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Usefulness of anterior cervical fusion using titanium interbody cage for treatment of cervical degenerative disease with preoperative segmental kyphosis

Kunihiko Hosoi, MD[a], Hitoshi Tonomura, MD, PhD[a], Ryota Takatori, MD, PhD[a], Masateru Nagae, MD, PhD[a], Yasuo Mikami, MD, PhD[b], Toru Osawa, MD, PhD[c], Yuji Arai, MD, PhD[a,*], Hiroyoshi Fujiwara, MD, PhD[a], Toshikazu Kubo, MD, PhD[a]

Abstract

Favorable bone fusion and clinical results have been reported for anterior cervical fusion (ACF) using titanium interbody cage (TIC). This method might induce postoperative subsidence and local kyphosis, but the relationship between radiological changes and preoperative local alignment is not known. The purpose of the present study is to investigate the impact of preoperative local alignment on the clinical and radiological outcomes of ACF using TIC.

The study enrolled 36 patients (mean age 49.8 years) who underwent single-level ACF using TIC for cervical degenerative diseases. Patients were divided into 2 groups by preoperative segmental lordotic angle at the operative level: group L, ≥0° (n=16); group K, <0° (n=20). Clinical outcomes included recovery rate according to the Japanese Orthopaedic Association score and complication rates. Radiological assessment was conducted for the cervical and segmental lordotic angles, subsidence, and bone fusion. Mann–Whitney test and chi-square test were applied to compare the outcomes.

The Japanese Orthopaedic Association score recovery rate was 77.2% in group L and 87.6% in group K, with no significant difference. No obvious complications were observed in any of the subjects. Mean cervical lordotic angles preoperatively and at last follow-up were 9.2±9.5° and 11.3±11.7°, respectively, in group L, and −1.3±12.8° and 4.6±13.3°, respectively, in group K. The mean segmental lordotic angles preoperatively and at last follow-up were 2.5±2.2° and 2.6±5.7°, respectively, in group L, and −4.5±2.8° and −1.4±5.8°, respectively, in group K. In group K, the cervical and segmental lordotic angles at the last follow-up were significantly greater than the preoperative angles. The change observed in group L was not significant. Subsidence of ≥3 mm was observed in 3 patients in group L and 4 patients in group K. None of the patients showed nonunion.

Anterior cervical fusion using TIC provided favorable clinical results regardless of preoperative segmental alignment. Although postoperative subsidence and kyphotic changes are concerns in patients presenting segmental kyphosis, ACF using TIC corrected both the entire cervical spine and segmental alignment. The TIC is useful for correction of the cervical alignment for patients with cervical degenerative disease with local kyphotic changes.

Abbreviations: ACF = anterior cervical fusion, AH = anterior height, CA = cervical lordotic angle, CDH = cervical disc hernia, CSM = cervical spondylotic myelopathy, CSR = cervical spondylotic radiculopathy, F/U = follow-up, JOA = Japanese Orthopaedic Association, PEEK = polyetherether ketone, PH = posterior height, postop = postoperative, preop = preoperative, SA = segmental lordotic angle, TIC = titanium interbody cage.

Keywords: anterior cervical fusion, cervical vertebrae/surgery, segmental kyphosis, spinal fusion/instrumentation, stand alone, subsidence, titanium cage

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[a] Department of Orthopaedics, [b] Department of Rehabilitation Medicine, Graduate School of Medical Science, Kyoto Prefectural University of Medicine, Kawaramachi-Hirokoji, Kamigyo-ku, [c] Department of Orthopaedics, Japanese Red Cross Kyoto Daiichi Hospital, 15-749 Honmachi, Higashiyama-ku, Kyoto, Japan.

[*] Correspondence: Yuji Arai, Department of Orthopaedics, Graduate School of Medical Science, Kyoto Prefectural University of Medicine, Kawaramachi-Hirokoji, Kamigyo-ku, Kyoto 602-8566, Japan (e-mail: yarai89046@nike.eonet.ne.jp).

