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ORIGINAL ARTICLE – OPEN ACCESS

One-Year Outcome Comparison of Polyetheretherketone Cage and Disc Prosthesis in Cervical Disc Replacement Surgery

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ABSTRACT

Objective: Anterior cervical microdiscectomy (ACD) is an established surgical method to treat cervical disc disease. Since ACD changes the natural distribution of biomechanical forces, grafts are often used. The most commonly used grafts are a polyetheretherketone (PEEK) cage or a cervical disc prothesis (CDP). This study is a comparison of the early period results of single-level ACD performed using a PEEK cage or a CDP.

Materials and Methods: A total of 80 patients with a single-level cervical disc herniation who underwent ACD with PEEK cage (n=40) or CDP (n=40) implantation between 2015–2018 at a single center were retrospectively evaluated. The Cobb angle, T1-slope angle, segmental fusion angle, cervical-tilt angle, and disc height at the operated level were measured using cervical lateral radiographs and magnetic resonance images obtained preoperatively and at 1 day, 1 month, and 12 months postoperative. Neck pain was also evaluated pre- and postoperatively.

Results: No statistically significant difference was seen between the groups in the parameters measured at the first and 12th months (p=0.481). In both groups, the preoperative and 12th-month measurements were found to be statistically significant (p=0.001). The development of adjacent segment disease (ASD) was not statistically different between groups.

Conclusion: Although a CDP has some advantages in short-term outcomes, there is still insufficient evidence regarding long-term outcomes, particularly regarding the prevention of ASD. CDP implantation offers an earlier return to work and no requirement for an external cervical orthosis, but due to the high cost and some specific complications, such as implant dislocation, heterotopic ossification, and fusion, CPD is still far from a gold-standard treatment option, even for selected cases.

Keywords: Adjacent segment disease, anterior cervical microdiscectomy, cervical disc disease, cervical disc prosthesis, polyetheretherketone cage

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INTRODUCTION

Cervical disc disease (CDD) is a group of disorders affecting the spine and nerve roots that generally develops in the third and fourths decades of life. CDD can present with symptoms of radiculopathy and myelopathy due to progressive foraminal and/or central stenosis. Although most symptomatic patients recover with conservative treatment, some have persistent and/or worsening symptoms that require surgery to remove the herniated disc and/or eliminate osteophytic compression.

Various methods have been used to achieve bone fusion, such as autologous iliac crest grafts and polyetheretherketone (PEEK) cages. Recently, a stand-alone PEEK cage has been preferred due to complications associated with the plate and screw stabilization used in anterior cervical microdiscectomy (ACD) with fusion (ACDF) (1, 2). The radiolucent nature and low elastic modulus of PEEK cages are appealing attributes in comparison with titanium and bone grafts used to provide spinal fusion. However, they also have potential drawbacks, such as pseudoarthrosis, subsidence, and displacement of the cage (3). Cervical disc prostheses (CDPs) were designed to have the biomechanical advantage of preserving segmental range of motion and cervical kinematics by theoretically reducing and/or preventing adjacent segment degeneration. However, the use of a CDP also includes potential complications, such as heterotopic ossification (HO) and implant dislocation or subsidence (4).

Spinal imbalance in the sagittal plane is an important factor in the clinical symptoms and pain caused by degenerative diseases (5, 6). The Cobb angle (angle between the horizontal lines drawn from the C2 and C7 inferior endplates), T1-slope angle (angle between the upper end plate of T1 and the horizontal reference line), segmental fusion angle (Cobb angle between the lines drawn from the superior endplate of the uppermost vertebral body and the inferior endplate of the lowermost vertebral body in the fused segment length), cervical tilt (angle between the line extending to the middle of the T1 superior endplate and vertical line through the middle of T1), and the anterior/posterior disc height are the parameters used to evaluate the cervical spine in the sagittal plane.

Some clinical studies have demonstrated that adjacent segment disease (ASD) developed less frequently in cases of the use of a CDP, whereas other studies have indicated that the incidence of ASD was similar after cervical disc arthroplasty and ACDF (6). The aim of the present study is to contribute to the literature regarding this controversial topic by comparing the use of a PEEK cage and a CDP in terms of fusion and ASD in patients who underwent single-level ACD at a single clinic.

MATERIALS and METHODS

Ethics approval for this retrospective study was obtained from the Noninterventional Clinical Research Ethics Committee of Sivas Cumhuriyet University on November 11, 2019 (no: 2019-11/09).

