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Original Article

Anatomy-related risk factors for the subsidence of titanium mesh cage in cervical reconstruction after one-level corpectomy

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Abstract: To clarify anatomy-related risk factors in the cervical spine with subsidence of titanium mesh cage (TMC) after one-level cervical corpectomy and fusion, we have assessed the radiological examinations and clinical outcomes for 236 patients. All the patients were underwent one-level corpectomy and TMC fusion between August 2003 and March 2006. The effects of the cervical posture, segmental curvature and endplate gradient on the postoperative phenomenon for these patients were evaluated. Our results suggested that in the patients who were followed up for 12 months, TMC subsidence occurred in 54 (28.6%) cases. C_6 corpectomy had a significant higher risk (26/60, 43.3%) for TMC subsidence, which was correlated with the variation of the gradient of the vertebral endplates against cervical levels. Although the clinical outcome was comparable with those in the literature, the patients may have subsidence-related problems such as neck-shoulder pain, neurological deterioration and instrumental failure. In conclusion, to reduce the incidence of subsidence, TMC design should be optimized to be in line with anatomic characteristics of the cervical spine.

Keywords: Cervical spine, corpectomy, titanium mesh cage, subsidence

Introduction

Many papers have reported that anterior cervical corpectmoy and fusion with titanium mesh cage (TMC) has been a safe and effective surgical treatment for cervical diseases [1-4]. TMC fusion facilitates the grafting of autogenously local bone and obviates complications of harvesting bone block. However, it requires a longer period to achieve a solid fusion than conventional auto-graft, and subsidence is frequently observed in the early postoperative period. Many factors, such as age, sex, fusion level, endplate preparation and bone mineral density, have already been known to be potential risk factors, but the anatomic factors of the cervical spine have not been emphasized [5-12].

Since the first description of cervical anterior corpectomy with fusion, many papers reported that it was an established treatment for cervical diseases with clinically satisfactory outcomes. However, the choice of materials for reconstruction after cervical corpectomy is still controversial. The traditional autologous bone graft has been demonstrated to yield a high fusion rate, but donor site complications were reported in approximately 15%, including subcutaneous hematoma, wound infection, and chronic wound pain. Allografts such as cow bone or hydroxyapatite graft were also used, but are questioned because of graft collapse and nonunion [13, 14]. As a solution to these problems, titanium mesh cage (TMC) has been developed and used, and the relevant investigations have proved advantages of a comparable fusion rate and non-existence of donor complications. However, postoperative subsidence was reported to be prevalent, which caused doubts about its value in cervical restoration. The purpose of this study was to elucidate the effect of the cer-

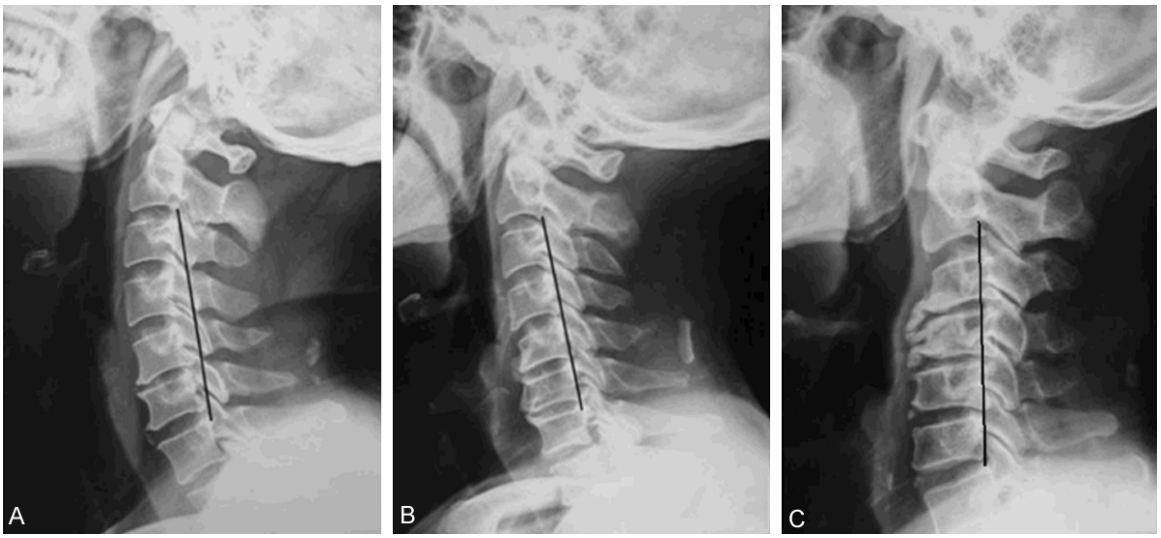

Figure 1. To describe the posture of the cervical spine, a line is drawn between the posterior inferior border of C2 and the posterior superior border of C_7. If the posterior walls of the vertebral bodies of C_3 to C_6 are located anteriorly to this line, it is called lordotic (A), if it is at this line, straight (B), and if it is posterior to this line, kyphotic (C).

