



Original Research

Efficiency of Horizontal Skin Incision at 1-Level And 2-Level Anterior Cervical Discectomy and Fusion: A Prospective Observational Study

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ABSTRACT

Objective: Horizontal skin incision is an optimal treatment approach in Anterior Cervical Discectomy and Fusion (ACDF). However, evidence comparing the efficiency of these incisions in 1-level and 2-level ACDF remained uncertain. The study aimed to assess and compare efficiency, clinical and cosmetic outcomes, along with patient and clinician satisfaction, and complications associated with horizontal skin incision in 1-level and 2-level ACDF procedures.

Materials & Methods: A prospective observational study recruiting 453 participants who underwent ACDF via horizontal skin incision was conducted between February 2023 to January 2024. Participants were divided into 1-level (n=256) and 2-level (n=188) ACDF groups. Operative parameters, cosmetic outcomes (POSAS, VSS), and postoperative complications were assessed. A follow-up at 3, 6, and 12 months was held. SPSS software v.26 was employed for data analysis, and a p-value of <0.05 was considered significant.

Results: The 2-level ACDF group showed significantly longer incision length, surgical duration, and hospitalization ($p < 0.001$). The 1-level ACDF exhibited superior results regarding scar visibility, symmetry, and patient satisfaction at each follow-up ($p < 0.05$). Mean POSAS and VSS scores were also significantly lower (better) in the 1-level group, indicating better cosmetic outcomes. Complications, including dysphagia and dysphonia, were significantly more prevalent in the 2-level ACDF group ($p < 0.05$), while wound-related complications were comparable across both groups ($p > 0.05$).

Conclusion: The horizontal (transverse) skin incision provided favorable outcomes across both groups. However, 1-level ACDF was associated with greater efficiency, minimal complications, and a higher satisfaction level among patients. Additionally, multiple-level ACDF has an increased risk of postoperative complications and blood loss.

Keywords: Discectomy, Incision, scar, cervical, Pseudoarthrosis.

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INTRODUCTION

Anterior cervical discectomy and fusion (ACDF) is a traditionally and widely performed surgical procedure for managing degenerative conditions of the cervical spine, particularly cervical disc herniation, myelopathy, and radiculopathy.^{1,2} ACDF was first introduced in the literature in 1955, when Robinson and Smith described a new surgical procedure to decompress the cervical spine via an anterior approach.³ Over 130,000 ACDF procedures are performed annually in the United States, with 5% yearly increase.⁴ Due to its evident safety and effectiveness, ACDF has been considered the gold standard treatment for cervical degenerative conditions (CDD) since its introduction in 1958.⁵

A recent survey in 2017 exhibited that 84.3% of surgeons used ACDF as the preferred procedure for treating CDD.⁶ Another prospective survey reported prolonged outcomes (>10 years) regarding ACDF, in which individuals showed improvement in pain and neurological deficits.⁷ This surgical procedure can be performed at one or multiple intervertebral levels. In 1-Level ACDF, the procedure is limited to one level and has high fusion rates (90%), whereas 2-Level ACDF involves adjacent cervical levels with a broader range of fusion (72%-97.5%).⁸

Although ACDF is associated with favorable clinical outcomes, certain postoperative complications, including pseudoarthrosis (non-union), implant complications, and adjacent segment degeneration (ASD), are also considered major concerns in clinical practice.⁹⁻¹¹