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1. Introduction

Anterior cervical fusion (ACF) is a surgical method for cervical degenerative diseases, first reported in 1958 by Cloward,[1] and Smith and Robinson.[2] Initially, the iliac crest autograft containing the inner and outer tables was harvested en bloc into the disc space. However, some problems such as subsidence, non-union, and kyphotic changes induced by postoperative weakening of the graft bone over time and insufficiency of the initial fixation[3–5] led to the combined use of anterior plate fixation in the 1970s. Although combined use of plate fixation somewhat improved subsidence, nonunion, and kyphotic changes, other complications such as dysphagia,[6] hypopharyngeal and esophageal perforation,[7] and instrumentation back-out[8] were reported. In addition, using large block of iliac crest autograft as graft bone caused invasion of the donor site and complications such as donor site pain and neuropathy.[9] The interbody cage was developed to reduce complications and invasion of the donor site. Cages of various shapes (cylindrical and rectangular) and materials (titanium, polylactic acid, allografts, polymethyl methacrylate, carbon, and polyetherether ketone [PEEK]) are available, and only the cancellous bone harvested from the iliac bone is packed in the cage for transplantation into the disc space. Favorable bone fusion and clinical results have been reported for these cages without the use of a plate,[2,10–13] and superiority to the iliac crest autograft alone was reported in terms of postoperative subsidence.[14] The cages are considered superior to the iliac crest autograft alone because they are not absorbed, unlike the autograft, and can maintain certain strength. On the contrary, the anterior approach to the disc space in a patient with preoperative local kyphosis requires considerable distractive force compared with that to the disc space with local lordosis. In vitro investigation showed a positive correlation between the distractive force of the disc space and the compression force to the transplanted cage.[15] Accordingly, compression force to the disc space becomes greater when conducting ACF in the disc space with local kyphosis, and increases in cage subsidence and the amount of correction loss are of concern. Such changes compromise the clinical result and induce degenerative changes in the adjacent intervertebral discs over the long term,[16–19] so postoperative subsidence and correction loss should be prevented. We hypothesized that using cage would prevent the aforementioned complications even in the presence of preoperative local kyphosis.

Based on this background, our study aimed to investigate the usefulness of ACF using the titanium interbody cage (TIC) alone in patients with preoperative local kyphosis by comparing the clinical results and radiological changes of patients with a cervical degenerative disease presenting preoperative local kyphosis who were treated by this method, with those of patients without preoperative local kyphosis.

2. Methods

2.1. Patients

This study was conducted by retrospective case selection after the approval of the ethics committee of the Kyoto Prefectural University of Medicine. In all, 36 patients included in this study received ACF using TIC into a single disc space between 2007 and 2014 for treatment of cervical disc hernia, cervical spondylotic radiculopathy, or cervical spondylotic myelopathy. Eight surgeons conducted the surgeries at this site and 5 affiliated sites. Surgery was indicated for patients who did not respond to conservative treatment for neck pain and neurological symptoms associated with the above diseases, and patients with a past history of rheumatoid arthritis and osteoporosis were excluded. The subjects were 18 men and 18 women with a mean age of 49.8 ± 14.6 years; a diagnosis of cervical disc hernia was made in 30 patients, cervical spondylotic radiculopathy in 4 patients, and cervical spondylotic myelopathy in 2 patients. The mean postoperative observation period was 37.5 months (12–96 months). The operative level was C3/4 in 4 patients, C4/5 in 6 patients, C5/6 in 23 patients, and C6/7 in 3 patients.

2.2. Surgical procedure

After interviewing the surgeons, it was clear that a standard or similar method had been used in all the cases included in this study. After expanding the disc space using a distracter by a left anterior approach, neural decompression was conducted by discectomy of the intervertebral disc under surgical microscopy. The cranial and caudal cartilaginous endplates were completely removed and the bony endplates were preserved. A TIC (Syncage-C; Synthesis, Paoli, PA) packed with the iliac crest autograft bone was used in this surgery. A cage size was selected from among the trial cages that demonstrated stability using the cranial and caudal adjacent disc height as a guide. An impactor was used to insert the cage to the position posterior to the anterior bone cortex of the vertebra, which was determined by radiographic examination, so the cage fits into the cranial endplate. When stability was confirmed after removing the distractor, the pilot bone that was a guide for bone fusion was transplanted anterior to the cage. A soft collar was used for 8 weeks for postoperative external fixation and activity of daily livings was permitted depending on pain intensity.

