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ORIGINAL ARTICLE

Comparison of fusion, arthroplasty and hybrid surgery outcomes in patients with two-level cervical disc disease

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ABSTRACT

Objectives: The study aims to explore the management of two-level cervical disc disease and to compare outcomes of anterior cervical discectomy and fusion (ACDF), cervical disc arthroplasty (CDA), and hybrid surgery (HS).

Patients and methods: Between December 2011 and December 2021, a total of 120 patients (76 males, 44 females; mean age: 44.8±8.1 years; range, 18 to 68 years) who were diagnosed as two-level cervical disc disease and underwent anterior cervical surgery were retrospectively analyzed. The patients were randomly divided into three groups as ACDF, CDA, and HS each consisting of 40 patients. The Neck Disability Index (NDI), Visual Analog Scale (VAS), clinical and radiological findings, and range of motion (ROM) data were evaluated.

Results: All of the groups showed a significant improvement according to clinical and radiological outcomes (p=0.01). The mean follow-up was 27.5±6.1 months for ACDF, 20.0±4.7 months for CDA, and 21.1±5.0 months for HS, showing consistency in monitoring post-surgery outcomes. The mean postoperative NDI scores were 13.4±5.6, 14.8±5.2 and 15.0±5.5 in the ACDF, CDA and HS groups, respectively (p=0.056). The mean postoperative ROM values were 20.82±5.66, 32.45±11.21 and 27.18±10.89, respectively (p=0.045).

Conclusion: All three surgical techniques, ACDF, CDA, and HS, are safe and successful in the treatment of two-level cervical disc disease. However, HS and CDA may be more preferable over ACDF attributed to their motion-preserving benefits and effectively combining fusion and motion preservation techniques, with comparable clinical and radiological outcomes.

Keywords: Anterior cervical discectomy and fusion, cervical disc arthroplasty, hybrid surgery, range of motion.

Neurosurgery is complicated by multiple-level cervical disc disease. Two-level cervical disc disease, a subset of this category, requires a nuanced understanding of pathophysiology and surgical options such as discectomy, fusion, and hybrid surgery (HS).[1] In recent years, cervical disc diseases requiring surgery have increased due to improved diagnostics and disease understanding.[2]

Two-level cervical disc disease is complicated in both its clinical presentation and surgical choice. The management of multi-level disease, particularly two-level pathology, is still debated.[3] Single-level cervical disc herniations have been extensively studied and have many treatment protocols. Fusion, arthrodesis, discectomy, and HS are all debated, each with pros and cons.[4]

Cervical disc disease treatment has long relied on anterior cervical discectomy and fusion (ACDF). Due to long-term concerns, particularly adjacent segment disease (ASD), cervical disc arthroplasty (CDA) and HS have been considered. Cervical disc arthroplasty is promising for preserving motion and reducing adjacent segment degeneration. The literature shows controversial results, particularly for multi-level disease.[5] Hybrid surgery, a fusion-arthroplasty procedure, is another choice. Better range of motion (ROM) protection is claimed for HS.[6] Hybrid

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procedures have yet to prove their superiority.[7] Patient selection, detailed surgical planning, and the choice between minimally invasive and complex surgical approaches must be tailored to each patient's pathology and health status.[8]

Despite surgical advances, no disc prosthesis has come close to "completely mimicking the natural disc physiology". This limitation emphasizes the need for continued innovation and evaluation of existing and new technologies, and clinical outcome variability emphasizes the need for personalized surgical planning.[9-11]

In the present study, we aimed to examine complex two-level cervical disc disease management in the practice of neurosurgery and to compare the outcomes of ACDF, CDA, and HS for two-level cervical disc disease.

PATIENTS AND METHODS

This single-center, retrospective study was conducted at the Department of Neurosurgery, University of Health Sciences, Bozyaka Training and Research Hospital between December 2011 and December 2021. Initially, medical records of a total of 146 patients with the diagnosis of two-level cervical disc disease who were treated surgically were reviewed. Finally, a total of 120 patients (76 males, 44 females; mean age: 44.8±8.1 years; range, 18 to 68 years) who met the inclusion criteria were enrolled. The patients were randomly divided into three groups as ACDF, CDA, and HS each consisting of 40 patients.