Despite variation in techniques, the anterior approach for ACDF allows exposure of the cervical vertebrae from C2 -T2 level and typically involves a horizontal skin incision along a neutral skin crease, dissection via platysma, retraction of sternocleidomastoid (SCM) and strap muscles,

lateral mobilization of carotid sheath, medial retraction of esophagus and trachea as a unit to protect the recurrent laryngeal nerve, followed by dissection of the longus colli muscles which are then split and retracted to expose the cervical spinal access.³ The Horizontal Skin incision in the Smith-Robinson approach (anterior) offers a cosmetically optimal alternative compared to oblique incision, providing safe access to the C-spine while reducing muscle damage, blood loss, wound complications, and visible scarring. However, an observable limitation of the horizontal skin incision is its limited extensibility, making precise preoperative localization of the optimal incision level critically important¹². Recent literature revealed that a double horizontal incision can improve cosmetic and functional outcomes with lower rates of persistent dysphagia and dysphonia.¹³ However, despite numerous studies describing performance and clinical outcomes of ACDF or ACCS, there is a limitation of literature regarding cosmetic and functional effects of different skin incision orientations. According to a 2022 study by Lee et al, double transverse incisions resulted in considerably improved scar appearance (as measured by POSAS and VSS) and decreased rates of persistent dysphagia when compared to longitudinal incisions in ACSS involving ≥ 3 levels.¹⁴ Additionally, technical reports like Rathod et al, (2018) have demonstrated that transverse neck incisions with stay sutures result in scars that are aesthetically acceptable and have no fibrosis.¹⁵ Transverse (midline) incisions in anterior cervical methods are also supported by patient preference data, where aesthetic results are the main concern.¹⁶ Although there is a lack of head-to-head comparative data for 1-level versus 2-level ACDF, these findings imply that incision orientation (transverse, vertical, or oblique) has a significant impact on both objective scarring outcomes and patient satisfaction.

Comprehensive data comparing the efficiency and clinical outcomes of horizontal skin incision in 1-Level and 2-Level ACDF remains limited.

Therefore, the present study aims to assess and compare the efficiency of cosmetic outcomes and clinical effectiveness of horizontal skin incision in levels of ACDF procedures.

METHODOLOGY

Study Design/Duration/Setting

A prospective and comparative observational study was conducted using a convenience sampling technique in Khyber Medical Center, Peshawar. The study was conducted from February 2023 to January 2024, with post-operative follow-up of 12 months, to assess and compare the surgical efficiency, cosmetic consequences, and complication profiles in patients undergoing 1-Level and 2-Level ACDF using horizontal skin incision via the Smith-Robinson approach. Institutional review board granted the ethical approval letter (Ref. no. Lo2/DME/KMC).

Inclusion Criteria

A total of 453 participants with an age greater than or equal to 18 years (both Male and Female) undergoing primary ACDF with horizontal skin incision were included. Out of the total, 265 patients were allocated to 1-Level and 188 patients to 2-Level ACDF.

Exclusion Criteria:

However, exclusion criteria encompassed participants with age < 18 years, multiple levels (>2), vertical and oblique skin incisions, revision surgery, prior cervical surgery, and incomplete follow-up data.

Sample Size

The OpenEpi calculator was employed for sample size calculation with a 95% confidence interval (CI) and an error margin of 5%. Written informed consent was obtained from all participants before the study was conducted.

Data Collection

Data was collected on demographic profile, operative parameters, clinical and cosmetic outcomes, patient satisfaction, and complications. Demographic and operative data were obtained from the patient's medical record, and clinical and cosmetic outcomes regarding quality scar appearance were measured via Patient and Observer Scar Assessment (POSAS) and Vancouver Scar Scale (VSS). Moreover, complications, including incision-related and swallowing and voice-related, were also assessed post-operatively. Post op dynamic X-rays or CT imaging at 6 or 12 months for confirmation of fusion/pseudarthrosis.

Data Analysis

Data analysis was done using SPSS version 26. Quantitative variables were presented in mean and standard deviation, and categorical variables in frequencies and percentages. The Shapiro-Wilk test was performed for normality testing. The association between categorical variables was analysed via the Chi-square test, and between-group comparison was conducted using a parametric (independent t-test). A p-value of <0.05 was considered statistically significant.