2.3. Clinical evaluation

Two authors not involved in the surgical procedures reviewed all the records. Clinical evaluation was made for the Japanese Orthopaedic Association (JOA) score and complications. Clinical results were evaluated based on the JOA score at baseline and at the last observation, and the recovery rate was calculated.

2.4. Radiological changes

Images of the cervical lordotic angle (C2-7 Cobb angle), the segmental lordotic angle (SA), subsidence, and bone fusion were evaluated. Simple lateral x-ray images were taken at baseline, immediately postoperatively, 1, 3, and 6 months after surgery, and at the last follow-up to measure the C2-7 Cobb angle, SA, anterior height (AH), and posterior height (PH) of the adjacent vertebral bodies of the operated segment (Fig. 1), and disc height. SA was defined as the angle formed by the cranial and caudal vertebral endplates at the operative level. AH and PH were defined as the distance between the upper end of the cranial vertebra and the lower end of the caudal vertebra of the anterior and posterior vertebra, respectively. Disc height was defined as the average of the distance between the lower end of the cranial vertebra and the upper end of the caudal vertebra of the anterior,

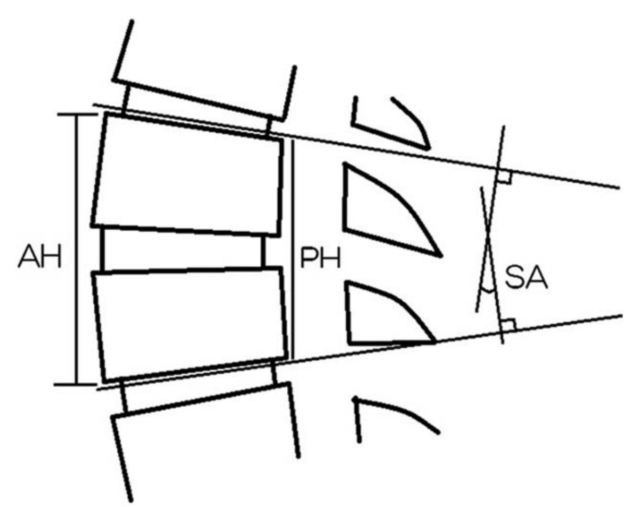

Figure 1. Radiological measurements. SA was defined as the angle formed by the cranial and caudal vertebral endplates at the operative level. AH and PH were defined as the distance between the upper end of the cranial vertebra and the lower end of the caudal vertebra of the anterior and posterior vertebra, respectively. A negative value denotes kyphosis. AH=anterior height, PH= posterior height, SA=segmental lordotic angle.

middle, and posterior vertebra, respectively. The mean AH/PH was calculated as the height of the adjacent vertebral bodies of the operated segment, and changes from immediately after surgery to the last follow-up were defined as the subsidence. Subsidence ≥3 mm was defined as subsidence present. Bone fusion was defined as present when the range of motion (ROM) at SA was ≤2 degrees by flexion and extension. To correct magnified simple x-ray pictures, percentage magnification was calculated based on the actual height of the cage and that of the cage of a simple x-ray picture, and the actual fixed disc space height was obtained.

2.5. Endpoints

Patients were divided into 2 groups by preoperative SA at the operative level: group L, ≥0° (n=16); group K, <0° (n=20). The patient demographic data are shown in Table 1. There were no significant differences between the 2 groups other than preoperative C2-7 Cobb angle and SA. Group comparisons were made for the clinical results and radiological assessment. The data are shown as mean ± standard deviation. The Mann–Whitney *U* test, chi-square test, paired *t* test, and 2-way repeated analysis of variance (ANOVA) were used for statistical analysis. The level of statistical significance was 5%.