In the selection process for our study, we meticulously adhered to a systematic approach to ensure fairness and eliminate selection bias. All patients met the prespecified inclusion criteria throughout the study period. These criteria were strictly followed to maintain uniformity across the groups and to ensure that the selection was solely based on the chronological order of patients meeting the study criteria, not on their clinical profiles or outcomes. This process aimed to enhance the study's validity by providing a clear and unbiased comparison between the different surgical techniques.

To further clarify, inclusion criteria included a diagnosis of two-level cervical disc disease confirmed by magnetic resonance imaging (MRI) and/or computed tomography (CT), symptomatic cervical radiculopathy or myelopathy, and failure of conservative treatment for at least six weeks. Patients with a history of previous cervical spine surgery, single-level or more than two-level cervical disease, and those with incomplete medical records were excluded from the study. This selection method was designed to ensure a homogenous study population and minimize confounding variables that could impact the outcomes of the respective surgical interventions.

Surgeries were performed by a single board-certified neurosurgeon with 10 to 20 years of experience in cervical spine surgery. Clinical and radiological outcomes were independently evaluated by another surgeon who was not involved in surgeries.

All surgical procedures were conducted utilizing a standardized anterior approach. The decision to opt for CDA, ACDF, or HS was contingent upon the surgeon's discretion, patient-specific considerations, and the unique pathology presented in each case. In the ACDF group, discectomy was followed by the placement of an intervertebral cage. In the CDA group, a cervical disc prosthesis was implanted following discectomy. In cases of HS, a combination of ACDF and CDA techniques was used to treat different levels, aiming to optimize spinal reconstruction and cervical ROM.

Sagittal vertical axis (SVA) distance from posterior-superior edge of C7 vertebra to vertical line through center of C2 vertebra. Cervical ROM was meticulously measured using dynamic X-rays, specifically flexion-extension X-rays, at preoperative assessments and during each follow-up visit. This method involves calculating C2-7 Cobb angle in flexion and extension respectively. The difference of the angles showed the ROM. Cervical lordosis (CL) the angel between the horizontal line of C2 inferior endplate and the horizontal line of C7 inferior endplate. T1 slope (T1S) the angel between horizontal line and the superior endplate of T1 (Figure 1).

Preoperative data included patient demographics, symptoms, neurological status, and radiological assessment using preoperative X-ray, CT, and MRI scans. Postoperative follow-up included clinical evaluation for symptom relief and neurological improvement, as well as radiological assessment using dynamic X-rays to evaluate fusion status, prosthesis position in cases of arthroplasty, and the integrity of hybrid constructs.

Primary postoperative outcomes were assessed using the Neck Disability Index (NDI) and Visual Analog Scale (VAS) for neck and arm pain. Radiological outcomes included the assessment of fusion status in the ACDF group, ROM in the group of CDA, and the effectiveness of hybrid constructs in the HS group. Secondary outcomes included perioperative complications and the need for additional surgeries.

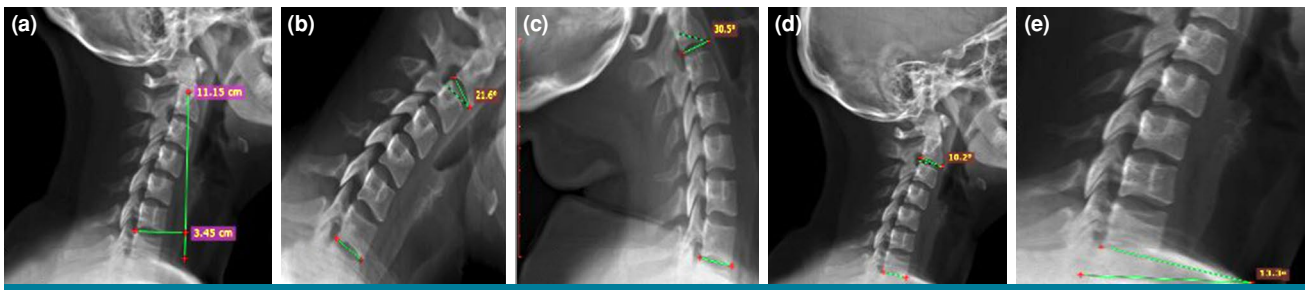

FIGURE 1. (a) Sagittal vertical axis (SVA). **(b, c)** Range of motion (ROM). **(d)** Cervical lordosis (CL). **(e)** T1 slope (T1S).