RESULTS

Demographics Profile

Table 1 represents the demographic profile of patients who underwent 1- 1-level and 2-level ACDF via horizontal skin incision. The average age of the participants was slightly higher in the 2-level ACDF group (54.1 ± 12.4 years) compared to the 1-level ACDF group (52.3 ± 11.8 years). The male population was predominant in both groups, with 156 males in the 1-level group and 107 in the 2-level group. Among 1-level ACDF participants, 34.3% had BMI <25kg/m², 41.9% between 25-30 kg/m² and 23.8% of individuals exhibited BMI

>30kg/m² Regarding the history of diabetes mellitus and smoking, 19.2% of patients in 1-level and 21.8% in 2-level had diabetes mellitus, and 30.9% and 36.2% of patients in 1-level and 2-level were smokers. Hypertension affected 27.9% and 30.9% of individuals in the 1- and 2-level groups. Moreover, occupational status revealed that the majority of individuals were homemakers in both groups (43.4% in the 1-level and 40.4% in the 2-level ACDF group), followed by manual laborers and sedentary workers, as shown in Table 1.

Table 1: Demographic Characteristics.

Demographics	1-Level ACDF N=265	2-Level ACDF N=188
Age (years) (mean ± S.D)	52.3±11.8	54.1±12.4
Gender [n(%)]		
- Male	156(58.9)	107(56.9)
- Female	109(41.1)	81(43.1)
BMI[n (%)]		
- <25kg/m ²	91(34.3)	58(30.9)
- 25 to 30 kg/m ²	111(41.9)	82(43.6)
- >30 kg/m ²	63(23.8)	48(25.5)
Diabetes Mellitus	51(19.2)	41(21.8)
Smoking history	82(30.9)	68(36.2)
hypertension	74(27.9)	58(30.9)
Occupation		
- Manual labor	82(30.9)	67(35.6)
- Homemaker	115(43.4)	76(40.4)
- Sedentary worker	68(25.7)	45(23.9)

N=456; ACDF=Anterior Cervical Discectomy and Fusion; S.D=Standard Deviation; n=frequency; %= percentage; kg/m² = Kilogram meter per square

Table 2: Intraoperative and Postoperative Characteristics of Horizontal Skin Incision at 1-Level and 2-Level of ACDF

Operative measures	1-Level ACDF N=265	2-Level ACDF N=188	p-value
Incision length(cm)	3.3 ± 0.4	4.4 ±0.5	<0.001**
Surgical duration (min)	82.5±14.3	112.6±19.5	<0.001**
Estimated blood loss (mL)	54.2±35.7	68.9±42.1	0.041**
Exposure adequacy (%)	100%	100%	-
Drain output(mL)	35.6 ±11.3	47.2±13.6	<0.001**
Hospital stays(days)	2.6±0.8	3.4±1.1	<0.001**

N=453; ACDF=Anterior Cervical Discectomy; **p<0.05= statistically significant, cm=centimeter; min=minutes; mL=milliliter; %=percentages

Intraoperative and Postoperative Characteristics

Intra and post-operative characteristics of horizontal surgical incision at 1-level and 2-levels of ACDF were evaluated using an independent t-test as the dataset showed normal distribution (Table 2). The operative characteristics across the 1-level and 2-level ACDF groups revealed statistically significant differences. Patients in 2-level ACDF had longer incision length (4.4 ± 0.5cm vs 3.3±0.4cm, p<0.001), surgical duration (112.6 ±19.5 min vs 82.5±14.3 min, p<0.001). Higher estimated blood loss (EBL) (68.9±42.1mL vs 54.2±35.7mL, p=0.041) and longer hospitalization (3.1±1.1 days vs 2.6±0.8 days, p <0.001) as compared to 1-level ACDF, indicating more surgical demands and postoperative needs in patients who underwent horizontal skin incision in a 2-level ACDF procedure. Efficiency reflects the entire technical and procedural optimization attained during the surgery. It includes the ability to finish the procedure within an acceptable complication-adjusted operative time, ease of operating exposure, and accuracy in neural decompression. Efficiency in this study was presented through measurable parameters such as operative duration, incision length, intraoperative blood loss, and hospital stay. Collectively, these parameters show how effectively the horizontal skin incision allowed for adequate surgical access

while maintaining patient safety and reducing physiological strain.

