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Preliminary Surgical Result of Cervical Spine Reconstruction with a Dynamic Plate and Titanium Mesh Cage

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Objective : The objective of this study was to validate the effects of a titanium mesh cage and dynamic plating in anterior cervical stabilization after corpectomy.

Methods : A retrospective study was performed on 31 consecutive patients, who underwent anterior cervical reconstruction with a titanium mesh cage and dynamic plating, from March 2004 to February 2006. Twenty-four patients had 1-level and 7 had 2-level corpectomies. Ten patients underwent surgery with a cage of 10-mm diameter and 21 with 13-mm diameter. Neurological status and outcomes were assessed according to Odom's criteria. Sagittal angle, coronal angle, settling ratio, sagittal displacement, and cervical lordosis were used to evaluate the radiological outcomes.

Results : In overall, 26 (83.9%) of 31 showed excellent or good outcomes. Thirteen percent (4 cases) of the patients developed surgical complications, such as hoarseness, transient dysphagia, or nerve root palsy. Seven (22.6%) patients had reconstruction failure : 5 (20.8%) in the 1-level corpectomy group and 2 (28.5%) in the 2-level corpectomy group. Revisions were required in 2 patients with plate pullout due to significant instability. However, none of 5 patients who demonstrated cage displacement or screw pullout, underwent a revision. Radiographs revealed bony consolidation in 96.3% of the patients, including 6 patients with implantation failure during the follow-up period.

Conclusion : Based on our preliminary results, the titanium mesh cage and dynamic plating was effective for cervical reconstruction after corpectomy. The anterior cervical reconsrtruction performed with dynamic plates is considered to reduce stress shielding and greater graft compression that is afforded by the unique plate design.

KEY WORDS : Cervical corpectomy · Dynamic plate · Titanium mesh cage.

Introduction

In treating degenerative, traumatic, and neoplastic disorders of the cervical spine, several authors have described cervical corpectomy and fusion with iliac crest autografts, allografts, or fibular strut grafts in conjunction with rigid anterior cervical plating (ACP)[3,4,13,17]. Although ACP-assisted stabilization may eliminate some of these complications, pseudoarthrosis and hardware failure rates of 2-8% have been reported with statically plated anterior cervical fusions which may require revision surgery[3,13,17,15,20,25]. Concern has been expressed that rigid fixation with static anterior plating may result in graft stress shielding, thereby reducing the mechanical loads that are important to successful graft healing[1,10,14]. Another alternative option is to use a semi-constrained dynamic plate device that allows micro-motion of the screws. This option is attractive for those who are concerned about uncontrolled and excessive settling and desire greater load sharing than that offered by the traditional rigid plate with fixed angle screws[2,12,14]. Recently, cervical titanium cages have been gaining acceptance as a method for ensuring cervical interbody arthrodesis, which also offers the greatest biomechanical resistance to axial loading forces[6,8,9,16,18,21,22,26]. However, conjecture continues over possible complications, such as erosion of adjacent endplates, settling, telescoping, and the presence of a solid fusion within the cage[9,15,16,21].

The objective of this study was to examine the efficacy and complications of dynamic anterior cervical fusion using a titanium mesh cage (TMC) and local autograft after cervical corpectomy for degenerative, traumatic, and neoplastic disorders.

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Materials and Methods

In this retrospective study, we evaluated 31 consecutive patients who underwent anterior cervical reconstruction using TMC and dynamic plating during a 2-year period (March 2004 to February 2006) with an average follow-up period of 13.6 months (range, 6 to 29 months). Their ages ranged from 18 to 75 years old. There were 27 male and 4 female patients. The following clinical data were collected : age, diagnosis, smoking history, type of surgery, site and extent of surgery (single or double corpectomies), and diameters of the cages (Table 1).

