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Multilevel Anterior Cervical Decompression and Fusion: Cervical Range of Motion and Clinical Outcomes

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Abstract

Background: Multiple level anterior cervical discectomy and fusion (ACDF) is indicated for those who suffer from multilevel stenosis or compression of the spinal canal. It was reported that this intervention would unfortunately lead to a loss of normal cervical range of motion (CROM). Although, fewer studies have demonstrated the exact impact of the procedure on CROM. In our study, short and midterm postoperative CROM was described. **Methods**: Ninety patients who underwent ACDF were followed up postoperatively for at least 3 months. Active CROM was measured in all patients preoperatively and in postoperative follow-ups by cervical spine X-rays in lateral dynamic view using Cobb's angle method. **Results**: Unfortunately, postoperative CROM was significantly diminished. At the short-term (3 months) follow-up there was a great limitation in CROM. While an obvious increase in CROM at the midterm (6 months) follow-up was observed in flexion especially. The reduction in global ROM (calculated as preoperative global ROM – 6 months postoperative ROM) was 4.1 and the reduction rate (calculated as reduction ROM divided by preoperative ROM) was 9.5%. The recovery ROM (calculated as 6 months postoperative ROM – 1 month postoperative ROM) was 8.2. The recovery rate (calculated as recovery ROM divided by 1 month postoperative ROM) was 26.5%. **Conclusion**: Active CROM following multiple level ACDF was obviously diminished. The most affected motion after surgery was flexion. It was noticed that at the short-term follow-up CROM would be more limited while after further follow up CROM was obviously improved even in neck flexion motion.

Keywords

Multilevel, Anterior Cervical Discectomy, Fusion, Cervical Range of Motion

1. Introduction

Disabling neck pain is a common complaint within the adult general population with prevalence estimates ranging from 2% to 13.5% [1]. The common diseases of sub-axial cervical spine mainly include various types of degenerative cervical spondylosis, cervical tumors, trauma, developmental deformity, and infectious diseases [2]. Neck pain and radiculopathy often result in considerable disability, substantial economic hardship, and are often treated with surgical intervention [1] [3] [4]. One of the most common surgical treatments for chronic neck pain and radiculopathy is an anterior cervical discectomy and fusion (ACDF). It is typically used when conservative management has been unsuccessful [1]. The aims of surgical treatment are to completely alleviate the compression of dural sac, reconstruct the stability of the cervical spine, and restore the curvature of the cervical spine in accordance with the biomechanical characteristics. Decompression and stabilization have been recognized surgical goals, and the techniques are generally well-established. With the research progresses of sagittal balance, it is taken more and more seriously for cervical sagittal alignment. Cervical sagittal balance was closely related to clinical prognosis. Therefore, the restoration of cervical spine alignment is a hot topic in recent years [2]. ACDF is thought to relieve pressure on nerve roots through decompression and is assumed to help to prevent further irritation at the level by fusing the vertebra above and below together [1] [5]. Traditionally, ACDF has developed as a standard surgical technique in treating radiculopathy. It is usually reported as a safe and efficient technique that has long-term clinically and radiologically successful outcomes [6] [7] [8]. The primary disadvantage of ACDF is that it converts a functionally mobile, mechanically stable spinal unit into a fixed, nonfunctional unit. Analysis of strain distribution of intervertebral discs after ACDF has shown an increase in longitudinal strain, most frequently at the levels immediately adjacent to the fused segment [9]. Many reports have shown evidence of the development of junctional degeneration adjacent to fused levels due to increased biomechanical stress and compensatory increase in motion at the adjacent level resulting from the reduced physiological motion of the spine after fusion [9] [10]. Because many people who are experiencing chronic radiculopathy and neck pain already have limited motion, the idea of losing more Range of Motion (ROM) is worrisome. When ROM is lost, it affects more than just the ability to turn the neck; it may also impact function and may limit activities of daily living [1].

2. Methods

The study was done prospectively on the accessible population (patients) presenting with multiple level operable cervical disc prolapses (in the period from June 2016 to October 2021) and meeting the eligibility criteria for anterior cervical discectomy and fusion. In our study, inclusion criteria include patients aged between 25 - 75 years old with symptoms of radiculopathy and/or myelo-

pathy, not responding to conservative treatment for greater than or equal to 3-6 weeks and objective evidence of cervical disc disease at two or more vertebral levels between C3-C7. Exclusion criteria include previous cervical operations, infection, tumor, trauma, neurological condition such as CVS and history of cervical fixation. This study is designed to include (90) patients with multiple cervical disc prolapses indicated for surgical intervention and fulfilling the inclusion criteria. All patients will be subjected to thorough history taking, full neurological examination and investigations in the form of full routine labs, plain X-rays (lateral, A-P, flexion and extension), MRI scan of the cervical spine. All operations were performed at a single institution between 2016-2021. Anterior fusion was performed with an interbody PEEK cage. An anterior right-sided approach was advocated for each patient. The operation time ranged from 90 to 180 min (mean 120 min). All patients were immobilized in rigid neck collars for 4 - 6 weeks after surgery. Radiographic evaluation was conducted using neutral lateral as well as flexion and extension lateral cervical plain radiographs before surgery and at short term and midterm follow-up for all patients. All patients were assessed using the NDI and VAS for neck pain before surgery and at short term and midterm follow-up (Table 1 and Table 2). In all patients, active CROM was measured preoperatively and postoperatively at both short-term (1 month) and midterm (6 months) follow-ups. Numerous methods of measuring CROM have been developed, including goniometry, inclinometers, electromagnetic methods, tape measurement, radiographic measurement, and visual

Table 1. Comparisons of NDI follow up among study group.

Variables	NDI (N = 30)		P-value	Sig.
	Mean	SD		
Preoperative	30.8	8.6		
After 1 month	19.6	5.9	<0.001	HS
After 6 months	13.6	5.3		

Table 2. VAS score (arm-neck) follow up among study group.

