Comparison of the Outcomes of Anterior Cervical Discectomy and Fusion and Cervical Disc Replacement for Cervical Disc Disease

Alper Tabanli, Emrah Akcay, Hakan Yilmaz, Cafer Ak, Onur Bologur and Engin Kayikci

Department of Neurosurgery, Bozyaka Education and Research Hospital, Izmir, Turkiye

ABSTRACT

Objective: To compare the radiological outcome and development of heterotopic ossification (HO) following single-segment anterior cervical discectomy and fusion (ACDF) and cervical disc replacement (CDR) for cervical disc herniation and evaluate their impact on surgical success.

Study Design: Descriptive comparative study.

Place and Duration of the Study: Neurosurgery Department at Bozyaka Education and Research Hospital, Izmir, Turkiye, between January 2020 and June 2022.

Methodology: Patients aged 18-70 years with radicular neck pain unresponsive to conventional medical treatment and an MRI--confirmed diagnosis were included. Patients with osteoporosis (OP) were excluded. Patients were randomised into two treatment groups (ACDF and CDR) and stratified by age and symptom severity. Radiographic assessments and HO classification according to McAfee were performed.

Results: Among the included patients, 56 underwent ACDF and 45 underwent CDR. The mean patient age was 48.29 ± 9.530 and 41.84 ± 7.239 years in the ACDF and CDR groups, respectively ($p < 0.001$). The postoperative disc height increased in both groups. The T1 slope was significantly higher preoperatively and in the early postoperative period in the CDR group than in the ACDF group ($p = 0.001$). HO was graded as 1, 2, 3, and 4 in 28 (27.7%), 6 (5.9%), 7 (6.9%), and 4 (3%) patients, respectively.

Conclusion: ACDF and CDR provided similar improvements in radiological measurements and pain relief. Although both procedures significantly enhanced the patient's quality of life and disability scores, HO was more prevalent following CDR during long-term follow-up.

Key Words: *Cervical disc replacement, Anterior cervical discectomy and fusion, Spinal surgery techniques, Heterotopic ossification.*

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INTRODUCTION

Anterior cervical microdiscectomy, a surgical procedure for cervical disc herniation-induced myelopathy and radiculopathy, has been the cornerstone of spinal surgery and is known for its successful outcomes.[1] The use of synthetic cages in fusion surgery has been a significant advancement that offers benefits such as accelerated fusion, reduced operative time, and the option to distract when necessary.[2] However, the occurrence of adjacent segment disease (ASD) after fusion, particularly with cervical cages, has led to the exploration of alternative techniques.

Correspondence to: Dr. Hakan Yilmaz, Department of Neurosurgery, Bozyaka Education and Research Hospital, Izmir, Turkiye
E-mail: dr_hakanyilmaz@hotmail.com

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Anterior cervical discectomy and fusion (ACDF) has been a major surgical option for cervical disc herniation, providing relief of the myelopathy- and radiculopathy-related symptoms. However, with recent improvements, cervical disc replacement (CDR) is considered an alternative with the aim of maintaining motion and reducing the rates of ASD. In spite of these advancements, a comparison of the effectiveness and long-term outcomes of ACDF and CDR remains unclear.[1-3]

CDR restores the height and alignment of the cervical disc, which preserves mobility after discectomy and reduces the load on adjacent segments, thereby preventing ASD.[3] The development of artificial discs focuses on maintaining the physiological range of motion (ROM) and increasing the disc height. A notable complication of disc replacement is heterotopic ossification (HO), which is characterised by unintended bone formation around the joint.

Studies describing the occurrence of HO after surgery and its effect on maintaining durable good results are lesser than studies comparing the clinical outcome of ACDF and CDR. Thus, this study, tried to bridge this gap by examining how often

patients who have undergone ACDF develop HO, and whether it affects the patient's radiological parameters and quality of life.[4,5] This study aimed to compare the cervical ROM and development of HO after ACDF and CDR for the treatment of cervical disc herniation.

