Preliminary Analysis of Adjacent Segment Degeneration in Patients Treated with Posterior Cervical Cages: 2-Year Follow-Up

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Key words
- Adjacent segment degeneration
- Cervical fusion
- Cervical radiculopathy
- DTRAX
- Kyphosis

Abbreviations and Acronyms
ACDF: Anterior cervical diskectomy and interbody fusion
ASD: Adjacent segment degeneration
ASDegeneration: Patients without clinical symptoms defined as adjacent segment degeneration
ASDisease: Patients with clinical symptoms defined as adjacent segment disease
DHR: Disk height ratio
HO: Heterotopic ossification
ICC: Intraclass correlation coefficient
KLOSG: Kellgren and Lawrence osteoarthritis severity grade
NDI: Neck disability index
PJK: Proximal junctional kyphosis
VAS: Visual analog scale

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OBJECTIVE: **Select patients with unremitting symptoms of cervical radiculopathy may be treated with indirect foraminal decompression and fusion via placement of a cervical cage placed bilaterally through a tissue sparing, posterior approach. Segmental fusion is known to affect adjacent segments. The aim of this study was to assess the affect of posterior fusion using bilateral cervical cages on adjacent segment degeneration (ASDegeneration) at 2 years postoperatively.**

METHODS: **Fifty-three patients enrolled in a prospective multicenter study who completed the imaging protocol were available for follow-up at 2 years. Lateral cervical radiographs were acquired preoperatively and at 1- and 2-years postoperatively. Imaging was evaluated for adjacent level degeneration using the following criteria: disk height ratio (DHR) defined as the ratio of the disk height and the lower vertebrae height measured at level above and below; proximal junctional kyphosis (PJK); Kellgren and Lawrence osteoarthritis severity grade (KLOSG); and heterotopic ossification (HO). The results were compared with a repeated analysis of variance test and Bonferroni correction; $P < 0.05$ was considered significant.**

RESULTS: **At 2 years postoperatively, there were no revision surgeries at the operated level or new surgeries at the adjacent levels. Of the 102 segments evaluated, ASDegeneration was identified at 21 levels cranial to and 21 levels caudal to the index level. At 2 years, new mild ASDegeneration signs developed at 3 levels: 1 in the level above and 2 in the level below the operated segment. In patients with pre-existing disk degeneration, mild progression of ASDegeneration signs developed in 6 upper and 2 lower segments. There were no significant changes in DHR and PJK in all patients; however, when patients with signs of ASDegeneration only were evaluated, a significant decrease of the DHR was found. The mean DHRs before surgery and 1 and 2 years after surgery in all patients were 44.0 ± 8.1, 44.0 ± 8.2, and 43.1 ± 8.4 ($P = 0.1006$) and in ASD patients were 43.8 ± 7.3, 41.9 ± 6.3, and 39.6 ± 8.3 ($P = 0.0062$), respectively. Overall, at 2 years postoperatively, ASDegeneration was identified in 9 patients (17.6% when compared with all evaluated patients before surgery).**

CONCLUSIONS: **In the current study, 5.9% of subjects treated with posterior cervical cages placed bilaterally between the facet joints developed adjacent segment degeneration at 2 years. Mild progression of existing degeneration was observed in 11.8% of subjects. Further evaluation to establish long-term incidence is needed.**

INTRODUCTION

Patients with cervical spondylotic radiculopathy who fail conservative management are often treated with an anterior cervical diskectomy and interbody fusion (ACDF).[1,2] Fusion in any segment of the cervical spine is known to influence adjacent segments.[3] Immobilization of any one segment can lead to excessive loading and increased range of motion in adjacent segments.[4] Long-term observation of patients treated with ACDF has revealed degenerative changes at the proximal or distal level to the fused segment.[5] Reported risk factors predisposing to adjacent segment degeneration (ASD) after ACDF are pre-existing disease and its natural history of progression, increased segment mobility, and disruption of anatomy.[6] Although patients who have undergone ACDF are at an increased risk for adjacent disk degeneration, it remains unclear how much degeneration is related to surgical procedure and arthrodesis versus the natural history of the degenerative disease.[5,6]

