Radiological analysis of titanium mesh cages used after corpectomy in the thoracic and lumbar spine: Minimum 3 years' follow-up

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This study analyses radiological outcome of titanium mesh cages used for anterior column support following corpectomy in the thoracic and lumbar spine in 34 patients with a minimum three-year follow-up. The aim of the study was to assess the complications and radiological outcomes of patients with structural cages implanted into the anterior column. Titanium mesh cages for the anterior column became popular for anterior column reconstruction following discectomy and corpectomy. Few clinical studies are published assessing their efficacy as a structural graft after corpectomy and factors for the development of settling and correction loss are not investigated enough. Thirty-four patients with minimum 3-year follow-up were analysed radiologically for correction achievement, cage settling and fusion inside the mesh cage. The effect of fixation technique, anatomical localisation and diagnosis for the development of settling were analysed. Measurements of preoperative and early postoperative local kyphotic angle revealed that a mean correction of 27° (range : 8 to 60) was obtained. While no dislodgement or fracture of titanium mesh cages was observed, there was a mean correction loss of 4° and settling (> 2 mm) was noted in 6 patients. Short posterior and only anterior instrumentation systems were associated with settling. The anatomical location and diagnosis did not affect the development of cage settling. Following corpectomy and mesh cage implantation, isolated anterior fixation or short posterior fixation do not provide enough stability, and correction loss and settling can occur.

Key words : spine ; thoracic ; lumbar ; cages ; radiological assessment.

INTRODUCTION

Several methods are used to achieve structural support and fusion after corpectomy for treatment of trauma, tumour, deformity and infection *(8, 10)*. Tricortical iliac grafts, fibula, and costal bone have been used extensively. More recently, femoral ring allografts packed with morselised auto – or allografts have been introduced as an option for this purpose. However, all the above-mentioned methods have disadvantages, and this has led surgeons to seek other alternatives. Bagby *(2)* introduced stainless steel basket implants for interbody fusion,

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and this was followed by the development of other prosthetic fusion implants, such as carbon-fiber constructs *(5, 6)* and various types of titanium mesh cages (TMCs) *(16, 20)*. In open-frame cages the graft bone is in direct contact with host bone, a feature that makes these devices biologically superior to closed implants. Mesh cages provide structural support while the cancellous bone inside the cage promotes fusion. Several studies have compared the biomechanical properties of interbody fusion cages, but these data cannot be extrapolated to the situation where the vertebral body is completely absent, as in the corpectomy setting *(4, 16, 20)*. Dvorak *et al (12)* reported 93% fusion with the use of TMCs after corpectomy.

In this study, we radiologically assessed outcomes in patients who had TMCs implanted to provide anterior spinal column support after corpectomy. All the cases had a minimum 3 years of follow-up, and we evaluated fusion status and the effects of several different fixation constructs on the occurrence of settling (subsidence) of the cage implants.

MATERIALS AND METHODS

From 1996 through 2000, 50 patients at our center underwent TMC reconstruction of the anterior spinal column after single - or multilevel corpectomy between Th2 and L5. Thirty-four (68%) of these patients had adequate radiological follow-up, and these cases were retrospectively analysed. The group comprised 19 females and 15 males, and the average age was 49 years (range : 17 to 86). The average follow-up period was 42 months (range : 38 to 68).

The preoperative diagnoses were traumatic fracture (*n* = 19), infection (*n* = 5), osteoporotic fracture (*n* = 5), and spinal deformity (*n* = 5). A total of 41 corpectomies were performed in the 34 cases (minimum one level, maximum four levels). After each corpectomy, the inferior and superior ends of the TMCs were trimmed to match the sagittal alignment of the abutting vertebral end plates. The bone obtained from the corpectomy, or if necessary an autograft from the iliac bone or the ribs, was used to fill the TMC. Great care was taken to pre-

serve as much subchondral bone as possible while preparing the end plates. The TMC was primarily stabilised by compression of the anterior or posterior instrumentation system, depending on the case. The choice of corrective procedure and selection of anterior or posterior instrumentation was made based on the degree of deformity, the local kyphotic angle, previous surgery, and preoperative diagnosis. Fixation was anterior only in 2 cases, short posterior in 7, and long posterior in 13, posterior and anterior in 12 cases.

