Cervical Spine Metastases: Techniques for Anterior Reconstruction and Stabilization

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Abstract

The surgical management of cervical spine metastases continues to evolve and improve. The authors provide an overview of the various techniques for anterior reconstruction and stabilization of the subaxial cervical spine after corpectomy for spinal metastases. Vertebral body reconstruction can be accomplished using a variety of materials such as bone autograft/allograft, polymethylmethacrylate, interbody spacers, and/or cages with or without supplemental anterior cervical plating. In some instances, posterior instrumentation is needed for additional stabilization.

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Introduction

The vertebral column is the most common site of skeletal metastases in cancer patients. It has been estimated that up to 70% of cancer patients harbor secondary spinal disease [1] and that 5–10% will develop symptomatic metastases to the spine [2]. Metastatic lesions are the most common malignant lesions of the spine and typically originate from breast, prostate, renal, thyroid, and lung carcinomas. Myeloma, lymphoma, and gastrointestinal carcinomas have also been known to metastasize to the spine [3, 4]. Among patients who exhibit symptoms, 10% have involvement of the cervical spine [5, 6].

Patients who have symptomatic cervical spine metastases usually report neck pain as their chief complaint (≥90%) [7]. Unremitting pain can cause difficulties with basic activities such as walking and getting dressed. Neurologic deficits can occur, including weakness, numbness, and even quadriplegia. Malignant spine tumors typically involve the vertebral body and spare the posterior elements [8]. Increasing tumor burden can weaken bony structural integrity leading to pathologic fractures, instability, and worsening pain. In these cases, traditional management including external radiation therapy and steroid administration are insufficient.

Anterior cervical corpectomy offers the most direct approach to a majority of cervical spine metastases [9]. This approach allows for decompression of neural elements, tumor excision, and effective reconstruction of the weight-bearing vertebral column. To achieve anatomic restoration of the sagittal and coronal planes while preserving the biomechanical properties of deformation and physiologic load bearing, many factors must be considered. Reconstructive materials frequently used include bone

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autograft, allograft, polymethylmethacrylate (PMMA), silastic tubes, titanium interbody spacers, titanium mesh cages (TMCs), expandable cervical cages (ECCs), or a combination of the above. An anterior cervical fixation plate is then often used to help with stabilization and to prevent distraction or subsidence [10]. Posterior instrumentation can also be used with or without bony grafting to supplement the anterior construct, most commonly for tumors at the cervicothoracic junction [11]. In this article, we will review the various techniques of anterior vertebral body stabilization and reconstruction after corpectomy for metastatic tumors of the subaxial cervical spine.

Surgical Indications

Spinal metastases are often treated first nonsurgically with radiation and/or steroids, but surgical intervention should always be a consideration. Indications for surgical intervention include intractable pain, pain that recurs or does not respond to standard oncological treatment, spinal cord compression with neurologic deterioration, mechanical instability, pending pathologic fractures, enlarging radioresistant tumors, or when there is an unknown primary tumor and stabilization and histopathological diagnosis is needed.

Surgical decompression and stabilization procedures have been shown to be more effective than nonoperative management for pain relief [12, 13]. Surgical treatment for cervical spine metastases will not cure disease but is used for palliation of pain, to improve ambulatory function, to restore stability, and to preserve neurologic function [11, 14]. Factors that help to determine which surgical approach should be chosen are the location of the metastatic lesion (anterior versus posterior), the levels involved (some authors recommend anterior stabilization in the subaxial spine), as well as the number of lesions [7]. In a review on surgical decision making by Fehlings et al. [11], the authors conclude that pain was the most important determinant of surgical stabilization at the occipital-cervical junction via a posterior approach. In the subaxial spine, the most common approach used was anterior (66%); however, many authors have recommended combined anterior and posterior reconstruction when two or more levels require treatment. At the cervicothoracic junction (C7-T2), posterior approaches with a posterolateral approach to the vertebral body were the mainstay of treatment of spinal metastases [11]. We will focus on techniques for anterior reconstruction and stabilization.

The surgeon must consider the patient's underlying disease process including overall longevity, quality of life, and whether the patient can handle a large operation. The patient's overall health, nutrition, medical comorbidities, primary cancer aggressiveness, extent of preoperative neurologic deficit (using Nurick Classification), level of preoperative function (using Japanese Orthopedic Association Scale), and level of pain should all be weighed into the decision regarding surgical decompression and stabilization when it is indicated. Survival period is often very closely related to the type of primary cancer. In some cases, a patient with a limited life expectancy from widespread disease may not benefit from a major spinal reconstructive surgery, as surgery is not without complications. If a patient has a good expected survival (some authors say a life expectancy greater than four months), then the surgeon may offer surgery; for those with life expectancies greater than six months, bone graft rather than PMMA is also a consideration [2, 7, 9, 15].

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Anterior Reconstruction and Stabilization Techniques

In the past, surgical treatment of metastatic cervical tumors with spinal cord compression included primarily decompressive laminectomy [3, 16]. This has gradually evolved over the past 20 years to a more direct anterior approach consisting of removal of the vertebral body followed by reconstruction and stabilization. In the subaxial cervical spine, tumors can be readily approached using a standard transverse cervical incision and anterior neck dissection similar to that used in anterior cervical diskectomy and fusion surgeries. It is important to consider many other factors when planning surgical intervention, such as preoperative tumor embolization for extremely vascular tumors, fiberoptic intubation (given the underlying disease and possible instability), neuromonitoring, and skeletal traction. Anterior cervical plating has also been frequently used in addition or adjunct to constructs to prevent construct failure from subsidence or settling. Additionally, a posterior approach may be needed in cases involving the cervicothoracic junction or in patients with significant instability, marked kyphotic deformity, or tumor involvement of all three columns [17, 18]. Combined approaches have higher associated morbidities and thus are often done as staged operations to allow the patient some time to recover.

