Three-level and four-level anterior cervical discectomies and titanium cage–augmented fusion with and without plate fixation

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Object. Cage-assisted anterior cervical discectomy and fusion (ACDF) has proven to be a safe and effective procedure for the treatment of one- and two-level degenerative disc disease (DDD). To the authors’ knowledge, clinical results after three- and four-level interbody cage–augmented ACDF have not been reported in the literature. The authors investigated the safety and effectiveness of titanium cages used in such procedures and evaluated the results in cases with or without plate fixation.

Methods. Fifty-six patients suffering from cervical DDD were divided into two groups. Group 1 included 32 patients who underwent titanium cage–assisted ACDF; Group 2 included 24 patients who underwent the same procedure, supplemented with plate fixation. The cervical DDD was confirmed by radiography and magnetic resonance imaging. The patients underwent radiographic evaluation to assess cervical lordosis, segmental height of cervical spine, the height of the foramina, and spinal stability. Neurological outcomes were assessed using the Japanese Orthopaedic Association (JOA) scores. Neck pain was graded using a 10-point visual analog scale (VAS). The follow-up period ranged from 13 to 28 months (mean 17.2 months).

In both Groups 1 and 2 significant increase (p < 0.001) was demonstrated in the JOA scores (preoperatively 10.7 ± 2.4 and 11.1 ± 2, postoperatively 13.9 ± 2.2 and 14.1 ± 2.3, respectively) and VAS pain scores (preoperatively 8.8 ± 0.9 and 8.5 ± 1, postoperatively 3.1 ± 2.1 and 2.8 ± 1.8, respectively); however, there was no significant intergroup difference. A significant increase in the cervical lordosis, foraminal height, and segmental height was observed in both groups. Good stability of cage fusion was obtained in both groups 12 months postoperatively (90.6% in Group 1 and 91.7% in Group 2); however, there were no statistically significant intergroup differences. The complication rate in Group 2 was higher than that in Group 1. The hospital length of stay in Group 1 was significantly lower than in Group 2 (p < 0.001).

Conclusions. Analysis of these findings demonstrated that titanium cage–assisted ACDF provided long-term stabilization, increased lordosis, increased segmental height, and increased foraminal height. In both groups good neurological outcomes were achieved and donor site morbidity was avoided. The lower complication rate and shorter hospital stay, however, make the cage-assisted fusion without plate fixation better than with plate fixation.

KEY WORDS • cervical spine • titanium cage • discectomy • spinal fusion

A posterior cervical discectomy has proved to be a safe and effective procedure for the treatment of DDD. Cervical discectomy followed by placement of a graft has been considered the classic operation; however, the choice of fusion materials and the use of internal fixation are controversial. Placement of interbody fusion cages can restore physiological disc height, provide immediate load-bearing support, and facilitate interbody arthrodesis. Furthermore, the use of the interbody fusion cage can avoid donor site morbidity. Clinical results have been encouraging after one- and two-level interbody cage–assisted fusion for cervical DDD. Procedures involving interbody cages and plate fixation for multilevel anterior cervical reconstruction have also been reported to yield good results. To our knowledge, however, clinical results after three- and four-level interbody cage–assisted ACDF for DDDs have not been reported. In this study, we investigated the safety and effectiveness of interbody cages used in the three- and four-level cervical spinal fusion and evaluated the results when performed with or without plate fixation.

Clinical Material and Methods

Patient Population

Fifty-six patients suffering from cervical DDD under-
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![Representative imaging studies. A: Lateral cervical x-ray film revealing C3–6 DDD with loss of normal cervical lordosis. B: Sagittal MR image demonstrating multilevel spondylosis with cord compression. C and D: Postoperative follow-up radiographs obtained at 1 month revealing good lordosis and well-positioned cages and plate fixation. E and F: Extension and flexion radiographs obtained at 12 months demonstrating no motion at the fusion segment, with the cages and plate system in place.](image)