Table 1. Summary of demographic data in 24 patients who underwent cervical spine stabilization with titanium mesh cage and semi-constrained anterior cervical plate

		No. of cases
Sex	Male : Female	25 : 6
Age (yrs)	Mean age ± SD	52.77 ± 15.65
Smoking		9
Diagnosis		
Degenerative	Spondylosis	11
	Migrating disc	6
	OPLL	4
Trauma	Compression Fracture	5
	Fracture & dislocation	2
Pathological	Infection	2 (TB : 1, Brucellosis : 1)
	Metastasis	1
No. of Corpectomies	Single : Double	24 : 7
Cage diameter	10mm : 13mm	10 : 21
Posterior fusion	Additional fixation	2
	Revision due to failure	2

OPLL : ossification of posterior longitudinal ligament; SD, standard deviation; TB, tuberculosis

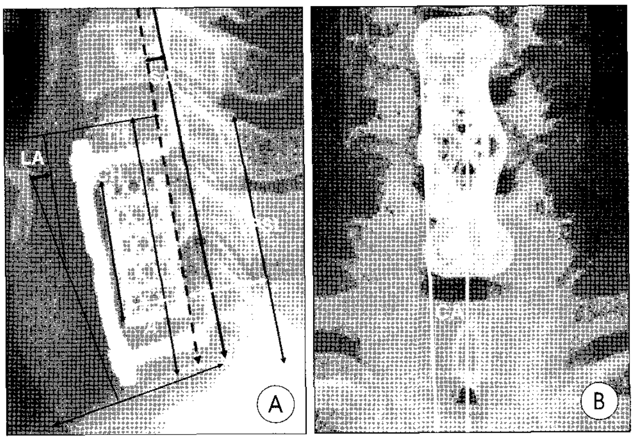

Fig. 1. A : Lateral radiograph obtained on a patient undergoing titanium mesh cage (TMC)-augmented stabilization after corpectomy. The settling ratio was determined by the ratio of the cage height (CH) and the distance between the superior end of the superior vertebra and the inferior end of the inferior vertebra (TH). Sagittal displacement was determined by dividing the distance between the posterior margins of the cage to the posterior spinal line (B) by the width of the cage (A). The sagittal angle (SA) was subtended by the posterior edge of the cage and the posterior spinal line. Local kyphosis (LA) was derived by the Cobb method of measurement. B : The coronal angle (CA) was subtended by the lateral margin of the TMC and the spinous process.

The patients underwent anterior cervical channel corpectomies and decompressions with conventional approach. Posterior cortical bone, adjacent vertebral endplates and osteophytes were removed with a 5-mm burr on a high-speed drill and a Kerrison punch. The Pyramesh cage (Sofamor-Danek; Memphis, TN., USA) was used with autologous bone chips that were harvested during the corpectomies. TMC endcaps were not used to obtain uniform distribution of strain under the cages. Atlantis plates (Medtronic Sofamor Danek) with variable screws were used in 27 patients, and ABC plates (Aesculup; Tuttlingen, Germany) were used in 4 patients.

The patients were instructed to wear a hard neck brace for 6 to 8 weeks postoperatively. Neurological status and outcomes were assessed according to Odom's criteria. Surgery-related complications were carefully monitored and evaluated. Postoperative radiographs were obtained monthly during the follow up period. Sagittal angles, coronal angles, settling ratios, and sagittal displacement of TMCs were used to evaluate the radiological outcomes (Fig. 1). Reduction of kyphosis (the change in Cobb's angle) was also determined between the preoperative and postoperative radiographs. The lines of measurement were taken from the superior endplate of the fused cephalad vertebra and the inferior endplate of the fused caudal vertebra. Sagittal alignment was measured before surgery, immediately after surgery, and at the final follow-up. The sagittal alignment was derived by Cobb's method of measurement between C2 and C7. The following potential hardware-related complications were monitored using serial postoperative radiography : cage migration or dislodgement, progressive instability, and plate and screw dislodgement. The antero-posterior or lateral X-ray films, taken immediately after the operation served, as a baseline. If the sagittal or coronal angles were changed more than 10 degrees, or the change in the sagittal displacement or settling ratio were more than 10% at each follow-up, significant instability and implant failure was con-

