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Clinical Article

Risk Factors and Radiologic Changes in Subsidence after Single-Level Anterior Cervical Corpectomy: A Minimum Follow-Up of 2 Years

Tae Yong An [1], **Ji-Yoon Kim** [2,3], **and Young-Seok Lee** [4,5]

[1]Department of Neurosurgery, Gyeongsang National University Hospital, Gyeongsang National University School of Medicine, Jinju, Korea
[2]Department of Anesthesiology, Pain and Critical Care Medicine, School of Medicine, Kyungpook National University, Daegu, Korea
[3]Department of Anesthesiology, Pain and Critical Care Medicine, Kyungpook National University Chilgok Hospital, Daegu, Korea
[4]Department of Neurosurgery, School of Medicine, Kyungpook National University, Daegu, Korea
[5]Department of Neurosurgery, Kyungpook National University Chilgok Hospital, Daegu, Korea

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Address for correspondence:
Young-Seok Lee
Department of Neurosurgery, School of Medicine, Kyungpook National University, 130 Dongdeok-ro, Jung-gu, Daegu 41944, Korea.
E-mail: leeys1026@hanmail.net

ORCID iDs
Tae Yong An
https://orcid.org/0000-0001-5587-0423
Ji-Yoon Kim
https://orcid.org/0000-0001-7998-8936
Young-Seok Lee
https://orcid.org/0000-0002-6881-812X

Conflict of Interest
The authors have no financial conflicts of interest.

ABSTRACT

Objective: Anterior cervical corpectomy using a titanium mesh cage may result in delayed nonunion and thus a change in cervical alignment, and patients may require revision surgery. We investigated the radiologic and clinical outcomes of cervical corpectomy and the risk factors for subsidence.
Methods: We studied 74 patients who underwent single-level anterior cervical corpectomy for cervical spondylotic myelopathy with or without ossification of the posterior longitudinal ligament between 2007 and 2014. Graft subsidence was considered present when there was a reduction in the anterior and posterior heights by an average of 4 mm or more 2 years after the operation. We measured cervical parameters before surgery, immediately after surgery, and 6, 12, and 24 months after surgery. The clinical outcomes were the neck and arm visual analog scale scores and reoperation rate.
Results: In the subsidence group, these values gradually decreased over the 24 months. The radiologic parameters did not differ between the 2 groups for 24 months after the onset of subsidence. There were no differences in clinical outcome or reoperation rate. In the analysis of the risk factors, subsidence occurred with a large T1 slope and a large change in the C27 Cobb angle (p=0.020 and p=0.026, respectively).
Conclusion: Subsidence gradually occurred after single-level anterior cervical corpectomy for up to 24 months. However, the presence of subsidence did not affect the radiologic and clinical outcomes. When the T1 slope was large and the C27 Cobb angle change was severe, more subsidence occurred.

Keywords: Cervical vertebrae; Compressive myelopathy; Reconstruction; Subsidence; Surgical decompression; Titanium mesh

INTRODUCTION

Degenerative cervical stenosis is a disease characterized by degenerative changes in the cervical spine that occur with aging, narrowing of the spinal canal and instability of the spine. If the motion segments continue to exhibit instability due to multilevel degenerative cervical stenosis and spinal cord compression continues, cervical spondylotic myelopathy with radiculopathy may occur. Once cervical spondylotic myelopathy is diagnosed, surgery should be performed in a timely manner to decompress the spinal cord, stabilize the spine and improve neural function.[6,17] Anterior cervical corpectomy and fusion (ACCF) is widely used for the treatment of multilevel degenerative cervical stenosis. This surgery is safe and highly effective in treating cervical degenerative disease. Many previous studies have shown good clinical results for this procedure because it allows direct decompression of the neural elements and immediate stabilization of the affected motion segments.[2,3,5,19,22] ACCF has been confirmed to be beneficial for solid fusion and the restoration of cervical alignment. The materials used for solid fusion and stabilization include tricortical autogenous iliac bone grafts, autogenous or allogenous fibular grafts, and titanium mesh cages.[12]