3. Results

3.1. Clinical results

The mean JOA score of the full study population increased from the baseline level of 12.2 ± 2.8 points to 16.1 ± 0.9 points at the last follow-up, giving a recovery rate of 84.1 ± 17.1%. Between-group comparison of the preoperative JOA score showed no significant difference, with 10.9 ± 2.5 points in group L and 12.8 ± 2.7 points in group K. The JOA score at the last follow-up was 15.6 ± 1.0 points in group L and 16.5 ± 0.5 points in group K, and the recovery rate was 77.2 ± 12.8% in group L and 87.6 ± 18.6% in group K; these differences were not statistically significant. No obvious complications were observed in any of the patients.

Table 1

Patient demographic data.

	Group L	Group K	P
Male/female	8/8	10/10	.737
Age, y	54.1 ± 11.2	46.4 ± 16.2	.115
Follow-up period, mos	41.2 ± 17.9	34.6 ± 27.7	.115
Surgical level			.578
C3/4	1	3	
C4/5	4	2	
C5/6	10	13	
C6/7	1	2	
Diagnosis			.706
CDH	14	16	
CSR	1	3	
CSM	1	1	
Disc height	4.5 ± 0.9	4.2 ± 0.9	.421
Preop CA, °	9.2 ± 9.5	−1.3 ± 12.8	.015
Preop SA, °	2.5 ± 2.2	−4.5 ± 2.8	<.001

CDH = cervical disc hernia, CSM = cervical spondylotic myelopathy, CSR = cervical spondylotic radiculopathy, preop CA = preoperative cervical lordotic angle, preop SA = preoperative segmental lordotic angle.

Table 2

Radiological results.

	Group L	Group K	P
Ope-change of SA, °	6.3 ± 3.9	8.8 ± 4.7	.04
Loss of SA, °	−6.1 ± 4.0	−5.7 ± 6.2	.643
Final correction of SA, °	0.1 ± 4.4	3.1 ± 5.0	.069
Final correction of CA, °	2.1 ± 9.7	5.8 ± 8.5	.164
Subsidence, mm	1.77 ± 1.28	2.12 ± 1.46	.463
Subsidence (number)	3	4	.742

CA = cervical lordotic angle, final correction of CA = the difference between last follow-up and the preoperative cervical lordotic angle, final correction of SA = the difference between the last follow-up and the preoperative segmental lordotic angle, loss of SA = the difference between the last follow-up and the immediately postoperative segmental lordotic angle, Ope-change of SA = the difference between postoperative and preoperative segmental lordotic angle, SA = segmental lordotic angle.

3.2. Radiological changes

3.2.1. *Cervical lordotic angle.* The mean C2-7 Cobb angle for the full patient sample was 3.5 ± 12.4° at baseline, increasing significantly to 7.6 ± 12.9° at the last follow-up. Preoperative C2-7 Cobb angle was 9.2 ± 9.5° in group L and −1.3 ± 12.8° in group K; this was a significant intergroup difference. The C2-7 Cobb angle at the last follow-up was 11.3 ± 11.7° in group L and 4.6 ± 13.3° in group K, showing no obvious intergroup difference. The amount of change in the C2-7 Cobb angle did not differ significantly between groups (Table 2). The C2-7 Cobb angle at the last follow-up was significantly greater than at baseline in group K, although no clear difference was observed in group L (Fig. 2, Table 3).

3.2.2. *Segmental lordotic angle.* The mean SA for the full patient sample was −1.4 ± 4.3° at baseline, 6.3 ± 4.9° postoperatively, and 0.4 ± 6.0° at the last follow-up; the difference between baseline and the last follow-up was significant. The baseline SA angle was 2.5 ± 2.2° in group L and −4.5 ± 2.8° in group K. The SA postoperatively was 8.8 ± 4.3° in group L and 4.3 ± 4.5° in group K. The SA at 1, 3, and 6 months after surgery was 4.3 ± 5.9°, 4.2 ± 5.9°, and 2.6 ± 6.0° in group L and −1.0 ± 5.5°, −1.1 ± 6.2°, and −1.4 ± 5.6° in group K. The SA at the last follow-up was 2.6 ± 5.7° in group L and −1.4 ± 5.8° in group K. A significant