Degenerative changes at the adjacent level can be divided into 2 categories: patients without clinical symptoms defined as adjacent segment degeneration (ASDegeneration) and patients with clinical symptoms defined as adjacent segment disease (ASDisease).[1,5,7] Symptomatic ASDisease in ACDF is reported to be approximately 3% per year,[4] whereas the prevalence is much higher for ASDegeneration.[8] In a meta-analysis involving 34,716 patients, Xia et al.[8] reported the prevalence of ASDisease was 6.3% (range, 0%–25%), whereas ASDegeneration was 32.8% (range, 7%–92%). Radiologic signs commonly identified in affected levels include anterior osteophyte formation, ossification of the anterior longitudinal ligament, posterior osteophyte formation, and disk height reduction.[5,9-13]

The concept of indirect neuroforaminal decompression has been described for cervical spondylotic radiculopathy.[14-16] Indirect posterior cervical nerve root decompression and fusion performed using a cervical cage placed bilaterally between the facet joints has been shown to result in favorable clinical outcomes at 12 months.[17] Stabilization achieved after bilateral posterior cervical cage implantation is reported to be similar to 1-level ACDF in biomechanical studies.[16] However, the influence of cervical cages on ASDegeneration and adjacent segment disease is unknown. Therefore, the objective of this study was to evaluate the influence of single-level indirect decompression and fusion on adjacent segments.

MATERIALS AND METHODS

A prospective, multicenter (n = 3), single-arm study was initiated in 2009. Institutional review board approval was obtained prior to study enrollment. Consecutive patients who met the inclusion and exclusion criteria and provided written informed consent were enrolled into the study. Inclusion criteria were as follows: single- or multilevel cervical spondylosis (documented on magnetic resonance imaging or computed tomography) with radicular symptoms referable to a single level that was confirmed by clinical neurologic examination, selective nerve root block or electrophysiologic studies, and no improvement after 6 weeks of nonsurgical treatment (collar immobilization, epidural steroid injections, physical therapy, or chiropractic management). Exclusion criteria were as follows: cervical spondylolisthesis of >3.5 mm, instability found on dynamic radiographs, myelopathy, cervical kyphosis, decreased bone mineral density (T score ≤−2.5), scoliosis, pregnancy, systemic inflammatory, metabolic or connective tissue disease, any metal allergies, prior fracture or fusion of the involved level, chronic infection, and involvement in worker's compensation and/or litigation.

Surgical Procedure

All enrolled patients underwent indirect decompression and posterior cervical fusion using a cervical intervertebral cage.[18] The procedure was performed under general anesthesia with the patient prone and the head resting on a donut. The shoulders were strapped down with tape, and fluoroscopy was used to visualize the cervical spine. The neck, upper back, and iliac crest were prepped. A Steinman pin was placed externally and lateral to the patient's neck and lined up with the intended facet using lateral fluoroscopy to establish a cranial-caudal incision site and trajectory to the spinal level. The incision was made one and a half fingerbreadths off the midline and extending down through the fascia. The ligamentum nuchae was identified to permit a slight medial to lateral trajectory to the joint. Blunt dissection was performed to expose to the intended facet and adjacent lateral mass, which could be directly visualized. Under fluoroscopy, an access chisel was inserted through posterior cervical incisions into both facet joints at the symptomatic level. If the patient had unilateral radiculopathy, the symptomatic side was done first. Lateral mass adjacent to the posterior facet was decorticated with a trephine decorticator. Facet end plates were decorticated with rasps, and the implant was deployed and anchored into the facet. Iliac crest aspirate with demineralized bone matrix was inserted through the guide tube onto the posterior facet and adjacent decorticated lateral mass.