However, ACCF requires more operative time and leads to more blood loss than does anterior cervical discectomy and fusion (ACDF). Moreover, ACDF maintained better cervical lordosis and segment height than ACCF.[9] These differences in results are mainly caused by the occurrence of graft subsidence over time. In addition to autogenous and allogenous fibular strut grafts, subsidence of the vertebral body occurs in titanium mesh cages.[7] Subsidence is caused by the concentration of stress on the implant, which causes cage and plate failure as well as nonfusion and cervical kyphosis worsening. In addition, anterior cervical corpectomy using a titanium mesh cage sometimes results in delayed nonunion and thus changes in cervical alignment, and patients may require revision surgery.[7,9] By reviewing the follow-up results of patients who underwent single-level corpectomy 2 years prior, we investigated the radiologic and clinical outcomes of cervical corpectomy and the risk factors for subsidence.

MATERIALS AND METHODS

Patient parameters

We investigated 74 patients who underwent single-level cervical corpectomy from 2007 to 2014. The study included patients with cervical spondylotic myelopathy with/without ossification of the posterior longitudinal ligament. Patients with infectious spondylitis, trauma and tumors were excluded from the study.

Corpectomy was performed at levels C4, C5 and C6, and age, sex, bone mineral density and the presence of ossification posterior longitudinal ligament (OPLL) were examined.

Surgical procedure

All patients underwent surgery performed by a single surgeon using the same procedure. The Smith-Robinson right-side anterior approach was performed for single-level corpectomy and intervertebral disc removal. Complete corpectomy, osteophyte removal, careful endplate preparation, and anterior cortical bone preservation were performed accordingly. The graft materials were placed in mesh cages (Medtronic, Memphis, TN, USA and Synthes Spine, West Chester, PA, USA) with autograft bone. Demineralized bone matrix and bone morphogenetic

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protein were not used. For anterior cervical plate augmentation, the Atlantis plate (Medtronic Sofamor Danek, Memphis, TN, USA) was used. We positioned a mesh cage on the anterior rim of the vertebral body to provide strong support and to prevent subsidence. The cage width was matched to the site of corpectomy to the greatest extent possible. For anterior cervical plate augmentation, the Atlantis plate (Medtronic Sofamor Danek) was used. All patients were advised to wear soft collars for 4 weeks after surgery.

Cervical parameters

Cervical parameters were measured with plain lateral radiography at 6, 12, and 24 months postoperatively. The cervical parameters measured were the anterior and posterior corpectomy heights (ACH and PCH), C27 Cobb angle, segmental angle, C27 sagittal vertical axis, neck tilt, T1 slope, and thoracic inlet angle (**FIGURE 1**). The ACH and PCH were measured between the upper endplate of the superior vertebral body and the lower endplate of the inferior vertebral body. The C27 Cobb angle was measured as the Cobb angle between the lower endplate of C2 and the lower endplate of C7. The segmental angle was measured as the Cobb angle between the upper endplate of the superior vertebral body and the lower endplate of the inferior vertebral body. The C27 sagittal vertical axis was measured as the distance between the plumb line from the center of C2 and the posterior inferior corner of C7. T1 slope was defined as the angle between the horizontal axis and the superior endplate of T1. Neck tilt was measured as the angle between the vertical line at the sternum tip and the line between the center of the sternum and the middle of the T1 upper endplate. The thoracic inlet angle was measured as the angle between the line perpendicular to the midpoint of the T1 lower endplate and the line between the center of the sternum and the middle of the T1 upper endplate. The thoracic inlet angles were measured as the sum of T1 slope and neck tilt.

Subsidence was considered present when there was a reduction in the ACH and PCH by an average of 4 mm or more 2 years after surgery.[16)]

Clinical outcomes

The subsidence group was divided into the subsidence group and nonsubsidence group. The clinical outcomes were the preoperative and postoperative neck and arm visual analog scale (VAS) scores.