Variables	VAS score (N = 30)		P-value	Sig.
	Median	IQR		
Arm pain				
Preoperative	7	2		
After 1 month	3	1	<0.001	HS
After 6 months	2	1		
Neck pain				
Preoperative	5	1		
After 1 month	4	2	0.02 <0.001	HS
After 6 months	2	1		

estimation [11]. However, none of these methods can be considered perfect in terms of reliability, validity, and clinical feasibility. Currently, the most widely used method for assessing CROM in the clinic is radiographic measurement, which is based mainly on the Cobb angle of C2-C7 in flexion and extension radiographs. However, this radiographic measurement includes only part of the cervical motion (C2-C7 segments), and only sagittal motion can be assessed [11]. Global lordosis will be measured on lateral neutral radiographs. Global lordosis will be measured from the Cobb angle between the lower endplate of C2 and C7. CROM is defined as the difference between Cobb angles on lateral flexion and extension radiographs and cranial and caudal segmental ROM were measured as well [12] [13]. In cases where the endplate is invisible because of the shoulder, the ROM will be defined as the difference between the flexion-extension angles measured from both superior endplates.

3. Statistical Analysis

Data were collected, coded, and entered into Microsoft Access. Data analysis was performed using Statistical Package of Social Science (SPSS-Version 18). The mean and standard deviation (SD) of assessed variable were presented. Categorical variables were expressed as numbers and percentages. Qualitative data were tested for normality using One-Sample Kolmogorov-Smirnov test. Mann-Whitney test was used to compare two independent groups and Chi square test (χ^2) was used to compare more than two groups. P-value of ≤ 0.05 was considered the cut-off point for statistical significance.

4. Results

Regarding demographic characters, the mean age of study group was (45.3 ± 8.2) years old ranged between 28 and 69 years old with 43.3% were males and 56.7% were females. In this study, nearly all patients presented with axial neck pain (80%). 72 patients (80%) presented by radiculopathy (42 of them had right radiculopathy and 30 had left radiculopathy). 15 patients presented by myelopathy (16.6%). Only three patients presented by U.L weakness without neck pain or radiculopathy. In our study, 57 patients (63.3%) were operated by double level discectomy while 24 patients (26.7%) were operated upon by 3 level discectomies. Only 9 patients (10%) were operated by 4 level discectomies. Our study showed that C5-6 and C4-5 were the most common levels to be operated. C3-4 ACDF was done in 10 patients (33.3%). C4-5 ACDF was done in 66 patients (73.3%). C5-6 ACDF was done in 84 patients (93.3%). C6-7 ACDF was done in 42 cases (46.7%). In our study, according to preoperative visual analogue scale (VAS) most patients were categorized to have moderate to severe arm pain (6 - 10). Mean preoperative VAS for arm pain was 6.53 ± 1.5 SD and for neck pain it was 4.73 ± 1.2 SD. Preoperative NDI in our study was 30.8 ± 8.6 SD. Postoperatively, our study proved that there was statistically significant improvement in both arm and neck pain. VAS score for arm decreased to 3.1 ± 0.96 SD after 1

month and to 1.87 ± 0.73 SD after 6 months with p-value < 0.05. Also, VAS score for neck pain decreased to 4.7 ± 1.46 SD after 1 month and to 2.53 ± 1.22 SD after 6 months with p-value < 0.05. Regarding NDI, our study showed statistically significant decrease to 19.6 ± 5.9 SD after one month and to 13.6 ± 5.3 SD after 6 months (Figure 1 and Figure 2).

The mean blood loss volume (107 ± 49.3 SD) ml; ranged between 55 and 210 ml. The mean operational duration was (120 ± 35.8 SD) minutes; ranged between 90 and 180 minutes, as regards hospital stay duration the mean was (1.9 ± 0.61 SD) days ranged between 1 and 3 days. In our study, Cobb's angle, which is the angle between the lower endplate of C2 and C7 (Figure 3). Cobb's angle in flexion and extension, CROM, cranial and caudal ROM were all evaluated preoperatively and postoperatively on short term and midterm periods. Regarding Cobbs angle, preoperative mean was 23.1 ± 9.9 SD. While postoperatively, it decreased to 21.1 ± 9.3 SD after 1 month and increased to 24.5 ± 9.6 SD after 6

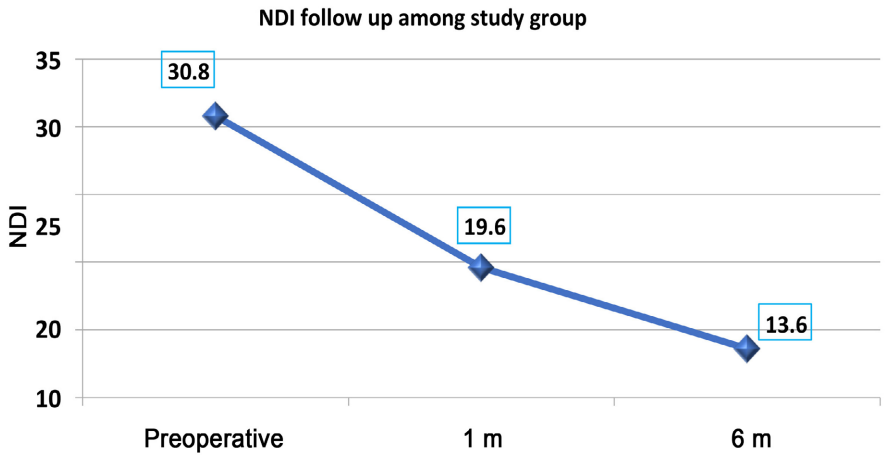

Figure 1. NDI follow up among study group.