went three- or four-level discectomies in our department between April 2001 and June 2002. We analyzed the clinical and radiographic outcomes of 32 patients who underwent interbody titanium cage–augmented ACDF (Group 1) and 24 patients who underwent the same procedure as well as plate fixation (Group 2). In Group 1, there were 13 men and 19 women, who ranged from 34 to 81 years of age (mean 54.1 years); in Group 2, there were 10 men and 14 women who ranged from 36 to 76 years of age (mean 55.5 years). The cervical DDD was confirmed by cervical spine radiography and MR imaging. Symptoms included neck pain, cervical radiculopathy, and myelopathy, which were refractory to medical management and rehabilitation. After anterior decompressive surgery and removal of the degenerative disc, the hypertrophied posterior longitudinal ligament, or the osteophyte of VBs, interbody titanium cages were placed in all cases. Overall, Group 1 included 26 three-level discectomies and six four-level discectomies; Group 2 included 20 three-level discectomies and four four-level discectomies. All patients were placed in rigid cervical collars for a mean period of 6.5 weeks postoperatively (range 4–8 weeks).

Preoperative Examination

The diagnosis of cervical DDD was based on clinical presentation and radiographic documentation. Preoperatively, all patients underwent cervical radiography and MR imaging. Clinical presentations included neck pain, radiculopathy, and/or myelopathy. Neurological status was classified according to the JOA scoring system. Neck pain was graded using a 10-point VAS (from 0 [no pain] to 10 [worst possible pain]). Comparison of pre- and postoperative pain status was performed using the Student t-test.

Operative Procedure

The patient was placed supine with mild neck extension after induction of general endotracheal anesthesia. A right-sided approach was performed via a transverse or longitudinal incision. The platysma was extensively undermined to provide tissue relaxation and prevent retraction-induced injury. The prevertebral fascia and longus coli muscles may be divided using electrocautery to visualize the uncovertebral joints. The operative levels were confirmed using fluoroscopy.
Commonly, only a transverse self-retaining retractor was placed to allow continued visualization. Occasionally a screw may be inserted in the VBs just above or below the targeted disc to be removed, and this will maintain the operative field. With the aid of an operating microscope, reaming of adjacent VBs, appropriate discectomy, removal of hypertrophied posterior longitudinal ligament, and drilling of the osteophyte were performed to decompress the spinal cord and nerve root. Based on the extent of the discectomy defect, an appropriate nonthreaded titanium cage (Advanced Spine Technology, Inc., Oakland, CA) was placed. The interbody fusion cage was filled with the mixture of bone chips obtained from the vertebrae and calcium sulfate bone graft substitute (OSTEOSET; Wright Medical Technology, Inc., Arlington, TN). For the patients of Group 2, a cervical dynamic fixation plate (Window; Advanced Spine Technology, Inc.) was used.

Follow-Up Course

The mean follow-up period was 17.2 months (range 13–28 months). At 1 year postoperatively, dynamic examination of the cervical spine including flexion–extension radiography was performed (Figs. 1–4). A 39-year-old woman with congenital cervical stenosis, multilevel disc degeneration, and kyphosis presented with neck pain, upper-limb pain and weakness, and an unstable gait (Fig. 4). Because the compression was predominantly anterior, ACDF was our treatment of choice. Postoperatively, her symptoms greatly improved and radiographs show a normal lordosis and a good stability. We performed x-ray studies in patients 12 months postoperatively to evaluate the cervical spinal curve, segmental height, and foraminal height. The cervical curvature was evaluated according to the method reported by Profeta, et al. A straight line was drawn from the posterior border of the dens to the posterior border of C-7. Another line was drawn from the posterior border of C-4 perpendicular to the first line, the intersected length of which was measured in millimeters as the degree of spinal curvature. It is difficult truly to assess “fusion” with titanium cages by plain radiographs because of their radiopaque characteristics. We measure the “stability,” instead of using the term “fusion,” based on the methods described in the previous studies of cervical interbody fusion with titanium cages. Radiographic

Fig. 2. Representative imaging studies. A: Lateral cervical x-ray film demonstrating C3–7 DDD. B: Sagittal MR image revealing multilevel spondylosis with cord compression. C and D: Postoperative x-ray films obtained at 1 month demonstrating good lordosis and well-positioned cages and plate fixation. E and F: Extension and flexion radiographs obtained at 12 months revealing no motion at the fusion segment, with the cages and plate in place.
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Assessment of the stability was based on the presence or absence of motion between the spinous processes of the fused levels on flexion and extension views. Good stability was defined according to the following criteria: 1) the absence of motion on flexion–extension radiographs and the absence of any dark halo around a cage on both antero-posterior and lateral radiographs; or 2) presence of bridging bone anterior or posterior to the cage. Clinical outcome was assessed 12 months postoperatively by using the JOA system and the VAS.

