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Expandable Cage for Cervical Spine Reconstruction

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Objective : Expandable cage used for spinal reconstruction after corpectomy has several advantages over nonexpendable cages. Here we present our clinical experience with the use of this cage after anterior column corpectomy with an average of one year follow up.

Methods : Ten patients underwent expandable cage reconstruction of the anterior column after single-level or multilevel corpectomy for various cervical spinal disorders. Anterior plating with or without additional posterior instrumentation were performed in all patients. Functional outcomes, complications, and radiographic outcomes were determined.

Results : There was no cage-related complication. Functionally, neurological examination revealed improvement in 7 of 10 patients and no patient had neurological deterioration after the surgery. Immediate stability was achieved and maintained throughout the period of follow-up. There was minimal subsidence (<2mm) noticeable in three of the cases that underwent a two-level corpectomy. Subsidence was noted in osteoporotic patients and patients undergoing multi-level corpectomies. Average pre-operative kyphotic angle was 9 degrees. This was corrected to an average of 5.4 degrees in lordosis postoperatively.

Conclusion : In conclusion, expandable cages are safe and effective devices for vertebral body replacement after cervical corpectomy when used in combination with anterior plating with or without additional posterior stabilization. The advantages of using expandable cages include its ability to easily accommodate itself into the corpectomy defect, its ability to tightly purchase into the endplates after expansion and thus minimizing the potential for migration, and finally, its ability to correct kyphosis deformity via its in vivo expansion properties.

KEY WORDS : Cervical corpectomy · Expandable cage · Spinal fusion · Interbody fusion.

Introduction

Common pathologies involving the cervical spine include fractures, tumors, and infections. When surgery is necessary because of spinal instability, neurological deterioration, or failure of non-operative treatment, autogenous bone graft and allogenous bone graft have been used to reconstruct the anterior column. Nevertheless, complications relating to the use of bone graft for spinal fusion have been well documented in the literature and have included donor-site morbidity[5,13], pseudoarthrosis[5,18], fatigue failure[20], graft subsidence and graft dislodgement. To ameliorate these problems, cervical cages have been developed and used for spinal surgery with good clinical outcomes[1,2,4,11,12,14-16]; however, some technical problems have been encountered in regards to cage placement. Adjusting the cage to fit snugly into the corpectomy defect is sometimes complicated by the cage's predefined endplate angle and height, resulting in the need to trim the cage intraoperatively. If the cage must be trimmed, correct rotation during placement must be ensured; otherwise, tilting of the implant may occur and may lead to failure of the construct. Furthermore, if intraoperative displacement of the implant occurs, cage removal may compromise the vertebral end-plate integrity. More recently, expandable cages have been developed in order to overcome the technical problems encountered during the placement of traditional non-expandable cages. In addition, its expandable nature provides an opportunity for kyphosis correction not easily accomplished via previously available cages. In this report, we reviewed our clinical experiences with the use of expandable cages after cervical corpectomy.

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Table 1. Demographics and clinical data

Case	Age (Year)	Gender	Diagnosis	Corpectomy	Anterior Construct	Posterior Construct	Frankel's		Sagittal Alignment (o)		Subsidence (mm.)	Complication	F/U (mo)
							Pre	Post	Pre (Kyphotic)	Post (Lordosis)			
1	47	M	Plasmacytoma C7	C7	C6-T1 DOC	-	E	E	5	10	0	None	12
2	40	M	C7 Fx/disl.	C7	C6-T1 DOC	C4-T2	B	C	5	10	0	None	15
3	72	M	C7-T1 Kyphosis/myelopathy	Partial C7/T1	C7-T1 ABC	C6-T1	C	D	12	6	1.3	None	14
4	58	F	Kyphosis C4-6	C4, 5, 6	C3-7 DOC	-	C	D	7	7	2.5	Transient Hoarseness	12
5	27	M	C4 Burst Fx	C4	C3-5 ABC	-	D	D	10	5	0	None	12
6	50	M	C6 Burst Fx	C6	C5-7 DOC	-	C	D	15	0	0	None	14
7	68	F	C5 Burst Fx	C5	C4-6 DOC	-	C	C	5	7	0	None	13
8	52	F	OM C5-6 Pathologic fracture	C5, 6	C4-7 C3 pl	-	C	D	7	9	1.5	Transient Dysphagia	15
9	52	F	C5-6 kyphosis/myelopathy	C5, 6	C4-7 ABC	C4-T1	C	D	17	0	1.7	None	12
10	51	M	C5 Fx/disl.	C5	C4-6 C3 pl	C3-T1	B	D	8	0	0	None	13