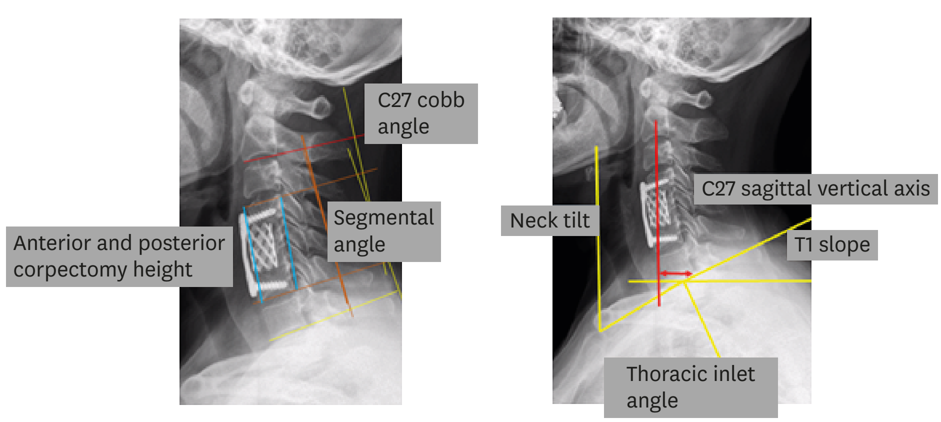

FIGURE 1. Cervical parameters assessed after single-level cervical corpectomy.

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RESULTS

Subsidence occurred in 20 of the 74 patients (27.0%). The mean age was 57.73±10.59 years, and there were 54 males and 20 females. The corpectomy site was C4 in 15 patients, C5 in 29 patients and C6 in 30 patients.

The subsidence group and the nonsubsidence group were compared. There were no significant differences in age, sex, the corpectomy level or the presence of OPLL between the 2 groups (**TABLE 1**).

Cervical parameters

The preoperative, postoperative, and pre-postoperative changes in the cervical parameters of the subsidence group and the nonsubsidence group were assessed. The preoperative T1 slope (p=0.020), change in T1 slope (p=0.026), and postoperative C27 Cobb angle (p=0.029) differed significantly between the 2 groups (**TABLE 2**). The preoperative T1 slope was 23.82°±7.37° in the nonsubsidence group and 28.46°±7.67° in the subsidence group (p=0.020). The change in the T1 slope was 2.26°±5.88° in the nonsubsidence group and −1.15°±5.23° in the subsidence group (p=0.026). In addition, the postoperative C27 Cobb angle was 8.94±8.92 mm in the nonsubsidence group and 14.10±8.62 mm in the subsidence group (p=0.029) (**TABLE 2**). We performed multivariate logistic regression analysis of the statistically significant factors. The preoperative T1 slope was a statistically significant factor (p=0.026) (**TABLE 3**).

In addition, the changes within the subsidence and nonsubsidence groups over time were assessed. In the subsidence group, the segmental angle and ACH decreased significantly from preoperatively to immediately after surgery and at 24 months postoperatively. In the subsidence group, the ACH significantly decreased from preoperatively to 24 months postoperatively, but the PCH did not decrease at 24 months postoperatively. That is, the ACH decreased more than the PCH did. The nonsubsidence group did not show changes over time in any of the cervical parameters (**FIGURE 2**).

Clinical outcomes

In the nonsubsidence group, the neck and arm VAS scores improved from 6.85±1.14 and 7.30±1.22 preoperatively to 2.07±0.86 and 1.77±0.72 postoperatively (p<0.001). In the subsidence group, the neck and arm VAS scores improved from 7.14±1.42 and 6.68±1.29 preoperatively to 1.95±0.86 and 1.64±0.69 postoperatively (p<0.001). In addition, there

TABLE 1. Parameters for the patients who did and did not exhibit subsidence after single-level cervical corpectomy

Parameters	All	Subsidence group (n=20)	Nonsubsidence group (n=54)	p-value
Age	57.73±10.59	57.37±11.07	58.70±9.35	0.635
Sex (M:F)	44:20	13:4	41:16	1.000
BMD	−0.30±1.46	−0.24±1.36	−0.42±1.69	0.667
Corpectomy level				0.879
C4	15	4	11	
C5	29	7	22	
C6	30	9	21	
Smoking	25	10	15	0.098
Hypertension	21	9	12	0.080
DM	10	2	8	0.719
Presence of OPLL	37	6	31	0.065

BMD: bone mineral density, DM: diabetes mellitus, OPLL: ossification posterior longitudinal ligament.