Cervical corpectomy for metastatic tumor with vertebral body reconstruction and stabilization has been accomplished using numerous techniques. Interbody fusion with or without anterior cervical plating has been done using autograft bone, allograft bone, or PMMA. Bone graft has advantages over PMMA, including proven durability of the construct after fusion has occurred [19, 20]; however, in patients with spinal metastases

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bone grafts have some disadvantages that must be taken into consideration. Although achieving solid bony fusion is desirable, successful fusion can be hindered by previous or planned radiation therapy or chemotherapy, the use of steroids, locally recurring tumor, and general malnutrition in a cancer patient. When using autograft bone, harvesting of the iliac crest for grafting can result in significant post-operative pain and morbidity, further affecting the quality of life in a patient with limited life expectancy. Thus, the use of bone for reconstruction should be limited to patients who are judged oncologically to have an expected survival of greater than 6 months.

PMMA-assisted reconstruction techniques

PMMA-assisted reconstruction achieves immediate stabilization after radical tumor resection and is a sensible alternative to bone grafting for cancer patients with limited life expectancy who still require further therapies for cancer treatment (Fig. 1). Other advantages to the use of PMMA constructs are that they negate the need for an external orthosis post-operatively, are easy to use and relatively inexpensive, avoid donor site complications, and are unaffected by tumor invasion. The PMMA needs to be securely anchored to the vertebral bodies encompassing the corpectomy defect for best results. Disadvantages of PMMA constructs include a possibility of graft dislodgement, esophageal perforation, or thermal damage to the spinal cord, which although rare, have been reported. Some long-term problems include regrowth of tumor causing construct failure and possibly necessitating repeat surgery.

Scoville et al. first described the use of PMMA in a patient with metastatic lymphoma in 1967 [21]. Initially, reports of graft dislodgement when PMMA was used as a simple spacer were discouraging [22]. Techniques were then implemented such as notching the endplates of the vertebral bodies above and below the corpectomy defect to provide better anchorage of the PMMA; however, these also had problems with construct failure and graft dislodgement [23]. Later constructs used Steinmann pins (Fig. 2), internal screws (Fig. 3), and Kirschner wires.

Steinmann pins and PMMA were used by Sundaresan et al. [24] in 101 patients who underwent corpectomies for metastatic spine tumors. The Steinmann pins were placed into the vertebral bodies above and below the corpectomy site, with Gelfoam or fat placed over the dura to protect against thermal injury. PMMA was poured into the cavity along with saline irrigation to dissipate the heat from the exothermic reaction of PMMA. Eighty-five percent of patients received pain relief postoperatively, and the ambulation rate also increased, from 55% to 78%. Despite improvements in technique, however, complications including dislodgement of pins resulting in esophageal perforation and spinal cord injury were reported.

Harrington [25] used a hook-and-rod system in attempt to decrease dislodgement rates. Harrington or Knodt rods are distraction rods that come in 4- to 10-cm lengths and are used with sacral hooks to augment fixation for PMMA. The endplates must first be prepared with a high-speed drill, the distraction rod is turned to progressively anchor the hooks into the endplates, and then PMMA is poured into the cavity (Fig. 4). Despite the addition of the distraction rods to the construct, this system also had problems with graft dislodgement and resulting esophageal obstruction.

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PMMA-assisted reconstruction techniques continue to improve and have been widely used with low complication rates, particularly with the addition of anchoring supplements.

Cervical prosthesis–PMMA constructs

In an effort to augment fixation without dislodgement of the graft, alternative devices were introduced with PMMA to create a construct. Ono et al. [26] described a technique by which patients with metastatic cancer of the cervical spine were treated with prosthetic vertebral body replacement surgery. The surgery was indicated in patients with severe pain or spinal cord and nerve root compression secondary to involvement of a single vertebral body. After corpectomy, a ceramic prosthesis with anterior, superior, and inferior portals was placed into the defect (Fig. 5). Anchor holes aligned with the superior and inferior portals are then created within the superior and inferior endplates, and the prosthesis is laid back into the corpectomy defect. PMMA is poured into the prosthesis through the anterior portal and allowed to fill in the superior and inferior portals and anchor holes to lock the prosthesis into place. The ridges at the superior and inferior endplates prevent posterior displacement of the construct. The spinal cord is also protected from the thermal damage of PMMA polymerization by the prosthesis. The authors reported positive results including pain relief in 94.1% of patients, motor recovery in 91.7%, and improved ambulation in 87.5%. Two patients in their series had recurrent tumor involving the adjacent vertebral bodies leading to loosening of the construct.

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Another technique described by Perrin and McBroom [4] involved placing a U-shaped stainless steel fixation device (Wellesley wedge) to bridge the corpectomy defect in 51 patients with symptomatic spinal metastases. This plate was then secured in place with screws both above and below the corpectomy (Fig. 6). PMMA is then carefully poured into the defect while the underlying trough in the device protects the spinal cord from thermal injury. This construct provides axial and rotational stability while preventing posterior displacement, but there have been reports of anterior displacement. Advantages and disadvantages are similar to the above PMMA-assisted reconstruction constructs.

Anterior cervical plate stabilization

In 1981, Caspar reported several advantages of the addition of cervical plating, including immediate stability, restoration of the normal lordotic curve, shortened time to attain fusion, enhanced fusion quality, and reduction of pseudoarthrosis rates to 2% [27]. Several constructs have incorporated anterior cervical locking plates and screws to reduce the rate of construct failure and anterior displacement in reconstruction after cervical corpectomy for spinal metastasis [20, 28-30]. Since the introduction of cervical plating, many improvements have been made to the technique. In 1999, Caspar reported a series of 30 patients who underwent anterior cervical decompression and cervical plate stabilization for neoplasms in the cervical vertebra [31]. Twenty-nine of 30 patients achieved a significantly improved quality of life with decreased pain and/or improved neurological status. Furthermore, 29 patients had long-term or lifelong mechanical stability in the cervical spine, and only one patient required a repeated posterior

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stabilization procedure. For vertebral body replacement, autologous tricortical iliac strut was used in 26 patients and PMMA in four patients. All but 3 patients underwent post-operative radiation therapy or a combination of radio- and chemotherapy. Solid fusion was obtained in all long-term survivors with bone grafting augmented by cervical plating, even after radiation therapy. Thus, the authors concluded that in patients with longer life expectancy, arthrodesis with bone graft is enhanced with the addition of anterior cervical plating.