vical posture, the segmental curvature and the endplate gradient on this unpreventable phenomenon.

Materials and methods

Patient population

Between August 2003 and March 2006, a total of 412 patients with cervical diseases underwent anterior cervical corpectomy and fusion with TMC. Anterior cervical plates were also employed to stabilize the affected segments. Among them, 236 cases of one-level corpectomy were investigated, and the remaining cases of two- or three-level procedures were not included in the study, because multilevel fusion with TMC, to our minds, significantly increased postoperative subsidence. This series included 128 men and 108 women and their mean age at operation was 51.3±6.4 years (ranging from 37 to 78 years). Preoperatively, the patients complained of neck pain, irradiating pain in arm and gait disturbance. At physical examination, they were found with sensory disturbance, motor problems and myelopathy signs. The diagnosis indicated cervical spondylitis myelopathy, cervical disc herniation and ossification of posterior longitudinal ligament. The level of corpectomy and fusion was performed due to spinal compression found in preoperative MR images: C_3 vertebra in 12 cases, C_4 in 68 cases, C_5 in 79 cases, and C_6 in 73 cases and C_7 in 14 cases.

Surgical technique

All the operations were performed by the same senior spine surgeon. Under general anesthesia, the patients were placed in the supine position with neck slightly extended. After necessary discectomies, the vertebral bodies were partially removed by an appropriate reamer until the posterior longitudinal ligament was fully exposed, which was excised when hypertrophied, ossified or when disc materials intruded posteriorly to the ligament. All cartilaginous endplates were removed down to the level of bleeding sub-chondral bone with curettes. TMC (Mesh, Depuy, U.S.A.) were then filled with autologous bone fragments from the excised vertebra, with end caps employed to increase contact areas in most cases. TMC were then inserted into the intervertebral space under distraction, which was between 2-3 mm for one-level corpectomy. The TMC was located at the anterior-middle column of the vertebrae, usually 2-3mm below the vertebral anterior border. Finally, anterior cervical plate fixation (Slimloc, Depuy, U.S.A.) was performed across the segments to be fused. Postoperatively, all patients were required to wear a Philadelphia hard cervical collar for 2 months.

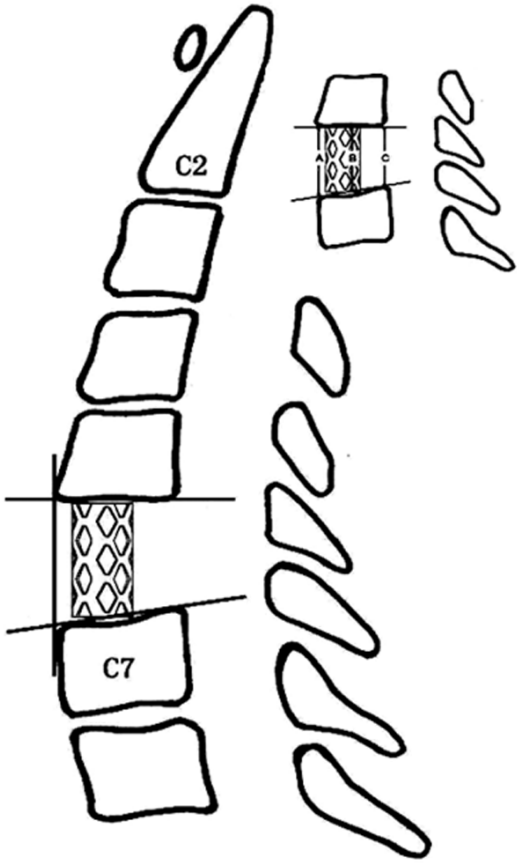

Figure 2. The gradient of the vertebral endplates is determined as the angle between the anterior wall of fusion segment and the border of endplates, and the segmental curvature is the angle between the borders of upper and lower endplates. In detail, A is the height of the anterior border, B is the height of the mid-portion, and C is the height of the posterior border.