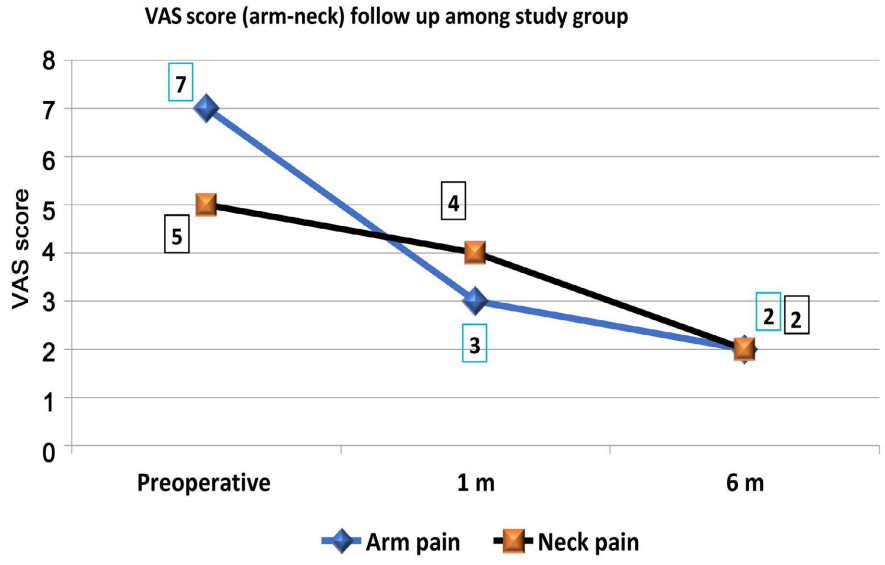

Figure 2. VAS score (arm-neck) follow up among study group.

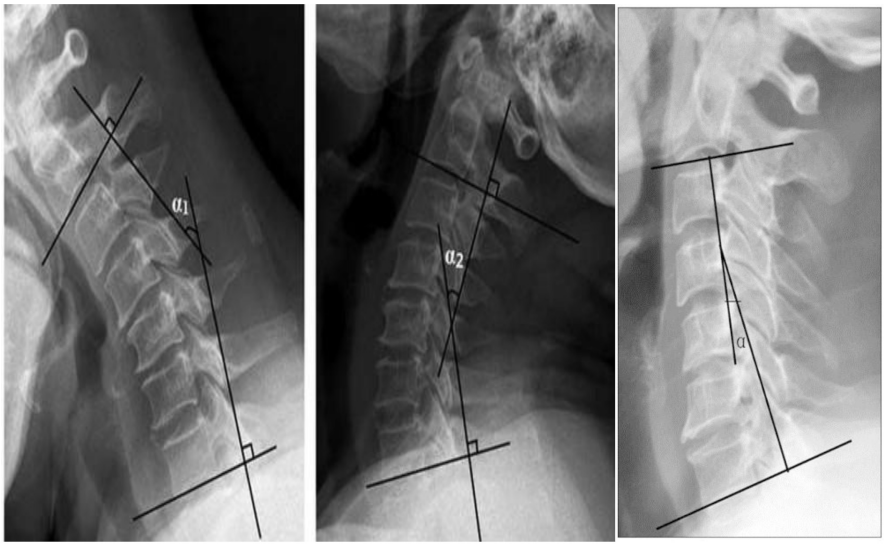

Figure 3. *α* C2-C7 Cobb angle or Global lordosis (angle between the lower endplate of C2 and C7). *α*1 + *α*2 = CROM.

months. There was no statistically significant difference in Cobbs angle with p-value > 0.05 1 month post-operation but there was a statistically significant increase in Cobbs angle 6 months post-operation with p-value < 0.05. Our study showed that preoperatively Cobb's angle in flexion was 22.9 ± 8.2 SD and in extension was 20.7 ± 6.5 SD. 1 month after surgery, Cobb's angle in flexion decreased to 14.6 ± 5 SD and increased to 19.7 ± 5.8 SD after 6 months. While Cobbs angle in extension decreased to 16.4 ± 5.5 SD after 1 month and increased to 19.7 ± 5.6 SD after 6 months. There was a statistically significant decrease in Cobb's angle in flexion and extension 1 month post-operation which then increased six months postoperative with p-value < 0.05 (Table 3). Preoperative Global CROM (the sum of Cobbs angle in flexion and extension) was 43.2 ± 11.7 SD. Global CROM showed significant decrease 1 month postoperatively to 30.9 ± 8.8 SD then increases after 6 months to 39.1 ± 8 SD with p-value < 0.05. In our study, preoperative cranial segmental ROM was 15.3 ± 4.3 SD and caudal segmental ROM was 13.1 ± 3.8 SD. Cranial ROM showed decrease to 12.1 ± 3.6 SD after 1 month and increased to 13.8 ± 3.9 SD after 6 months. Also caudal ROM decreased to 10.03 ± 2.6 SD after 1 month and increased to 11.2 ± 2.9 SD after 6 months (Table 4). Our study showed that 53.3% of cases showed short term postoperative complications, 41 (45.6%) of complicated cases showed temporary dysphagia which improved after one month follow up, with only two patients (2.2%) were complicated by migration of prosthesis, four patients (4.4%) were complicated by superficial wound infection which was managed by repeated dressings, local and systemic antibiotics while CSF leakage occurred in only one case (1.1%) and was managed conservatively.

Case Presentation

Case 1: 45 years old female patient presented to us complaining of gradual

Table 3. Comparison of Cobbs angle among study group.

Variables	Cobbs Angle (N = 30)		P-value	Sig.
	Mean	SD		
Cobbs angle (Global lordosis)				
Preoperative	23.1	9.9	0.11 **<0.001**	NS **HS**
After 1 month	21.1	9.3		
After 6 months	24.5	9.6		
Cobbs angle in flexion				
Preoperative	22.9	8.2	**<0.001**	**HS**
After 1 month	14.6	5		
After 6 months	19.7	5.8		
Cobbs angle in extension				
Preoperative	20.7	6.5	**<0.001**	**HS**
After 1 month	16.4	5.5		
After 6 months	19.7	5.6		

Table 4. Comparisons of ROM follow up among study group.