Abbreviations : DOC : DOC plate (Depuy-Acromed), ABC : ABC locking plate (Aesculap), C3 pl : C3 locking plate (Osteotech), OM : Osteomyelitis

Materials and Methods

Patient population

Between January, 2001 and March, 2003, 10 consecutive patients underwent expandable cage reconstruction of the anterior cervical spine between C3 and C7 after single-level or multilevel corpectomy. Radiographic and functional outcome evaluations were acquired on all 10 patients with an average postoperative follow-up of 13.2 months.

There were four females and six males. Average age was 51.7 years (27~72 years). In our series, the clinical diagnoses consisted of : 5 cervical fracture dislocations, 1 plasmacytoma, 1 bacterial oseomyelitis, and 3 severe kyphotic deformities with myeloradiculopathy. Patients' clinical diagnosis and demographic data are shown in Table 1.

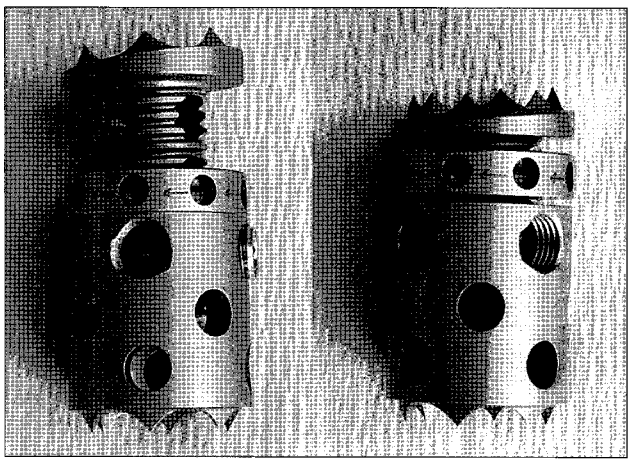

Fig. 1. The Vertebral body replacement expandable cage consists of a central piece and end cap pieces with small spikes at the end for additional stability.

Most of the patients in our series (9 out of 10) presented primarily with spinal cord compression and myelopathy. Only one patient (case #1) presented with intractable neck pain. Six patients underwent one-level corpecteomies whereas two-level and three-level corpectomy were performed in three and one patient respectively.

Surgical technique

The Vertebral body replacement(VBR) expandable cage (Osteotech, Eatontown, New Jersey, USA) was used in all 10 patients for anterior column reconstruction after corpectomy. The expandable VBR cage is a commercially available expandable titanium cage consisting of a round flat endplate surface with small spikes (Fig. 1). Rotational stability is enhanced when the spikes are firmly purchased into the endplates of the corpectomy defect. This cage is available in three different endplate diameters of 12, 14, and 16mm and a distractible height ranging between 10 and 65mm.

All patients had anterior cervical corpectomy and decompression performed by the senior author using a standard transcervical supraclavicular approach. Microsurgical techniques were performed during decompression in all cases. Adjacent vertebral endplates and osteophytes were removed using a high speed drill. Endplates were meticulously prepared after corpectomy. The appropriate VBR implant size was determined by using a caliper to measure the height and width of the corpectomy defect. Autograft bone from the corpectomy and iliac

crest was used to fill the cage. Expansion of the cage can be done by either an expansion instrument or an expansion wrench. First, VBR cage was expanded up to the length of dead space and the bone filling was done. And this distracted and bone filled VBR cage was inserted into the grafting site and final distraction was carried out. Once distracted to its final length, additional graft material could be added to fill the end pieces completely. If repositioning was required, the expansion instrument was turned in the opposite direction to close the VBR assembly. As expansion of the cage occurs, increasing stiffness of endplate purchase can be felt and visualized. In this respect, a tight fit of the cage into the corpectomy defect can easily be achieved and deformity correction is possible. Once expansion of the cage is completed to satisfaction, the end piece can be secured to the central core using a locking set screw thereby preventing further collapse of the expansion. If desired, additional bone graft or bone substitute could be placed around the implant.

