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The use of titanium surgical mesh-bone graft composite in the anterior thoracic or lumbar spine after complete or partial corpectomy

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Abstract Various conditions such as fracture, dislocation, tumor, or infection adversely affect the vertebral body and lead to instability. Restoration of a stable anterior column is essential for normal spinal biomechanics. Various biological and mechanical spacers have been used to reconstruct the anterior column after corpectomy. In this retrospective review, the authors evaluated clinical charts and radiographs of 13 patients receiving titanium surgical mesh (TSM)-bone graft composite to reconstruct the anterior spinal column in the thoracic or lumbar region. The objective of this review was to evaluate the stability and efficacy of the TSM-bone graft composite in the anterior spine after a complete or partial corpectomy. Sixteen patients with involvement of the thoracic or lumbar vertebral column after trauma, tumor, or infection underwent partial or complete corpectomy. In all patients the anterior defect was reconstructed using a TSM-bone graft composite. Three patients died within 12 months postoperatively

due to primary malignant process. Thirteen of 16 patient charts and radiographs were evaluated for anterior fusion status, settling of the TSM-bone graft composite, and hardware failure. No pseudoarthroses were noted. Evidence of solid anterior fusion was noted in all patients. The average settling of the TSM-bone graft construct was 3 mm. All patients presenting with only pain and no neurological symptoms ($n = 9$) experienced early pain relief. For patients presenting with neurological symptoms ($n = 4$), the recovery was complete in three and partial in one. No patient was made neurologically worse, and there were no vascular injuries intra- or postoperatively. The study suggests that TSM-bone graft composite offers excellent biomechanical stability in the immediate postoperative period, permitting progressive maturation of the fusion mass.

Key words Thoracic spine · Lumbar spine · Corpectomy · Titanium surgical mesh

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Introduction

The stability of the anterior column of the spine (the vertebral bodies) is affected by conditions such as tumor, fracture, and infection [1, 4, 5, 7–12, 15–18, 20–23, 26–28, 30]. Destruction of the vertebral body may lead to localized kyphosis or severe pain and may progress to

neurological involvement. Reconstruction of the anterior column defect may be achieved by means of various biological and mechanical implants [7, 9, 10–12, 15–18, 20–23, 27, 28, 30–33]. Biomechanically, 80–85% of the axial forces on the upright spine are distributed through the anterior column, and reconstruction of the anterior column is essential to restore normal spinal biomechanics [2, 19, 21, 22].

Any implant used for vertebral body replacement must provide immediate stability in the early postoperative period, which must be maintained long enough to permit gradual bony arthrodesis. The present report discusses the use of a titanium surgical mesh (TSM)-bone graft composite as an anterior column replacement after partial or complete corpectomy in the thoracic or lumbar spine.

To the best of our knowledge, at the time of writing there is no published report in the English literature describing the mid-term follow-up of patients who have a TSM-bone graft composite for vertebral body replacement.

Materials and methods

Sixteen patients (eight male and eight female) received a TSM-bone graft composite to reconstruct the anterior spinal column in the thoracic or lumbar region from a single surgeon's private practice. All patients had involvement of the anterior thoracic or lumbar spinal column following trauma, tumor, or infection. Indications for surgery were: severe pain secondary to vertebral body destruction ($n = 11$), neurological symptoms ($n = 4$), and a combination of pain and neurological symptoms ($n = 1$) (Table 1). The average age was 54 years (range: 18–83 years). The diagnoses were frac-

ture ($n = 8$), tumor ($n = 6$), and postoperative osteomyelitis ($n = 2$). The vertebral involvement was thoracic ($n = 9$) or lumbar ($n = 7$). Of the six tumor patients, four patients eventually died as a result of primary malignant pathology (two patients within 6 months, one patient within 12 months, and one patient 2 years postoperatively); the three patients who could not be followed for 24 months were excluded from this study. Average follow-up for the other twelve patients was 55 months (range: 24–77 months). All patients were managed with complete or partial corpectomy at the involved levels followed by reconstruction of the defect with TSM-bone graft composite.