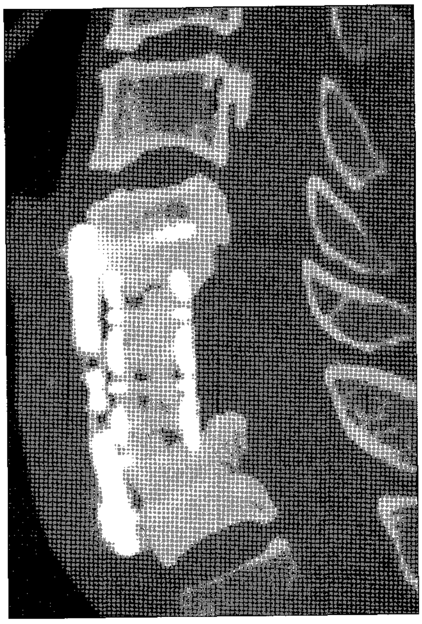

Fig. 2. Postoperative sagittal reconstruction of axial computed tomography scans confirmed adequate graft/fusion cephalad and caudad within titanium mesh cage (TMC) 6 months after corpectomy and TMC augmented stabilization.

Table 2. Summary of clinical results and surgical complications in 31 patients who underwent anterior cervical fusion with titanium mesh cages

		No of cases (%)
Neurologic outcomes (Odom's criteria)		
Excellent	No complaints referable to cervical disc disease; able to continue daily occupation without impairment	14 (45.2)
Good	Intermittent discomfort related to cervical disease, but not significantly interfering with work	12 (38.7)
Satisfactory	Subjective improvement, but physical activities limited	3 (9.7)
Poor	No improvement or worse compared with the condition before the operation	2 (6.4)
Complications	Total	4 (12.9)
	Dysphonia	1
	Transient dysphagia	2
	Hematoma	0
	Nerve root palsy	1
	Wound infection	0

sidered to be present.

Cervical 3-dimensional computed tomography (CT) scans with sagittal reconstruction were evaluated to assess the pattern of the bone fusion within the cage. Solid bony fusion criteria included a lack of bony lucency, presence of bony trabeculation at the cage/vertebral interface on the radiographs, and bone growth into the central TMC on 3-dimensional CT (Fig. 2). Dynamic radiographs were used to confirmed the lack of translation and less than 10 degrees of angulation between extension and flexion[22].

Results

Clinical outcomes

Overall, at the last follow-up, 26 patients experienced improvement of clinical symptoms, 3 patients showed limited improvement, 2 remained unchanged, but no worsening, after surgery (Table 2). In 7 cases of the trauma group, five with compression fractures showed either good or excellent improvement, but two with severe fracture-dislocations did not show any recovery. Surgery related complications included transient dysphonia in one patient, severe dysphagia in two (a gastric feeding tube was required in one patient), and C-5 nerve palsy in one that was recovered fully 6 weeks after surgery (Table 2). There were no wound infections, cerebrospinal fluid leaks, respiratory difficulties, vertebral or carotid artery injuries, or esophageal injuries.

Table 3. Summaries of radiological data (mean ± standard deviation) that changed in 31 patients during the follow-up period

		Value
Sagittal angle of cage (degrees)	Postop	3.26±4.39
	Final F/U	4.42±5.17
Coronal angle of cage (degrees)	Postop	3.09±2.34
	Final F/U	3.87±3.93
Local lordosis on operative segment (degrees)	Preop	5.48±8.57
	Postop	8.65±8.19
	Final F/U	8.43±6.71
C2-7 lordosis (degrees)	Preop	14.61±10.53
	Postop	18.56±9.49
	Final F/U	18.29±7.67
Change of SD ratio (%)		4.53±7.04
Change of settling ratio (%)		4.16±3.67