Since the cage was not designed to be a standalone device, additional anterior plating was placed in all cases. A DOC plate (Depuy-Acromed, Raynham, MA, USA) was used in five cases, an ABC plate (Aesculap, Tuttlingen, Germany) in three cases, and a C-3 (Osteotech, Eatontown, New Jersey, USA) in two cases. In our series, six patients underwent a one-level vertebrectomy, whereas two-level and three-level vertebrectomies were carried out in three patients and one patient, respectively.

If posterior column integrity was compromised, an additional posterior stabilization was also performed using the mini-polyaxial screw Summit system (Depuy-Acromed). A combined anterior and posterior instrumentation was performed in four cases. Two patients had three column traumatic injuries, one patient had severe postlaminectomy kyphotic deformity, and one patient had severe degenerative kyphotic deformity at the cervicothoracic junction. The remaining cases in our series (six patients) had an anterior approach only (Table 1).

All of these anterior plating and posterior stabilization procedures were done with single anesthesia. All patients wore cervical orthoses after surgery for 6 weeks. Cervicothoracic orthoses were worn in three cases.

Evaluations of functional outcome and complication

The functional outcomes were reviewed using the Frankel neurological performance scale. Nine patients presented with myelopathy, and only one patient (case #1) presented with intractable pain without neurological deficit.

Only one patient had a Frankel Grade E at presentation. One patient presented as a Frankel Grade D, six patients were a Frankel Grade C, and two patients were a Frankel Grade B. Patients with fracture dislocation were operated on within eight hours.

Perioperative complications such as wound infection, CSF leak, visceral injury, dysphonia, dysphagia, respiratory difficulties, and neurological deterioration were noted if present.

Radiographic evaluation

The following potential hardware-related complications were monitored using serial radiography : cage migration, dislodgement, progressive instability, and plate and screw dislodgement. Serial radiographs were obtained at 24~48 hours, 3 months, 6 months, and 1 year postoperatively. Dynamic flexion-extension radiographs were also obtained to evaluate stability, which was defined as <3mm of translatory movement and a <5 degree change in angulation between flexion and extension.

Reduction of kyphosis (change in Cobb angle) was also determined between preoperative and postoperative radiographs. Sagittal alignment was measured before surgery, immediately after surgery, and at a final follow-up. The sagittal alignment was derived by the Cobb method of measurement. The lines of measurement were taken from the superior endplate of the cephalad vertebra fused and the inferior endplate of the caudal vertebra fused.

The subsidence or settling of the cage was observed from the radiographic studies in a sequential fashion. The subsidence (mm) was a combined measurement of the distance of the cage sinking into the upper and lower end plate.

Results

Functional outcome

Overall, at last follow up, neurological examination revealed improvement in 7 of 10 patients and no patient had neurological deterioration after the surgery (Table 1). Five cases in our series suffered a severe fracture-dislocation and we found out that the neurological outcome was unpredictable even though all the trauma cases were operated on within 8 hours of injury. In the trauma group, three had at least one Frankel's grade improvement whereas the other two had no recovery. On the contrary, all three cases in the deformity group had at least one Frankel's grade recovery. These findings imply that the onset and severity of the initial injury must play an important role in neurological recovery.

Surgery-related complications

There were no wound infections, cerebrospinal fluid leaks, respiratory difficulties, vertebral or carotid artery injuries, recurrent laryngeal nerve palsy, superior laryngeal nerve palsy, or esophageal injury. One patient who underwent two-level corpectomies had transient difficulty of swallowing, which fully recovered in 6 weeks. Another patient who underwent

three-level corpectomies developed transient hoarseness, which fully resolved in 4 weeks.