A total of 80 patients with a single-level cervical disc herniation who underwent ACD followed by PEEK cage (n=40) or CDP (n=40) implantation between January 2015 and December 2018 were evaluated. The patients underwent neurologic examinations and 2-way cervical radiography preoperatively and at 1 day, 1 month, and 12 months postoperative and cervical magnetic resonance imaging (MRI) preoperatively and at 12 months postoperative. The Cobb angle, anterior and posterior disc heights, T1 slope angle, segmental fusion angle, and the cervical tilt were measured from cervical MRI results and 2-way cervical direct radiographs. Neck pain was evaluated preoperatively and at 12 months postoperative using a visual analog scale (VAS).

Statistical Analysis

The data were analyzed using IBM SPSS Statistics for Windows, Version 22.0 (IBM Corp., Armonk, NY, USA). As a Kolmogorov-Smirnov test indicated that the data were normally distributed, an independent-samples t-test was used to compare the measured variables between 2 independent groups, and a paired-samples t-test was used to compare repeated measures between patients. Multiple measurements from the same patients obtained at different times and conditions were compared using repeated-measures analysis of variance with a Bonferroni test and a chi-squared test to identify significantly different groups. The data were presented as the arithmetic mean and SD or as the number and percentage. The significance level was set at 0.05.

RESULTS

The study group included 11 (27.5%) men and 29 (72.5%) women who underwent PEEK cage implantation and 14 (35.0%) men and 26 (65.0%) women who underwent CDP implantation. The mean age of the patients in the PEEK cage and CDP groups was 48.12±11.51 years and 44.27±9.42 years, respectively (χ^2=0.52; p=0.469). CDD had developed in the C5–6 region in 45 patients (56.3%) and C6–7 in 28 patients (35.0%) (χ^2=4.84; p=0.304).

There was no significant difference in the Cobb angle (Fig. 1a, b, 2a, b), T1 slope angle, or cervical tilt measured using 2-way cervical radiographs obtained preoperatively and at 1 month and 12 months postoperative between the groups (p>0.05). There were no significant differences in the segmental fusion angles measured preoperatively and at 1 month postoperative between the groups

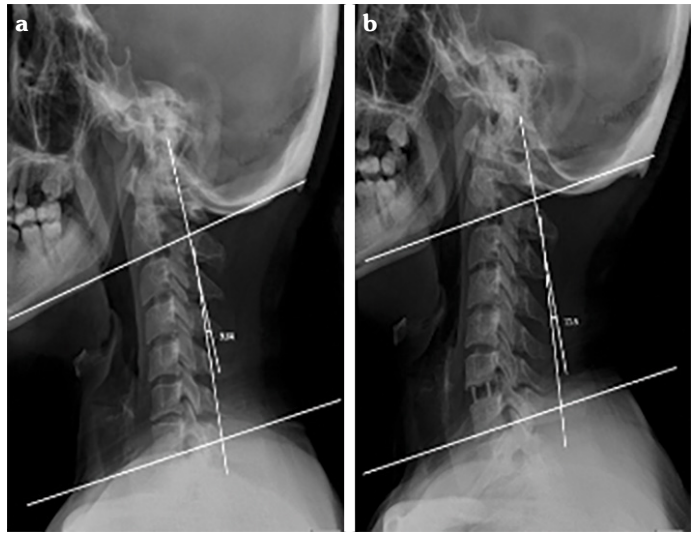

Figure 1. (a) Measurement of the Cobb angle (the angle between the horizontal lines drawn from the lower endplates of the C2 and C7 vertebrae) before placement of a polyetheretherketone (PEEK) cage; (b) Measurement of the Cobb angle after PEEK cage placement

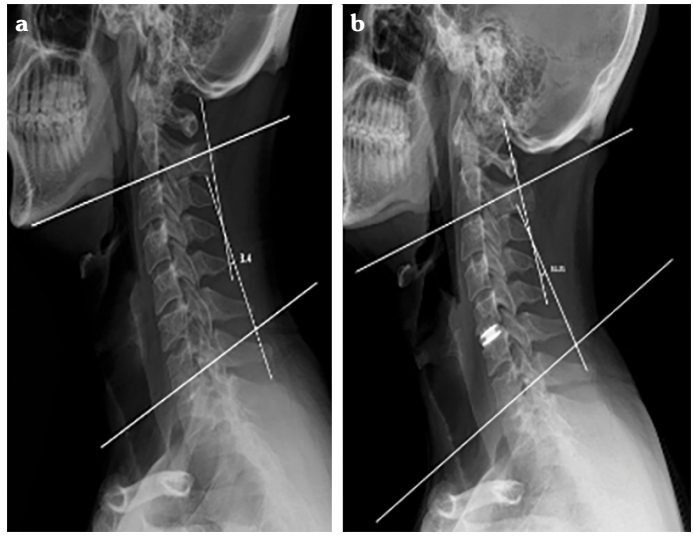

Figure 2. (a) Measurement of the Cobb angle (the angle between the horizontal lines drawn from the lower endplates of the C2 and C7 vertebrae) before the prosthesis was placed; (b) Measurement of the Cobb angle after prosthesis placement

(p>0.05), but there was a significant difference between the groups at 12 months (p<0.05) (Table 1, 2).