METHODOLOGY

Patients aged 18-70 years who presented to the Neurosurgery Department of Bozyaka Education and Research Hospital, between January 2020 and June 2022 with cervical pain radiating to the arm and neck and who underwent single-segment CDR or ACDF due to non-responsiveness to 3 weeks of medical treatment were included in the study. The authors ensured a homogeneous population of patients, only patients with cervical radicular pain that was confirmed by magnetic resonance imaging (MRI) were included in the study. The exclusion criteria were multisegment discectomy, cervical spondylosis with spondylotic myelopathy, traumatic disc herniation, and previous cervical spine surgery. The exclusion criteria were expanded to include patients with systemic diseases that affect bone metabolism, such as osteoporosis, which could confound postoperative results.

The following patient data were collected: Age, gender, symptoms, neurological status, MRI findings, and surgical outcomes.[1]

The radiographic parameters assessed were Cobb's angle, heights of the anterior and posterior discs, T1 slope, angle of the fused segment, cervical tilt, and vertical axis of the sagittal cervical alignment (Figure 1). These measurements were obtained preoperatively, early in the postoperative period, and three months and one year after the surgery.

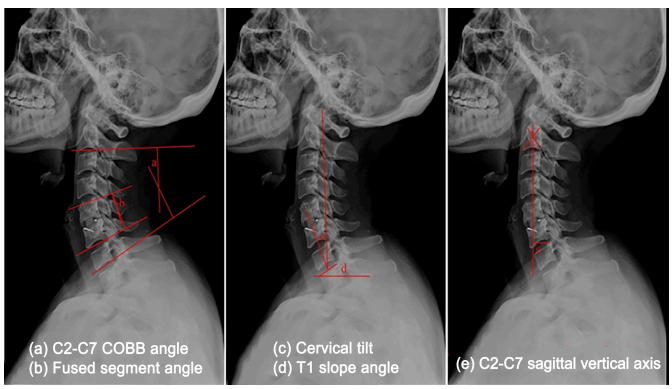

Figure 1: Parameters for sagittal cervical alignment.

The patients were randomised into two groups, CDR and ACDF, using a computer-generated random number table. Randomisation was stratified on the basis of age and symptom severity to ensure the groups were balanced.

The goal of ACDF is to increase the disc height, which could affect the sagittal alignment of the neck. Disc height has been implicated in the development of HO; however, its direct effect remains unclear.[3] HO, a complication seen following prosthetic surgeries such as hip and knee arthroplasty,[6] has been increasingly reported following disc replacement surgeries. HO was classified by McAfee in 2003,[7] and this classification was adapted for HO in cervical surgery by Mehren *et al*. in 2005.[8] HO can result from trauma to the longus colli muscles or excessive endplate removal, which could lead to fusion (Table I).[7]

Table I: Classification of heterotopic ossification (HO).[7]

Grade 0	**Absence of HO**
Grade 1	Presence of HO in front of vertebral body but not in the anatomic disc space
Grade 2	Presence of HO in the disc space, possibly affecting the prosthesis's function
Grade 3	Bridging HO with prosthesis's motion still preserved
Grade 4	Complete fusion of the segment with absence of motion in flexion/extension

HO, Heterotopic ossification

Operative techniques for CDR and ACDF were standardised. For CDR, a motion-preserving device was implanted after discectomy. In ACDF, discectomy was followed by insertion of a polyetheretherketone (PEEK) cage filled with autograft. All surgeries were performed by the same team of experienced surgeons to minimise variability in surgical technique.

To control for potential confounders, all surgeries were performed by the same surgeon, and postoperative evaluations were performed by an independent investigator blinded to the surgical technique used.

Statistical analyses were performed using IBM SPSS V22. Descriptive data were expressed as mean ± standard deviation, numeric data as median and range, and categorical data as frequency and percentage. Repeated measures of ANOVA and Friedman's test were used for time-point comparisons, and Bonferroni correction was used for multiple comparisons. The differences between the ACDF and CDR groups were analysed using Student's t-test or Mann-Whitney U test, and the categorical variables were compared using Pearson's Chi-square test. Statistical significance was set at $p < 0.05$.

The sample size was calculated based on previous studies reporting a 15% difference in the primary result of increased disc height between the CDR and ACDF groups. Assuming an alpha of $p < 0.05$ and a power of 80%, a total of 120 patients (60 patients per group) were required.