There were no cases of anterior plating hardware failure such as screw loosening or backout, plate breakage, or plate pullout noted on radiographic images. There was also no evidence of cage-related complications including extrusion of the cage, cage migration, or significant settling of the cage.

Radiographic outcomes

Preoperative kyphotic alignment ranged between 5-17 degrees with an average kyphotic angle of 9 degrees. Postoperative alignment was neutral in three patients and lordotic in the remaining cases. No significant changes in the alignment occurred in our series. The alignment was maintained throughout the period of follow-up. Average alignment at final follow-up was 5.4 degrees in lordosis.

In three patients, mild changes (< 2mm) in the subsidence were recorded. Interestingly, those three cases are the patients who underwent two- or more level corpectomies. The diagnosis of osteoporosis was also apparent in two of these three patients. Cage subsidence was noted only during the first four months after surgery and did not occur after six months in our series. Of note, the patient who had a three-level corpectomy with anterior construct only (case 4) had the most subsidence in our series (2.5mm) by three months of follow-up; however, no further subsidence or failure of the construct occurred at one year follow-up. The remaining six patients (one-level corpectomy) did not suffer from cage subsidence on serial radiographs.

Dynamic x-rays at the final follow-up showed no evidence of abnormal movement and also no line of lucency at the bone-cage interface. Internal stability was achieved immediately after surgery and was maintained throughout the period of follow-up. Since we could not justify the routine use of postoperative CT on these patients, the absolute determination of bridging bone and thus fusion was difficult to assess. Nevertheless, dynamic x-rays did not reveal any evidence of instability during the duration of our follow-up.

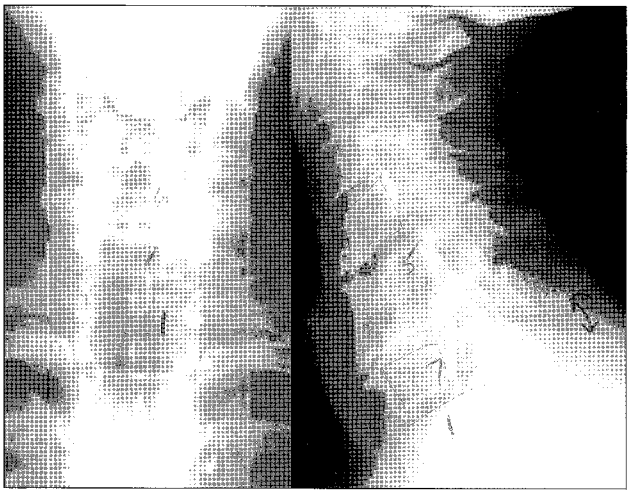

Fig. 2. Plain x-rays revealing a kyphotic deformity at C5-6 with pathological fracture. C5 and C6 intervertebral disc is also affected secondary to chronic infection process.

Case Illustration

This is a 52 years old patient who suffered from kyphotic deformity secondary to pathologic fracture from chronic osteomyelitis. She suffered a progressive neurological deficit for several months and presented with a Frankel neurological

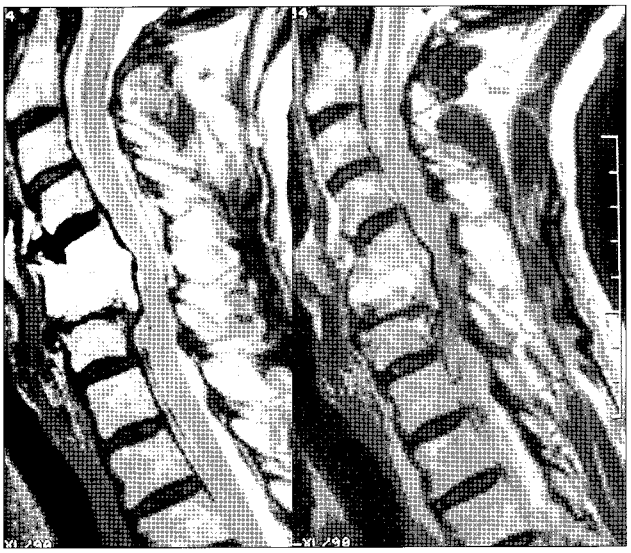

Fig. 3. Magnetic resonance image showing a kyphotic deformity of the cervical spine with spinal cord compression.