Variables	Adjacent ROM (N = 30)		P-value	Sig.
	Mean	SD		
Global ROM				
Preoperative	43.2	11.7	**<0.001**	**HS**
After 1 month	30.9	8.8		
After 6 months	39.1	8		
Cranial ROM				
Preoperative	15.3	4.3	**<0.001**	**HS**
After 1 month	12.1	3.6		
After 6 months	13.8	3.9		
Caudal ROM				
Preoperative	13.1	3.8	**<0.001**	**HS**
After 1 month	10.03	2.6		
After 6 months	11.2	2.9		

onset and progressive course of right brachialgia and right upper limb weakness for 3 months. It showed that Global lordosis was 20 and global ROM was 50 (30 for ROM in extension and 20 for ROM in flexion). Cranial adjacent ROM was 17 (12 for extension and 5 for flexion). The previous patient was operated upon by 4 level ACDF and one month post-operative showed that global lordosis was 26 and global ROM reduced to 32 (29 for extension and 3 for flexion). Cranial ROM decreased to 15 (13 in extension and 2 in flexion). While 6 months post-operative

global lordosis was 20 and global ROM increased to 36 (33 for extension and 3 for flexion). Cranial ROM increased to 20 (17 for extension and 3 in flexion) (Figures 4-6).

Case 2: 53 years old female patient presented to us complaining of gradual onset and progressive course of neck pain, left brachialgia, tingling & numbness of left hand for 1 year and showing that Global lordosis was 25 and global ROM was 54 (20 for ROM in extension and 34 for ROM in flexion). Cranial adjacent ROM was 28 (18 for extension and 10 flexion). One month post-operative showed that global lordosis was 20, global ROM reduced to 30(18 for extension and 12 for flexion). Cranial ROM decreased to 18 (12 in extension and 4 in flexion). While 6 months post-operative global lordosis was 26 and global ROM increased to 50 (25 for extension and 25 for flexion). Cranial ROM also increased to 22 (12 for

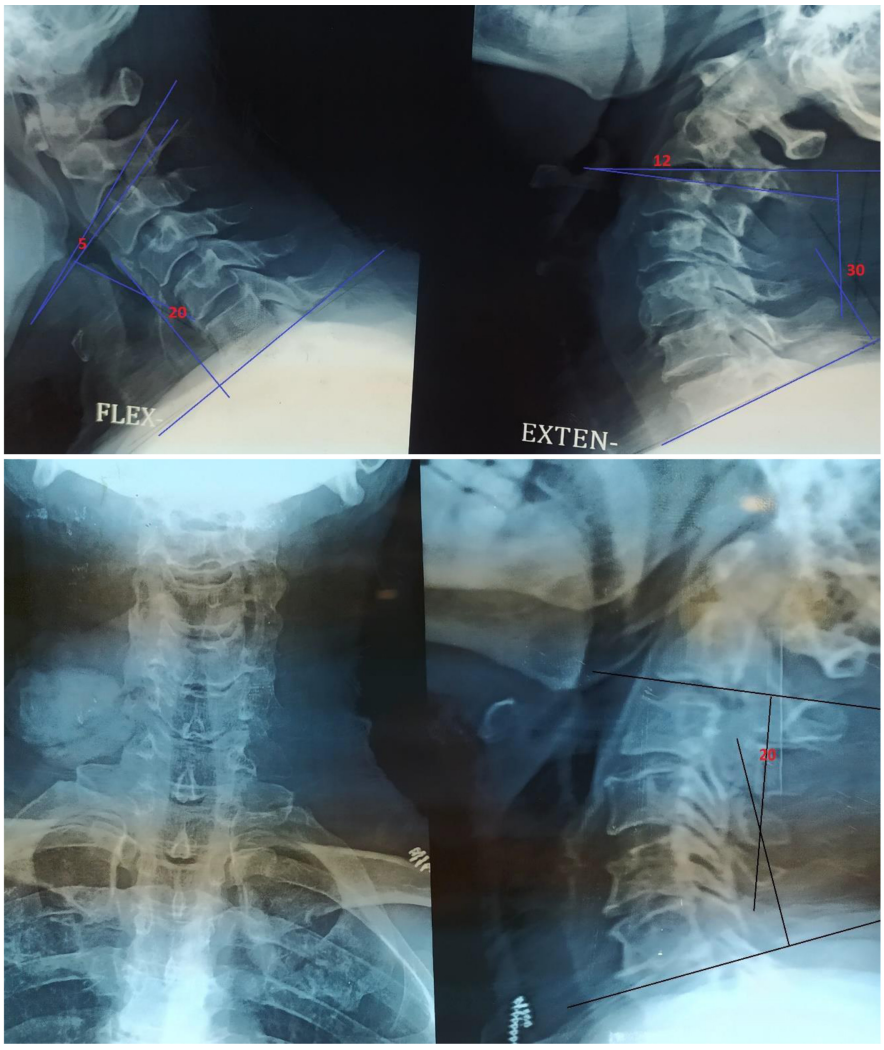

Figure 4. Preoperative cervical spine X-ray (AP, lateral, extension, flexion) of a 45 years old female patient presented to us complaining of gradual onset and progressive course of right brachialgia and right U.L weakness for 3 months. It showed that Global lordosis was 20 and global ROM was 50 (30 for ROM in extension and 20 for ROM in flexion). Cranial adjacent ROM was 17 (12 for extension and 5 for flexion).