The radiological evaluations for each case were as follows : 1) upright preoperative (supine for trauma cases) and early-postoperative coronal and sagittal radiographs ; 2) coronal, sagittal and oblique radiographs at final follow-up examination ; and 3) high-resolution computed tomography (CT) with coronal or sagittal reconstruction at final follow-up. The local kyphotic angle was measured between the superior end plate of the upper vertebra (the one cranial to the corpectomy site) and the inferior end plate of the lower vertebra (caudal to corpectomy). For each patient, we measured the kyphotic angle preoperatively, early postoperatively and at the latest follow-up. The average correction (in degrees) and the loss of correction were calculated accordingly. Settling was assessed by measuring the subsidence relative to the rhomboid-shaped fenestrations on the cages *(12)*. Settling in excess of 2 mm was considered abnormal. All radiographic measurements were made by a single independent observer (an orthopaedic spine surgeon) who was not involved in the care of these patients.

Statistical analysis was done to assess how different fixation systems, corpectomy levels, and preoperative diagnosis were related to abnormal settling/loss of correction. Patients were categorised according to fixation method, diagnosis, and anatomical location of corpectomy (thoracic, thoracolumbar, lumbar), and proportions of cases with abnormal settling in each group were compared using the Z test with Minitab Statistical Software (Minitab Inc USA). Fusion status was assessed using plain radiographs, according to the grading system published by Bridwell *et al (8)*. In this system, Grade I indicates definite fusion (fused

Table I. — Analysis of abnormal settling/loss of correction
according to fixation systems

Fixation system	N°. of patients	Abnormal settling/loss of correction (n [%]))
Anterior only	2	1 (50%)
Short posterior	7	5 (71%)
Long posterior	13	0
Posterior + Anterior	12	0

with remodelling and trabeculae present) ; Grade II indicates probable fusion (graft intact, not fully remodelled, no areas of lucency) ; Grade III indicates unlikely fusion (graft intact but lucency where it contacted the host bone surface) ; Grade IV indicates non-union (graft bone resorbed) ; and Grade V indicates that fusion could not be assessed. All cases were analysed for occurrence of complications with anterior and/or posterior instrumentation systems, such as loosening, failure, and/or migration.

RESULTS

Comparison of the preoperative and early-postoperative local kyphotic angle measurements revealed a mean correction of 27° (range : 8 to 60) in the 34 patients. None of the TMCs fractured or became dislodged ; however, radiological follow-
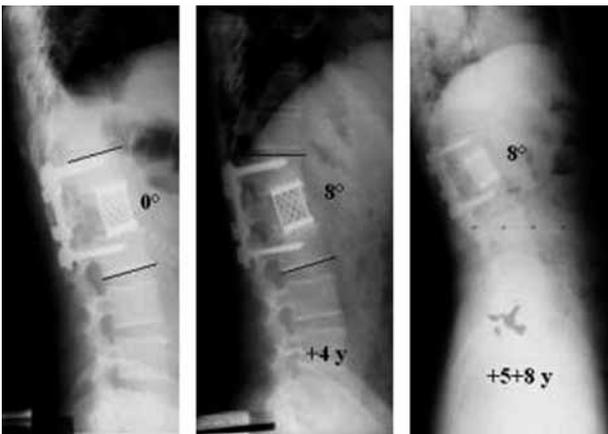

Fig. 1. — Early postoperative (A) and 4 years (B) and 5 years 8 months (C) follow-up upright lateral radiographs of a patient with L1 burst fracture operated with corpectomy + titanium mesh cage + short posterior instrumentation. Note there is settling at the 4-year follow-up which did not increase later, indicating fusion achievement.
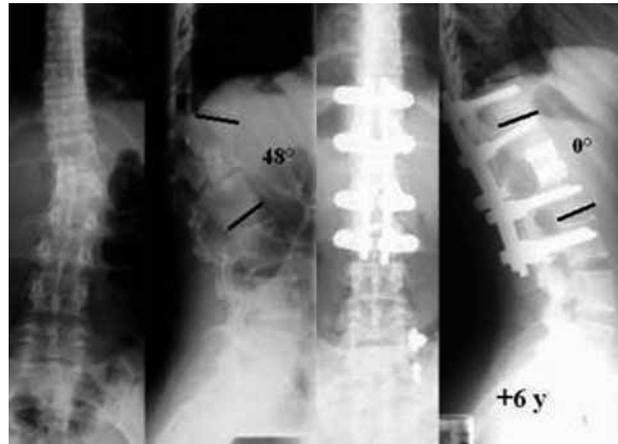

Fig. 2. — Preoperative (A) and 6-year follow-up (B) upright AP and lateral radiographs of a patient with lumbar kyphosis after an operation due to L1 burst fracture. Fibula was used as structural support in the index operation. She was treated with corpectomy + titanium mesh cage + long posterior instrumentation. Note that there is no settling.

up revealed loss of correction (mean : 4°) and abnormal settling (> 2 mm) in six cases. None of the other 28 patients experienced either of these problems.