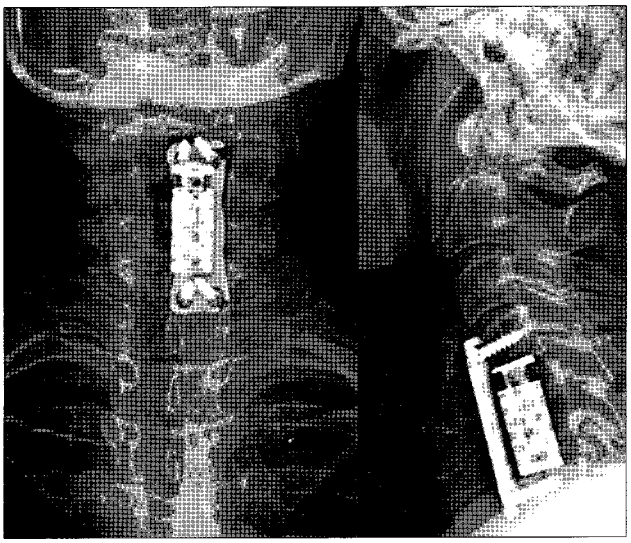

Fig. 4. Antero-posterior and lateral postoperative x-rays showed expandable cage replacement spanning from C4-C7 after C5 and C6 corpectomies, with anterior construct only. The alignment of cervical spine is well maintained and the patient has gained her neurological function back.

grade C at our institution. She was also diagnosed with osteoporosis. Plain radiographs (Fig. 2) and MRI (Fig. 3) of the cervical spine revealed a kyphotic deformity at C5 and C6 with significant spinal cord compression. C5-6 was also affected by the infection process. Anterior corpectomy of C5 and C6 to decompress the spinal cord was performed following by placement of the expandable cage. Bone filling was done with autogenous iliac cancellous bone. Anterior plating (C3 plate, Osteotech) was placed from C4 to C7. Postoperative X-rays (Fig. 4) showed a good alignment of the cervical spine with expandable cage spanning from C4 to C7 with anterior construct. Patient was sent to a rehabilitation care facility for 6 weeks after the surgery and she gradually showed recovery in her neurological function. At the last follow-up, 12months after the surgery, she had gained recovery of her neurological function to a Frankel grade D.

Discussion

Anterior column reconstruction after corpectomy is a necessary step to restore the axial height and the sagittal plane contour. Bone is considered the best material for bridging the gap and achieving permanent stability through fusion. But it has some problems of graft dislodgement, discordance between cervical lordotic curvature and straight graft bone, harvest site complications, etc. Other authors preferred the use of allografts with their potential hazards and reported a high fusion rate.

The use of cages for spinal surgery have been shown to be effective in providing effective anterior column support and long term stability;[2,4,12,14,15] however, after the corpectomy, the implantation of the currently available nonexpandable cages can often be demanding. For nonexpandable cages, adjusting the cage size to the endplates and height of the corpectomy defect has been limited by predefined cage endplate angle and height, resulting in the need to trim the cage intraoperatively. If the cage must be trimmed, correct rotation of the cage must be ensured, otherwise tilting of the implant may occur. Furthermore, if intraoperative displacement of the implant occurs, removing the cage during the operation might compromise endplate integrity. Finally, direct correction of internal kyphosis of the anterior column is difficult with currently available nonexpandable cages.

In attempts to overcome the technical problems associated with nonexpandable cages, expandable cages for vertebral body replacement in the cervical spine have been recently developed. The expandable cage can offer several advantages. First, it can be expanded to provide the best optimal fit into the corpectomy defect. Second, the correction of kyphosis deformity due to its in-vivo expansion properties is possible. Third, its porous nature will allow for ingrowth of bony elements. And lastly, the expandable cage endings with spikes and relatively large implant-bone interface allow for excellent purchase into the vertebral endplates minimizes cage migration and sinking-in. Overall, it has provided immediate stability and maintains its corrective alignment throughout the period of follow-up. Disadvantages include cost, difficulty in assessing fusion on plain radiographs, potential difficulty in cases requiring surgical revision, the potential of stress shielding that may affect fusion, and small fusion area.