There were significant differences between the groups in both the anterior and posterior disc heights measured using cervical MRI obtained preoperatively and at 12 months post surgery (p<0.05) (Table 1, 3).

A significant difference in the fusion rate at 12 months was observed between the PEEK cage and CDP groups (p<0.05). In the PEEK cage group, 67.5% of the patients had fusion at the operated level at 12 months, while 25% demonstrated fusion in the CDP group (p=0.012) (Table 4).

Table 1. Comparison of T1-slope angle, fusion, cervical-tilt angle, and anterior and posterior disc heights of patients with a polyetheretherketone cage and cervical disc prosthesis measured preoperatively and in the postoperative 1st and 12th months

	PEEK			CDP		
	M	SD		M	SD	
T1-slope angle						
Preoperative	19.62	5.50	F=6.11	21.82	5.89	F=0.66
1st month	21.43	6.05	p=0.001*	21.45	5.97	p=0.77
12th month	22.56	5.54		21.91	5.84	
Fused						
Preoperative	9.40	4.50	F=1.21	8.28	4.90	F=0.07
1st month	10.43	5.21	p=0.30	8.40	5.03	p=0.92
12th month	10.84	3.91		8.60	5.72	
Cervical-tilt angle						
Preoperative	2.75	0.56	F=40.04	2.98	0.98	F=15.72
1st month	2.42	0.53	p=0.001*	2.51	0.76	p=0.001*
12th month	2.17	0.46		2.40	0.58	
Pair anterior						
Preoperative	3.40	0.90	t=7.93	4.79	0.91	t=4.66
12th month	4.71	0.80	p=0.001*	5.37	0.72	p=0.001*
Pair posterior						
Preoperative	3.61	0.99	t=7.13	4.76	0.82	t=5.18
12th month	4.51	0.73	p=0.001*	5.34	0.68	p=0.001*

*: Significant (p<0.05). CDP: Cervical disc prosthesis; PEEK: Polyetheretherketone; M: Mean; SD: Standard deviation

Table 2. Comparison of measured angles between patients who underwent polyetheretherketone cage and cervical disc prosthesis implantation

	Preoperative			Postoperative 1 month			Postoperative 12 months		
	M	SD		M	SD		M	SD	
Cobb angle									
PEEK	11.52	6.13	t=0.21	11.17	6.65	t=0.99	14.18	7.25	t=0.20
CDP	11.19	7.35	p=0.830	12.87	8.47	p=0.321	13.78	9.94	p=0.839
T1-slope angle									
PEEK	19.62	5.50	t=1.72	21.43	6.05	t=0.01	22.56	5.54	t=0.51
CDP	21.82	5.89	p=0.089	21.45	5.97	p=0.989	21.91	5.84	p=0.611
Segmental fusion angle									
PEEK	9.40	4.50	t=1.06	10.43	5.21	t=1.77	10.84	3.91	t=2.04
CDP	8.28	4.90	p=0.290	8.40	5.03	p=0.080	8.60	5.72	p=0.044*
Cervical-tilt angle									
PEEK	2.75	0.56	t=1.29	2.42	0.53	t=0.59	2.17	0.46	t=1.95
CDP	2.98	0.98	p=0.198	2.51	0.76	p=0.553	2.40	0.58	p=0.054

*: Significant (p<0.05). CDP: Cervical disc prosthesis; PEEK: Polyetheretherketone; M: Mean; SD: Standard deviation

A comparison of the prevalence of ASD at 12 months postoperative revealed no significant difference between the patient groups (p>0.05). ASD developed in 15% of the patients with a PEEK cage and 7.5% of patients who received a CDP (χ^2=1.12; p=0.288) (Table 4).