Postop : immediately postoperative; F/U : follow up; SD : sagittal displacement

Radiological outcomes and fusion rates

The mean sagittal angle of the TMCs was 3.26±4.39° immediately after surgery, and 4.42±5.17° at the final follow-up. The mean coronal angle was 3.09±2.34° after surgery, and 3.87±3 .93° at the final follow-up. The mean change in sagittal displacement was 4.52±7.03% and the mean change in the settling ratio was 4.16±3.67%. The mean values of each parameter are described in Table 3. In patients with 10-mm cages, none experienced a change in the sagittal angle of more than 10 degrees, a change in sagittal displacement of more than 10%, or a change in the settling ratio of 10%, indicate of significant instability (Fig. 3). Only 1 patient experienced a change in the

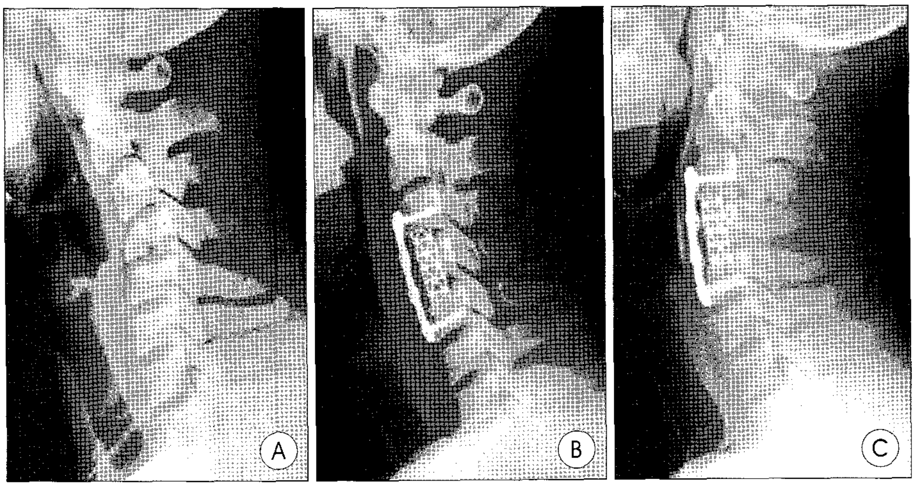

Fig. 3. A : Preoperative radiograph of a 37-year-old female with a C4 compression fracture. B : 1-month postoperative radiograph of the same patient after a C4 corpectomy and reconstruction using a 10-mm titanium mesh cage. C : A lateral radiograph 12 months after surgery demonstrating minor pistoning of the cage and extensive bone growth around the cage; but no implant failure and kyphosis. The patient had a cervical lordosis and successful clinical outcome.

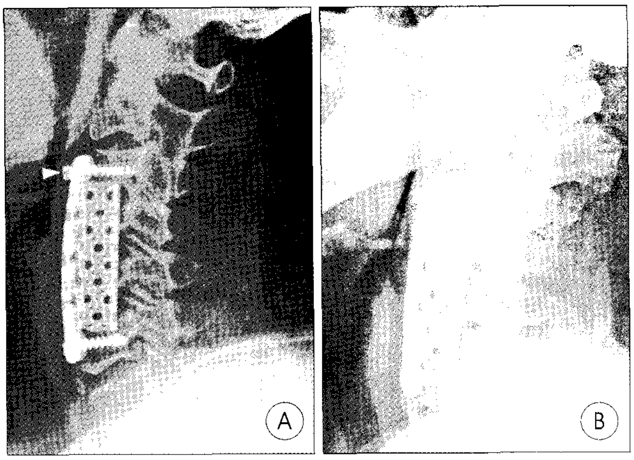

Fig. 4. A : Lateral radiograph of failure of a 2-level corpectomy reconstruction using a 13-mm titanium mesh cage 2.5 months after decompression of ossification of the posterior longitudinal ligament. The screw has pulled out of the cephalad part of the vertebral body (arrowhead). B : Lateral radiograph 6 months after surgery demonstrating a non-union with presence of peri-implant lucencies (white arrow).