Kandziora et al[9] performed a biomechanical study of the expandable cages and demonstrated that all stand-alone implants were not able to restore normal stability of the motion segment in extension. Therefore, anterior stabilization performed using stand-alone nonexpandable or expandable cages is not suitable for vertebral body replacement in the cervical spine. There were no biomechanical differences between the nonexpandable and expandable cages. Furthermore, there were no biomechanical differences between the tricortical iliac crest graft and the cages, except for Synex-C (Mathys, Bettlach, Switzerland) in rotation. In contrast, the cages plus anterior stabilization and the cages plus anteroposterior instrumentation significantly increased stiffness in all test modes compared with the intact motion segment. Therefore, cage fusion plus anterior or combined anterior-posterior stabilization is preferred over a stand-alone implant. In comparison with stand-alone cage implants, additional anterior plating demonstrated a further increase in stiffness of up to 254%, especially in extension[9].

There are some debatable problems for the replacement of corpectomy site. First, bone fusion area is similar or smaller at the elongating portion than non-expandable mesh cages. Second, bone particle impaction into the elongated VBR cage is somewhat difficult and maybe insufficient filling. As for these reasons, expandable cages had been used for the purpose of strut rather than fusion, and used in the replacement of the spine neoplasm in previous studies. But recently these are started to be used for the purpose of fusion in traumatic and osteoporotic fractures by some European surgeons[10,17].

Ulmar et al[19] reported 53 expandable titanium cage replacement cases of malignancies, traumatic and osteoporotic patients. Average follow up was 18.9 +/-19.9 months. They concluded the using of expandable cage can provide sufficient stabilization of the vertebral column, pain reduction and neurological improvement with an acceptable perioperative complication rate.

Krbec et al[10] reported 34 cases of patients used with Synex System (Synthes Spine, PA, USA). Total 34 cases were divided as 14 vertebral fracture cases, 6 post-traumatic kyphosis, 8 metastatic tumors and 6 primary tumors. They also used this

system with additional stabilization by either posterior or anterior fixation. Follow up was 2 to 24 months and the result was successful.

These biomechanical and clinical reports[9,10,17] made us to try to use this expandable cage for the fusion of corpectomy site with additional anterior and/or posterior instrumentation.

In our series, no stand-alone expandable cages were performed with respect to previous biomechanical studies[7,9]. Four cases underwent a combined anterior and posterior reconstruction and instrumentation. The remaining six cases had anterior stabilization only. We found no cage-related complications or failures at final follow-up. Overall complications were similar to other reports[8,11] including one transient difficulty in swallowing and transient hoarseness. In our series, a wide decompression (>16mm) had been performed in order to maximize neurological recovery. Seven cases had improvement of at least one Frankel grade at last follow-up. It has been postulated that the preservation of the endplates may prevent potential telescoping of the cage device (cage subsidence). End caps, designed to prevent telescoping by increasing the contact surface area, increase the cage's maximum load-bearing ability but do not affect the construct's stiffness.

ElSaghir et al[6] reported a prospective study comparing anterior and posterior plating in cervical corpectomy. Each group comprised of 30 patients who were candidates for cervical corpectomy. In the first group, anterior plating was done using Orosco-type titanium plates. In the second group, lateral mass plating was done. In all cases, titanium cages were used to reconstruct the corpectomy defect. Pseudarthrosis was not encountered in either group. Posterior plating was better than anterior plating in terms of overall construct stability and related complications. Screw breakage was encountered in seven patients with anterior plating (23.33%). This complication was not seen in the group with posterior plating. Sinking-in of the cage was encountered in 7 cases with anterior plating and in only 3 cases with posterior plating. However, the difference between the groups was not statistically significant.