Clinical Evaluation

Study subjects completed the Neck Disability Index (NDI), SF-12v2 Health Survey forms, and a visual analog scale (VAS) for both neck and arm pain before surgery and at each follow-up visit (2 and 6 weeks and 3, 6, 12, and 24 months postoperatively).

Adverse and serious adverse events, as defined by 45CFR46, were recorded. Pain, neurologic, and function symptoms were considered complications when a subject's complaint for any of these symptoms resulted in an unscheduled visit or when a subject presented with new or worsening pain, neurologic, and/or function symptoms compared with the previous visit. Indications for revision surgery were as follows: device failure or migration, radicular symptoms referable to a single level confirmed by clinical history and neurologic examination, selective nerve root block or electrophysiologic studies, and advanced imaging (e.g., computed tomography scan, computed tomography myelogram, magnetic resonance imaging) with no improvement after 6 weeks of nonsurgical treatment.

Radiographic Evaluation

All enrolled subjects underwent standing plain film radiographs of the cervical spine with anterior-posterior and lateral views in neutral, flexion, and extension positions before surgery and at the 6-week and 3-, 6-, 12-, and 24-month follow-up visits. A computed tomography scan of the cervical spine was obtained at the 12-month time point. All images were reviewed by 2 fellowship-trained orthopedic spine surgeons with 8 and 10 years of experience, respectively. Radiographic measurements were performed using Surgimap (Surgimap Spine, New York, New York, USA) software with integrated calibration. Surgimap allows for measurements of 0.1°. For each measurement, the means from 2 reviewers were calculated and used for analysis.

The following quantitative parameters were assessed on the neutral lateral radiographs before the surgery and at 2-year follow-up: segmental lordosis at the treated level measured with the Cobb method[19]; overall cervical lordosis measured between C3 and C7 using the Cobb method; and anterior, middle, and posterior disk height at the treated level defined as the shortest distance between the superior and inferior end plates of the vertebral bodies at the treated level.

Fusion at the treated level at 2-year follow-up was assessed quantitatively on

the lateral radiographs in flexion/extension views and was defined as change in interspinous distance <2 mm and translational motion <2 mm. Bridging bone on 1-year computed tomography scan was reported; computed tomography scans were not performed at 2-year follow-up.

Qualitative evaluation of implant position on radiographs acquired at 2-year follow-up involved analysis for signs of implant failure, screw back-out, device migration, or radiolucency around the implant.

Radiographic Evaluation of ASD

Lateral cervical standing radiographs were taken in a neutral position preoperatively and at 1 and 2 years postoperatively. The following evaluations were performed:

1) Disk height was measured in the middle of the disk.
2) Disk height ratio (DHR) was calculated as the ratio of the disk height (measured at mid-disk) to the height of the superior vertebrae. At C2-C3, the height of the C3 vertebra was used to calculate the ratio.
3) Proximal junctional kyphosis (PJK) was measured from the caudal end plate of the cranial vertebra of the instrumented level to the cephalad end plate of the vertebra adjacent to the cranial vertebra of the instrumented level.[6] Development of a new or increased kyphotic angle was considered to be a positive value.
4) Heterotopic ossification (HO) severity was assessed according to Park et al.[9] and scored as follows: grade 0 (no ossification), grade 1 (ossification extending across <50% disk space), grade 2 (ossification extending ≥50% across of the disk space), and grade 3 (complete bridging of the disk space).
5) Kellgren and Lawrence osteoarthritis severity grade (KLOSG) (Table 1).[21]

Radiographs were blinded and independently reviewed in random order by 2 orthopedic surgeons not involved in subject care. Each surgeon was blinded to previously documented measurements. Each independent observer assessed the grade of the adjacent segment pathology and measured disk height at the upper and lower adjacent segments and kyphosis at the upper level. One observer (orthopedic surgeon with 11 years of experience) performed all measurements one time. The second observer (orthopedic surgeon with 6 years of experience) performed all measurements twice, with a 4-week no assessment interval taken between measurements. Intra- and inter-rater reproducibility of all measurements were tested and quantified by the intraclass correlation coefficient (ICC) and the median error for a single measurement.[22] For the pathology grading scores expressed in categorical values, reproducibility was tested and quantified by the weighted Cohen κ.[23] In the case of measurement discrepancies between surgeon observers, the preoperative and 1- and 2-year follow-up radiographs were examined once again, collectively by 2 researchers, until a consensus was reached.