Radiological examination

Lateral view of the cervical spine with the patient in a standing position was taken preoperatively and 1 day postoperatively, and at regular intervals thereafter until fusion was achieved. The lateral plain radiographs of the cervical spine were evaluated. The posture of the cervical spine in the neutral position was described as lordotic, straight, or kyphotic (**Figure 1**). Furthermore, the gradient of the vertebral endplates adjacent to the fusion segments, segmental curvature (the angle of the endplates), and the height of the fusion segments (the height of the anterior border, the mid-portion, and posterior border at the lateral radiograph) were measured (**Figure 2**). Subsidence was defined as loss of more than 3 mm in any of the three measured heights when TMC had clearly penetrated the vertebral endplates.

Graded outcome

In the study of graded clinical outcome, a modified Odom's scheme was used. *Excellent* was defined as complete relief of symptoms; *good* as intermittent discomfort, but there was no interference with daily activities; *fair* as subjective improvement, but there was impaired physical activity; *poor* as no improvement at all; and *worse* as actual worsening of the symptoms.

Statistical analysis

Statistical analysis was performed by Mann-Whitney U test, Fisher's exact test and Student's *t*-test for multiple comparisons by Statistic Analysis System (SAS statistic software, Statistic Institute of Second Military Medical University). Results are expressed as the groups mean ± SD. The *p* value (two-tailed) of less than 0.05 was considered statistically significant.

Results

Radiological findings

In this study, 47 patients were lost at the last follow-up of the 12 months, and all the radiographs of the remaining 189 patients were independently evaluated by two surgeons and one radiologist. When there was difference in views between the two surgeons, the opinion of the radiologist was decisive. At the last follow-up, we concluded that subsidence of TMC occurred in 54 (28.6%) cases, which was tabulated against the fused level. Subsidence occurred in 2 out of 11 cases at C_3, 11 of 56 cases at C_4, 14 of 52 cases at C_5, 26 of 60 cases at C_6, and 1 of 10 cases at C_7. The results showed the TMC implanted for C_6 corpectomy had a statistically significant higher risk of subsidence as compared with the other levels ($P<0.0001$).

There was no significant difference in the cervical posture between subsidence and no subsidence before operation, after operation and at the final follow-up (**Table 1**). In most patients, the cervical posture improved postoperatively and remained the status till the last follow-up.

Table 1. Relation between the presence of subsidence and the posture of the cervical spine

		Before operation	After operation	Last follow-up
Posture (n)				
No subsidence	Lordotic	67	96	85
	Straight	41	33	43
	Kyphotic	27	6	7
Subsidence	Lordotic	26	44	40
	Straight	17	8	9
	Kyphotic	11	2	5
P value		0.43	0.37	0.32

Table 2. Relation between the different heights of the fusion segments before and immediately after operation, and at last follow-up

		Before operation	After operation	Last follow-up
Height (mm)				
No subsidence*	A	21.3±0.8	23.9±0.9	23.4±0.7
	B	22.8±1.0	25.4±0.9	25.0±0.7
	C	20.7±0.7	23.1±0.8	22.6±0.6
Subsidence*	A	20.5±1.0	23.4±1.0	20.7±0.8#
	B	21.8±0.9	25.1±0.8	21.7±0.7
	C	20.1±0.8	23.3±0.9	19.2±0.8#

*A is the height of the anterior border, B is the height of the mid-portion, and C is the height of the posterior border of the fusion segments. #In the patients with TMC subsidence, the loss of height of the posterior border is significant more than that of the anterior border (4.1±0.5 mm vs. 2.6±0.6 mm, P<0.001).

In most subsided instances, the cages had sunken into the posterior part of the superior endplate of the lower vertebral body, and only 7 cages had penetrated the inferior endplate of the upper vertebral body. The height of fusion segments decreased more at the posterior border of the vertebral body, and less at the anterior border (4.1±0.5 mm vs. 2.6±0.6 mm P<0.001) (**Table 2**). The gradient of both upper and lower endplates increased against the level of the vertebrae, and reached the maximum at C_6 level, then decreasing at C_7. However, the segmental curvature of different levels was comparatively stabile against the cervical level (**Figure 3**).