TABLE 2. Cervical parameters of the subsidence and nonsubsidence groups

Parameters	Subsidence group (n=20)	Nonsubsidence group (n=54)	*p*-value
Preoperative C27 Cobb angle (°)	14.95±10.82	11.02±10.28	0.154
Preoperative segmental angle (°)	5.85±7.11	2.98±8.13	0.168
Preoperative ACH (mm)	5.57±0.79	5.64±0.48	0.721
Preoperative PCH (mm)	5.42±0.77	5.56±0.46	0.448
Preoperative C27 sagittal vertical axis (mm)	22.11±12.85	21.22±10.98	0.769
Preoperative T1 slope (°)*	28.46±7.67	23.82±7.37	0.020
Preoperative thoracic inlet angle (°)	78.25±10.19	76.39±8.59	0.437
Preoperative neck tilt (°)	49.80±7.55	52.58±6.81	0.135
Δ C27 cobb angle (°)	−0.85±7.40	−2.07±7.64	0.539
Δ Segmental angle (°)	1.10±6.95	1.41±6.67	0.862
Δ ACH (mm)	0.19±0.42	−0.03±0.49	0.091
Δ PCH (mm)	0.14±0.51	−0.06±0.42	0.514
Δ C27 sagittal vertical axis (mm)	−2.29±9.64	2.41±10.62	0.088
Δ T1 slope (°)*	−1.15±5.23	2.26±5.88	0.026*
Δ Thoracic inlet angle (°)	−0.37±1.18	1.15±9.63	0.487
Δ Neck tilt (°)	0.79±5.19	−1.11±8.15	0.337
Postoperative C27 cobb angle (°)*	14.10±8.62	8.94±8.92	0.029
Postoperative segmental angle (°)	6.95±6.88	4.39±6.52	0.144
Postoperative ACH (mm)	5.75±0.52	5.61±0.38	0.192
Postoperative PCH (mm)	5.44±0.66	5.50±0.38	0.683
Postoperative C27 sagittal vertical axis (mm)	19.82±9.98	23.63±9.38	0.132
Postoperative T1 slope (°)*	27.31±6.54	25.63±5.39	0.268
Postoperative thoracic inlet angle (°)	77.89±9.89	76.13±8.19	0.441
Postoperative neck tilt (°)	50.58±7.41	50.49±6.93	0.963

ACH: anterior corpectomy height, PCH: posterior corpectomy height.
**p*-value<0.05.

TABLE 3. Multivariate analysis logistic regression analysis of risk factors for subsidence after single-level anterior cervical corpectomy

Parameter	OR	95% CI		*p*-value
		Lower	Upper	
Preoperative T1 slope	0.916	0.847	0.989	0.026

OR: odds ratio, CI: confidence interval.

TABLE 4. Clinical outcomes of the subsidence and nonsubsidence groups

Parameters	All	Subsidence group (n=20)	Nonsubsidence group (n=54)	*p*-value
Preoperative neck VAS	7.07±1.34	7.14±1.42	6.85±1.14	0.398
Postoperative neck VAS	1.98±0.86	1.95±0.86	2.07±0.86	0.634
Preoperative arm VAS	6.85±1.29	6.68±1.29	7.30±1.22	0.045
Postoperative arm VAS	1.67±0.70	1.64±0.69	1.77±0.72	0.557

VAS: visual analog score.

were no significant differences in neck and arm VAS scores between the nonsubsidence and subsidence groups ($p>0.05$) (**TABLE 4**).

DISCUSSION

Cervical corpectomy can be used to treat almost any pathology that causes spinal compression, such as osteophytes, discs, and ossified posterior longitudinal ligaments[8,18]; after corpectomy, the anterior column may be supported using structural autogenous and allogenous grafts and titanium mesh cages.[12] This surgery can be used to relieve symptoms associated with cervical spondylotic myelopathy and preserve structural stability.