There was no significant difference between the 2 groups in the persistence of neck pain at 12 months compared with the preoperative period (p>0.05) (Table 4). In the PEEK cage group, 35% of the patients reported that their neck pain decreased postoperatively, but that mild, intermittent pain persisted, while 65% re-

Table 3. Comparison of disc heights on cervical magnetic resonance imaging obtained preoperatively and at 12 months postoperative

	Preoperative			12 months postoperative		
	M	SD		M	SD	
Anterior disc height						
PEEK	3.40	0.90	t=6.81	4.71	0.80	t=3.79
CDP	4.79	0.91	p=0.001*	5.37	0.72	p=0.001*
Posterior disc height						
PEEK	3.61	0.99	t=5.65	4.51	0.73	t=5.25
CDP	4.76	0.82	p=0.001*	5.34	0.68	p=0.001*

*: Significant (p<0.05). CDP: Cervical disc prosthesis; PEEK: Polyetheretherketone; M: Mean; SD: Standard deviation

Table 4. Fusion rates and comparison of adjacent segment disease and visual analog scale neck pain scores in the polyetheretherketone and cervical disc prosthesis groups at 12 months postoperative

	PEEK		CDP		
	n	%	n	%	
Fusion					
Yes	27	67.50	10	25.0	p=0.012
No	13	32.50	30	75.0	
Adjacent segment disease					
Yes	6	15.0	3	7.5	χ^2=1.12
No	34	85.0	37	92.5	p=0.288
Neck pain					
Partial improvement	14	35.0	12	30.0	p=0.481
Complete resolution	26	65.0	28	70.0	

*: Significant (p<0.05). CDP: Cervical disc prosthesis; PEEK: Polyetheretherketone

ported that their neck pain had completely resolved. In the CDP group, 30% of patients stated that their neck pain had decreased, but that they still had mild, intermittent pain, and 70% reported that their neck pain had completely resolved (p=0.481).

DISCUSSION

Various medical and surgical methods have been used over the years to treat CDD, which is a painful condition that can seriously affect daily life. The accumulation of knowledge, experience, and technological advances have led to improved treatment methods and better results.

For the last 50 years, anterior approaches have been preferred for the surgical treatment of CDD. Anterior surgery demonstrated satisfactory results in patients without pronounced signs of posterior compression in preoperative evaluations (7). The first debate regarding CDD surgery was whether to perform fusion after ACD (8). In the early 1980s, Lunsford et al. (9) reported in a series of 253 cases that not performing fusion after ACD resulted in a higher incidence of residual shoulder and neck pain because it did not ensure normal alignment and stability of the spine. Another problem that has occurred after ACD without fusion is segmental kyphosis (10).

Fusion materials (e.g., bone graft, PEEK cage) and disc prostheses have been used to maintain disc height and prevent the loss of segmental and global lordotic alignments postoperatively. To increase the fusion rate, especially in patients with multilevel fusion, a stable segment was created with support from an anterior plate (8, 9).

As shown in Table 2, global and segmental normal cervical lordosis was achieved in both the PEEK cage and the CDP groups. Our results are consistent with those reported in the literature (11, 12).

One of the goals of using CDP and PEEK cages is to restore lost disc height to prevent segmental kyphosis and provide normal lordotic cervical alignment. Several studies have shown that loss of anterior disc height disrupts the segmental angle toward kyphosis (13, 14). Restoring disc height decreases nerve root compression by increasing the foraminal height and correcting cervical alignment. As presented in Table 3, the results of the present study are consistent with those seen in the literature. Bertagnoli et al. (15) noted that segmental anterior disc height increased by 79% (3.4±1.0 vs. 6.1±1.0 mm; p<0.0001), and posterior disc height increased by 53% (3.0±0.8 vs. 4.6±0.7 mm; p<0.0001), which were considered clinically significant changes. Given the heterogeneity of the implants used, it was determined that providing a

postoperative disc height of 5 mm could be considered suitable sagittal alignment (16).

ACDF has been performed for approximately 50 years and has proven effective in eliminating the pathology. However, a 1995 study by Goffin et al. (17, 18) indicated that 60% of patients who underwent fusion developed ASD, which led surgeons to seek mobility-preserving interventions as alternatives to fusion. CDP was developed for this purpose. That is, to provide restoration of cervical anatomic disc height and lordosis and prevention of fusion after ACD, thereby preserving mobility and preventing the development of ASD due to the load on the adjacent segment. Although the outcomes of a first cervical disc replacement procedure were poorer than expected, the improvements provided by new prostheses designed based on technological advances have allowed this technique to be used more frequently by spine surgeons since the late 1990s (19, 20).

The literature provides a great deal of data that compare the clinical, radiological, and biomechanical outcomes of surgeries performed using a CDP or a PEEK cage. Some published reports have indicated that CDPs yielded better clinical outcomes and lower rates of implant-related complications and reoperations, while others have suggested the opposite (15, 21). There is still no consensus on this subject.