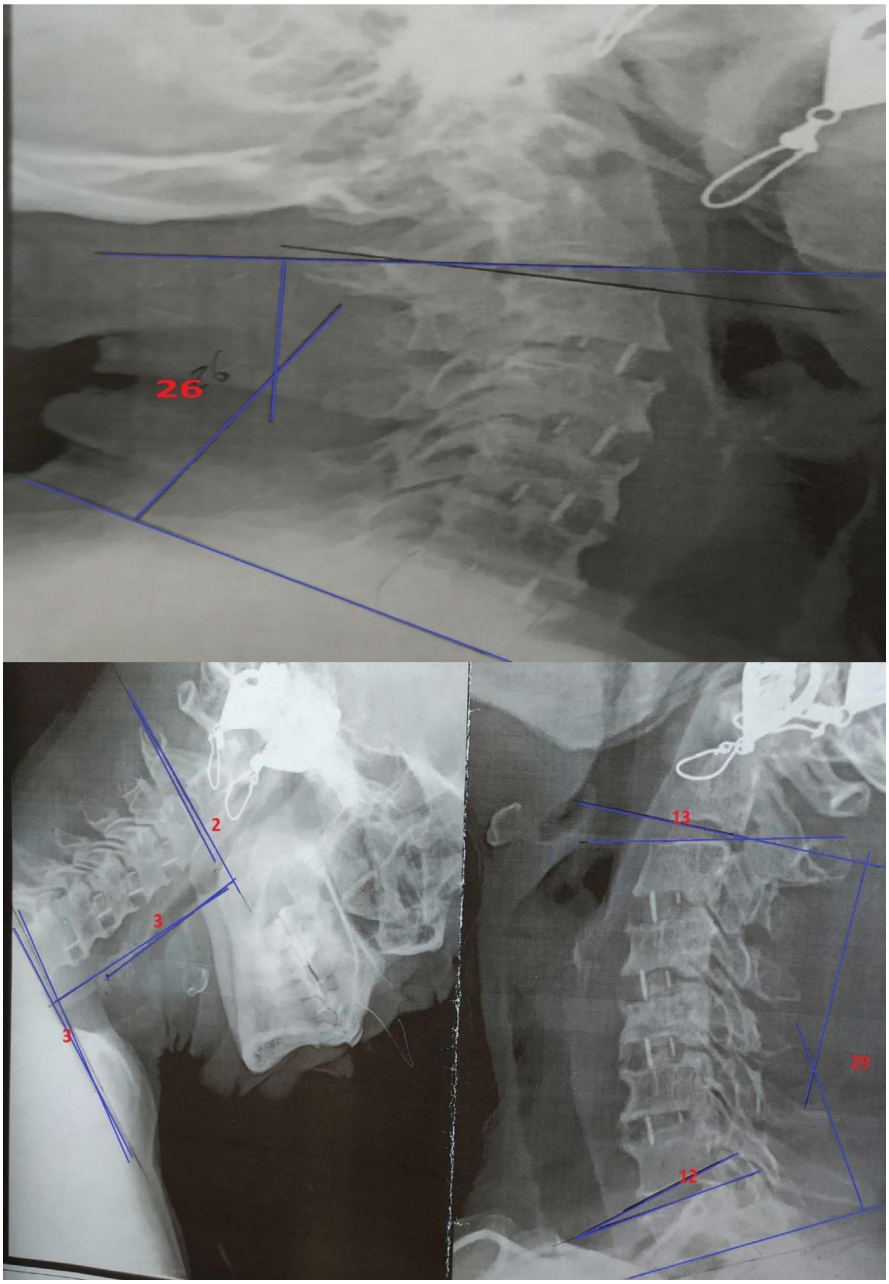

Figure 5. 1 month Postoperative X-ray Cervical spine flexion, extension and lateral views of the previous patient operated upon by 4 level ACDF showed global lordosis was 26 and global ROM reduced to 32 (29 for extension and 3 for flexion). Cranial ROM decreased to 15 (13 in extension and 2 in flexion).

extension and 10 for flexion) (**Figures 7-9**).

5. Discussion

Anterior cervical discectomy and fusion (ACDF) is a common and well-accepted surgical procedure utilized for treating cervical disc diseases. It is the most frequently performed surgical treatment for several cervical spinal diseases, including herniated disc, compressive myelopathy, trauma and degenerative disease.

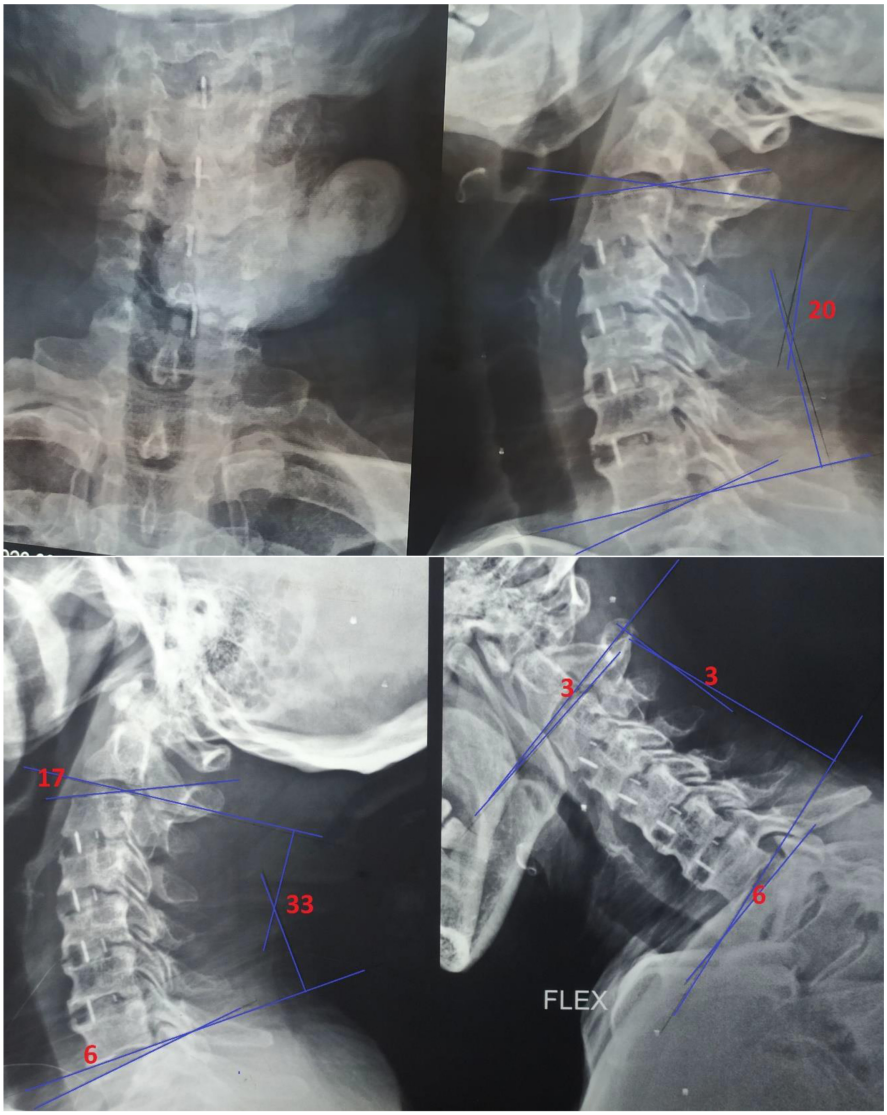

Figure 6. 6 months Postoperative X-ray Cervical spine flexion, extension, A-P and lateral views global lordosis was 20 and global ROM increased to 36 (33 for extension and 3 for flexion). Cranial ROM increased to 20 (17 for extension and 3 in flexion).