Despite the many aforementioned advantages of cervical plating, some disadvantages do exist. These include a longer operative time, screw loosening, hardware breakage, or pain caused by the presence of hardware necessitating re-operation for hardware removal.

Coaxial double-lumen PMMA reconstruction

Many techniques for PMMA reconstruction have been developed to prevent thermal injury to the underlying spinal cord after corpectomy. Cooper et al. [32] initially described the use of silastic tubing packed with PMMA for vertebral body reconstruction of the thoracic and lumbar spine in 1992. This technique involves placing key holes into the adjacent vertebral bodies and then inserting a chest tube into these holes. The chest tube is then impregnated with PMMA.

Miller et al. [20] later used this technique for vertebral body reconstruction in patients with metastasis to the cervical spine. Twenty-nine patients were treated using the coaxial, double-lumen, PMMA technique followed by subsequent anterior cervical plating. This technique is similar to that of Cooper et al. [32]; however, these authors

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added a second, "outer" chest tube to catch any PMMA that may extrude from the first chest tube (Fig. 7). This is all done while the anesthesiologist is holding manual distraction from above. Once the PMMA has cooled slightly and has become viscous, the outer chest tube is removed. Manual distraction is removed once the PMMA has completely hardened. Patients experienced a significant improvement in spinal axial pain, radiculopathy, and gait. Two patients required additional posterior stabilization secondary to progression of disease.

The authors noted good results without construct failure when PMMA was used in conjunction with anterior plate and screw fixation. Advantages of this technique are that PMMA has excellent mechanical properties under compressive forces such as those encountered in the cervical spine. The use of coaxial tubes protects the spinal cord from thermal damage. PMMA is also easy to use, relatively inexpensive, and offers instantaneous stability in comparison to bone grafts. Reported complications included two patients who had CSF seromas postoperatively that were cured with lumbar drainage, two patients with epidural hematomas requiring evacuation, and a patient with a pulmonary hemorrhage requiring eventual ventilator dependence.

Cage constructs

Several other artificial materials have been developed as vertebral body reconstruction devices. Synthetic cages have been made from titanium fiber mesh, carbon fiber spacers, ceramic, ceramic/glass, or expandable titanium cages [33]. See Table 1 for a summary of the different cage constructs and fusion rates. Advantages to cage constructs include restoration of vertebral body height and lordosis without the need for

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harvesting autograft from another site and immediate strong anterior column support. Expandable cages offer the additional advantage of direct application and maintenance of distraction force with a simple one-step, kyphosis-correcting device without the need for dangerous impaction (necessary with single-height devices) over the spinal cord. These cages can also span multiple levels. Disadvantages include increased expense in comparison with allograft or the possibility of cage migration, fracture, or subsidence.

Titanium interbody cage-assisted PMMA reconstruction

The first reports of TMCs for vertebral body reconstruction after cervical corpectomy were for treatment of cervical spondylosis [34, 35]. To account for varying patient size, these cylindrically shaped interbody reconstruction devices are available in several configurations and diameters. After corpectomy, the distance between vertebral body endplates is measured, and the titanium cage can be cut to the appropriate length. The teeth of the cage can be trimmed so that the cage is placed in proper lordosis. Caspar pin retractors or laminar spreaders can be used to aid in distraction and cage insertion. The cage can be filled with PMMA to achieve immediate stabilization for cancer patients who are likely to receive postoperative radiation and have limited life expectancies, or autograft or allograft can be used if the goal is bony fusion.

Liu et al. performed reconstruction of the cervical spine using a titanium cage–silastic tube construct injected with PMMA followed by placement of an anterior cervical plate in a small cohort of 6 patients with cervical spine metastasis [36]. A 32-French chest tube cut to the same length as the TMC and incised longitudinally was placed circumferentially around the cage and secured to the cage with sutures at each end. Once

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the construct had been tapped to fit snugly into the corpectomy defect, the TMC was injected with PMMA (Fig. 8). As with the method described above, the chest tube protected the underlying dura from thermal injury. Once the construct was fully hardened in place, an anterior cervical locking plate was placed to prevent anterior displacement (Figs. 9 and 10). Two patients required subsequent posterior stabilization, but overall the authors noted no complications such as neurological worsening, postoperative hematoma, wound infection, subsidence, graft dislodgement, or construct failure during a follow-up period of 1–19 months (mean 6.8 months).

Sung et al. used a similar construct in 11 patients with symptomatic cervical spinal metastasis, but they inserted a TMC already filled with PMMA and did not use a chest tube [37]. The TMC was placed into the defect under distraction, and the construct was then augmented with anterior cervical plating. All 11 patients showed motor improvement and had significant improvements in neck pain. None of the patients required posterior stabilization, although the authors reported that one patient experienced construct failure at 33 months. The authors did not detail how the hardware had failed, only that the patient remained asymptomatic and opted for no further surgery.

Titanium interbody cage-assisted calcium phosphate ceramic reconstruction

Chuang et al. [10] reported 17 patients with cervical radiculomyelopathy from metastasis-induced pathologic fractures of the cervical spine. They performed anterior corpectomies and inserted TMCs filled with triosite (calcium phosphate ceramic) into the vertebral body defects. Their experience indicated that the use of triosite ceramic shortened hospital stays, reduced blood loss, and reduced operation times. Triosite was

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also used to spare the patient from autologous iliac crest harvesting and because corpectomy bone was unusable secondary to neoplastic changes. The upper and lower end caps of the TMCs were both locked in place to avoid settling or subsidence of adjacent vertebral endplates. An anterior cervical plate was then placed for further stabilization of the construct. The authors noted a significant improvement in pain control in all patients. They reported no surgical-related morbidities or ceramic-related complications. On postoperative radiological assessment, they noted no significant settling, telescoping, or destruction of endplates in the adjacent vertebrae. One difficulty identified with the use of this construct was surveying for fusion postoperatively because the use of Triosite ceramic has been noted to delay radiographic fusion. While only 9 of the 17 patients were alive at 12 months to undergo CT scanning, all showed intercage trabeculation supporting the occurrence of true interbody fusion.