Statistical analysis

Statistical analysis was performed using the IBM SPSS for Windows version 25.0 software (IBM Corp., Armonk, NY, USA). Continuous variables were expressed in mean ± standard deviation (SD), while categorical variables were expressed in number and frequency. Pre- and postoperative scores were compared using paired t-test. Comparison between different treatment groups was performed using Student t-test and analysis of variance (ANOVA) test. Sensitivity analyses were also conducted to determine whether specific subgroups of patients might be contributing disproportionately to this variability. Data including age, baseline severity of symptoms, and other clinically relevant factors that could influence outcomes were analyzed. A p value of <0.05 was considered statistically significant.

RESULTS

Baseline and demographic characteristics of the patients are shown in Table I. Patient demographics, including age and sex distribution, were comparable across the groups, indicating no significant differences (p>0.05). The mean follow-up was 27.5±6.1 months for ACDF, 20.0±4.7 months for CDA, and 21.1±5.0 months for HS, indicating consistency in monitoring postoperative outcomes.

Analyzing the clinical findings, significant improvements were observed in both NDI and VAS scores postoperatively across all groups, demonstrating substantial alleviation of neck pain and disability. Specifically, the mean postoperative NDI scores were significantly reduced to 13.4±5.6 for ACDF, 14.8±5.2 for CDA, and 15.0±5.5 for HS (p=0.056) from the mean preoperative scores of 24.2±10.3, 21.1±9.8, and 18.9±10.1, respectively (p=0.691). Similarly, the mean VAS scores significantly decreased to 2.1±1.2 for ACDF, 2.0±1.1 for CDA, and 2.1±1.2 for HS (p=0.011), from preoperative scores of 7.3±1.5, 7.5±1.4, and 7.4±1.5, respectively (p=0.844) (Table II). These results indicated the effectiveness of all three surgical approaches in managing neck pain and improving patient quality of life.

The mean preoperative SVA was similar among the three groups, with 1.82±1.26 in the ACDF group, 1.61±0.59 in the CDA group, 1.91±1.11 in the HS group and the difference was not statistically significant (p=0.120). The mean pre- and postoperative T1S was not significantly different among the three groups, with 25.85±6.87, 24.90±7.12 in the ACDF group, 22.52±3.87, 19.41±4.29 in the CDA group, 24.38±5.91, 22.27±4.52 in the HS group (p=0.391 and p=0.506). The mean pre- and postoperative CL was not significantly different among the three groups, with

TABLE I
Baseline and demographic characteristics of patients

	ACDF (n=40)		CDA (n=40)		HS (n=40)		
	n	Mean±SD	n	Mean±SD	n	Mean±SD	*p*
Age		55.6±7.9		41.0±7.9		46.5±9.1	0.039*
Sex							0.072
Male	26		25		25		
Female	15		14		15		
Follow-up duration (month)		27.5±6.1		20.0±4.7		21.1±5.0	0.068

ACDF: Anterior cervical discectomy and fusion; CDA: Cervical disc arthroplasty; HS: Hybrid surgery; SD: Standard deviation; * p<0.05.

TABLE II
Clinical Findings according to treatment groups

	ACDF			CDA			HS			
	n	Mean±SD	*p*	n	Mean±SD	*p*	n	Mean±SD	*p*	*p*
Preoperative NDI score		24.2±10.3			21.1±9.8			18.9±10.1		0.694
Postoperative NDI score		13.4±5.6			14.8±5.2			15.0±5.5		0.056
Preoperative-postoperative NDI		–5.17±4.13			–4.43±3.21			5.01±3.78		0.081
Preoperative VAS score		7.3±1.5			7.5±1.4			7.4±1.5		0.844
Postoperative VAS score		2.1±1.2			2.0±1.1			2.1±1.2		0.011*
Preoperative-postoperative VAS score			0.01			0.01			0.01	0.493
Preoperative radiculopathy	33			30			36			
Postoperative radiculopathy	2			2			1			
Preoperative myelopathy	7			10			4			
Postoperative myelopathy	1			2			1			

ACDF: Anterior cervical discectomy and fusion; CDA: Cervical disc arthroplasty; HS: Hybrid surgery; SD: Standard deviation; NDI: Neck Disability Index; VAS: Visual Analog Scale; * p<0.05.