Results

Neurological Outcome

The clinical and radiographic outcomes are summarized in Table 1. The mean preoperative JOA scores in Groups 1 and 2 were 10.7 ± 2.4 and 11.1 ± 2, respectively, and the mean postoperative scores increased to 13.9 ± 2.2 and 14.1 ± 2.3, respectively. The intergroup differences between the pre- and the postoperative JOA scores were statistically significant (p < 0.001). Preoperative cervical pain was present in 15 (46.9%) of Group 1 patients and in 10 (41.7%) of Group 2 patients, and it persisted postoperatively in four patients in each group (12.5 and 16.7%, respectively). In Groups 1 and 2, the mean postoperative VAS pain scores were 3.1 ± 2.1 and 2.8 ± 1.8, respectively, compared with preoperative scores of 8.8 ± 0.9 and 8.5 ± 1, respectively. There was a significant relief of cervical pain after surgery in both groups (p < 0.001 in each). A significant improvement in the JOA scores and VAS pain scores occurred in each group; however, there was no significant intergroup difference (Table 1).

Radiographic Outcome

Group 1. The mean postoperative cervical lordosis was 0.2 ± 0.3 cm, whereas it was 0 ± 0.3 cm preoperatively; the difference was statistically significant (p < 0.05). The mean postoperative height of foraminal and segmental cervical spine was 9.3 ± 1.2 mm and 8.9 ± 1.2 cm, respectively, compared with a mean preoperative foraminal height and segmental height of 8.3 ± 0.8 mm and 8.7 ± 1.3 cm, respectively; the difference was statistically significant (p < 0.05 for both). Good cervical stability was obtained in 90.6% of the Group 1 patients 1 year postoperatively.
Group 2. The mean postoperative cervical lordosis was $0.3 \pm 0.5$ cm, whereas it was $0.2 \pm 0.4$ cm preoperatively; the difference was statistically significant ($p < 0.05$). The mean postoperative height of foramina and segmental cervical spine was $9.8 \pm 1$ mm and $9 \pm 1.1$ cm, respectively, whereas preoperatively it was $8.6 \pm 1.6$ mm and $8.8 \pm 1.2$ cm, respectively; the difference was statistically significant ($p < 0.05$ in both). Good spinal stability was observed in 91.7% of Group 2 patients 1 year postoperatively.

Groups 1 and 2. A significant increase in the cervical lordosis, foraminal height, and segmental height was demonstrated in all patients regardless of group. Good cervical spine stability 1 year postoperatively was achieved in greater than 90% of patients overall; however, there were no statistically significant intergroup differences (Table 1).

Surgery-Related Complications

In Group 1, there were no cases of spinal cord or nerve injuries, cerebrospinal fluid leaks, or infections, nor were there tracheal, vascular, or esophageal injuries, except for one case of transient hoarseness. Cage extrusion or breakage did not occur. In two (6.3%) of 32 cases subsidence occurred but produced no symptoms. The subsidence occurred within the first 3 months but no further progression was demonstrated on follow-up radiographs 12 months after surgery. The mean hospital LOS was $7.4 \pm 1.3$ days. In Group 2, there were two cases of transient hoarseness and three cases of transient dysphagia. In three asymptomatic patients, hardware failure occurred (two screw fractures and one screw pullout). In the patient in whom screw pullout developed, cage subsidence also was found. There were no cases of plate fracture. The mean hospital LOS was $10.2 \pm 1.5$ days. The hospital LOS in Group 1 was significantly lower than that in Group 2 ($p < 0.001$).