The bone graft packed within the TSM was autograft only ($n = 2$), allograft only ($n = 4$), a combination of both autograft and allograft ($n = 5$), a combination of allograft with Pro Osteon (Interpore International, Irvine, Calif.) ($n = 1$) or a combination of allograft with Grafton Demineralized Bone Matrix (Osteotech, Shrewsbury, N. J.) ($n = 1$). In cases of vertebral fracture, autologous bone graft from the corpectomy itself was used to fill the TSM. In cases of spinal metastasis, autologous bone graft was harvested from the iliac crest and packed in the mesh. If adequate autologous bone was not obtained or if the bone quality was poor, bone bank cancellous allograft with or without osteogenic agents was used. All 13 patients received supplemental rod instrumentation. Eight patients received an anterior rod system; three patients with involvement of the posterior elements received a combination of anterior and posterior rod systems; two patients presenting with vertebral body infection received posterior instrumentation only.

Table 1 Patient summary

No.	Age ^a	Sex	Vertebral level	Primary	Symptoms	Levels spanned	Postop results	FU months	Complications	Secondary procedures
1	41	M	L2	Trauma	Back pain	L1-L3	Pain free ambulation	54	None	None
2	75	F	T12	Trauma	Back pain	T11-L1	Pain free ambulation	77	None	None
3	38	F	T9	Trauma	Back pain	T8-T10	Pain free ambulation	69	MVA rod and cage failure	Posterior reinstrumentation
4	62	M	L1	Trauma	Sphincter dysfunction, perianal hypoesthesia	T12-L2	Complete neurological recovery	68	None	None
5	71	F	T12	Trauma	Back pain	T12-L1	Pain free ambulation	36	Kyphosis and sagittal imbalance	Extension osteotomy
6	26	M	L3	Trauma	Polytrauma	L2-L4	Pain free ambulation	44	None	None
7	67	F	T9/T10	Breast cancer	Back pain	T8-T11	Pain free ambulation	27	None	None
8	61	F	T4	Breast cancer	Long tract signs, unsteady gait	T3-T5	Complete neurological recovery	24 deceased	None	None
9	71	F	T12	Trauma	Back pain	T10-L2	Pain free ambulation	72	None	None
10	32	M	L3	Trauma	Back pain, radicular symptoms	L2-L4	Wheelchair ambulation: talar fracture	48	None	None
11	18	M	L1	Aneurysmal bone cyst	Back pain	T12-L1	Pain free ambulation	31	None	None
12	83	M	L5	Infection	Back pain/bedridden	L3-S1	Pain free ambulation	48	None	None
13	62	F	L5	Infection	Back pain/L5 paresis	L4-S1	Pain free ambulation	24	None	None

^a All ages reported are at the time of surgery

Surgical technique

The involved vertebra was accessed via a standard transthoracic, transperitoneal or retroperitoneal approach depending on the level of the pathology. The appropriate vertebral levels were confirmed with intraoperative radiographs. Screws for the anterior rod instrumentation were then inserted in the anterolateral aspect of the vertebral bodies immediately adjacent to the involved vertebra.

A partial or nearly total corpectomy was performed at the involved vertebral level leaving a thin bony shell at the opposite cortex. The cartilaginous end plates of the vertebrae immediately adjacent to the corpectomy level were abraded with a burr until punctate bleeding appeared. Care was taken not to damage the bony end plates. A caliper was used to measure the height of the intervertebral spacer required.

TSM of adequate diameter was fashioned and trimmed to fit the defect snugly. The mesh was then filled with cancellous bone graft. In all cases a bone mill was used to refine and morcellize the graft to be packed in the cages. With the TSM-bone graft composite ready for implantation, the receptor site was distracted with intervertebral spreaders. The mesh was gently packed into the vertebral defect, ensuring tight subchondral contact. The serrated edges of the mesh prevented any movement of the construct, thereby allowing immediate compression on the TSM-bone graft construct once the intervertebral spreaders were removed. Additional cancellous bone graft was packed around the TSM, promoting bony growth around the implant. The rod instrumentation system was then used to supplement and stabilize the TSM-bone graft reconstruction. Instrumentation extended from vertebrae immediately adjacent to the affected level, thereby limiting the number of vertebral segments immobilized. In cases where posterior instability may have been present, an instrumented posterior fusion was performed spanning only the levels instrumented anteriorly. Patients were mobilized on the 2nd day postoperatively with a brace only for ambulation (3 months). The construct was considered primarily stable; however, patients were braced for comfort.

In the three patients with tumor, two patients had metastasis from breast cancer and one patient had an aneurysmal bone cyst. One of two patients with metastatic tumor received postoperative radiotherapy (total dosage of radiation was 3000 rads). The other patient did not receive postoperative radiation.