As noted, the subgroups with different instrumentation constructs were compared for settling/ loss of correction (table I). This problem occurred in 1 (50%) of the 2 anterior instrumentation cases and 5 (71%) of the 7 short posterior instrumentation cases (fig 1). There was no settling/loss of correction in the patients with long posterior fixation (13 cases) (fig 2), posterior and anterior fixation (12 cases). The cases with short posterior fixation had the highest proportion of settling/loss of correction, and this frequency was significantly higher than the frequencies observed with all other fixation methods except for anterior fixation only (p < 0.001). The rate of settling/loss of correction in the patients with anterior fixation only was 50%, but this frequency was not significantly higher than the frequencies observed with the other fixation systems (p > 0.05 for comparison with short posterior system, p > 0.1 for comparison with all other fixation systems). These results are likely due to the small number of cases with anterior fixation only.

Settling/loss of correction occurred in 5 (26%) of the 19 burst fracture cases, and in 1 (20%) of the

Table II. — Analysis of abnormal settling/loss of correction according to diagnosis

Diagnosis	N°. of patients	Abnormal settling/loss of correction (n [%])
Burst Fracture	19	5 (26%)
Osteoporotic Fracture	5	1 (20%)
Deformity	5	0
Infection	5	0

5 osteoporotic fracture cases (table II). The influence of diagnosis on the development of settling/ loss of correction was not significant (p > 0.001).

Evaluation of settling/loss of correction relative to anatomic location of corpectomy revealed that the rate of this problem was highest in the cases with corpectomy in the lumbar region (30%) (table III). The corresponding rates for the subgroups with corpectomy in the thoracic and thora-

Table III. — Analysis of abnormal settling/loss of correction according to location of corpectomy

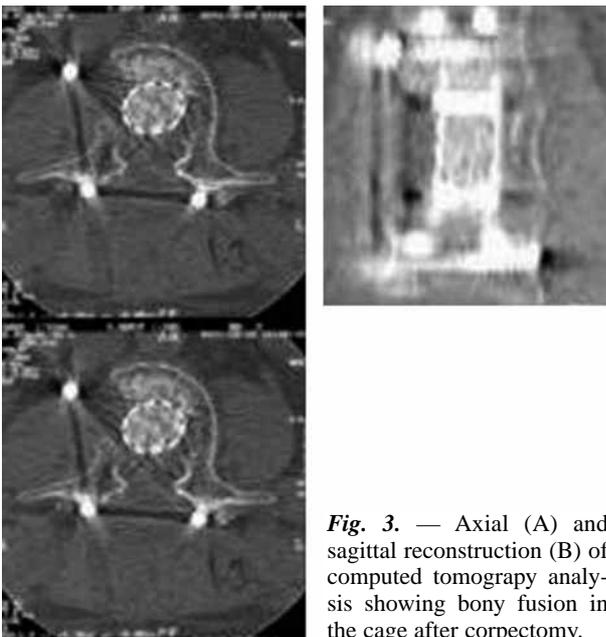| Corpectomy location	No. of patients	Abnormal settling/loss of correction (n [%])
Thoracic	6	1 (17%)
Thoracolumbar	18	2 (11%)
Lumbar	10	3 (30%)

Fig. 3. — Axial (A) and sagittal reconstruction (B) of computed tomograpy analysis showing bony fusion in the cage after corpectomy.

columbar regions, respectively, were 17% and 11%. Though settling/loss of correction was most frequent in the lumbar region subgroup, there were no significant differences among the rates for the different anatomical locations (p > 0.001).

The plain radiographs at final follow-up revealed Grade I fusion in 24 patients and Grade V fusion (unable to be assessed) in 10 cases. The high-resolution CT at final follow-up allowed for better evaluation of graft bone in the TMC and fusion status and these images confirmed fusion in all cases, including those with settling/loss of correction (fig. 3).

There were no hardware complications associated with the anterior or posterior instrumentation systems.

DISCUSSION

This study evaluated the efficacy of TMCs combined with autografts as providers of structural support and fusion after corpectomy, and investigated for possible links between certain parameters and settling/loss of correction.

