exhibited significantly smaller Δ PSTT than ACCF reflected the optimized prevertebral disturbance of the low-profile design of Zero-*P* (VA). Consequently, ACXF group experienced a relatively lower dysphagia rate, with only one patient affected and promptly alleviated after appropriate conservative treatment.

Bony fusion and subsidence represent two critical parameters directly linked to surgical outcomes. The conventional use of TMC in ACCF has been praised for satisfactory fusion effect. Nevertheless, the TMC had been noticed with a high rate of subsidence, which could lead to cervical instability, recurrent neurological deteriorations, implant failure and even necessitate revision surgery [21]. Chen et al. reviewed 300 ACCF cases with TMC and reported that 79.7% of cases were observed with reduction in FSU height during 1 year [22]. The potential factors contributing to the elevated incidence of subsidence with TMC may include stress concentration resulting from the mismatch between TMC and endplate interfaces, as well as the high stiffness of TMC and excessive endplate grinding during insertion [23, 24]. In ACXF, we apply in situ bone graft instead of TMC, where we trim and reinsert the V-shaped autologous bone mass from local vertebrae, thereby preserving structural integrity. Based on our experience, the graft remains spontaneously stable without the need for additional fixation under longitudinal pressure and extrusion from bilateral inclined bony surfaces. The use of in situ bone graft in combination with the Zero-*P* (VA) systems enables even interface contact, significantly reducing stress concentration and creating a stable biomechanical environment. Accordingly, our data demonstrated better maintenance of FSU height 1 year after ACXF and confirmed significantly lower subsidence rates of ACXF at all time points compared to contemporary data from ACCF with TMC, as reported by us and previous studies [12, 25]. Furthermore, the bone graft exposes sufficient bone marrow and allows direct cancellous–cancellous bone contact with the residual vertebra. This facilitates the crawling of new bone without obstruction from cortical bone. Consequently, ACXF group achieved a satisfying fusion rate in the early stages and 1 year after the surgery. Besides, in situ graft approach could substitute iliac bone harvesting and eliminate the risk of donor-site complications.

In other aspects, ACXF group showed comparable efficacy in reconstructing the cervical lordosis and sagittal alignment in comparison with ACCF group. Short-term RASP did not reveal any significant intergroup difference. The above parameters warrant close monitoring during the medium- to long-term follow-up assessments.

It is noteworthy that the adoption of ACXF should be considered with caution for patients with dural adhesions, as the direct separation of the adherent posterior longitudinal ligament and dura sac from an anterior approach carries a

significant risk of CSF leakage. Additionally, ACXF is a relatively intricate and technically demanding procedure, especially with decompression after two-step corpectomy, which may pose challenges for grasping. Lastly, during installation of the Zero-*P* (VA) systems, there exists a risk of screws crossing the graft–vertebra interface and drilling into the graft, which could compromise the holding force of screws and graft vascularization, and further affect the holistic stability of internal fixation and fusion outcome. A modified and dedicated internal fixation system for ACXF technique might be the ultimate solution. Despite these limitations, our study underscored the inspiring outcomes and reduced incidence of adverse events with ACXF. Therefore, it is suggested as a viable surgical alternative for select two-level CS patients, meriting further in-depth investigation.

Some limitations of this study should be emphasized. First, concerning that ACXF was still in its infancy, this study was designed as a non-randomized, single-centre retrospective comparison with a small sample size and short follow-up time, thus some confounders were unavoidable and the level of evidence was low. A multicentre prospective randomized comparison study with a large sample and long-term follow-up should be conducted in the future to corroborate the long-term outcomes and reliability of ACXF. Moreover, further biomechanical and basic research is needed to elucidate the fate of reinserted V-shaped autologous bone mass and its impact on the biomechanical environment of the responsible vertebra and adjacent segments.

Conclusion

ACXF presents a promising surgical option for two-level CS patients with extensive disc prolapses, localized retrovertebral osteophytes or segmental OPLL and with compression width less than 12 mm. It could achieve sufficient decompression and simultaneously mitigate the occurrence of adverse events. Nonetheless, there are some inherent limitations with ACXF that necessitate future improvement and modification.

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Data availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of West China Hospital, Sichuan University (No. 2022(305)).

Consent to participate Informed consent was obtained from all individual participants included in the study.

Consent to publish The authors affirm that human research participants provided informed consent for publication of the images in Fig. 5.

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