This procedure is used to decompress the spinal cord and nerve root, and to stabilize the affected segments [14] [15]. Our study proved that there was statistically significant improvement in both arm and neck pain after the surgery inflicted by improvement of VAS and NDI. Data in this study showed that patients had an obvious reduction in active CROM following multilevel anterior cervical decompression and fusion. There was a statistically significant decrease in global ROM 1 month post-operative which then increased 6 months post-operation. This was explained by post-operative neck muscle spasm with straightened cervical lordosis due to physiological gardening reaction referred to wound incision. The reduction in global ROM (calculated as preoperative global ROM – 6 months postoperative ROM) was 4.1 and the reduction rate (calculated as reduction ROM divided by preoperative ROM) was 9.5%. The recovery ROM

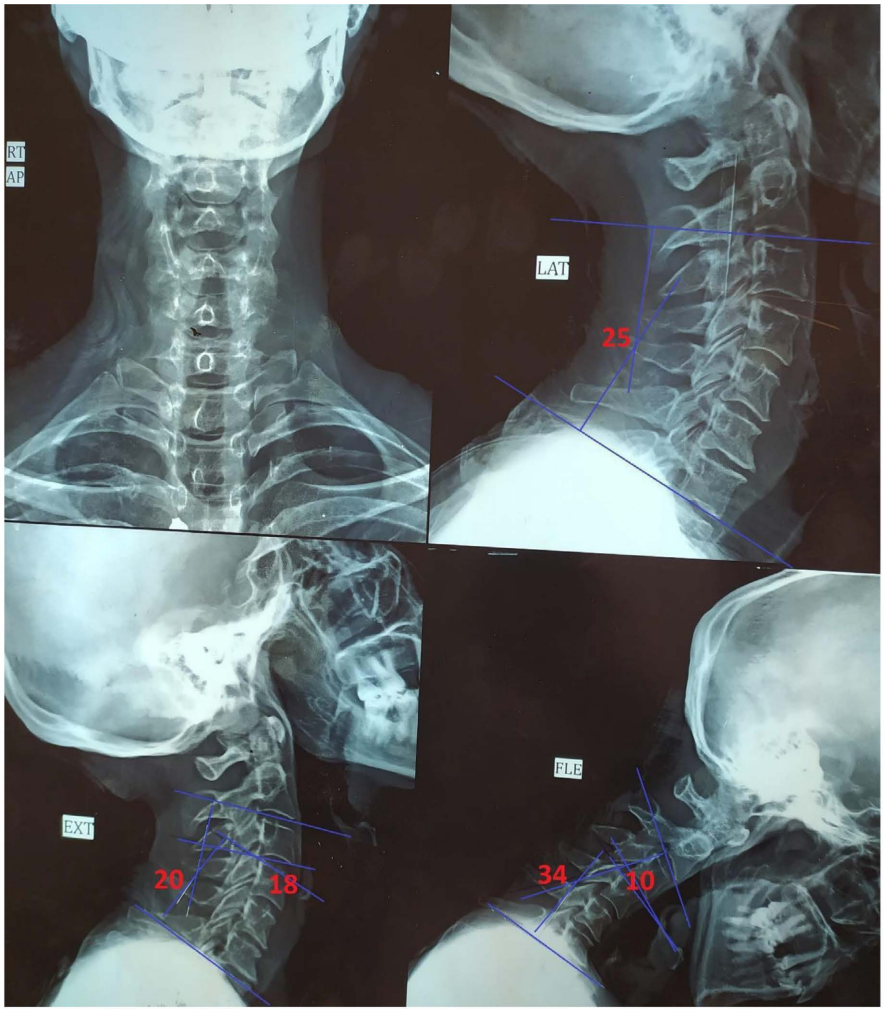

Figure 7. Preoperative cervical spine X-ray (AP, lateral, extension, flexion) of A 53 years old female patient presented to us complaining of gradual onset and progressive course of neck pain, left brachialgia, tingling & numbness of left hand for 1 year and showing that Global lordosis was 25 and global ROM was 54 (20 for ROM in extension and 34 for ROM in flexion). Cranial adjacent ROM was 28 (18 for extension and 10 flexion).

(calculated as 6 months postoperative ROM – 1month postoperative ROM) was 8.2. The recovery rate (calculated as recovery ROM divided by 1month postoperative ROM) was 26.5%. Flexion was the most affected component of CROM. Reduction in flexion ROM was 3.2 and recovery ROM was 5.1. Reduction rate was 14% and recovery rate was 34.9%. In contrast, Reduction in Extension ROM was 1 and recovery ROM was 3.3. Reduction rate was 4.8% and recovery rate was 20.1%. Our study also showed that there was a statistically significant decrease in cranial and caudal segmental ROM 1 month post-operative which then increased 6 months post-operation. Reduction in cranial ROM was 1.5 and Recovery ROM was 1.7. Reduction rate was 9.8% and recovery ROM was 14%. Reduction in caudal ROM was 2.8 and recovery ROM was 1.17 (**Figure 10** and **Figure 11**). Reduction rate was 21.4% and recovery rate was 11.7%. In Zhang *et al*. study, global ROM decreased to 30.1 ± 6.9 after 3 months then increased to