Clinical and Cosmetic Outcomes Following Horizontal Skin Incision

Table 3 summarizes the clinical and cosmetic outcomes after horizontal skin incision in the 1-level and 2-level ACDF groups. Findings exhibited that scar visibility and scar symmetry showed significantly

greater proportion of low visibility and excellent symmetry in the 1-level ACDF group at 3, 6, and 12 months (all $p < 0.05$, chi-square testing), indicating better aesthetic outcomes following horizontal skin incision in the 1-level ACDF group. Similarly, patients in the 1-level ACDF group were statistically highly satisfied with appearance at 3 months (79.2% versus 52.1%, $p < 0.001$), 6 months (75.5% versus 54.3%, $p = 0.003$), and at 12 months (67.2% versus 41.5%, $p = 0.002$) (via chi-square testing).

Furthermore, cosmetic results assessed through POSAS and VSS showed significantly superior results in the 1-level ACDF group after horizontal skin incision, i.e., lower mean score indicated better outcomes at 3, 6, and 12 months (POSAS: $p = 0.021, 0.017, 0.014$; VSS: $p = 0.031, 0.026, 0.024$), indicating better scar quality and aesthetic healing. However, Clinician-Rated Cosmetic Satisfaction was greater in both groups, indicating a comparable finding ($p > 0.05$) at all time points. These findings indicated that

horizontal skin incisions offered acceptable cosmetic outcomes collectively; 1-level ACDF was associated with better scar visibility, symmetry, and patient satisfaction compared to 2-level procedures, exhibiting greater efficiency of horizontal skin incision in the 1-level ACDF procedure.

Postoperative Complication

Table 4 represents the postoperative complication profile in patients undergoing 1-level and 2-level ACDF via horizontal skin incision, analyzed through an independent t-test. It had been observed that wound and adverse events, including erythema/seroma, wound dehiscence, surgical site infection, keloid formation, pseudoarthrosis, were comparable across both groups, indicating statistical non-significance (all $p > 0.05$); however, such complications were higher in the 2-Level ACDF group. Furthermore, none of the group revealed complications of skin tenting.

Table 3: Clinical and Cosmetic outcomes following horizontal incision at 3, 6, and 12 months postoperatively.

Outcome measure	Timepoint	1-Level ACDF N=265	2-Level ACDF N=188	p-value
Scar visibility (low/mod/high)	3 months	235(88.7%)/30(11.3%)/0	120(63.8%)/68(36.2%)/0	<0.001**
	6 months	225(84.9%)/40(15.1%)/0	125(66.5%)/63(33.5%)/0	<0.001**
	12 months	210(79.2%)/55(20.8%)/0	130(69.1%)/58(30.9%)/0	0.037**
Scar symmetry (% Excellent)	3 months	190(71.7%)	102(54.3%)	0.008**
	6 months	180(67.9%)	98(52.1%)	0.015**
	12 months	160(60.4%)	86(45.7%)	0.03**
Patient satisfaction with appearance (high/moderate/low)	3 months	210 (79.2%) / 48 (18.1%) / 7 (2.6%)	98 (52.1%) / 72 (38.3%) / 18 (9.6%)	<0.001**
	6 months	200 (75.5%) / 50 (18.9%) / 15 (5.7%)	102 (54.3%) / 66 (35.1%) / 20 (10.6%)	0.003**
	12 months	178 (67.2%) / 64 (24.2%) / 23 (8.7%)	78 (41.5%) / 72 (38.3%) / 38 (20.2%)	0.002**
POSAS Score (Mean ± SD)	3 Months	20.4 ± 3.9	23.1 ± 4.2	0.021**
	6 Months	19.1 ± 3.8	22.2 ± 4.0	0.017**
	12 Months	18.2 ± 3.6	21.3 ± 4.1	0.014**
VSS score (Mean ± SD)	3 Months	3.6 ± 1.4	4.2 ± 1.5	0.031**
	6 Months	3.3 ± 1.3	4.0 ± 1.5	0.026**
	12 months	3.1±1.2	3.8±1.4	0.024**
Clinician-Rated Cosmetic Satisfaction (% Excellent)	3 Months	240 (90.6%)	165 (87.8%)	0.387 ^{n.s}
	6 Months	248 (93.6%)	168 (89.3%)	0.234 ^{n.s}
	12 Months	245 (92.4%)	170 (90.4%)	0.478 ^{n.s}