Outcome and complications

The clinical outcome was comparable with those in the previous reports. Ninety-seven (51.3%) patients had an *excellent* outcome, 47 (24.9%), a *good* outcome, 28 (14.8%) *fair*, 14 (7.4%) *poor*, and 3 (1.6%), a *worse* outcome. The outcome was not related to the occurrence of subsidence (P=0.466). But neck-shoulder pain was more frequently observed in the patients of subsidence group (38/54 vs. 29/135, P<0.001). Another subsidence-related problem was neurological deterioration. In four patients, neurological deterioration was definitely correlated with TMC subsidence because they occurred at a matched time, and one patient underwent posterior revision surgery (**Figure 4**). In the other two patients, screw breakage occurred with obvious subsidence of TMC, though bony fusion had already been achieved. Anterior revision surgery was performed to replace the broken screws.

Discussion

In the process of anterior cervical corpectomy and fusion, restoration of the intervertebral space and enlargement of the neural foramen has been thought to be the key point for satisfactory clinical outcome. Although the clinical relevance of subsidence is still controversial, the acquired advantages may be diminished and devalued by subsidence. Nakase[5] reported kyphotic deformity; instrument failure and neurological deterioration might develop following subsidence, and possibly need revision surgery. Das[6] and Kanayama[7] also dealt with these complications with TMC subsidence in their reports.

In this group, however, subsidence did not produce significant clinical effects and severe cervical kyphosis. The reason might be that only the patients with one-level corpectomy were studied. However, axial pain was more frequently observed in the patients with postoperative subsidence. Bucking of the ligamentum flavum and stenosis of the neural foramen following subsidence were possibly responsible for this postoperative pain. When they resulted in recompression of the spinal cord and the nerve roots, neurological deterioration might develop.

In terms of biomechanics, TMC subsidence may also damage the inherent stability of fixed segments and increased stress load on the

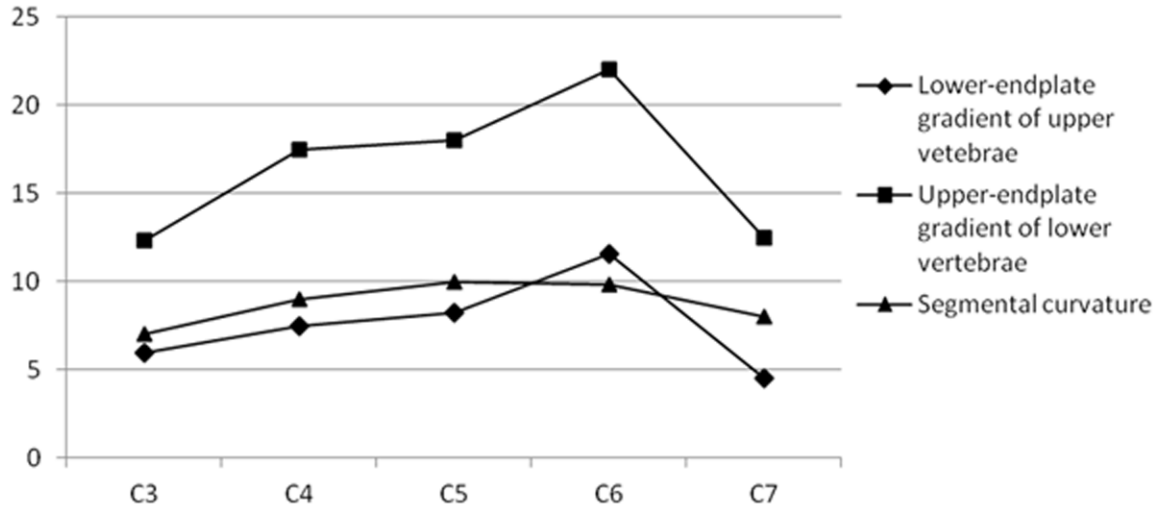

Figure 3. Degrees of the endplate gradient and the segmental curvature at different fusion levels. The gradient of both upper and lower endplates increased against the level of the vertebrae, and reached the maximum at C_6 level, then decreasing at C_7. The segmental curvature of different levels was comparatively stabile against the cervical level.

screw-plate structure. Daubs[8] ever reported seven patients had catastrophic failure of fixation with TMC subsidence and distal plate extrusion. In this study, screw breakage occurred in two cases of obvious subsidence, though bone fusion was definitely achieved. And still there was need for revision surgery.