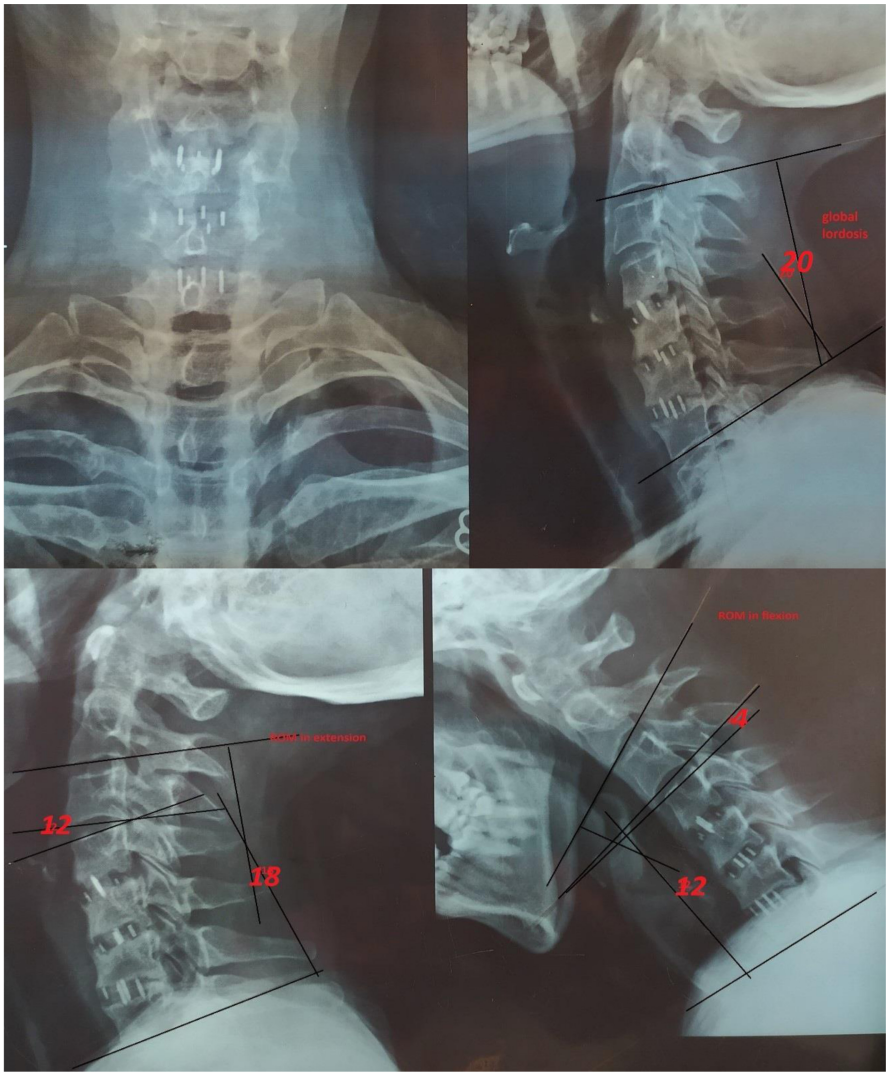

Figure 8. 1 month Postoperative X-ray Cervical spine AP, lateral, flexion and extension views show that global lordosis was 20, global ROM reduced to 30 (18 for extension and 12 for flexion). Cranial ROM decreased to 18 (12 in extension and 4 in flexion).

32.3 ± 8.1 SD after 6 months. Reduction ROM was 18.4 and recovery ROM was 2.2 while reduction rate was 36.3% and recovery rate was 7.3% [9]. In WU *et al*. study, global ROM decreased to 70.8 ± 11.8 after 3 months and then increased to 83.1 ± 12.1 after 12 months. Reduction in global ROM was 22.8 and recovery global ROM was 12.3. Reduction rate in global ROM was 21.5% and recovery rate was 17.4%. Flexion ROM decreased to 28.7 ± 6.9 after 3 months and then increased to 36.6 ± 10.9 after 12 months. Reduction in flexion ROM was 12.2 and recovery was 7.9. Reduction rate was 25% and recovery rate was 27.5%. Regarding extension ROM, it decreased to 42.1 ± 9.6 after 3 months and then increased to 46.5 ± 7.9 after 12 months. Reduction in extension ROM was 10.6 and recovery was 4.4. Reduction rate was 18.6% and recovery rate was 10.5%. Comparison of the preoperative and 6 months postoperative ROM revealed that patients had significantly reduced ROM after surgery. The greatest rate of reduction