Expandable cylindrical cages

ECCs have been used widely and successfully in the reconstruction of the thoracic and lumbar spine. Within the past decade they have been used more in frequently in the cervical spine. ECCs are a recent variation of the TMC but have the capability of being adjusted to fit the height of the corpectomy defect and thus span multiple levels. Ideally, these cages create a stable substitute for the vertebral body, resist axial loading, have a large interbody–bone interface to facilitate fusion and prevent migration and subsidence, and restore height and sagittal alignment [28, 29, 38]. There are many different variations of expandable vertebral body replacement systems, some specifically for the thoracic and lumbar spine, and some approved for use in the cervical spine. Below we will discuss

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some of the different types of expandable cages that have been used specifically in the cervical spine.

Synex ECC

The Synex ECC is made from titanium alloy and has a self-locking ratchet expansion mechanism for easy insertion into the vertebral body defect. It is available in a variety of heights (23–73 mm) and end plate sizes (21 x 22 mm or 25 x 28 mm) for use in the cervical, thoracic, or lumbar spine (Fig. 11). In 2006, Auguste et al. [29] reported a retrospective case series of 22 patients who had undergone placement of a Synex ECC (Synthes Spine, West Chester, PA) in the cervical spine for various pathological conditions, including osteomyelitis, spondylotic myelopathy, fracture, tumor metastasis, and severe stenosis. Although only one patient underwent surgery for spinal metastasis, this series was the largest at that time documenting the use of expandable cages after corpectomies in the cervical spine. Fifteen of the patients had multilevel corpectomies, including two at three levels. After corpectomy, calipers were used to approximate the cage size needed, and an ECC was carefully chosen with the appropriate angled end pieces to match the anatomy of the defect. Osteofil and bone morphogenic protein were used to pack the ECCs in patients with osteomyelitis or cancer. All patients had anterior cervical plating to augment the construct. Posterior instrumentation was used in 14 patients to supplement anterior reconstruction for those with two- or multi-level corpectomies and a preoperative kyphotic deformity greater than 15 degrees. All patients remained in a cervical collar for 6–12 weeks postoperatively. After a mean follow-up of 22 months, the authors noted successful fusion on radiographs in 100% of cases and

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sustained kyphotic correction in 10 of 11 patients presenting with kyphotic deformity. Three patients experienced dysphagia (all of which resolved over time), and there were no instances of hardware failure, hardware migration, fracture, or recurrent disease.

Overall, the authors had excellent results with this ECC and endorsed its use for vertebral reconstruction in the cervical spine. They reported that the major benefit of this device is that it maintains the structural strength of conventional TMCs and has the added benefit of height adjustability. This eases insertion, removes the need for dangerous impaction over the spinal cord, eliminates the need for cage cutting, causes less trauma to the endplates, creates an optimal fit, and corrects kyphosis in one step. There were no major complications, including pseudarthrosis or hardware failure; however, three patients experienced transient dysphagia.

Telescopic Plate Spacer

The Telescopic Plate Spacer (TPS; Interpore Cross International, Irvine, CA) is a rectangular titanium cervical plate–interbody spacer that has been approved by the U.S. Food and Drug Administration for C3 to T3 vertebral body replacement in patients with metastatic spinal disease (Fig. 12). It is a single construct that combines an anterior plate with an intervertebral column spacer. The spacer portion is placed within the corpectomy defect, and the end pieces are fixed with 0 degrees at the caudal surface and 10 degrees at the cranial surface. The phalanges prevent the TPS from dorsal displacement. The device is distracted open until it fits snugly in the defect while simultaneously correcting kyphosis. The height can be adjusted from 22 to 29 mm for a one-level corpectomy and from 34 to 50 mm for a two-level corpectomy [28, 39]. The set screw is then tightened to lock the spacer portion of the device at the desired height. The implant has a large contact area with a hollow core that can be packed with bone graft.

In 2002, Coumans et al. [40] reported their results using the TPS with allograft in a prospective human study of 15 patients with metastatic spine disease. The patients had a significant improvement in pain scores, vertebral height, and kyphosis correction. The four postsurgical complications were pneumonia, temporary recurrent laryngeal nerve palsy, cerebrospinal fluid leak requiring lumbar drainage for three days, and esophageal rent requiring nasogastric feeding for five days. There were no neurologic complications or hardware failures. Nine of the 12 patients still alive at 12-month follow up demonstrated bony fusion on computed tomography scans and exhibited no movement on flexion and extension x-rays.

Arts and Peul [28] in 2008 reported their three-year experience (October 2004 to November 2007) with six different vertebral body replacement systems. Out of 60 total patients, 41 patients had cervical spine disease and 27 patients had reconstruction using TPS. Ninety-five percent of the patients had improved Frankel grades after surgery, and bony fusion was achieved in 93% of all cases. The authors noted favorable clinical outcomes but also higher complication and reoperation rates than previously reported. Eighteen patients had complications, including 5 cases of hardware displacement, all of which involved TPS cages. One patient developed acute hypotensive shock secondary to cage migration and rupture of the aorta. After emergent surgery, repair of the aorta, and second-stage cage implantation, the patient fully recovered. Half of the patients were noted to have graft subsidence, and 12 patients (20%) underwent revision surgery.

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Anterior distraction device

The Anterior Distraction Device (ADD; Ulrich Medical, Ulm, Germany) is used for reconstructing the vertebral column from C3 to T3 and has mostly been evaluated in patients with cervical stenosis and myelopathy. ADD is available in 3 outer diameters (12, 14, and 16 mm), with 0-degree fixed angulation of the caudal end piece and 0- or 6-degree angulation of the cranial end piece. There is a small central cavity that can be filled with autograft or allograft bone. Distraction ranges from 10 to 13 mm to 39 to 65 mm. The cage is distracted by counterclockwise rotation of a distraction ring (Fig. 13). After 2002, the ADD implants were equipped with plates (wings) and thus those placed since then do not need additional anterior cervical plating.