RESULTS

A total of 101 patients underwent surgery for cervical disc herniation. Of the 101 patients, 62 (61.3%) were women and 39 (38.6%) were men. The C3–C4, C4–C5, C5–C6, and C6–C7 levels were involved in 5 (5%), 14 (13.9%), 44 (43.6%), and 38 (37.6%) patients, respectively. Among the included patients, 56 (55.4%) received polyetheretherketone cage (PC) and 45 (44.5%) received prosthesis (PR) after anterior cervical discectomy, respectively. The mean ages of the patients who received PC and PR were 48.29 ± 9.530 and 41.84 ± 7.239 years, respectively; the difference in age was not statistically significant ($p < 0.001$a). The gender distribution was similar between the two groups ($p = 0.329$b).

There were no significant difference in the C2-C7 Cobb's angles between the different time points in the PC and PR groups ($p = 0.169$ and $p = 0.780$, respectively). The C2-C7 Cobb's angle was

statistically significantly higher 3 months after PR than after PC (p = 0.036). However, long-term follow-up did not reveal any significant differences between the two groups. In the PR group, differences in the C2-C7 Cobb's angle at different time points were not statistically significant (p >0.05). Thus, neither ACDF nor CDR caused a statistically significant difference in the C2-C7 Cobb's angle (Table II).

Table II: Comparison of C2-C7 Cobb angle measurements and cervical tilt values of individuals in two groups.

	PC (n = 56)	PR (n = 45)	p-value[a]
Preop Cobb	13.59 ± 4.586	14.2 ± 6.086	0.569
Early Postop Cobb	12.62 ± 4.321	13.94 ± 5.345	0.173
Postop 3 month Cobb	12.76 ± 3.937	14.48 ± 4.183	0.036
Postop 1 Cobb, Cobb, Cobb, for the year Cobb	12.76 ± 4.598	13.96 ± 4.888	0.210
p[b]	0.169	0.780	
Cervical tilt of preop	15.92 ± 5.554	17.18 ± 6.283	0.288
Early postop cervical tilt	15.18 ± 4.82	17.68 ± 5.001	0.013
Postop 3 month cervical tilt	15.62 ± 4.459	16.53 ± 5.08	0.340
Postop 1 cervical tilt year	14.92 ± 5.972	16.7 ± 4.801	0.107
p[b]	0.333	0.148	

a: Student's t-test; mean ± standard deviation. b: ANOVA test in repeated measurements; mean ± standard deviation. PR, Prosthesis; PC, Polyetheretherketone cage; Preop, Preoperative; Postop, Postoperative.

There was no significant difference in the cervical tilt between the different time points in both PC and PR groups (p = 0.333 and p = 0.148, respectively). The cervical tilt was only statistically significantly higher in the early postoperative period after PR group than after PC (p = 0.013). However, long-term follow-up did not reveal any significant differences (Table II). Thus, neither ACDF nor CDR caused a statistically significant difference in the cervical tilt.

There was a statistically significant difference in disc height between the different time points in both the PC and PR groups (p <0.001 and p <0.001, respectively). Furthermore, in both the groups, the preoperative disc height was lower than the height at all postoperative time points. There was no difference in the disc heights between the PC and PR groups at each time point (p >0.05, Table III). Thus, the disc height increased following ACDF as well as CDR, and neither method was superior to the other.

There was no difference in the fused segment angles between the different time points in the PC group; however, the difference was significant in the PR group (p = 0.169 and p = 0.014, respectively). The difference in the PR group was caused by differences in the preoperative and 1-year postoperative fused segment angles. Furthermore, the fused segment angles were statistically significantly higher 3 months after PR than after PC (p = 0.035). Thus, CDR produced a significant increase in the fused segment angle and led to better physiological lordosis than ACDF (Table III).

There was no difference in the T1 slope between different time points in the PC group; however, there was a significant difference in the T1 between two time points in the PR group (p = 0.280 and p = 0.001, respectively). This difference in the PR group was caused by the difference in T1 slope values between before and 3 months after the operation. The T1 slope was significantly higher in the PR group than in the PC group at both preoperative and early postoperative time points (p = 0.03 and p = 0.043, respectively). Thus, CDR produced a significant increase in the T1 slope and led to better physiological lordosis than ACDF (Table III).