Although the comparison of ASD development between the 2 groups in our study suggested better outcomes in the CPD group, the difference was not statistically significant. Despite the fact that CDPs were developed to prevent ASD, some recent studies evaluating the results of long-term follow-up suggest that CDPs are not superior to PEEK cages in this regard. Kearns et al. (18, 22) reported that the annual incidence of reoperation due to ASD was 2.3% in patients who underwent CDP implantation, similar to the 2.9% annual incidence in patients who underwent fusion. In contrast, a 2016 meta-analysis conducted by Zhang et al. (6) that included 12 studies and a total of 3234 patients revealed an incidence of ASD of 6% in the CDP group and 12% in the fusion group, and that CDP was statistically superior in terms of reoperation due to ASD.

The literature offers several articles that discuss the long-term outcomes of CDP in relation to HO, with quite different incidence rates (23, 24). While Leung et al. (21) reported a rate of 18.2%, Zhao et al. (25) determined a rate of 69% at the end of a 10-year follow-up period.

In our study, the prevalence of fusion at 1-year postoperative was 25% in the CDP group. This is higher than rates reported in the literature. The outcomes of a total of 77 single-level disc prosthesis implantations performed by Mehren et al. (26) at 2 centers indicated that HO manifested as total fusion in 7 patients (9.1%) at the end of 1 year.

Since the surgical approach for ACD with a PEEK cage or a CDP is not very different, there is no significant difference in surgical complications. Dysphagia, dysphonia, hemorrhage, recurrent laryngeal nerve injury, esophageal injury, tracheal injury, dural tear, hematoma, and spinal cord injury are potential complications of both approaches, however, dysphagia may be an exception (27). Complications specifically associated with CDP include segmental kyphosis, implant dislocation, HO, and infection.

It has been reported that a CDP is superior to a PEEK cage in terms of neurological recovery. Early mobilization and return to work are among the important advantages of CDP implantation (28). In our study, no significant difference between the groups in neck pain resolution or recovery of neurological losses was observed (Table 4). Studies have also revealed no significant difference between the 2 approaches in neck and arm pain assessed at 24 months (12, 19, 27).

In a retrospective comparative study performed by Röllinghoff et al. (29), 42 patients with unilateral cervical radiculopathy underwent shell cage fusion (23 patients) or Prestige (Medtronic, Inc. (Minneapolis, MN, USA) cervical disc arthroplasty (19 patients). The mean follow-up period was 17.5 months (range: 5.6–42.1 months). The authors reported that both treatments yielded significant improvement in all of the clinical parameters (VAS, Oswestry Disability Index, 36-Item Short Form Health Survey scores) ($p<0.001$) with no statistically significant differences between the groups. From a radiological point of view, a marked but statistically nonsignificant increase in segmental height was detected in both treatment groups. The authors found that the segmental angle had also increased significantly in both groups ($p<0.05$). As in other studies, they noted that they could not explain why better radiological results did not correspond to better clinical outcomes within the study period.

A prospective, randomized, multicenter study at 31 research centers with 7 years of prospective follow-up was conducted to evaluate the long-term safety and efficacy of cervical disc replacement with the Prestige cervical disc in 541 patients with single-level CDD and radiculopathy. The researchers found that cervical disc arthroplasty provided biomechanical stability and global neck mobility, it had the potential to preserve motion at the operated level and reduce the incidence of ASD. They found that the Prestige disc provided good clinical outcomes and preserved segmental motion (30).

Bartels et al. (31) noted in their meta-analysis that global cervical mobility did not change in patients who underwent single-level disc prosthesis implantation. They did not recommend the use of a CDP in the Netherlands because they judged that it served clinically as an expensive spacer.

CONCLUSION

Based on our results and those of larger studies in the literature, although CDPs may seem to be superior in terms of short-term outcomes, studies from large series with long-term follow-up suggest that there is insufficient evidence that a CDP prevents ASD. Therefore, the issue remains unsettled.

Published meta-analyses indicate that CDP implantation has some advantages, such as an earlier return to work and no requirement for cervical orthosis, but due to specific complications, such as implant dislocation, HO, and fusion, as well as the high cost, CPD is far from being the gold standard treatment option, even for selected cases.

Longer-term research is needed to evaluate ASD after both procedures to determine the true clinical significance. This would be best achieved in larger, prospective, randomized trials.

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Informed Consent: Written informed consent was obtained from patients who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – BS; Design – BS; Supervision – BS; Resource – BS; Materials – AI; Data Collection and/or Processing – AI, BS; Analysis and/or Interpretation – AI, BS; Literature Search – AI, BS; Writing – AI, BS; Critical Reviews – BS

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