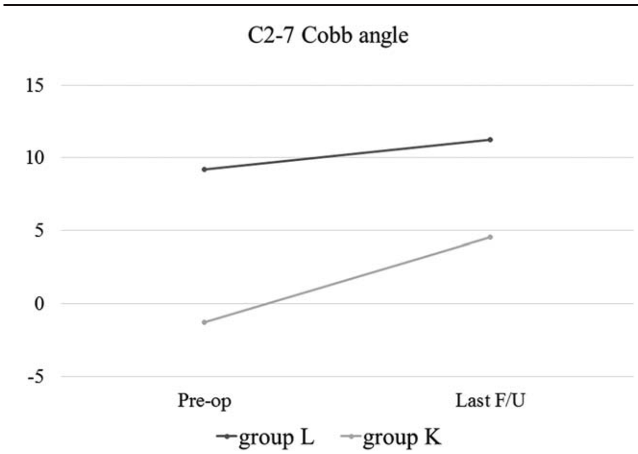

Figure 2. Sequential change in the C2-7 Cobb angle in each group. The cervical lordotic angle (C2-7 Cobb angle) at the last follow-up was significantly greater than at baseline in group K, although no significant change was observed in group L. Last F/U = last follow-up examination, preop = preoperative.

Table 3

Cervical lordotic angle (°).

	Preop	Last F/U	P
Group L	9.2±9.5	11.2±11.7	.384
Group K	−1.3±12.8	4.6±13.3	<.001

Last F/U=last follow-up, preop=preoperative.

Table 4

Segmental lordotic angle (°).

	Preop	Last F/U	P
Group L	2.5±2.2	2.6±5.7	.851
Group K	−4.5±2.8	−1.4±5.8	.003

Last F/U=last follow-up, preop=preoperative.

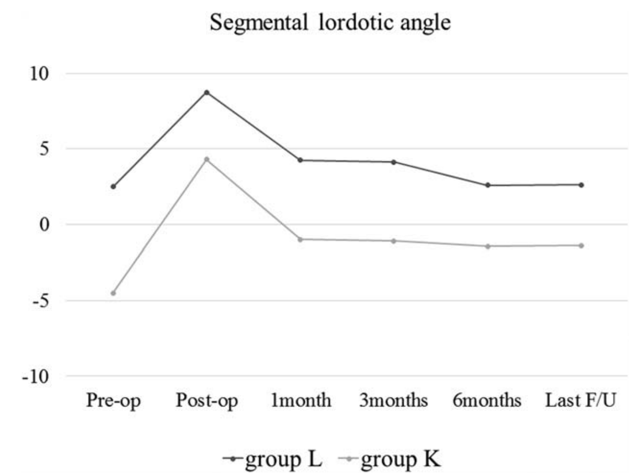

Figure 3. Sequential change in the segmental lordotic angle in each group. The segmental lordotic angle at the last follow-up was significantly greater than baseline in group K, but no significant change was observed in group L. No obvious correction loss was observed since 6 months after surgery in both groups. Last F/U=last follow-up examination, postop=postoperative, preop=preoperative, SA=segmental lordotic angle.

intergroup difference was observed for both. For both groups, a significant difference was observed between baseline and postoperative SA, and between postoperative SA and the last follow-up. The amount of change in SA from baseline to after surgery differed significantly between groups. There was no significant intergroup difference of the correction loss (Table 2). The SA at the last follow-up was significantly increased compared with the baseline in group K, although no obvious difference was observed in group L (Fig. 3, Table 4).

3.2.3. Subsidence. A significant intergroup difference was not observed in either the amount or incidence of subsidence (Table 2).

3.2.4. Bone fusion. Bone fusion. Bone fusion was observed in all patients within 6 months after surgery.

3.3. Case presentation

A 29-year-old woman received ACF to treat cervical disc hernia at C5/6. Obvious subsidence was not observed at postoperative month 38, and bone fusion was achieved. The cervical lordotic angle of 9° at baseline increased to 14° at the last follow-up. The segmental lordotic angle of −5° at baseline increased to 5° postoperatively, and was 0° at the last follow-up (Fig. 4). The baseline JOA score of 14.0 points improved to 15.5 points.