N=453; ACDF=Anterior Cervical Discectomy; POSAS= Patient and Observer Scar Assessment Scale, VSS= Vancouver Scar Scale, ** $p < 0.05$ = statistically significant; n.s: $p > 0.05$ =non-significant

In contrast, statistically significant differences were found regarding dysphasia and dysphonia across both groups. Dysphagia was identified as significantly more frequent in the 2-level ACDF group compared to the 1-level group at 3 months (12.2% vs 6.0%, $p=0.021$), 6 months (9.0% vs 3.4%, $p=0.013$), and 12 months (6.4% vs 1.5%, $p=0.008$). Similarly, dysphonia was also significantly greater in the 2-level group at 3, 6, and 12 months (all $p<0.05$) as shown in Table 4, indicating greater surgical dissection and retraction in 2-level ACDF might increase the risk of temporary and persistent swallowing and voice impairment, even with the use of cosmetically favorable horizontal incision.

DISCUSSION

The current study demonstrated that horizontal (transverse) skin incision yielded better cosmetic outcomes in both 1-level and 2-level ACDF. Horizontal skin incisions seem to be the better choice for ACDF procedures for surgeons.

There has been increased concern regarding post-operative cosmetical satisfaction and scar visibility in the neck region, as it remains an important human body part regarding beauty⁽¹⁴⁾. In the present study, cosmetic outcomes were assessed through POSAS and VSS and exhibited significantly optimal findings in the 1-level ACDF group after horizontal skin incision at 3, 6, and 12 months of follow-up (POSAS: $p=0.021$, 0.017, 0.014; VSS: $p=0.031$, 0.026, 0.024), indicating

Table 4: Postoperative complications.

Complications		1-Level ACDF N=265	2-Level ACDF N=188	p-value
Wound and incision-related complications		5 (1.9%)	7 (3.7%)	0.248 ^{n.s}
- Erythema/seroma		1 (0.4%)	1 (0.5%)	0.928 ^{n.s}
- Wound Dehiscence		3 (1.1%)	4 (2.1%)	0.372 ^{n.s}
- Keloid formation		2 (0.8%)	3 (1.6%)	0.412 ^{n.s}
- Surgical site infection		0 (0.0%)	1 (0.5%)	0.331 ^{n.s}
- Revision of incision		5 (1.9%)	7 (3.7%)	0.248 ^{n.s}
- Pseudoarthrosis		4(1.5%)	7(3.7%)	0.108 ^{n.s}
- Skin tenting		0(0.0%)	0(0.0%)	-
Swallowing & voice	3 months	16(6.0%)	23(12.2%)	0.021**
Dysphagia	6 months	9(3.4%)	17(9.0%)	0.013**
	12 months	4(1.5%)	12(6.4%)	0.008**
Dysphonia	3 months	11(4.1%)	18(9.6%)	0.031**
	6 months	6(2.3%)	13(6.9%)	0.019**
	12 months	3(1.1%)	10(5.3%)	0.015**