Schenke and Eif [41] reported the use of ADD after corpectomies for cervical stenosis and myelopathy in 42 patients over a 5-year period. More than two-thirds of the patients had two or more vertebral bodies resected. Neurologic improvement was noted in 71%, while 26% of patients were stable neurologically and one deteriorated. Patients were kept in a cervical collar for at least 4 weeks postoperatively, and x-rays done during follow-up examinations showed good results. Five reoperations were needed, four because of screw loosening. One patient had a postoperative hemorrhage, and two patients were noted to have subsidence of the graft into the adjacent endplates. In the study by Arts and Peul [28], one case involved the use of an ADD, but it is unclear what the clinical implication or outcome was in this single case. More research on the use of the ADD in vertebral body reconstruction for cervical spine metastasis is needed.

Cervilift expandable cage

The Cervilift expandable cage (Deltacon GmbH, Werneck, Germany) comes in two sizes and is designed for vertebral body replacement in the cervical spine. The implant diameter is 11 or 14 mm, and the central compartment can be filled with bone graft. Heights vary from 13 to 20 mm for the smaller size and from 18 to 30 mm for the larger size. Extension pieces range from 5 to 10 mm and can be placed on either end to increase the implant height. End caps are angled for fit into the corpectomy defect and are available in 0, 3, and 5 degrees. The implant can be distracted by inserting an expander and rotating counterclockwise. Subsequent anterior cervical plate fixation is necessary. Arts and Peul [28] used only 2 of these constructs in their study of vertebral body replacement systems, and information on outcomes for this individual construct was not detailed. More research on this construct is needed to document its utility in cervical spine reconstruction.

Summary

The mainstay of management of symptomatic cervical spine metastasis is anterior cervical corpectomy followed by vertebral body reconstruction and stabilization. Many techniques have been used over the past few decades with varying degrees of success. Reconstruction with PMMA using an interbody spacer is an effective option for patients with widespread metastasis and limited life expectancy. For patients with a life expectancy greater than 6 months, bone allograft is often favored instead of PMMA. The use of anterior cervical plating has been shown to provide extra support to these constructs and decrease construct failure. The advent and use of ECCs has so far been favorable, with many authors citing their ease of use, improved fit, biomechanical

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strength and stability, and ability to restore height and correct kyphosis in one step as advantages. Posterior stabilization should be considered as a supplement to anterior constructs, especially in patients requiring corpectomies of more than two levels and kyphotic deformity greater than 15 degrees.

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Figure Legends

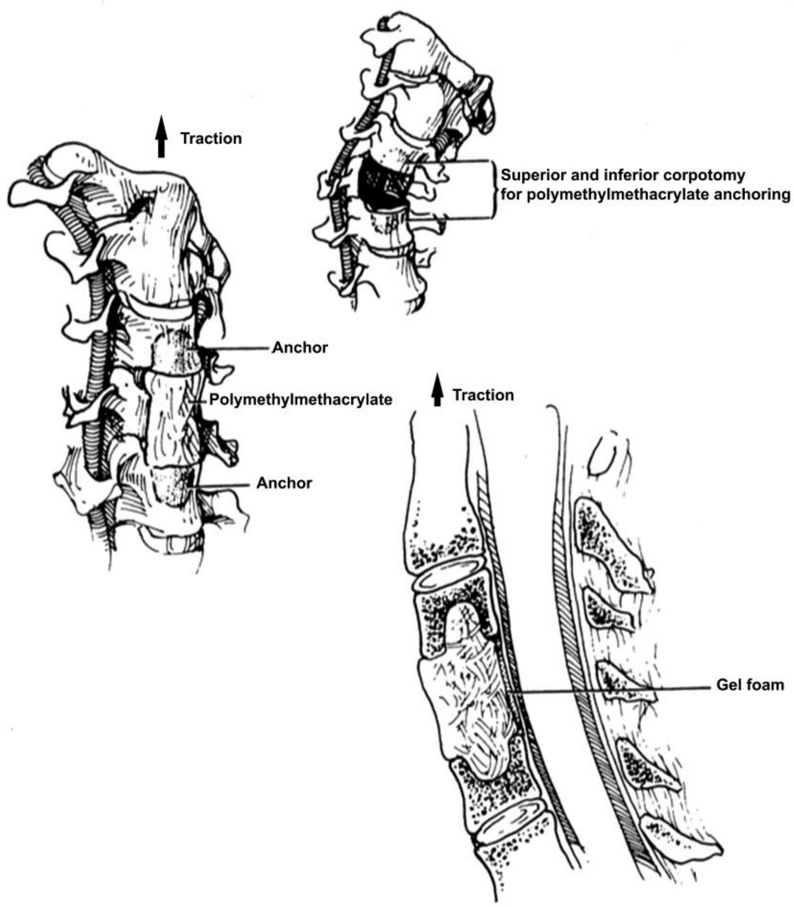

Fig. 1. PMMA-assisted anterior vertebral body reconstruction. This technique includes notching the adjacent vertebral bodies to provide better anchorage for the PMMA. (From Sherk HH, editor. The cervical spine: an atlas of surgical procedures. Lippincott-Raven; 1994. p. 280; with permission.)