Table 1. Classification of Radiologic Adjacent Segment Degeneration According to Kellgren et al[20]

Grade	Definition
0	Absence of degeneration in the disk (no ossification of the ALL), osteophytes ALL
1	Minimal anterior osteophytosis (or ossification of the ALL)
2	Definite anterior osteophytosis, possible narrowing of the disk space, some sclerosis of the vertebral plates
3	Moderate narrowing of the disk space, definite sclerosis of the vertebral plates, osteophytosis
4	Severe narrowing of the disk space, sclerosis of the vertebral plates, multiple large osteophytosis

ALL, anterior longitudinal ligament.

Table 2. Radiographic Degeneration Signs at Adjacent Segments

Grading Scale	Grade	Cranial Segment	Caudal Segment
KLOSG	4	—	—
	3	6	8
	2	13	10
	1	2	3
	0	—	—
HO	3	—	2
	2	7	4
	1	11	11
	0	3	4

KLOSG, Kellgren and Lawrence osteoarthritis severity grade; HO, heterotopic ossification.

The height of a disk was defined as normal when it was equal (±10%) to the height of the disk located one level cranially or caudally, on the condition that the comparison segment did not show evidence of degeneration. Otherwise, the next level was considered for disk height assessment.[5] A decrease of the DHR at the same cervical spine segment of >10% was defined as a significant decrease.

By using the DHR and 2 degeneration scores, ASDegeneration was defined as any change from the preoperative status. In the case of progression of degeneration found in more than one pathology grading scale, the most severe degree of degeneration was used for evaluation.[5] Therefore, any minimal changes were identified.

Statistical Analysis

Normal distribution of continuous values was analyzed using the Shapiro-Wilk test. The results were compared with a repeated analysis of variance test and Friedrichson test, with $P < 0.05$ considered significant. Results of ASDegeneration and surgery incidence revealed in this study were compared with published data for ACDF using the Fisher exact test, with $P < 0.05$ considered significant. ICC values were categorized as follows: poor (<0.4), fair to good (0.4–0.7), and excellent (>0.7).[24] Interpretation of the strength of the Cohen weighted κ agreement was performed according to the criteria of Landis and Koch.[23]

The data were analyzed using JMP 10.0.2 (SAS Institute Inc., Cary, North Carolina, USA) statistical software.

RESULTS

Of the 60 subjects enrolled in the study, 53 were available at the 2-year follow-up interval; 6 were lost to follow-up and 1 died secondary to cardiac arrest during a

cholecystectomy procedure. ASD evaluation was performed on 51 of 53 available study subjects. Preoperative films were unavailable in one subject, and poor radiographic quality did not allow reliable evaluation in another. The number of treated levels are as follows: 3 (5.9%) at C3-C4, 5 (9.8%) at C4-C5 (9.8%), 35 (68.6%) at C5-C6, and 8 (15.7%) at C6-C7.

Signs of ASD were observed at baseline for 42 segments in 32 subjects (62.7%). Of these 32 subjects, 10 (19.6%) showed degeneration at both adjacent segments, 11 showed degeneration at the cranial level only, and 11 showed degeneration at the caudal segment (Table 2). No signs of ASDegeneration at baseline were noted for 19 (37.3%) subjects.

At 1 year postoperatively, 2 subjects (2/19, 10.5%) free from ASD at baseline developed mild signs of degeneration at the caudal segment (Table 3). In 2 subjects, progression of previously existing degeneration was found at the cranial segment; one subject had ASD at both the cranial and caudal levels. The one-year incidence of ASDegeneration was 5.9% (3 of 51 evaluated subjects).