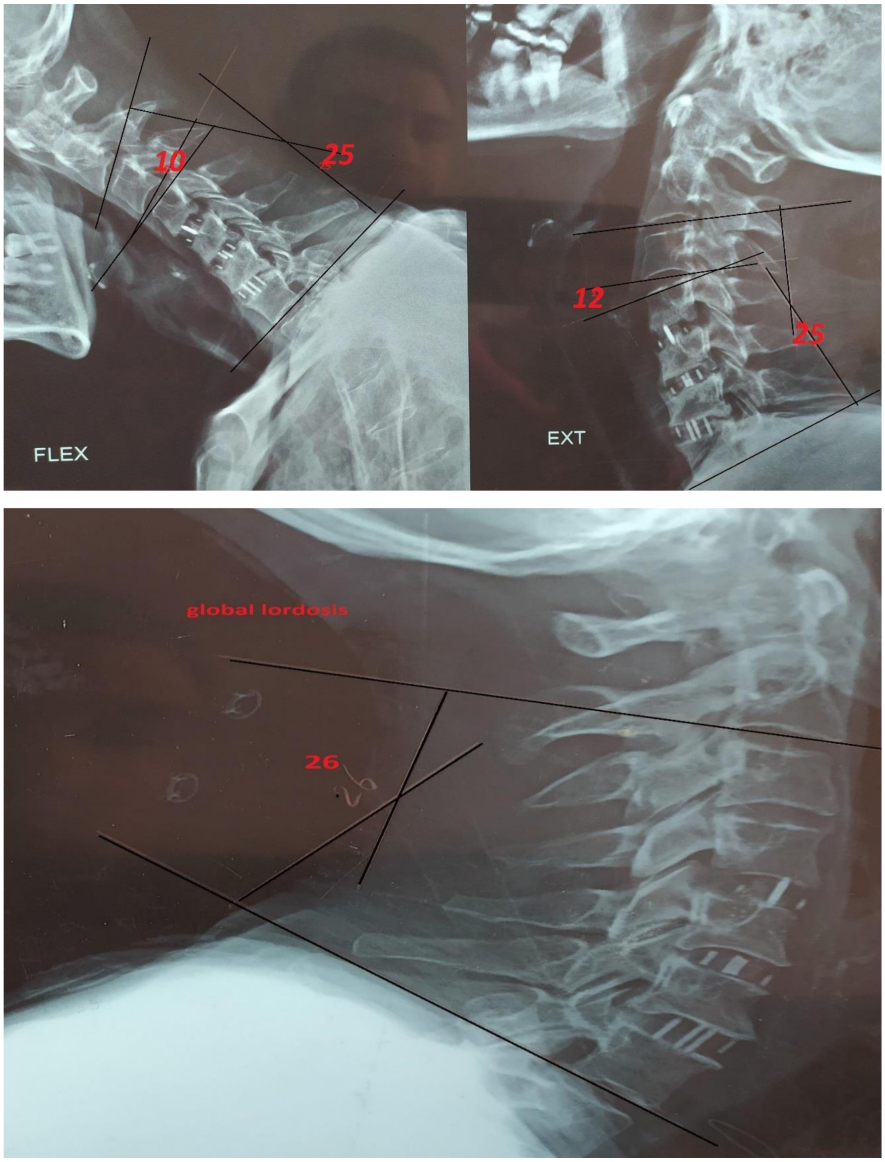

Figure 9. 6 months Postoperative X-ray Cervical spine flexion, extension and lateral views show that global lordosis was 26 and global ROM increased to 50 (25 for extension and 25 for flexion). Cranial ROM also increased to 22 (12 for extension and 10 for flexion).

at the 6 months follow-up was observed in flexion (14%) rather than extension (4.8%). Greater limitation in cervical ROM was observed at the short-term follow-up. From the short-term to the midterm follow-up, an obvious increase in ROM was observed [16]. The greatest recovery was observed in flexion (34.9%). Two main factors may have contributed to the recovery of neck motion. Muscle restraint and ligaments are the primary passive limiting elements of the cervical spine. Adhesion and edema of the soft tissue around the anterior cervical approach and muscle spasm following a long period of cervical immobilization limited neck motion in the early stage. During convalescence (3 - 6 months postoperatively), the wound adhesions gradually decreased, allowing increased neck

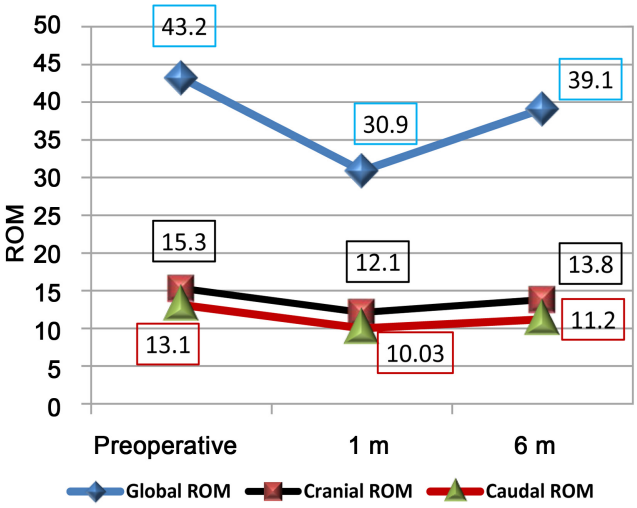

Figure 10. ROM follow up among study group.

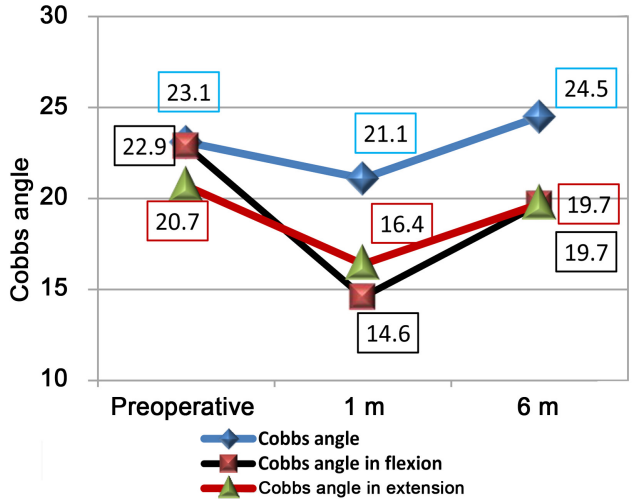

Figure 11. Cobbs angle follow up among study group.

motion in the later postoperative period. Another factor was the compensatory motion of the adjacent level. Authors of original studies have reported compensation for loss of motion at the fusion level and a trend of increased angular motion at the adjacent level, especially at 6 months postoperatively. Auerbach *et al.* have reported that increased angular motion was seen not only in the adjacent level, but also in the second and third adjacent cranial levels [17]. Although compensatory motion would accelerate degeneration of the adjacent level, it might also contribute to greater improvement of total neck motion in the midterm postoperative period. Because of the high recovery ROM in the cervical spine postoperatively, we postulated that compensatory motion could appear in the adjacent level as well as throughout the unfused cervical spine, including the upper cervical. Our study proved that there was significant increase in cranial and caudal ROM in the midterm postoperative period (recovery rate for cranial ROM was 14% and for caudal Rom was 11.7%).

6. Conclusion

Active CROM following multiple level ACDF was obviously diminished. The most affected motion after surgery was flexion. It was noticed that at the short-term follow-up CROM would be more limited and restricted while after further follow up on long or even midterm follow up CROM was obviously improved even in neck flexion motion.

Disclosure

The authors report no fund was received for this work from any organization.

Declaration

Authors declare that the article has been approved by hospital ethics committee and signed informed consents were collected from each patient.

Conflicts of Interest

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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