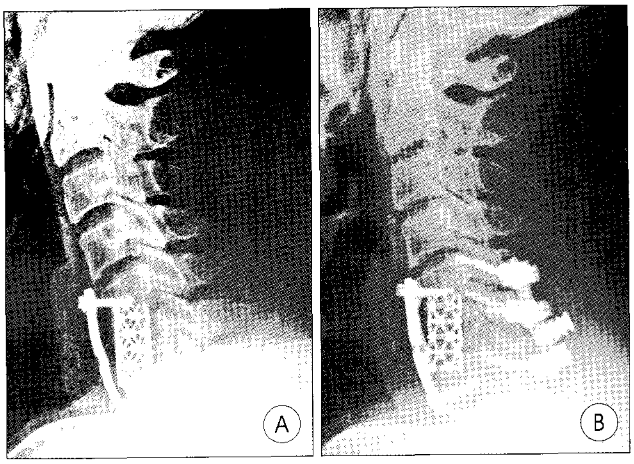

Fig. 5. A : Lateral radiograph of failure of a 1-level corpectomy reconstruction using a 13-mm titanium mesh cage 4.5 months after surgery for cervical myelopathy. The plate had pulled out of the cephalad part of the vertebral body. B : Lateral radiograph 6 months after the revision surgery demonstrating a successful fusion with only posterior lateral mass screw-rod fixation.

coronal angle of more than 10 degrees. In patients with 13-mm cages, 1 experienced a significant change in the sagittal angle of more than 10 degrees, 1 with a change in the coronal angle, and 2 with changes in sagittal displacement. One patient experienced a significant change in the settling ratio and non-union (Fig. 4). Finally, successful fusions were achieved in 30 patients, including 6 patients who had implantation failures. Among these cases, one patient with plate pullouts underwent posterior fusions with lateral mass screw and rod systems (Fig. 5). The average time required to achieve a solid fusion was 5.4 months. The radiological fusion rate in our study was 96.3%.

Failure of implantation

Seven (22.6%) patients showed failure of implantation (Table 4). There were 5 (20.8%) failures in the 1-level group and 2 (28.5%) in the 2-level group. In contrast, there was one (10%) failure in the 10-mm diameter group of TMCs and six (28.6%) in the 13-mm group. However, there were no case of early construct failures within 6 weeks. Of the seven failures, three occurred within 12 weeks postoperatively, and remaining four occurred after 12 weeks. Despite the construct failures in this series, there were no neurologically worsened cases. There were no esophageal, tracheal, or vascular injuries resulting from the extruded devices. Two (6.5%) of the failure patients needed surgical revisions. One patient underwent posterior fixations with lateral mass screw and rod systems. Despite caudal plate dislodgement, however, one patient refused revision surgery because of lack of significant clinical symptoms. There were no implant failures following the revision surgeries at the last follow-up, and all the patients showed successful fusions.

Table 4. Clinical data for seven patients with failed implantations

Age (yrs) /sex	Diagnosis	No. of corpectomy (level)	Cage size (mm)	Radiologic findings	Duration btwn OP and failure	Revision
M/18	C4 compress Fx	1 (C4)	10	Severe lateral tilting (10° >)	6 months	No
M/66	Cervical spondylosis	1 (C6)	13	Plate pullout (superior) Cage displacement (10%>) Severe sagittal angle (10° >)	4.5 months	Yes (Post fusion)
F/54	OPLL	2 (C4, 5)	13	Screw pullout (superior) Severe subsidence (SR >10%) Non-union	2.5 months	No
M/65	Cervical spondylosis	1 (C6)	13	Cage displacement (10%>)	3 months	No
M/56	TB spondylitis	2 (C3, 4)	13	Screw pullout (superior) Severe lateral tilting (10° >)	3 months	No
M/42	Severe migrating cervical HNP	1 (C6)	13	Screw breakout (inferior)	5 months	No
M/69	Cervical spondylosis	1 (C4)	13	Plate pullout (inferior)	3.5 months	Required but refused