At 2 years, 1 subject (1/19, 5.3%) free from ASD at baseline developed new mild signs of degeneration at the cranial segment. Progression of degeneration from the one-year evaluation was found for 5 subjects (5/32, 15.6%): 3 at the cranial adjacent segment, and 2 at the caudal segment (Table 3). This equates to 15.6% of all patients and 7.8% of evaluated adjacent segments. In 2 patients, progression of disk degeneration was found at both adjacent segments (Table 3) (Figures 1 and 2).

At 2 years postoperatively, ASDegeneration was identified in a total of 9 subjects (17.6% of all evaluated subjects). Comparing grading score distribution in patients prior to surgery and 1 and 2 years after surgery, no statistically significant difference was found in KLOGS ($P = 0.1441$) and we observed only a slightly significant difference for distribution in HO ($P = 0.0498$). Comparison of DHR and PJK preoperative values with the results at 1- and 2-years after surgery in all patients did not reveal a statistically significant difference (Table 4). Comparison of DHR and PJK preoperative values to the results at 1 and 2 years after surgery among patients with ASDegeneration revealed a statistically significant decrease of DHR (Table 4). The measurements revealed excellent inter-rater agreement for DHR (ICC = 0.97, SEM = 4.54) and PJK (ICC = 0.89, SEM = 1.46) and excellent intra-rater agreement for DHR (ICC = 0.91, SEM = 2.15) and PJK (ICC = 0.89, SEM = 1.42). The excellent intra-rater agreement was revealed for HO grading and KLOSG with the weighted κ of 0.813 and 0.772, respectively. The moderate inter-rater agreement was revealed for HO grading and KLOSG with the weighted κ of 0.671 and 0.628, respectively. A comparison of the current study with published data for ACDF, all with similar follow-up, shows a lower ASDegeneration rate in the current study and a comparable reoperation rate for ASDisease (Table 5). There were no revision surgeries at the operated level or at adjacent levels at the 2-year follow-up interval.

Table 3. Grading in Patients Who Showed Adjacent Segment Degeneration Progression

		KLOSG			HO		
Subject Number	Adjacent Segment	Preoperative	1 Year	2 Years	Preoperative	1 Year	2 Years
1	Caudal	0	2*	2	0	1*	1
2	Cranial	2	3*	3	1	1	1
2	Caudal	2	2	3*	0	0	0
3	Cranial	2	3*	3	1	1	1
3	Caudal	0	2*	2	0	1*	1
4	Cranial	0	0	2*	0	0	1*
5	Cranial	3	3	4*	2	2	2
6	Cranial	3	3	3	1	1	2*
7	Cranial	2	2	3*	2	2	3*
8	Cranial	1	1	2*	2	2	3*
9	Caudal	2	2	3*	1	1	2*

KLOSG, Kellgren and Lawrence osteoarthritis severity grade; HO, heterotopic ossification.
*Progression.

Clinical Evaluation

There was a significant decrease in the mean score from baseline on the NDI and VAS for neck and arm pain and an increase in the mean score for physical and mental