Clinical charts and radiographs were independently reviewed by an examiner not involved in the care of these patients. Standard PA and lateral flexion-extension radiographs were taken postoperatively at 3 and 6 weeks, 3, 6, and 12 months, and yearly thereafter; these were read for anterior bony fusion, settling of the TSM-bone graft composite, or failure of instrumentation. Fusion was considered solid when there were no lucencies at the TSM-vertebra interface or presence of mature bony trabeculae around the TSM bridging the adjacent vertebral bodies. Since the implants often obstruct the view of the TSM-vertebra interface, presence or absence of lucencies at those interfaces is not always possible to detect. The TSM implant was evaluated for settling, extrusion and breakage or fracture. The settling depth was measured on lateral radiographs using the superior and inferior edges of the TSM spacer and the edge of the resected vertebral body as constant landmarks.

Results

Ambulation

Twelve patients were ambulating with considerable pain relief (more than 80% of the preoperative value on a subjective analog scale) on the 3rd postoperative day, and this was maintained at the latest follow-up. One patient with

polytrauma was only ambulatory in a wheel chair, due to a lower limb fracture.

Neurological recovery

For patients presenting with neurological symptoms ($n = 4$), the recovery was complete in three and partial in one.

Fusion status

No obvious pseudoarthroses were noted in any of the 13 patients. Solid anterior fusion was apparent as assessed on plain radiographs.

Settling of the TSM-bone graft composite

At the latest follow-up, the average settling of the TSM-bone graft construct was 3 mm (range: 0–7 mm). There were no extrusions or breakages/fractures of the TSM. There were no vascular or neurological complications related to the surgical procedure.

Complications and secondary procedures

One patient had an motor vehicle accident (MVA) leading to anterior rod breakage and TSM cage impaction into the vertebral end plates. Although this patient obtained an apparent solid fusion, the settling of TSM cage and resultant kyphotic deformity progressed. Therefore, this patient received subsequent posterior instrumentation. One patient with severely osteoporotic bone demonstrated continued progression of kyphosis at the level above surgery (T12) and underwent posterior extension osteotomy for correction of sagittal imbalance.

Discussion

Traumatic, infective, neoplastic, or degenerative conditions in origin adversely affect the vertebral body or the anterior spinal column [1, 4, 5, 7–12, 15–18, 20–23, 26–28, 30]. This may lead to acute and/or chronic pain, instability, deformity, and neurological deficits. Conservative or non-operative therapy may not always satisfy the treatment objectives. The surgical approach used may be anterior, posterior, or a combination of both [1, 4, 5, 7–12, 15–18, 20–23, 26–28, 30]. These conditions are often managed effectively through an anterior approach, since the underlying pathology is in the anterior spinal column [4, 7–12, 15–18, 20–22, 26–28]. A complete or partial corpectomy may be required to prevent or treat neural involvement or to manage the mechanical instability. This

Fig. 1 A 44-year-old man presented with severe back pain secondary to a post-traumatic burst fracture of L2. He was neurologically intact. CT scan demonstrated destruction of L2

Fig. 2A, B Same patient as in Fig. 1. He was treated with anterior retroperitoneal corpectomy L2, anterior reconstruction of L2 with TSM-bone graft composite, and anterior TSRH instrumentation L1-L3. At a 54-month follow-up, radiographs suggest a solid anterior fusion

Fig. 3 An 18-year-old man presented with acute onset of low back pain without any neurological involvement. Preoperative lateral radiograph showed destruction of the L1 body. Needle biopsy yielded a diagnosis of aneurysmal bone cyst

Fig. 4 Same patient as in Fig. 3. He underwent L1 corpectomy via a retroperitoneal approach and reconstruction using TSM-allogenic cancellous bone composite stabilized with anterior "double upright" TSRH instrumentation. Postoperative lateral view suggests a solid anterior fusion, and the patient is ambulating pain free

Fig. 5A, B A 32-year-old man presenting with a burst fracture of L3 was treated initially with reduction of the fracture via posterior instrumentation and fusion. The patient continued to suffer radicular symptoms

Fig. 6 Same patient as in Fig. 5. He was treated with anterior retroperitoneal corpectomy at L3, decompression of the thecal sac, anterior reconstruction of L3 with TSM-bone graft construct, and anterior single-rod TSRH instrumentation. At a 48-month follow-up, a solid bridge of bone is visible in the anterior space and the patient is pain free

destabilizing procedure entails stable reconstruction of the corpectomy defect [6, 13, 24, 33]. See Figs. 1–6 for case examples using TSM-bone graft construct to reconstruct the corpectomy defect.