*N=456; ACDF=Anterior Cervical Discectomy; ** $p<0.05$ =statistically significant; ^{n.s} $p>0.05$ =nonsignificant*

better scar quality and aesthetic healing. Similarly, a previous study determined that horizontal skin incisions produced cosmetically superior results at a follow-up of 4 weeks, while a longitudinal skin incision permits greater exposure and is predominantly beneficial for a multiple-level procedure. Moreover, that study also found that all the wounds were completely recovered by the time of suture removal, and there were no occurrences of wound infection, necrosis, Wound Dehiscence, or bruises at the site of incision and stay sutures.¹⁷ However, the current study found the incidence of several complications, including erythema/seroma, wound dehiscence, surgical site infection, keloid formation, and pseudoarthrosis in 1-level and 2-level ACDF groups undergoing horizontal skin incision, and both groups exhibited comparable differences ($p>0.05$).

The present study also focused on only a single horizontal skin incision in 1-level and 2-level ACDF procedures and found that dysphagia and dysphonia were significantly more prevalent in the 2-level ACDF group compared to the 1-level group at 3, 6, and 12 months (all $p<0.05$). In contrast, in a previous study, the double transverse incision was compared with the longitudinal incision in

patients undergoing anterior cervical spinal surgery (ACSS), and the DT group exhibited significantly better outcomes regarding dysphagia and dysphonia, particularly in multilevel procedures, and dysphagia in DT group were also decreased postoperatively from 6 to 24 months, indicating prolong benefits of using horizontal (transverse) incision approach.¹⁸ Another study reported that participants undergoing ≥ 3 -level ACSS experienced higher rates of dysphagia and dysphonia than single or 2-level ACSS.¹⁹⁻²²

Despite the strength of the current study, while evaluating the efficiency of horizontal skin incision in ACDF, certain limitations were also acknowledged. The current study was a single-center study, minimizing the external validity and generalizability of the findings as surgical techniques, patient population, and pre-/intra/post-operative protocols vary across organizations. Additionally, while horizontal incisions were evaluated for their efficacy and operative benefits, the absence of a comparative group using vertical and oblique incisions limits findings regarding the relative superiority of this approach. Efficiency was mainly assessed through quantifiable parameters such as incision length, surgical time, and estimated blood loss. However, efficiency in the neurosurgical context includes not only operative speed but also tissue handling, exposure adequacy, neural element decompression precision, and complication-adjusted operative performance. These factors collectively reflect the surgeon's ability to achieve desired outcomes with minimal tissue damage and resource utilization. However, other factors such as intraoperative visibility, surgeon ergonomics, and learning curve were not objectively measured. Future multicenter, randomized studies incorporating different incision orientations, objective ergonomic assessments, and extended follow-up are warranted to comprehensively evaluate the clinical utility and long-term efficacy of horizontal skin incisions in cervical spine surgery.

CONCLUSION

It has been concluded that horizontal (transverse) skin incision provided favorable outcomes across both groups. However, 1-level ACDF via horizontal skin incision was associated with greater efficiency, minimal complications, and a higher satisfaction level among patients. Additionally, multiple-level ACDF has an increased risk of postoperative complications, greater blood loss, and longer incision length. Therefore, careful consideration is required for multilevel ACDF following horizontal incision.

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Additional Information

Disclosures: No conflicts of interest are reported by the authors.

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AUTHORS CONTRIBUTIONS

Sr.#	Author’s Full Name	Intellectual Contribution to Paper in Terms of:
1.	Sohrab Khan & Saifullah Khalid	1. Study design and methodology
2.	Fazal Wahid, & Sohrab Khan	2. Paper writing
3.	Saifullah Khalid	3. Data collection and calculations
4.	Sohrab Khan & Saifullah Khalid	4. Analysis of data and interpretation of results
5.	Sohrab Khan & Saifullah Khalid, Fazal Wahid	5. Literature review and referencing
6.	Fazal Wahid	6. Editing and quality insurer