Fx : fracutre, HNP : heniated nuclus pulposus, OP : operation, OPLL : ossification of posterior longitudinal ligament, post : posterior, SR : Change of settling ration, TB : tuberculosis

Discussion

The goals of cervical internal fixation are to enhance stability of an unstable segment, to improve the fusion rate, to correct spinal deformities, and to decrease the need for cumbersome bracing[3,5,7]. Titanium mesh cages (TMCs) have been recently introduced to provide an anterior structural support without harvesting tricortical bone blocks after corpectomies[6,8,11,18,22,24,27]. They also offer the advantages of immediate restoration and maintenance of intervertebral disc height, enlargement of a stenotic neural foramen, and stabilization of the cervical spine[16].

Previous reports on the use of TMCs and rigid, constrained anterior plating after cervical corpectomies, have shown favorable outcomes, with successful fusion rates ranging from 95% to 100% and implant complication rates of 6% to 28%[8,18,27]. The initial report of this technique by Majd et al.[18] indicated only one (2.9%) cage extrusion. Thalgott et al.[27] also observed a 100% fusion rate with only one patient having significant subsidence of the cage and screw back-out. Although many investigators previously have reported the benefits of TMCs and rigid fixation in reconstruction of the cervical spine following cervical corpectomies, some of recent reports have warranted the caution. Hee et al.[15] reported specifically on the complications of this technique in multilevel corpectomies. Their overall complication rate was 33%. Of their 21 patients, 6 (28%) had cage, plate, or screw complications; and three (14%) had significant subsidence. More recently, Daubs reported that the failure rate of fixation with cage subsidence and distal plate extrusion was 30% (7 of 23 patient), which was higher than previous reported results[9].

The most reliable theory for the high failure rate is that the constrained plate is unable to overcome graft subsidence and to shied the graft from the sharing load[9,14,16,25]. There is evidence to suggest that eliminating mechanical loads on healing bone with rigid fixation may result in negative bone remodeling and net bone loss; whereas, less rigid fixation that permits a certain degree of micro-motion may accelerate the time to union[9,23]. Dynamic cervical plates have been designed to provide advantage of these properties and are gaining acceptance as a form of fixation that may stimulate faster healing and reduce the risk of pseudoarthrosis and implant failure[2,14]. The Atlantis variable construct is a semi-constrained system, which allows for rotational motion at the plate-screw interface on both ends of the plate[1,12]. The ABC plate also allows translational subsidence because the plate has a slotted hole at the most proximal and distal ends[14].

Barnes et al.[1] presented a retrospective review of 77 patients in whom they performed anterior interbody fusions using the Atlantis plate system and autologus bone grafts. In this report, overall good-to-excellent outcomes were observed in 75% of patients and osseous fusion was demonstrated in 93.5%. In Epstein's report on one-level anterior corpectomies with fusions using iliac autografts and Atlantis hybrid plates, the Atlantis plates contributed to successful fusions in 87% of patients[12]. In another report, forty-two consecutive patients with dynamic ABC plated one-level cervical fusion utilizing iliac crest autografts and fibula allografts were evaluated[14]. In this report, only four (9.5%) of the 42 patients developed postoperative plate or graft-related complications. However, the clinical advantages of TMCs have yet to be completely defined in cervical corpectomy models with dynamic cervical instrumentation.

Narotam et al.[22] reported their experiences with titanium mesh cages and constrained plates in cervical corpectomies. 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 was changed by 3.9%. The mean coronal and sagittal angles were changed by 2.89 degrees and 2.09 degrees at 1 year, respectively, or at the last follow-up from the baseline. Kanayama et al.[16] reported that the degree of lordosis of the operative segments was $5.0 \pm 6.9°$ preoperatively, $6.9 \pm 5.6°$ immediately after surgery, and $5.0 \pm 4.7°$ at the final follow-up. Das et al.[8] also reviewed 38 cases treated with titanium mesh cages and rigid anterior plating and reported that 30 (79%) patients achieved a solid fusion in lordosis, whereas 6 (16%) had a kyphotic fusion.