Table III: Comparison of disk height, fused segmental angle, and T1 slope values of individuals in two groups.

	PC (n = 56)	PR (n = 45)	p-value[a]
Preop disk height[1]	4.7 (1.8 – 6.5)[2,3,4]	4.3 (2.1 – 6.1)[2,3,4]	0.098
Early postop disk height[2]	5.9 (4.9 – 7.6)[1]	6.1 (5.1 – 8.6)[1]	0.293
Postop 3 month disk height[3]	5.9 (3.4 – 8)[1]	6.1 (5.1 – 8.1)[1]	0.261
Postop 1 year disk height[4]	6 (3.4 – 7.8)[1]	6.1 (5.1 – 8.3)[1]	0.177
p[b]	<0.001	<0.001	
Pre-op fused segmental angle	3.3 (0.6 – 13)	3.3 (0.6 – 9.4)	0.361
Early postop fused segmental angle	3.3 (0.6 – 14.8)	3.3 (0.8 – 8.6)	0.720
Postop 3 month fused segmental angle	3 (0.4 – 10.6)	3.8 (1.1 – 9.4)	0.035
Postop 1 Year fused segmental angle	3.2 (0.7 – 11.8)	3.6 (0.6 – 8.1)	0.105
p[b]	0.127	0.014	
Preop slope[1]	16.4 (3.6-32.7)	22.2 (5.8-32.9)[3]	0.037
Early postop slope[2]	17.4 (7.5-32.8)	20.8 (8.1-31.7)	0.043
Postop 3 month slope[3]	15.25 (7.9-33.6)	21.1 (1.20-31.10)[1]	0.051
Postop 1 year slope[4]	15.95 (8.6-32.1)	20.9 (5.8-29.6)	0.115
p[b]	0.280	0.001	

a: Mann-Whitney U test; median (min-max). b: Friedman test; median (min-max). PR, Prosthesis; PC, Polyetheretherketone cage; Preop, Preoperative; Postop, Postoperative.

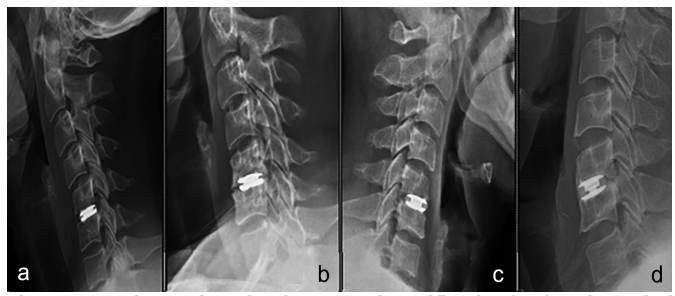

Figure 2: Grade 3 and grade 4 heterotopic ossification (HO) at the end of the first year.

There was no statistically significant difference in the sagittal vertical alignment (SVA) (C2–C7 sagittal vertical axis) between the different time points in the PC and PR groups (p = 0.472 and p = 0.891, respectively). Similarly, there was no significant difference in the SVA between the PC and PR groups at each time point (p >0.05).

There was a significant difference in the visual analogue scale (VAS) scores between the different time points in both the PC and PR groups (p <0.001 and p <0.001, respectively). The preoperative VAS score was significantly higher than the VAS score at all other postoperative time points. However, there was no significant difference in the VAS score between the PC and PR groups at each time point. Thus, although both CDR and ACDF effectively improved the VAS scores, neither was superior to the other.

There was no significant difference in the neck disability index (NDI) between the different time points in the PC and PR groups (p = 0.742 and p = 0.275, respectively). Similarly, there was no significant difference in the NDI between the PC and PR groups at each time point.

There was no significant difference in the Japanese orthopaedic association (JOA) score between the different time points in the PC and PR groups (p = 0.994 and p = 0.842, respectively). Similarly, there was no significant difference in the JOA scores between the PC and PR groups at each time point (p >0.05).