Risk factors for TMC subsidence had been discussed a lot in the literature. Age and sex were often suspected to predict subsidence. Older women, especially, were thought to have a higher chance because of osteoporosis. Wrong surgical technique was also held responsible for TMC subsidence. Over-distraction, rigorous cleaning and damaging of the endplates and rigid implantation should be avoided. Despite careful attention to surgical details, we still had a high incidence of subsidence. In this study, we noticed the C_6 corpectomy was most susceptive to subsidence, which was similar to the results that the interbody cages (Syncage-c and carbon fiber cages) implanted at C_{6-7} level had the highest chance to subsidence. The difference was that interbody cages tended to subside at the anterior border of the superior endplate, while TMC tended at the posterior border of the inferior endplate [15, 16]. The reason for this was not clear. The preliminary data from this study suggested that the orientation of endplates was possibly responsible for this tendency. We noticed that the incidence of TMC subsidence at different levels was correlated with the gradient of adjacent endplates, which was at the highest point when C_6 vertebra was excised.

The currently used TMC design is a cancellous hollow cage, with a large bony contact area to promote fusion between the vertebral bodies. Before bony fusion, however, the contact surface of TMC with endplates was very limited, and high stress shielding facilitates subsidence [17]. The gradient of the endplates made the contact area too small and increased the load on the endplate excessively, especially at the posterior border of the lower endplate. Another factor was the size of TMC, especially its width. TMC should rest on the epiphyseal ring to have sufficient support. The third problem with TMC was that it was to be clipped before its application. If manual clipping was not suitable and sharp fingerprints penetrated into the vertebral endplates, subsidence was likely.

Some improvements had been made in the use of TMC. The incidence of subsidence was first expected to be decreased with the use of end caps, which was designed to increase contact surface, but the results might be disappointing. In our opinion, TMC should be designed to be more in line with the anatomical characteristics of the cervical spine, especially the endplates: 1) Changes should be made for both upper and lower butt ends of TMC. Fornix shape is more

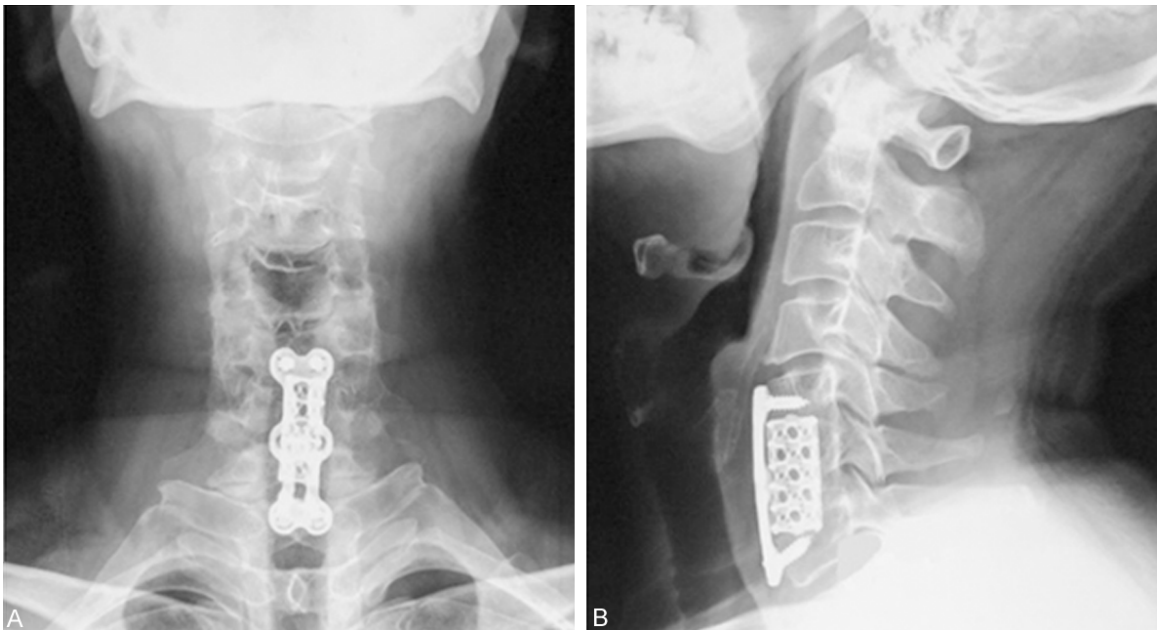

Figure 4. A and B. Radiograph demonstrating the subsidence into C_7 of TMC after 3 months, and the patient complained of neurological deterioration.

consistent with adjacent lower endplates and oblique shape for upper endplates; 2) To enlarge the contact surface of TMC and get more support from the epiphyseal ring, a wider cage should be developed; 3) A set of TMC with different heights for one or two-level corpectomy is needed and incorrect manual clipping for TMC must be avoided during the operation. The butt ends of TMC should be more consecutive and smooth.