In our series, the overall settling ratio and sagittal displacement were comparable with previous reports and early implant failure was absent. The average preoperative local lordotic angle was 5.48 degrees and was corrected to an average of 8.65 degrees postoperatively. This was maintained throughout the follow-up period. In addition, there was no significant change in sagittal alignment (C2-7 lordosis) on follow-up, even in the group where subsidence was observed. This seems to be an additional advantage of dynamic cervical plates. The overall fusion rate in this study was 96.5% (30 of 31), including one case of revision. This fusion rate is also comparable to other reports as Martin et al.[19] reported a fusion rate of 90% using freeze-dried allografts in one-level procedures, and Majd et al.[19] reported radiographic fusion rate of 97%.

As other hardware- or cage-related complications that were observed in previous reports, most of the failures in our series seemed to occur by the similar mechanism of cage subsidence (pistoning theory) into the caudal part of the vertebral bodies, followed by plate or screw extrusions[9,15,16,21]. DiAngelo et al.[10] demonstrated that the instantaneous axis of rotation is shifted anteriorly after application of an anterior plate. The outcome is a reversal of the loading pattern in a long strut graft in that no loading of the graft occurs under flexion moments, and profound, excessive compression of the graft occurs under extension loads. This results in graft cavitation through the caudal vertebral endplate and the plate subsequently kicking out of the lower vertebral body by an excessive load. However, the balance of the load in dynamic configuration is not carried by the plate, but rather by the graft and posterior elements[23].

Interestingly, as in our series, there was a trend toward higher failure rates in the 13-mm group compared with those of the 10-mm group, although this did not reach statistical significance (p= 0.32). The greatest subsidence (change of settling ratio > 10%) in our series occurred in a patient using a 13-mm cage. Although the use of a dynamic plate diverted the bulk of the load from the graft to the posterior elements[23], a larger moment arm may be generated at the posterior ends of the larger TMC, potentially leading to cage settling and plate dislodgment.

In addition, the titanium mesh cage, with its small footprint and sharp edge, may be more susceptible to fatigue failure and subsidence through a pistoning mechanism. End-caps for the mesh cages were introduced later to avoid the problem of sharp edges and to increase the surface area of contact. Although the end-cap does increase the surface area of contact of the cage with the vertebral body endplate, it decreases the surface area of contact with the bone graft, which may affect the fusion rate[9,28]. To understand such a difference in failure rates between cage sizes, however, requires further biomechanical evaluation and a prospective randomized study.

Conclusion

Based on preliminary results of our series, the use of the TMCs and dynamic cervical plates is effective for cervical reconstruction after single and double-level corpectomies. Effective arthrodesis and a low incidence of complications following anterior cervical reconstructions performed utilizing dynamic plates, are attributed to reduced stress shielding and greater graft compression afforded by the unique plate design. Applying the TMCs for anterior cervical fusions also seems biomechanically advantageous with low morbidity of the graft sites.

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Commentary

This is a faithful article analyzing the fusion rate and complication of the titanium mesh cage with dynamic cervical plate for cervical reconstruction. The paper shows nice postoperative cervical radiography with reliable measurement methods. The results contain not only good clinical course but also distressing complication with honesty. The conclusions based on the results were also moderate. However, the titanium mesh cage has been used for over a decade as a fusion material for the spinal reconstruction, and the benefits of dynamic anterior cervical plate has been well known. In the view of innovation, I'm afraid this paper appears to be running behind in creativity.

Although its statistical significance is low, it is interesting result that small diameter of mesh cage showed low failure rate than larger diameter of mesh cage. I consider it could be made up with lager case study. The readers may expect to see further research on titanium mesh cage and dynamic plate with more matured result through large study with warm congratulation following this successful and interesting result.

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