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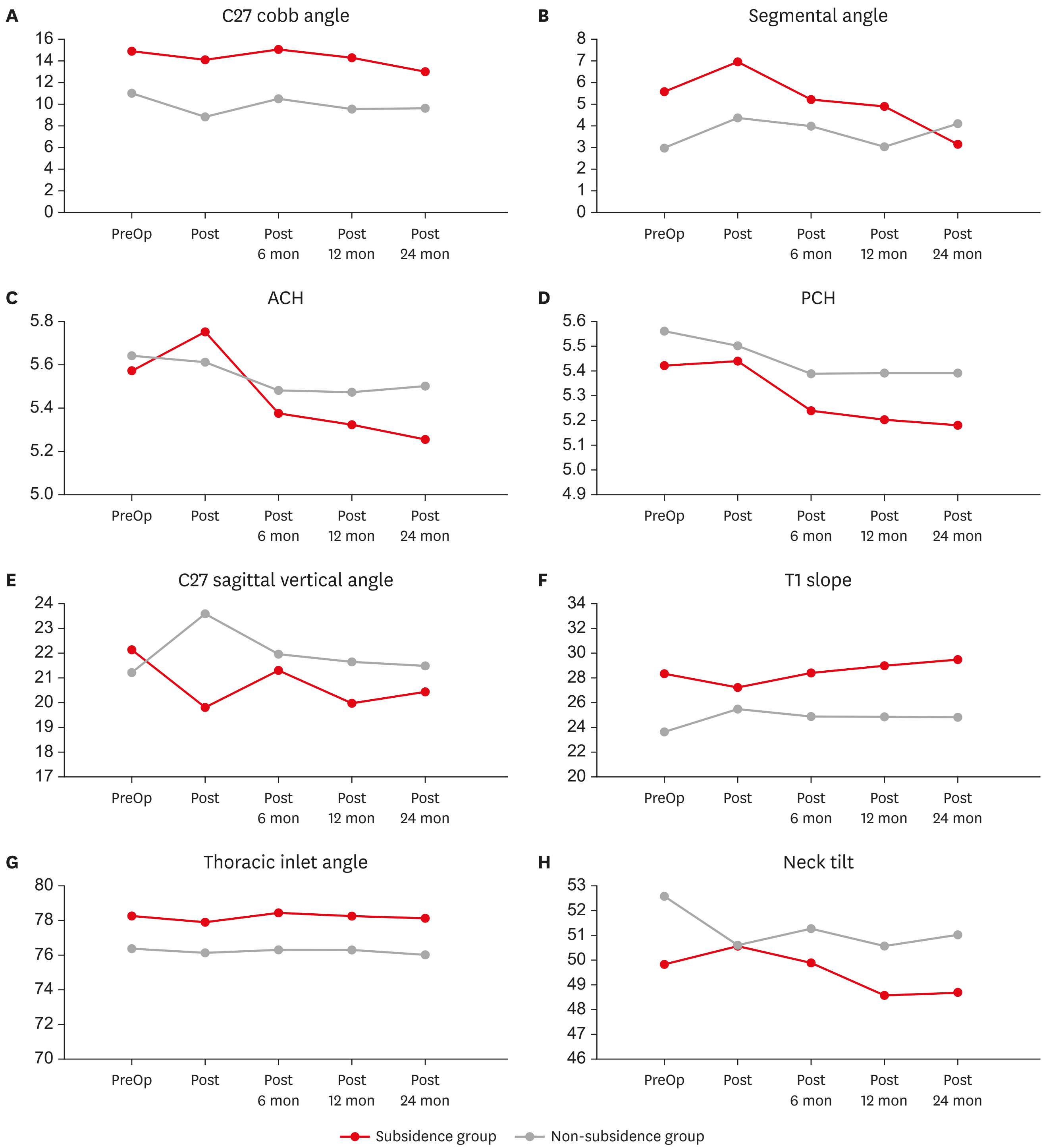

FIGURE 2. Cervical parameters were assessed preoperatively, immediately postoperatively, 6 months postoperatively, 12 months postoperatively, and 24 months postoperatively. (A) C27 Cobb angle, (B) segmental angle, (C) ACH, (D) PCH, (E) C27 sagittal vertical angle, (F) T1 slope, (G) thoracic inlet angle, (H) neck tilt.
ACH: anterior corpectomy height, PCH: posterior corpectomy height.