8.81±12.23, 5.92±9.32 in the ACDF group, 12.42±11.88, 12.17±11.73 in the CDA group, 11.53±9.62, 11.16±9.78 in the HS group (p=0.212 and p=0.498). However, we found a significant difference in postoperative C2-7 SVA (p<0.05). While comparing ACDF/HS groups, and ACDF/CDA groups, there was a significant difference in postoperative C2-7 SVA. Postoperative ROM was significantly lower in the fusion group compared to the CDA group (p<0.05). There was no significant difference in ROM between the hybrid and CDA groups (Table III). T1S and CL metrics were observed to maintain consistent levels across all treatment groups, suggesting the preservation of sagittal balance following the surgical procedures (Table III).

There were five cases of transient dysphagia in the ACDF group, two in the CDA group, and three in the HS group. The symptoms of all of the patients were resolved at the end of 12 months. There was no infection or neurological deficiency in any patient.

DISCUSSION

The main findings of this study show the efficacy of ACDF, CDA, and HS in managing two-level cervical disc disease.[12] Notably, our results revealed significant improvements in both VAS and NDI scores postoperatively across all three treatment modalities, highlighting their clinical utility. Furthermore, the comparison between postoperative ROM in the CDA and HS groups

TABLE III
Radiological outcomes

	ACDF	CDA	HS		ACDF *vs.* HS	HS *vs.* CDA	ACDF *vs.* CDA
Measurement (degree)	Mean±SD	Mean±SD	Mean±SD	*p*	*p*	*p*	*p*
Preop C2-7 SVA	1.82±1.26	1.61±0.59	1.91±1.11	0.120	0.085	0.133	0.745
Postop C2-7 SVA	2.31±1.19	1.54±0.76	1.28±1.28	0.048*	0.031*	0.091	0.022*
Preop T1S	25.85±6.87	22.52±3.87	24.38±5.91	0.391	0.523	0.341	0.231
Postop T1S	24.90±7.12	19.41±4.29	22.27±4.52	0.506	0.421	0.382	0.079
Preop ROM	33.11±18.11	38.4±15.4	39.71±17.39	0.231	0.861	0.716	0.902
Postop ROM	20.82±5.66	32.45±11.21	27.18±10.89	0.112	0.181	0.309	0.045*
Preop CL	8.81±12.23	12.42±11.88	11.53±9.62	0.212	0.237	0.841	0.254
Postop CL	5.92±9.32	12.17±11.73	11.16±9.78	0.498	0.153	0.371	0.231

ACDF: Anterior cervical discectomy and fusion; CDA: Cervical disc arthroplasty; HS: Hybrid surgery; SD: Standard deviation; SVA: Sagittal vertical axis; T1S: T1 Slope; ROM: Range of motion; CL: Cervical lordosis; * p<0.05.

versus the ACDF group presents a compelling argument for the motion-preserving advantages of the former techniques. These improvements were statistically significant, demonstrating the potential for these surgical options to offer substantial relief and functional recovery to patients suffering from this condition. This study builds upon and extends the current literature by providing a comprehensive evaluation of these three surgical techniques, emphasizing the role of patient-specific surgical planning and execution.[13,14]

The clinical improvements observed in our study, evidenced by the significant reductions in VAS and NDI scores across all groups, are consistent with the broader body of literature on cervical spine surgery. The improvements in the ACDF, CDA, and HS groups were comparable, suggesting that all three techniques are viable options for treating two-level cervical disc disease. These findings are in line with research by Scott-Young et al.[15] and Dugailly et al.,[16] and extends the scope of inquiry to include HS, thereby addressing a gap in research that often overlooks the potential of combining techniques.[17]

In the ACDF group, the high fusion rate (93.3%) corroborates the findings from previous studies.[18,19] The effectiveness of ACDF in achieving spinal stability is critical in managing multilevel cervical disc disease.[20] The ROM in 96.7% of the CDA group reflects the benefits of CDA in maintaining cervical spine mobility.[21]