In conclusion, a high incidence of subsidence has been found in the use of TMC for cervical corpectomy. Although several factors were responsible for this problem, mismatch between TMC ends and adjacent endplates was evident. We hold that efforts should be made to optimize TMC design before its application. And then more satisfactory clinical outcome could be achieved.

Disclosure of conflict of interest

None.

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References

[1] Majd ME, Vadhva M and Holt RT. Anterior cervical reconstruction using titanium cages with anterior plating. Spine (Phila Pa 1976) 1999; 24: 1604-1610.

[2] Eck KR, Bridwell KH, Ungacta FF, Lapp MA, Lenke LG and Riew KD. Analysis of titanium mesh cages in adults with minimum two-year follow-up. Spine (Phila Pa 1976) 2000; 25: 2407-2415.

[3] Riew KD and Rhee JM. The use of titanium mesh cages in the cervical spine. Clin Orthop Relat Res 2002; 47-54.

[4] Chuang HC, Cho DY, Chang CS, Lee WY, Jung-Chung C, Lee HC and Chen CC. Efficacy and safety of the use of titanium mesh cages and anterior cervical plates for interbody fusion after anterior cervical corpectomy. Surg Neurol 2006; 65: 464-471; discussion 471.

[5] Nakase H, Park YS, Kimura H, Sakaki T and Morimoto T. Complications and long-term follow-up results in titanium mesh cage reconstruction after cervical corpectomy. J Spinal Disord Tech 2006; 19: 353-357.

[6] Das K, Couldwell WT, Sava G and Taddonio RF. Use of cylindrical titanium mesh and locking plates in anterior cervical fusion. Technical note. J Neurosurg 2001; 94: 174-178.

[7] Kanayama M, Hashimoto T, Shigenobu K, Oha F, Ishida T and Yamane S. Pitfalls of anterior cervical fusion using titanium mesh and local

autograft. J Spinal Disord Tech 2003; 16: 513-518.
[8] Daubs MD. Early failures following cervical corpectomy reconstruction with titanium mesh cages and anterior plating. Spine (Phila Pa 1976) 2005; 30: 1402-1406.
[9] Hasegawa K, Abe M, Washio T and Hara T. An experimental study on the interface strength between titanium mesh cage and vertebra in reference to vertebral bone mineral density. Spine (Phila Pa 1976) 2001; 26: 957-963.
[10] Dorai Z, Morgan H and Coimbra C. Titanium cage reconstruction after cervical corpectomy. J Neurosurg 2003; 99: 3-7.
[11] Narotam PK, Pauley SM and McGinn GJ. Titanium mesh cages for cervical spine stabilization after corpectomy: a clinical and radiological study. J Neurosurg 2003; 99: 172-180.
[12] Hee HT, Majd ME, Holt RT, Whitecloud TS 3rd and Pienkowski D. Complications of multilevel cervical corpectomies and reconstruction with titanium cages and anterior plating. J Spinal Disord Tech 2003; 16: 1-8; discussion 8-9.
[13] Malloy KM and Hilibrand AS. Autograft versus allograft in degenerative cervical disease. Clin Orthop Relat Res 2002; 27-38.
[14] Zdeblick TA and Ducker TB. The use of freeze-dried allograft bone for anterior cervical fusions. Spine (Phila Pa 1976) 1991; 16: 726-729.
[15] van Jonbergen HP, Spruit M, Anderson PG and Pavlov PW. Anterior cervical interbody fusion with a titanium box cage: early radiological assessment of fusion and subsidence. Spine J 2005; 5: 645-649; discussion 649.
[16] Bartels RH, Donk RD and Feuth T. Subsidence of stand-alone cervical carbon fiber cages. Neurosurgery 2006; 58: 502-508; discussion 502-508.
[17] Akamaru T, Kawahara N, Sakamoto J, Yoshida A, Murakami H, Hato T, Awamori S, Oda J and Tomita K. The transmission of stress to grafted bone inside a titanium mesh cage used in anterior column reconstruction after total spondylectomy: a finite-element analysis. Spine (Phila Pa 1976) 2005; 30: 2783-2787.