Cervical corpectomy is a useful surgical method, but the incidence of complications such as respiratory distress and graft subsidence, dislodgement, and migration with screw pullout is relatively high. A failure rate of 71% has been reported for 3-level fixed plated reconstruction, and a high early failure rate of 75% has been reported for the use of titanium mesh cages

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and fixed anterior plate reconstruction in multilevel corpectomy.[4,21,23] Many studies have been conducted on the complications after cervical corpectomy, especially subsidence, which increases the concentration of stress on the implants and leads to anterior plate and instrument failure, which is likely to cause and worsen neurological symptoms.[7,26] One study retrospectively reviewed the outcomes of anterior cervical corpectomy and titanium mesh cage fusion. The subsidence rate of cervical corpectomy was reported to be 30.8% (4.2±2.1 mm). Thus, subsidence after corpectomy and mesh cage fusion is unavoidable and an important complication.[19] Many factors affecting subsidence after surgery have been studied. Many of these factors are related to aging, especially in postmenopausal women with osteoporosis, reduced bone quality of the vertebrae and a reduced thickness of the endplate.[10,19]

However, few studies have studied cervical parameters related to sagittal balance and radiologic features. Thus, we studied the risk factors and radiological changes in subsidence by reviewing 2 years of follow-up data of patients who underwent single-level anterior cervical corpectomy. The larger the T1 slope and C27 Cobb angle are after surgery, the higher the subsidence rate.

There are several factors that may explain the results. Corpectomy constructs lead to large loads on the bone grafts and endplates because of the limited contact area between the mesh cage and endplates. Biomechanical studies have suggested that the lever arm at the distal end of the plate increases with the length of the plate, and the constructs with long, fixed moment arms tend to exert far more load on the caudal screw bone interface than do rostal contracts, which frequently result in construct failure at the caudal ends of the construct.[24,25,27]

Titanium mesh cages have several advantages and disadvantages.[12,13] First, the spike is fixed to the upper and lower vertebral bodies, enhancing graft stability. However, the spike easily penetrates into the vertebral body and causes subsidence. In particular, subsidence often occurs in multilevel corpectomy. In addition, the titanium mesh cage is filled with an autogenous cancellous bone graft to promote early fusion.[5] In other words, extrusion, migration, or collapse of the cage is possible, but a loss of lordosis may occur due to subsidence after surgery.[26] However, subsidence occurred in our study, resulting in a loss of lordosis, which is consistent with the results of other studies, but the presence of subsidence did not affect the clinical outcome.

Brodke et al.[1] found that the static plate decreases due to a low load-sharing capacity after 10% subsidence occurs. Early reconstruction failure occurred in 3 out of 6 people when the lordotic angle was more than 15 degrees. Hyperlordosis of the cervical spine yields high shear stress at the bottom of the fused segment, which can lead to anterior slippage of the construct.[21] Herrmann and Geisler[11] confirmed that device failure and pseudoarthrosis occur at the end of long-segment constructs rather than at the top of the fused segment. The authors speculated that the long lever arm of the anterior plate transmits unacceptably high forces to the inferior level of the fusion area. In particular, patients with continuous micromotion and hyperlordotic alignment in the cervical spine, which can lead to reconstruction failure, were found to have increased levels of shear stress in the bottom of the fusion area.[11,20,21]

The risk factors for subsidence are an older patient age, more corpectomy levels, severe osteoporosis, excessive endplate removal and intraoperative overdistraction.[15] In addition,

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metal attributes and the shape of the graft are also important risk factors.[28] T1 slope is one of the sagittal spine parameters and is an important parameter for cervical sagittal balance. To date, many normal or physiological parameters of cervical alignment remain controversial. Because cervical vertebrae are the most mobile part of the spine, unlike thoracic vertebrae, normative values for the sagittal balance have a large variation. The average reported T1 slope is 25.7 to 33. degrees, which can be affected by aging or posture.[14] As shown in our study, an increased C27 Cobb angle and large T1 slope cause an empty space in the vertebral body graft, which is believed to induce subsidence.

The limitations of this study include its retrospective nature and the fact that only a small number of cases were included. In addition, the study did not accurately present how much T1 slope affects subsidence occurrences, and there are limitations that do not include an analysis of factors that would otherwise have affected. Therefore, based on the results of our study, a prospective study is needed to further evaluate the risk factors for and radiologic changes in subsidence after anterior cervical corpectomy.

CONCLUSION

Subsidence gradually occurred after single-level anterior cervical corpectomy for up to 24 months. However, it did not affect the radiologic and clinical outcomes because subsidence occurred simultaneously in front and back of the cage. When the T1 slope was large and the C27 Cobb angle change was severe, more subsidence occurred after anterior cervical corpectomy. If a patient exhibits the above cervical parameters after surgery, the patients' symptoms need to be carefully examined and evaluated.

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