Narotam et al[12] reported their experiences of using titanium mesh cage in cervical corpectomy. The mean cage height-related settling rates were 4.46% at 3 months, 3.89% at 6 months, and 4.35% at 1 year. The mean sagittal displacement changed by 3.9%. The mean coronal and sagittal angles changed 2.89° and 2.09° at 1 year, respectively, or at last follow up from baseline. No significant differences in the radiological indices were seen when multilevel vertebrectomy cases were compared with single-level vertebrectomy.

In our series, no significant subsidence or sagittal malalignment occurred at the final follow-up. Three patients (30%) had mild subsidence (<2mm.) during the first four months after the surgery without any clinical sequelae. Interestingly, two of three patients were diagnosed with osteoporosis as their co-morbidities. Furthermore, all subsidence occurred in patients with two-level corpectomies despite additional posterior stabilization. The greatest subsidence (2.5mm) in our series occurred in a patient with severe osteoporosis who underwent a three-level corpectomy with anterior construct only. Based on our series, osteoporotic patients and patients undergoing multi-level corpectomies will be at risk for cage subsidence. Additional posterior construct may help minimize the chance of significant subsidence. Average pre-operative kyphotic angle was 9 degrees and was corrected to an average of 5.4 degrees of lordosis postoperatively. This was maintained throughout the period of follow-up. In addition, there was no significant change in sagittal alignment on follow up, even in the group where subsidence was noticed. Maintenance of sagittal alignment may be an additional advantage of expandable cage usage.

To date, clinical reports of using expandable cages for vertebral body reconstruction after cervical corpectomy have been sparse. Coumans et al[3] reported the use of telescopic plate spacer in 15 cases of spinal tumors. This special implant incorporates anterior plating and expandable spacer together. Neither failure of instrumentation nor significant subsidence occurred in their series. Lordotic angle was maintained in all of their patients. Our previous report[17] on the use of expandable cage in spinal reconstruction for tumors involving the thoracic, thoracolumbar, and lumbar area showed immediate stability without cage-related complications in 15 patients. In this report we provide our clinical series of an additional 10 patients, with an average of one year follow-up, of using expandable cages after cervical corpectomies. Overall, expandable cages as used in our series provided immediate stability after cervical corpectomy and have maintained this stability throughout the period of follow-up as evidenced by lack of movement on dynamic x-rays and maintenance of sagittal alignment. Both safety and efficacy of using the VBR expandable cage for vertebral body reconstruction after cervical corpectomy is evident in this one year follow up report. We will continuously investigate the long term clinical and radiologic results.

Conclusion

The VBR expandable cage is safe and effective devices for vertebral body replacement after cervical corpectomy when used in combination with anterior plating with or without additional posterior stabilization. In our series, there were no surgically related or cage-related complications. Subsidence was more likely to occur in osteoporotic patients or patients who underwent multi-level corpectomies. Tight acc-

ommodation into the corpectomy site and correction of the normal cervical lordotic curvature could be achieved easily.

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Commentary

Zhang et al used expandable cylindrical titanium cages for anterior column reconstruction in ten patients with metastatic tumor, trauma and kyphotic deformity secondary to degeneration and spondylosis.

As is intuitively understood, the cylindrical cages do not provide stability against extension and therefore need to be used in combination with anterior cervical plate or posterior fixation systems. The titanium implants restore lordosis immediately, as compared with other non-expandable system. Within the relatively short follow-up period up to 15 months, the sagittal alignment stayed restored with little subsidence, except for those with osteoporosis. Usefulness and efficacy in restoring the immediate stability and alignment, in cases with healthy bony substance is well demonstrated.

However, for long-term efficacy and safety of the devise, we have to wait for a study with much longer follow-up. Of a specific concern is the inherent limitation in providing surface contact between the bony graft material and the inlay vertebral bone surface. Since the bottom and top plates of the expandable cages are designed to provide a large contact area to prevent subsidence, the contact of the autologous bone material packed into the cylinder with the inlay cancellous bone is limited.

Therefore, concerning a proof of long-term efficacy in patients with spondylotic kyphosis or cervical trauma in young patients, we have to wait for another study. By contrast, the present paper provides persuasive demonstration that the authors' technique using the implant is relatively simple and especially useful for patients with destructive metastatic vertebral body lesions, whose prospect of survival is limited.

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