4. Discussion

For ACF using cage, Fujibayashi et al[12] reported a JOA recovery rate of 96.2%, whereas Zhou et al[20] reported a recovery rate of 93.4%. Wu et al[18] reported that the recovery rate at 37.1% was "satisfactory." The recovery rate of the full population in our study was 84.1%, and none of the patients developed any complications. ACF using TIC is considered useful for treating cervical degenerative disease based on the previously published reports. The recovery rates for group L (77.2±12.8%) and group K (87.6±18.6%) were not significantly different, and ACF with a TIC is likely to achieve a favorable clinical result even in cases with preoperative kyphotic changes. The bone fusion rate of ACF

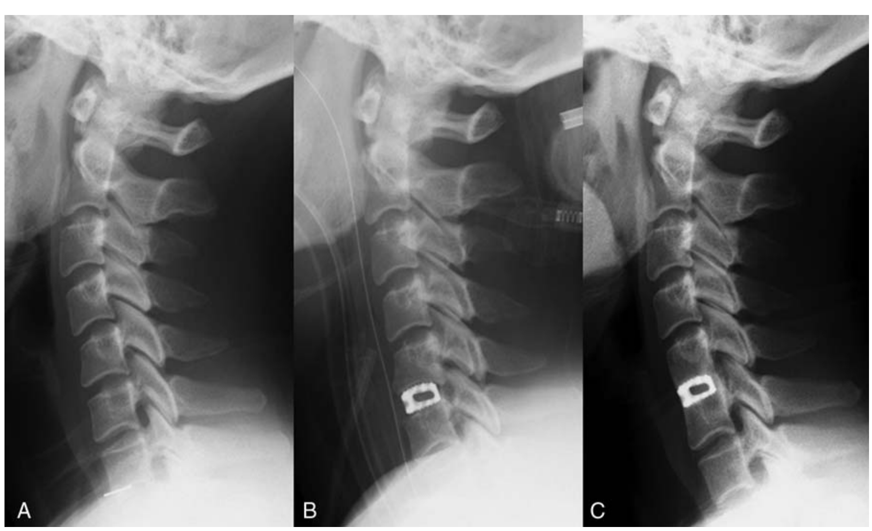

Figure 4. Case presentation. A 29-year-old female patient received ACF at C5-6. Plain lateral radiographs at (A) preoperative, (B) immediately postoperative, and (C) postoperative year 3 visits. Local kyphosis at C5-6 changed lordotically. ACF=anterior cervical fusion.

using TIC has been reported by numerous researchers, and ranges from 88.8% and 100%.[12,13,21] The bone fusion rate in this study was 100%, and nonunion did not occur, suggesting no impact of preoperative kyphotic changes on bone fusion.

Major concerns about ACF using cage include subsidence and correction loss. Significantly fewer occurrences of subsidence have been reported compared with autografts, but subsidence of approximately 2 mm would spontaneously develop even with the use of a cage. Subsidence is thought to be caused by operative procedures such as the handling of the endplate, type/size, and position of cage, and also concomitant diseases such as rheumatoid arthritis, osteoporosis, and kyphotic changes of the cervical spine. Of these, the incidence of kyphotic changes of the cervical spine was reported at 13.3% in asymptomatic adult patients in their 20s to 70s,[22] and it is frequently observed in daily clinical examination. Kyphotic changes of the cervical spine are known to place dynamic load on the spinal cord. When the cervical spinal column is flexed, the cervical spinal canal elongates and the cord is stretched and lengthened,[23] and progression of local kyphosis increases intramedullary pressure at the operative level.[24] Laminoplasty is therefore not effective in patients with a cervical degenerative disease presenting kyphotic changes, and ACF is indicated.[25] However, compression force to the disc space is increased by ACF for treatment of a kyphotic change and might compromise clinical results due to occurrences of subsidence and correction loss, although the details are unknown. In this study, it was possible to investigate the usefulness of ACF using TIC to treat patients who have cervical degenerative disease with kyphotic changes while minimizing the confounding factors, because standardized surgical procedures for this method were employed by several experienced surgeons, and none of the cases was complicated by rheumatoid arthritis or osteoporosis.