Discussion

Segmental Height and Immediate Stability

The interbody cage used in the study is a rectangular block of biocompatible titanium alloy in which holes and
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<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>Summary of clinical and radiographic data obtained in patients who underwent cage-assisted ACDF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group 1</td>
</tr>
<tr>
<td>cervical pain (VAS score)</td>
<td>8.8 ± 0.9</td>
</tr>
<tr>
<td>JOA score*</td>
<td>3.1 ± 2.1</td>
</tr>
<tr>
<td>preop</td>
<td>postop</td>
</tr>
<tr>
<td>segmental height (cm)†</td>
<td>8.7 ± 1.3</td>
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<tr>
<td>foraminal height (mm)†</td>
<td>8.9 ± 1.2</td>
</tr>
<tr>
<td>lordosis (cm)†</td>
<td>8.3 ± 0.8</td>
</tr>
<tr>
<td>preop</td>
<td>9.3 ± 1.2</td>
</tr>
<tr>
<td>postop</td>
<td>0.0 ± 0.3</td>
</tr>
<tr>
<td>postop</td>
<td>0.2 ± 0.3</td>
</tr>
<tr>
<td>good 1-yr stability rate</td>
<td>29 (90.6%) of 32</td>
</tr>
</tbody>
</table>

† p < 0.001, preoperative compared with postoperative values.

Improvement of Sagittal Balance and Risk of Subsidence

Like auto- and allograft, cages provide a load-sharing support; however, unlike those grafts, cages are not associated with implant collapse, and improvement of sagittal balance can be obtained. In our patients the mean cervical lordosis was significantly increased after surgery regardless of whether plate fixation was also performed; however, the mean postoperative cervical lordosis has not been reported to increase in the cases involving autologous iliac crest graft fusion. The same finding was noted in the study of Savolainen, et al., in which 40% of the patients who underwent autograft-assisted fusion with or without plates suffered postoperative kyphosis.

One of the concerns about titanium cages, particularly when used in long cervical reconstructions, relates to subsidence over time. In our study, subsidence occurred within the first 3 months, but no further radiographic progression was observed at 12-month follow-up evaluation. Interestingly, these progression-free cases of subsidence, despite causing mild kyphosis, did not produce any symptoms. We do not think that subsidence, in itself, is detrimental because settling of the cage and the contained bone graft may lead to faster healing. The clinical significance of the final kyphotic angle is unclear. Clinical outcomes in patients with increased kyphosis, compared with those with decreased kyphosis, were no worse according to some but were worse according to others. The other concern regarding the titanium cage is how to avoid subsidence and the resultant deterioration of sagittal alignment. The endplates are prepared by removing the cortical cartilaginous layers. This procedure is important to ensure good contact between the cage–VB interface and thus good stability of the cage. Avoiding overdrilling of the endplates may lessen the chance of significant subsidence or postoperative kyphosis.

Avoiding Donor Site Complication and Achieving Good Stability

The cancellous bone graft harvested from the anterior VB edge or spur, mixed with calcium sulfate bone graft substitute, was packed into the cage cavity for maximum contact with living spongy bone on either side of the cage. The bleeding vertebral bone can enhance osteogenesis and bone fusion. In addition, the calcium sulfate bone graft substitute provides an osteoconductive matrix for ingrowth of blood vessels and osteogenic cells. Based on the methods described in the previous studies of cervical titanium cage–assisted interbody fusion, successful fusion was defined as either the absence of motion on flexion–extension radiographs or the radiographic presence of bridging bone or the absence of any dark halo around a cage. In the aforementioned studies, interbody cages were shown to be safe and effective in anterior cervical spine surgery. For the one-level procedures, the fusion rates in the titanium cage–treated group at 12 (98.5%) and at 24 months (100%) were higher than those in the autograft bone–treated group at 12 (80.5%) and at 24 months (93%). For the two-level procedures, the fusion rates of the cage-treated group and the autograft bone group were not different at 12 months (80.4 and 83.3%, respectively); however, the fusion rate of the cage group at 24 months increased to 93.1% and was higher than that of the autograft bone group (81.8%). Compared with the results of cage fusion, those associated with allograft were unsatisfactory. Martin, et al., reported a fusion rate of 90% after implanting freeze-dried allografts after one-level discectomy, which decreased to 72% after two-level fusions. It is difficult, however, to arrive at a true assessment of fusion when titanium cages are evaluated radiographically, unless signs of osseous consolidation are detected either anterior or posterior to the cage. Although fusion after titanium cage implantation may be deduced from the long-term stability and absence of bone rarefaction around the cage, it is not completely representative of true fusion. Therefore, in this study we measured the stability instead of measuring fusion when evaluating the results of titanium cages in the cervical interbody fusion. In our experience, the rates of good stability for one-level discectomy and cage fusion at 12 and 18 months were 93.1 and 100%, respectively, and for two-level procedures at 12 and 18 months, 92.8 and 94.1%, respectively (un-
published data). To our knowledge, clinical results of three- and four-level interbody cage fusion for cervical DDDs have not reported. Analysis of our results showed a good stability rate both in the cage-alone group (90.6%) and in that involving plate fixation (91.7%).