In evaluating the comparative effectiveness of ACDF, CDA, and HS, it is essential to consider not only the clinical and radiological outcomes but also the potential complications associated with each technique. While our study highlights the motion-preserving benefits and clinical efficacy of CDA and HS over ACDF, it is also crucial to address the risk profiles associated with these procedures.[22]

As a well-established technique, ACDF is associated with potential complications such as ASD, dysphagia, and pseudoarthrosis. However, its high fusion rates and effectiveness in decompression have made it a standard treatment for cervical disc disease.[23] The main goal of CDA is to preserve motion and potentially reduce the incidence of ASD, yet concerns remain regarding device migration, heterotopic ossification, and the need for revision surgery. Hybrid surgery, which combines the principles of ACDF and CDA, offers a balanced approach by preserving motion at one level while providing stability at another. This technique, while innovative, requires careful patient selection and consideration of the cumulative risks of both ACDF and CDA, including the complexities of managing a hybrid construct.[24]

By incorporating a detailed discussion on these complications, we attempted to provide a holistic view of each surgical option's risk-benefit profile, reinforcing the conclusion that HS and CDA may offer advantages in certain patient populations due to their motion-preserving capabilities.[7] Nonetheless, the choice of surgical technique must be tailored to the individual patient, considering both the potential benefits and the complication risks.[25]

The low complication rates observed in the present study are lower than those reported in larger series,[22] which may be due to the focused nature of our retrospective analysis. Retrospective studies can sometimes underreport complications.[23] These results suggest that both three procedures were found to be safe in the treatment of two-level disc disease.

Interestingly, the segmental ROM (segment ROM) exhibited a notable postoperative change. Specifically, there was a significant reduction in the ACDF group, with a p value of 0.03, reflecting the anticipated outcome of fusion surgery. Meanwhile, the HS group showed a moderate reduction in segment ROM. This contrasts with the CDA group, where segmental motion was essentially maintained. These observations underscore that while ACDF leads to a decrease in segmental motion, both CDA and HS preserve overall sagittal alignment, a key factor for patient functionality and quality of life post-surgery. This underscores the importance of individualized surgical approaches that consider each patient's unique spinal alignment and the need for motion preservation. This outcome is noteworthy, as it underlines the efficacy of HS in maintaining motion at the operated segments, a crucial factor in the long-term functionality and satisfaction of patients.

Despite the strengths of our study, there are some limitations. The retrospective design and the single-center nature of the study may limit the generalizability of our findings. Additionally, follow-up period may not adequately emphasize the durability of surgical interventions, long-term complications, potential impact of heterotopic ossification or the development of ASD, a known concern in cervical spine surgery.[21,24,25] Furthermore, our analysis revealed that hybrid treatment presented better segmental ROM than ACDF. This outcome is noteworthy as it underlines the efficacy of HS in maintaining motion at the operated segments, a crucial factor in the long-term functionality and

satisfaction of patients. These findings indicate that while ACDF leads to a reduction in segmental motion, both CDA and HS maintain overall sagittal alignment, which is crucial for patient functionality and postoperative quality of life. The results highlight the need for tailored surgical approaches in treating cervical disc diseases, considering individual spinal alignment and motion preservation.

Additionally, focusing on patient-reported outcomes and quality of life measures would provide valuable insights into the patient-centered aspects of these surgical techniques.[26] This holistic approach would not only aid in better understanding the efficacy of surgical interventions, but also in optimizing patient satisfaction and overall treatment outcomes.

In conclusion, our study results suggest that all three surgical techniques, ACDF, CDA, and HS, are safe and successful in the treatment of two-level cervical disc disease. However, HS and CDA may be more preferable over ACDF attributed to their motion-preserving benefits and effectively combining fusion and motion preservation techniques, with comparable clinical and radiological outcomes.

Ethics Committee Approval: The study protocol was approved by the Izmir Bozyaka Training and Research Hospital Clinical Research Ethics Committee (date: 20.04.2022, no: 2022/66). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Patient Consent for Publication: A written informed consent was obtained from each patient.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Idea/concept, design, data collection and/or processing, analysis and/or interpretation: A.T.; Control/supervision, references and fundings, critical review, material: A.T., T.K.E.; Literature review, writing the article: T.K.E.

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