The reported incidence of subsidence after transplantation of a TIC is 9% to 44%.[10,12,21] The incidence of subsidence associated with the TIC in this study was 19.4% of the full population, which is comparable with previous reports. The incidence of subsidence in group L and group K was 18.8% and 20.0%, respectively, which demonstrated that subsidence was not more common in patients with preoperative kyphotic changes. Lee et al[26] reported that preoperative segmental lordotic angle was not a risk factor for subsidence, which supports the result of this study. Other concerns about long-term risks of TIC included the displacement and extrusion of a transplanted cage. A careful follow-up over long-term with respect to them was needed.

The cervical alignment after ACF is considered to affect the clinical outcome. Katsuura et al[16] demonstrated that cervical kyphosis and local kyphotic malalignment after ACF were factors promoting the degenerative process of adjacent intervertebral discs. Hu et al[17] found that clinical outcome was superior in patients with postoperative lordosis restoration compared with patients in the maintained group or kyphotic group. Other reports revealed that maintaining lordosis at C2-7 was vital in achieving favorable long-term clinical results.[18] Subsidence of cage after ACF might alter the entire cervical alignment. With respect to the changes in the cervical alignment before and after ACF using TIC, Yamagata et al[10] reported recovery of the cervical lordotic angle by 1.9° and the segmental lordotic angle by 3.4°, whereas Cabraja et al[11] observed recovery of the cervical lordotic angle by 2.39° and the segmental lordotic angle by 1.35°. Fujibayashi et al[12] found there was no significant difference in the segmental lordotic angle at baseline and at the last follow-up. Correction loss of the segmental lordotic angle after ACF using PEEK cage has been reported at 0.99°[27] and 2.57°.[28] The result of our study showed correction loss of about 6° at the last follow-up compared with immediately after surgery in both group L and group K. However, a comparison with baseline showed the correction of cervical lordotic angle to be 4.1°, and that of the segmental lordotic angle to be 1.0° in the entire population. The correction of the cervical lordotic angle to be 2.1° and that of the segmental lordotic angle to be 0.1° in Group L, and correction of the cervical lordotic angle to be 5.8° and that of the segmental lordotic angle to be 3.1° in Group K. No correction loss was observed in either the segmental lordotic angle or the cervical lordotic angle at the last follow-up compared with baseline in the nonkyphosis group and kyphosis group, and the segmental and cervical lordotic angles were significantly corrected particularly in the kyphosis group. All patients had achieved bone fusion within 6 months after surgery and correction loss of the segmental lordotic angle stopped to increase around this time point in both groups. A positive correlation has been found between the final cervical lordotic angle and the segmental lordotic angle when bone fusion was achieved after ACF.[19] The result suggested a close relationship between the local alignment and the cervical alignment, and the correction angle of a cage transplantation site is considered to affect the entire cervical alignment. A TIC is considered useful for correction of the cervical alignment in patients with a cervical degenerative disease with kyphotic changes, although the correction angle is limited.

The limitations of this study include the lack of assessment of factors such as bone quality that might affect subsidence and correction loss, and the inability to establish the severity of local kyphosis to be treated. Small sample size and lack of randomization may have impact on the validity of our results due to possible investigators bias. The short follow-up period was also considered to be the limitation of this study. This study demonstrated the favorable clinical outcome of ACF using TIC regardless of preoperative local alignment. However, the radiological issues about subsidence and correction loss remained. Further investigations are important towards addressing these issues, and towards developing new ACF therapeutic strategy.

5. Conclusions

Anterior cervical fusion using TIC was shown to achieve favorable bone fusion and clinical outcome, even in cases with kyphotic changes. The preoperative alignment with this method had no impact on the occurrence of subsidence. The segmental lordotic angle and the entire cervical lordotic angle were significantly corrected in the kyphosis group, and we suggest that a TIC is useful for correction of cervical alignment in patients with a cervical degenerative disease with local kyphosis.

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