In our study, the use of titanium cage after discectomy has provided further advantages, including the absence of donor site complications, an easier implantation technique, and good immediate and long-term stabilization. The complication rate has been shown to be lower for the cage-treated group (11.8%) than the autograft bone–treated group (20.4%).7 Sawin, et al.,17 reported a 25.3% donor site morbidity rate, including pain, hematoma formation, fracture, and meralgia paresthetica. Savolainen, et al.,18 also reported donor site complications in 16% of patients who underwent procedures involving autograft.

Necessity of Plate Fixation in Cage Fusion

Rigid anterior cervical plate fixation may eliminate the mechanical load that is important in graft-related healing.13 Rigid fixation may also prevent gap closure from occurring at the site of healing as graft subsidence or contact osteolysis occurs. Alternatively, dynamic cervical plates allow for axial settling to accommodate a potential biological or mechanical shortening of the anterior graft. This process is thought to occur while the graft is either resorbed in the healing process or while the relatively dense graft (for example, the titanium cage) subsides into the VB. Therefore, in this study we chose a dynamic cervical plate because it would share the load more effectively than the locked cervical plates, especially in a model simulating graft subsidence, but it would be less stiff because of its dynamic design. Dynamic plate fixation has been reported to reduce the risk of pseudarthrosis and to stimulate faster healing.2 In our study, in greater than 90% of patients who underwent fusion and dynamic plate fixation, a good level of stability was achieved 1 year after surgery. Nonconstrained plate devices are more prone to failure than more constrained systems.8,10,13 In our study, only the dynamic plate system was used, and instrumentation failure was noted in three asymptomatic patients (two screw fractures and one screw pullout).

Some authors have reported that cervical plate fixation increases fusion rates, allows an earlier return to work, and limits subsidence and kyphotic deformity.4,18 Geer, et al.,2 have observed greater incidences of kyphotic deformities, failed fusion, and subsidence in autograft bone–treated patients compared with those treated with allograft and fixation.5 Cervical plate fixation, however, is not free from complications and morbidity. Lowery and McDonough10 have reported a hardware failure rate of 35% in a series of 133 patients. Esophageal injury is also more common in the patients treated with anterior cervical surgery and cervical plate fixation; compared with plate fixation, interbody cages are recessed below the margin of the VB, providing a so-called no-profile internal fixation that avoids esophageal complications.7 In addition, because the application of a plate over four to five VBs requires greater soft-tissue retraction, it results in a higher incidence of dysphagia and hoarseness. Zdeblick and coworkers26,27 found that although fixation prevented graft extrusion, it failed to increase the histologically verified bone union rate significantly in their goat model. Thus, supplemental internal fixation did not reliably prevent graft collapse. In our study, the rigidity of the outer cage prevented graft collapse, the toothlike serrations of cage provided immediate segmental stability, and the hollow inner space allowed insertion of mixture of autograft bone and artificial bone to assist bone fusion. Analysis of our results demonstrated there was no difference between the stability rates in Groups 1 and 2. Improvement of kyphosis was also found in both Groups 1 and 2, despite the lack of intergroup statistical significance. There was a significant improvement in postoperative neurological function and neck pain in both groups, although the difference was not statistically significant. The complication rate in Group 2, however, was higher than that in Group 1. In addition, the hospital LOS in Group 2 was significantly longer than that in Group 1.

Conclusions

Interbody cage–based fusion with or without plate fixation in the three- and four-level cervical discectomies achieved good stability and neurological outcome; however, there was a lower complication rate in the patients in whom supplemental plate fixation was not performed. Analysis of our results indicates that interbody fusion without plate fixation is a safe and effective method for the anterior cervical discectomy.

References

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