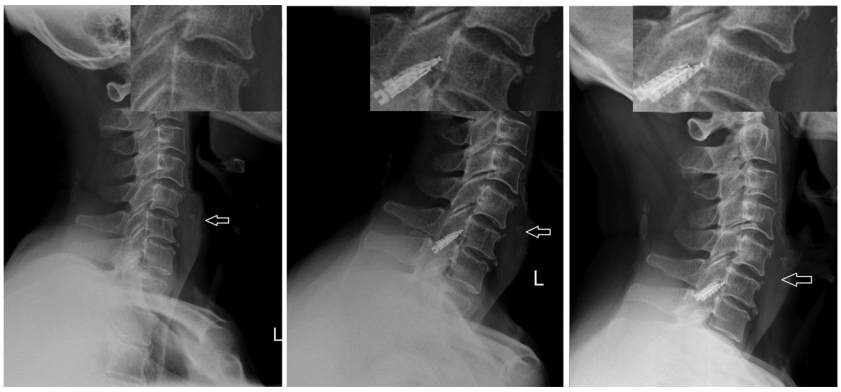

Figure 1. Radiographs of a subject with adjacent segment degeneration taken preoperatively (*left panel*), 1 year after surgery (*middle panel*), and 2 years after surgery (*right panel*). Cranial segment degenerative changes graded at baseline, 1yr, 2yr: 2,2,3 on KLOSG and 2,2,3 on HO.

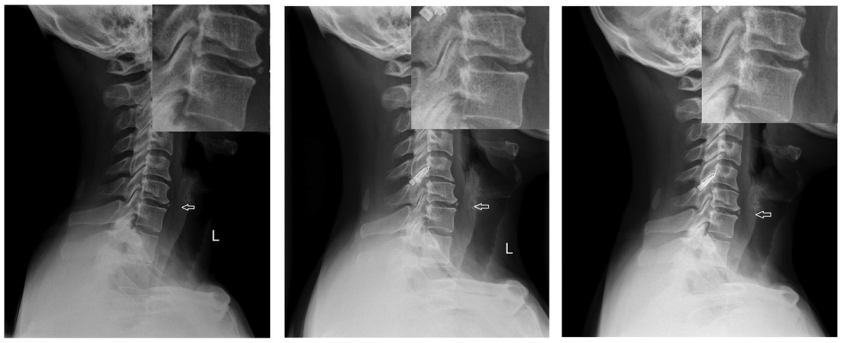

Figure 2. Radiographs of a subject with adjacent segment degeneration taken preoperatively (*left panel*), 1 year after surgery (*middle panel*), and 2 years after surgery (*right panel*). Caudal segment degenerative changes graded at baseline, 1yr and 2yrs: 2,2,3 on KLOSG and 2,2,3 on HO.

Table 4. Disk Height Ratio and Proximal Junctional Kyphosis

Assessment	Preoperative	1 Year	2 Years	*P* Value
PJK* (all patients, N = 51)	−1.02 ± 4.6	−0.86 ± 4.7	−0.59 ± 5.4	0.3015
PJK* (ASDegen patients, n = 7†)	1.85 ± 5.1	0.7 ± 3.7	3.1 ± 4.2	0.0853
DHR‡ (all segments, N = 102‡)	44.0 ± 8.1	44.0 ± 8.2	43.1 ± 8.4	0.1006
DHR‡ (ASDegen patients, n = 11§)	43.8 ± 7.3	41.9 ± 6.3	39.6 ± 8.3	0.0062

PJK, proximal junctional kyphosis; ASDegen, adjacent segment degeneration; DHR, disk height ratio.
*Friedman test; level of significance $P < 0.05$.
†Patients with degeneration of the upper level.
‡Repeated-measures analysis of variance.
§DHR patients with degeneration progression.

Table 5. Comparison of the Current Study with Published Data for Anterior Cervical Diskectomy and Interbody Fusion (Similar Follow-Up Periods)

Study	Subjects	ASDegen (%)	Scale	ASDisease Reoperation (%)	Follow-Up Mean/Minimum (months)
Current study	51	17.6	KLOSG, Park HO	0	24/24
Robertson et al.[25]	158	34.6	Authors' method	3.2	24/24
Coric et al.[11]	133	24.8	Authors' method	6.1	24/24
Li et al.[26]	116	24.1	Authors' method	0	31/24
Chung et al.[10]	56	44.7	Robertson method	Not reported	20/12
Ishihara et al.[27]	112	Not reported	Hillibrand method	6.3	24/24

ASDegen, adjacent segment degeneration; ASDisease, patients with clinical symptoms defined as adjacent segment disease; KLOSG, Kellgren and Lawrence osteoarthritis severity grade; HO, heterotopic ossification.

components of the SF-12v2 (indicating clinical improvement) at each follow-up time point up to 2 years (Table 6). There were no statistically significant differences in clinical outcomes between the 1 and 2 year time points.