Several techniques are available for anterior thoracolumbar reconstruction after corpectomy [7, 9, 10–12, 15–18, 20–23, 27, 28, 30–33]. Traditionally, autograft or allograft has been used, with mixed results [7, 8, 15–18, 20, 27]. Autologous grafts such as tricortical iliac strut, resected rib strut, or fibular strut are different from each other as well as from allograft in respect of biomechanics and biology [27, 31]. They each have individual advantages and disadvantages [31]. When more than one vertebral body is resected, it is not always possible to procure a strut graft of appropriate length, especially when using autograft. While the use of allograft circumvents morbidity of the donor site in autograft harvesting, disadvantages include the (remote) risk of disease transmission, the possibility of an immunological reaction, and the increased risk of delayed union or nonunion of the graft [32]. Patients receiving autograft or allograft alone may need to be immobilized or require a supportive brace for an extended period until bony incorporation occurs. This is not always possible in a patient with poor general

health where early mobilization is needed to prevent morbidity.

Many patients with spinal tumors receive radiation therapy as a part of treatment protocol for their primary malignancy. Animal studies have shown that radiation has adverse effects on the biomechanical as well as biological properties of bone [3, 12, 29]. A canine model has shown that early postoperative irradiation resulted in a substantial reduction in stiffness of the iliac crest strut used for a partial corpectomy defect [3]. The inferior biological properties were evident by reduced revascularization and new bone formation at the graft-bone junction. The authors suggest that a delay in postoperative irradiation may maximize the chances of a bony arthrodesis. This may not be possible, however, in a clinical setting. Incorporation of strut grafts after local radiotherapy may be delayed or prevented, depending on the dosage of the radiotherapy. It has been suggested that the dose should be limited to 1500 rads or less, but then the incidence of tumor recurrence is high [12].

To overcome these drawbacks, alternatives to autograft and allograft with better biomechanical but minimal biological potential have been used to reconstruct the anterior corpectomy defect [4, 10–12, 17, 24, 25, 28, 32]. Polymerized methylmethacrylate (PMMA) acts primarily as a spacer and has no biological properties of its own. The stability of PMMA implants is known to decrease with time under conditions of cyclical loading [25, 32]. McAfee et al. [25] reported on the failure of stabilization of the spine with methylmethacrylate. They suggest that PMMA used after neoplastic destruction of two or more vertebral bodies may make early augmentation with posterior fusion and stabilization necessary.

The aim of achieving immediate internal stability and promoting early bony fusion led to the use of the TSM-bone graft composite. The stability of TSM has been tested in a static peak load test and a cyclic endurance test with more than one million cycles confirming the excellent material and biomechanical characteristics of the mesh [22].

In another experimental study, TSM demonstrated greater resistance to subsidence under axial loads than other spacers such as iliac crest, rib, or humerus [14].

TSM is available in various diameters and is easily cut and trimmed by the surgeon to provide custom reconstruction of the anterior column defect. This allows for the considerable intraoperative flexibility that is indeed required for reconstruction of larger defects. In the initial design, the mesh had to be rolled into a cylinder and then assembled. TSM was reinforced by means of rings that attached to either ends of the TSM after trimming. Fenestrated plates could be attached to the top of these rings to provide for additional support. Now preset as a cylinder, the fenestrations in the TSM and its circular shape allow for containment of the bone graft so that TSM acts as a bony conduit. The available diameters of the oval mesh allow maximal surface contact of packed cancellous bone with the vertebral body receptor sites. Additional cancellous graft packed circumferentially around the mesh allows increased graft-surface contact.

Solid anterior arthrodesis was achieved in all of our 13 patients within 12 months postoperatively, as assessed by radiographic criteria. This is possible only when graft is maintained in a healthy and stable anterior environment promoting revascularization. No patient was made neurologically worse postoperatively. Although only one patient in our series received secondary surgery due to progressive osteoporotic kyphosis, severe osteoporosis may limit the initial primary stability of TSM.

Conclusion

TSM-bone graft composite provided stable biomechanical support in the early and late postoperative periods. Solid anterior fusion was achieved early, and stable internal fixation spanned only a minimum number of levels. As a result, patients experienced early pain-free mobilization.

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