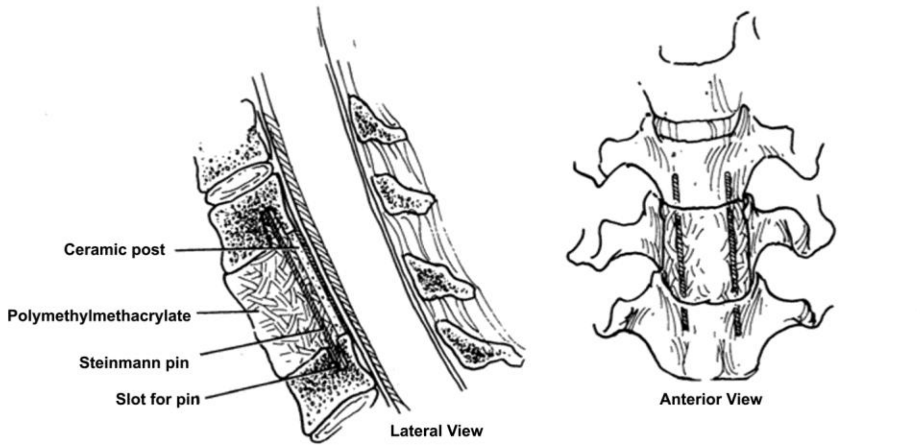

Fig. 2. Anterior vertebral body reconstruction using Steinmann pins placed in the vertebral body above and below the corpectomy defect followed by PMMA poured into the defect. (From Sherk HH, editor. The cervical spine: an atlas of surgical procedures. Lippincott-Raven; 1994. p. 281; with permission.)

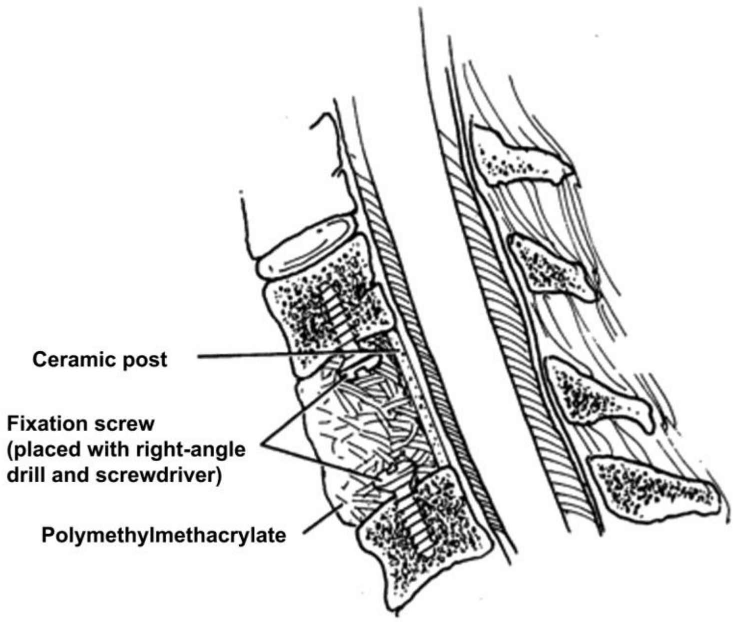

Fig. 3. Anterior reconstruction with PMMA and internal screws placed in the adjacent vertebral bodies. (From Sherk HH, editor. The cervical spine: an atlas of surgical procedures. Lippincott-Raven; 1994. p. 281; with permission.)

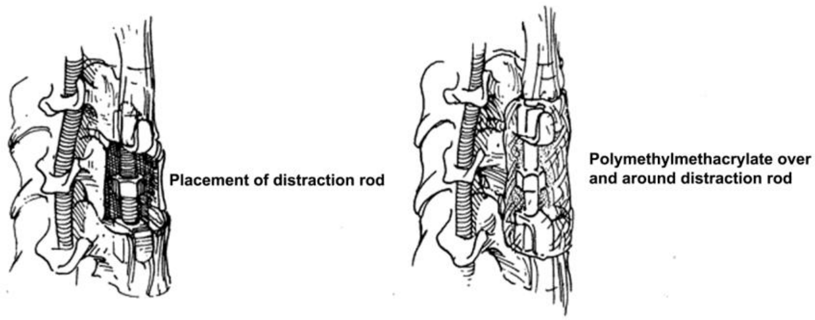

Fig. 4. Anterior reconstruction using combination of PMMA and Knodt distraction rod and hooks. (From Sherk HH, editor. The cervical spine: an atlas of surgical procedures. Lippincott-Raven; 1994. p. 282; with permission.)