All of the patients demonstrated improvement on their NDI when compared with preoperative scores; this improvement was maintained at 2 years. Of the 53 patients, 2 had an increase in arm pain and 2 had an increase in neck and arm pain. Three patients had no change in neck pain and 1 patient had no change in neck and arm pain scores for the VAS. There was no correlation between outcomes and ASDegeneration or ASDisease.[17,28]

Perioperative complications were previously reported in detail.[17] There were no revision surgeries at the index or adjacent levels at the 2-year follow-up. Additionally, there were no device migrations, expulsions, or breakages.

Radiographic Evaluation

The procedure did not alter overall cervical lordosis or segmental lordosis at the treated level (Table 7). There was a slight but statistically significant decrease in the posterior disk height at the treated level at 2-year follow-up.

The radiographic fusion rate, as defined by <2 mm change in interspinous distance measured on flexion extension radiographs taken at 24 months, was noted in 50 of 51 subjects (98.1%). Overall, the change in the interspinous distance was 0.78 ± 0.58 mm, with a range of 0.04 to 2.16 mm. Translational motion at the treated level of <2 mm was noted for all of the 51 subjects. There were no radiographic signs of implant loosening, breakage, migration, or screw back-out. Evidence of bridging trabecular bone on computed tomography scan was present in 93.3% of subjects at 12 months.

DISCUSSION

Reoperations at the adjacent segment are typically performed in patients with radicular symptoms who are nonresponsive to conservative management.[8,10] In this study we reported no reoperations caused by adjacent segment disease in the 2 years after indirect posterior cervical decompression and fusion. Importantly, all noted cases of new ASDegeneration were very mild. One of

Table 6. Patient-Reported Outcomes

Clinical Assessment Tool	Baseline	12 Months	24 Months	Baseline Versus 12 Months (*P*)	Baseline Versus 24 Months (*P*)	12 Versus 24 Months (*P*)
NDI	32.2	8.1 ± 7.0	9.1 ± 7.7	<0.0001*	<0.0001*	0.2*
VAS neck pain	7.5 ± 0.8	2.2 ± 2.2	2.6 ± 2.7	<0.0001*	<0.0001*	0.28*
VAS arm pain	7.4 ± 0.9	2.3 ± 2.4	2.6 ± 2.9	<0.0001*	<0.0001*	0.27*
SF-12 PCS	34.3 ± 6.0	45.5 ± 8.6	43.7 ± 8.4	<0.0001*	<0.0001*	0.05†
SF-12 MCS	40.3 ± 7.6	51.3 ± 7.5	51.4 ± 8.8	<0.0001†	<0.0001†	0.93†

Values are mean ± SD or as otherwise indicated.
NDI, neck disability index; VAS, visual analog scale; PCS, physical component score; MCS, mental component score.
*Wilcoxon signed-rank test.
†Paired *t* test.

the disk degeneration indicators is the DHR reduction in time in ASDegeneration patients.[24] The fact that the DHR did not change significantly in time when all patients were considered (without and with ASDegeneration together) shows that most evaluated disks were stable and not affected by ASDegeneration.

When evaluating ASDegeneration in ACDF patients, high numbers of heterotopic/adjacent segment ossification are reported.[9,29] HO is associated with fusion, anterior plate fixation, and surgical disruption of soft tissues, similar to the anterior longitudinal ligament.[9,10] In the case of ACDF, the influence of a wide anterior approach with tissue dissection should be taken into consideration. In the case of the posterior cervical decompression and fusion described here, the risk factor associated with a fixating plate and wide anterior approach is avoided.