In the study, 28 (27.7%), 6 (5.9%), 7 (6.9%), and 4 (3%) patients had grade 1, 2, 3, and 4 HO, respectively (Figure 2). Furthermore, 17 (37.7%) of the 45 patients who underwent CDR

developed significant HO at the end of the first year. Because 11 of these patients developed severe HO by the end of the first postoperative year, this number may increase with longer follow-up, particularly among patients with higher grades. Furthermore, CDR is likely to be less effective in maintaining long-term mobility (Figure 2).

DISCUSSION

After the initiation of surgery management for cervical disc herniation, initial discussions focused on fusion following anterior cervical discectomy.[9] Several studies have compared the clinical, radiographic, and biomechanical outcomes of patients undergoing ACDF and CDR.[10,11] Some studies report that CDR helps maintain cervical physiologic mobility, leading to better clinical outcomes. However, other studies have claimed the opposite. Thus, there is no clear consensus on this issue due to the development of postoperative complications such as axial pain, malalignment, ASD, and HO.[12]

Cervical disc disease is most commonly observed in patients aged 40-60 years, with no clear gender prevalence.[13] In this study, the mean age of the patients in the PC and PR groups was 48.29 ± 9.530 and 41.84 ± 7.239 years, respectively; patients in the fourth decade of life were the most commonly affected. However, there was no difference in the gender distribution.

Fusion materials, such as bone graft and PC, are frequently used to increase the disc height and prevent loss of segmental and global lordosis. However, in CDR, a PR is used to maintain mobility. In this study, the global and segmental cervical lordosis was normal in the PC and PR groups, which is consistent with the findings of previous studies.[14]

The purpose of using PC and PR after anterior cervical discectomy is to prevent segmental kyphosis and restore the normal lordotic cervical alignment. Decreased anterior disc space height can cause segmental misalignment and kyphotic angulation.[15] Thus, restoring the disc height helps correct cervical alignment and relieve the compression on the nerve root. In this study, the disc height was increased in both PC and PR groups, with neither procedure proving to be superior (Table II).

Cervical disc prostheses are designed to restore cervical disc space and ideal cervical lordosis as well as prevent fusion after discectomy.[16] Hilibrand *et al*. reported a relative incidence of 3% of postoperative ASD per year.[17] This study, found a lower annual incidence, which may be attributed to the shorter follow-up period. Studies with a longer follow-up may report higher rates.[18]

CDR, as an alternative to ACDF, aims to preserve segmental ROM and function and minimise the risk of adjacent segmental degeneration.[19] However, the postoperative segmental ROM often differs from the preoperative value, and it can decrease shortly after the procedure.[20] Factors that contribute to the decrease in segmental ROM include limited preoperative ROM, avoidance of forward bending during postoperative radiography, and postoperative neck pain.[21] Longer follow-up studies have demonstrated a significant improvement in postoperative segmental ROM from the preoperative value.[22]

A previous study with a one-year follow-up[23] reported more mobile segments than a study with a five-year follow-up, and the rates of grade 4 HO were lesser after CDR than after ACDF. Grade 4 HO bridges the disc space and limits segmental ROM. Therefore, the increased segmental ROM following CDR may be attributed to the low prevalence of grade 4 HO. In this study, the HO grade varied among patients, indicating the need for further studies with longer follow-ups.[24]

This study had several limitations, including its retrospective nature, single-centric design, and short to medium-term follow-up period. These aspects may affect the long-term applicability and generalisability of the findings.

CONCLUSION

Both ACDF and CDR effectively improve cervical alignment, disc height, and patient's quality of life, and one is not superior to the other. Although CDR better preserves ROM, both procedures demonstrated an increase in HO rates over time, potentially limiting segmental ROM during long-term follow-up. Nonetheless, CDR has the potential to maintain segmental ROM and delay the onset of ASD.

ETHICAL APPROVAL:
The study was approved by the local Ethics Committee of the Hospital for Education and Research of the University of Health Sciences (12/02/2020-04).

PATIENTS' CONSENT:
The consent of the patients was taken prior to the initiation of this study.

COMPETING INTEREST:
The authors declared no conflict of interest.

AUTHORS' CONTRIBUTION:
AT: Data collection and design of the work.
EA: Final approval of the version.
HY: Drafting the manuscript.
CA: Data analysis and interpretation.
OB: Critical revision of the manuscript.
EK: Design of the work.
All authors approved the final version of the manuscript to be published.

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