The ideal material for grafting after corpectomy should have osteoinductive properties that promote fusion, and should retain structural support until solid fusion has been achieved. Hollowell et al (15) reported a comparative analysis of thoracolumbar interbody constructs, and found that the TMC provided the greatest resistance to axial load. Titanium mesh cages with this structural property, in combination with morselised autograft material, are a good alternative for support and fusion after corpectomy. TMCs are superior to autografts and allografts in terms of mechanical failure when used for interbody fusion also (5, 10-12, 17, 20, 22).

Rapid and strong fusion requires good surface contact and stability in the fusion region (4, 18). Shono et al (21) reported better stability with anterior instrumentation after corpectomy than with posterior instrumentation, whereas Vahldiek and Panjabi (25) found that the best stability was achieved with combined anterior and posterior fixation. A similar study by Oda et al (19) investigated the biomechanics of anterior and posterior instrumentation systems and different combinations of these after vertebrectomy in cadaver spines.

These authors found that short posterior and anterior systems alone were not sufficient for good stability ; only combined anterior/posterior fixation was adequate. The literature contains only one clinical study on the use of mesh cages after corpectomy, and this investigation did not address possible links between fixation systems and settling/loss of correction (12). Eck et al (13) analysed outcomes with TMCs using radiography, and noted abnormal settling in 36% of their intervertebral body fusion cases and 47% of their corpectomy cases. However, as above, this research did not assess potential links between types of fixation systems and settling/loss of correction. In our study, we observed high rates of settling/loss of correction only in the subgroups with anterior fixation only (50%) or short posterior fixation (71%). This problem did not occur in any of our cases in which combined anterior and short-posterior, anterior and long-posterior, or long-posterior fixation systems were used. All 34 patients in our study had a minimum of 3 years of follow-up, and the clinical outcomes in this series indicate that anterior and short-posterior fixation provide insufficient stability after corpectomy. These findings are in line with published biomechanical studies. We also observed trends towards settling/loss of correction in the lumbar regions. This conflicts with the work of Dvorak et al (12), which indicated higher risk with corpectomy/TMC implantation in the thoracic region. The biomechanical properties of the thoracolumbar and lumbar regions make these zones more vulnerable to abnormal settling and loss of correction after this type of procedure.

The gold standard for assessing fusion is surgical exploration (9, 23). Only a few studies have analysed incorporation of bone inside TMCs histologically (1, 24). Togowa et al (24) examined needle biopsies of tissue obtained from within cages in cases of radiographically successful intervertebral body fusion at the time of pedicle screw removal. They documented incorporation of bone at all eight spinal levels. In our investigation, we evaluated fusion radiologically. One study by Brantigan et al (7) compared radiological fusion assessment with surgical exploration. The statistics for radiological analysis revealed sensitivity 97%, positive predictive value 94.4%, and overall accuracy 93%, and the authors concluded that radiological interpretation of fusion is highly reliable. Similar work by Blumenthal and Gill (3) revealed 69% correlation between radiology and surgical exploration, thus the authors claimed that radiological assessment missed one of every five cases of surgically confirmed fusion. Only one published study has investigated achievement of fusion with TMC implantation after corpectomy, and this work did not evaluate graft material inside the mesh, but only the graft around the cage (14). Analysis with 1-mm slice CT images is superior to plain radiography especially for assessing fusion inside the cage. In our series, 1-mm CT analysis revealed fusion in all the patients with grade 1-2 fusion and in cases in which fusion was unassessable with plain radiography. This revealed fusion in all the cases including the ones with settling/loss of correction. Settling/loss of correction occurred in the first year and did not progress after that. In other words, fusion was achieved and this prevented any further settling.

Tricortical iliac grafts with cortical and spongious components provide good structural support and are highly osteoinductive for fusion but there have been reports of collapse and structural loss of iliac grafts in osteopenic patients (10, 11, 16). Femoral ring allografts packed with autograft material seem to be a good alternative, but their diameters are restricted and trimming for adaptation to sagittal alignment is technically demanding. Primary stability cannot be achieved with ring grafts, and additional fixation is needed to prevent dislodgement (10). Compression after TMC implantation results in end plate interdigitation, which provides primary stability.

Titanium mesh cage implantation is a good option for supporting the anterior spinal column after corpectomy. These cages are available in different shapes, diameters, and heights, and insertion of autografts inside the mesh strongly promotes osteoinduction. Titanium mesh cages can be easily trimmed for adaptation to sagittal inclination, and interdigitation of the cage with the vertebral body end plate provides primary stability. Use of anterior fixation alone or short posterior fixation alone after corpectomy and TMC implantation provides inadequate stability, and may be associated with

loss of correction and abnormal settling To avoid such problems, either combined anterior and posterior or long-posterior fixation systems should be used.

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