Mild acceleration of progression could be noticed when comparing ASDegeneration in the first year and the second year of follow-up; however, a longer observation period is necessary for reliable assessment. The rate of ASDegeneration in the current study is lower than that reported in the literature after ACDF (Table 5).

In all cases of ASDegeneration reported herein, radiographic changes were very mild. At times it was difficult to discern true progression from radiographic artifact. The authors hypothesize that the cases of ASDegeneration progression are secondary to natural history and not the result of the procedure. Similarly cases of de novo radiographic ASDegeneration were very mild and rare. In addition, radiographic adjacent segment pathology after fusion does not correlate with clinical outcomes.[8,12,30] Rather, the degree of the degenerative change observed after surgery is reported to correlate with time since surgery.[5] In a meta-analysis, Xia et al.[8] demonstrated that one-fifth to one-third of patients with ASDegeneration had clinically symptomatic ASDisease, with a small subset requiring surgical intervention.

PJK is typically described to be associated with multilevel fusion than single-level cervical procedures. Change in segmental alignment was previously reported after cervical cage placement.[17] In patients who demonstrated ASDegeneration progression, a tendency toward kyphosis was seen at 2 years; however, none of the patients treated in this study with cervical cages demonstrated a statistically significance change in PJK when compared with presurgical measurements.

Several methods and grading scores for ASDegeneration are available.[4,5,9-11,13,20,25,31] Currently, there is no gold standard for this type of evaluation. Each classification system has its own advantages and limitations. Based on studies by Walraevens et al.[32] and Kettler and Wilke,[33] we have chosen to use a quantitative analysis of disk height, assessment of osteophytes, and overall qualitative disk evaluation. To avoid possible measurement differences on consecutive radiographs in the same subject, either because of radiograph quality or technical error, the disk ratio was used in lieu of disk height measurements. Anterior ossification can be assessed using various methods; however, HO grading according to Park et al.[9] appears to be the most reliable.

To perform a qualitative assessment of ASDegeneration, all disk heights and the surrounding structures should be evaluated. There are many ASDegeneration grading classifications,[4,5,31,33] but we used KLOGS.[20,21] Our choice is based on studies demonstrating good to excellent interexaminer agreement[12,34,35] and on the analysis of Kettler and Wilke,[33] who assessed the different grading classifications.

A limitation of this study is the relatively short follow-up for this type of spine pathology. Although these results are promising, long-term assessment for ASDegeneration/ASDisease will be required to determine the fate of adjacent disks in patients with single-level radiculopathy treated with cervical cages placed in facet joints via a posterior approach. Replication of these findings with a larger cohort of patients would also be advantageous to support the findings.

Table 7. Radiographic Parameters Measured Preoperatively and at 24-Month Follow-Up Interval

Parameter	Preoperative	24 Months	Net Change	*P* Value, Paired *t* Test
Overall cervical spine lordosis	14.7° ± 8.9°	13.3° ± 8.3°	−1.4°	0.40
Segmental lordosis at treated level	2.4° ± 2.3°	2.5° ± 2.4°	0.1°	0.83
Anterior disk height (mm)	3.2 ± 1.2	2.8 ± 1.4	−0.3	0.12
Mid-disk height (mm)	4.2 ± 1.1	4.0 ± 1.0	−0.2	0.33
Posterior disk height (mm)	2.6 ± 0.9	2.1 ± 0.6	−0.5	0.001*

*Statistically significant difference.

CONCLUSIONS

In the current study, 5.9% of subjects developed adjacent segment degeneration at 2 years after fusion with bilateral posterior cervical cages. Mild progression of degeneration was observed in 11.8% of subjects. Of 8 segments with degeneration at baseline, 7 showed progression by the 2-year follow-up. Cervical fusion with cervical cage placement does not appear to induce rapid progression of ASD. Further evaluation is needed to establish the long-term incidence rate.

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Conflict of interest statement: K. Siemionow is a consultant for Providence Medical Technologies and the company's implant was used to treat the patients analyzed in this radiographic study.

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