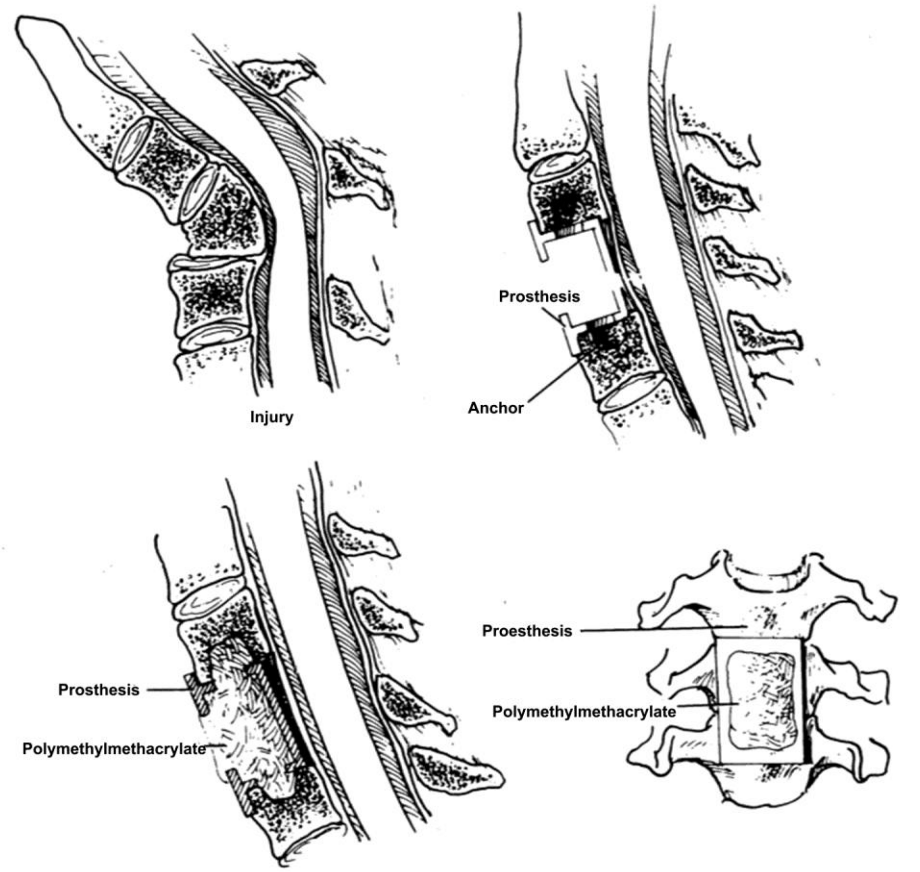

Fig. 5. Anterior reconstruction using a ceramic interbody prosthesis filled with PMMA. (From Sherk HH, editor. The cervical spine: an atlas of surgical procedures. Lippincott-Raven; 1994. p. 284; with permission.)

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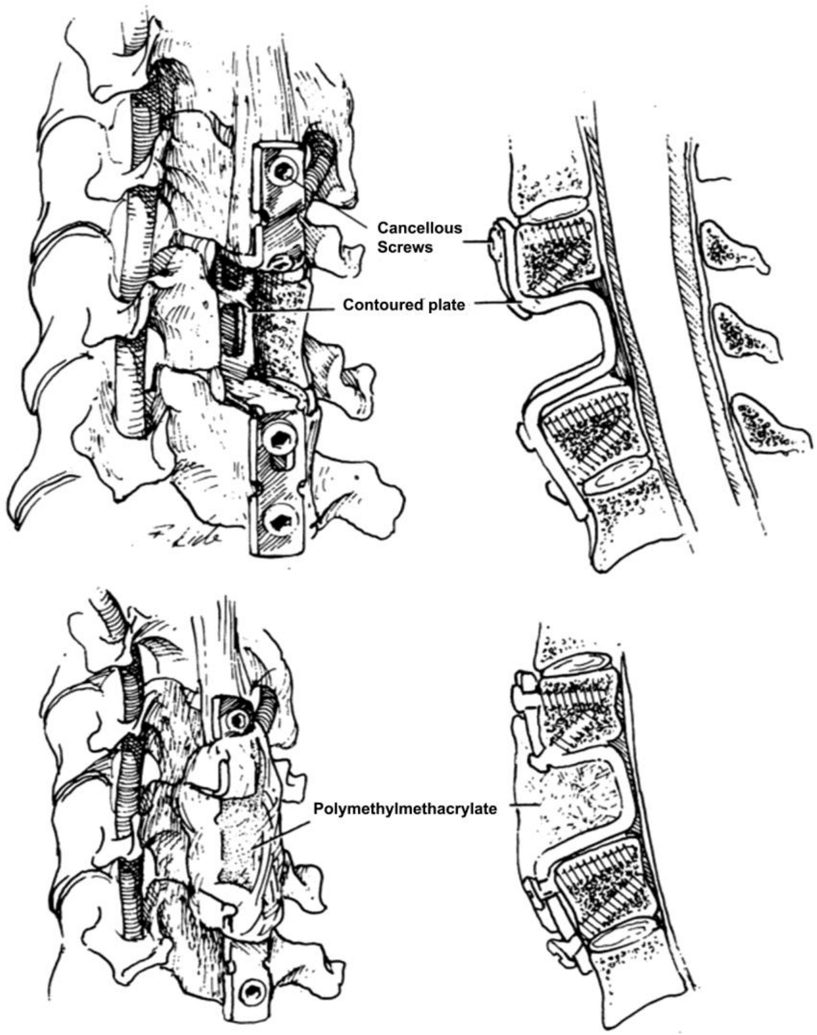

Fig. 6. Anterior reconstruction using Wellesley wedge (U-shaped fixation device) filled with PMMA. (From Sherk HH, editor. The cervical spine: an atlas of surgical procedures. Lippincott-Raven; 1994. p. 283; with permission.)

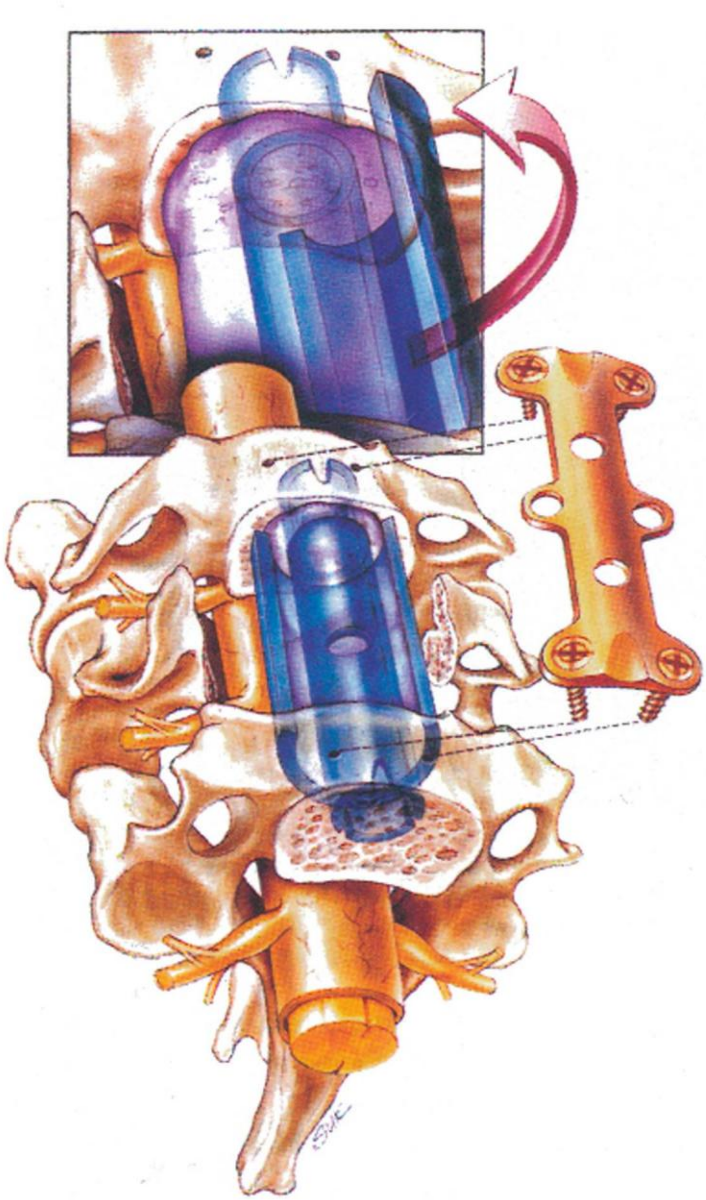

Fig. 7. Anterior reconstruction using a coaxial double-lumen chest tube interposed in the corpectomy defect and impregnated with PMMA. (From Miller DJ, Lang FF, Walsh GL, Abi-Said D, Wildrick DM, Gokaslan ZL. Coaxial double-lumen methylmethacrylate reconstruction in the anterior cervical and upper thoracic spine after tumor resection. J Neurosurg (Spine 2) 2000;92:184; with permission)

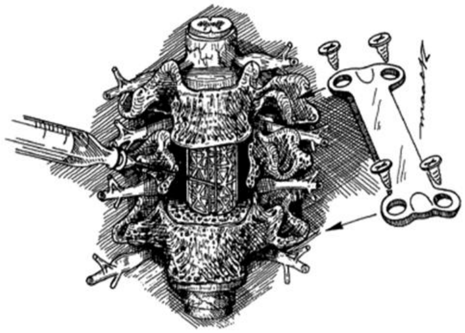

Fig. 8. Technique depicting anterior reconstruction with a titanium interbody cage–silastic chest tube construct filled with PMMA. The construct is further augmented with anterior cervical plating. (From Liu JK, Apfelbaum RI, Schmidt MH: Surgical management of cervical spinal metastasis: anterior reconstruction and stabilization techniques. Neurosurg Clin N Am 2004; 15:413-424; with permission.)

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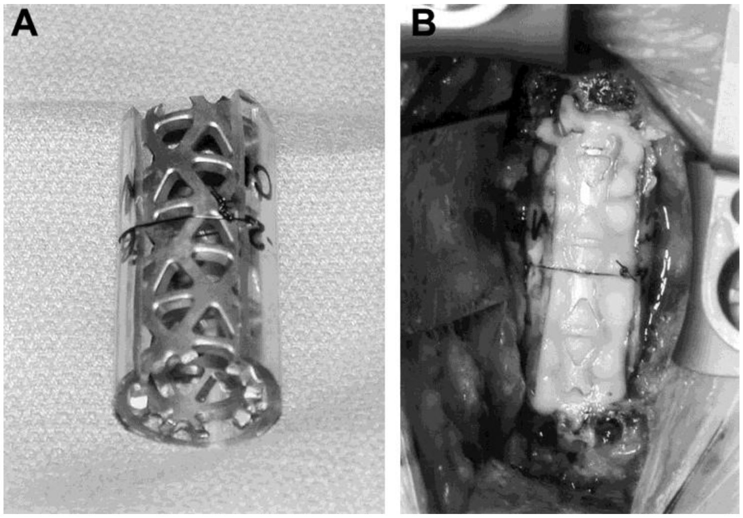

Fig. 9. Intraoperative photographs demonstrating the Pyramesh cage–silastic tube reconstruction with PMMA. (A) Titanium mesh cage is placed within a silastic chest tube and secured with a suture across the incised ends. The anterior defect in the chest tube allows for injection of PMMA. (B) PMMA-impregnated titanium cage–silastic tube construct within the vertebral body defect. (From Liu JK, Apfelbaum RI, Schmidt MH: Surgical management of cervical spinal metastasis: anterior reconstruction and stabilization techniques. Neurosurg Clin N Am 2004; 15:413-424; with permission.)

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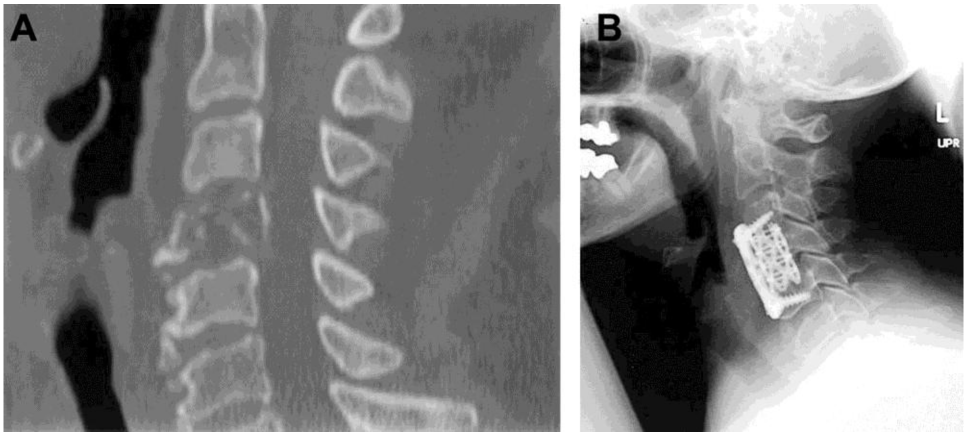

Fig. 10. Anterior reconstruction after a C4 corpectomy for a renal cell metastasis using a titanium mesh interbody cage and chest tube construct filled with PMMA supplemented by an anterior cervical plate. (A) Preoperative sagittal CT reconstruction showing bony destruction of the C4 vertebral body. (B) Postoperative lateral cervical radiograph. (From Liu JK, Apfelbaum RI, Schmidt MH: Surgical management of cervical spinal metastasis: anterior reconstruction and stabilization techniques. Neurosurg Clin N Am 2004; 15:413-424; with permission.)

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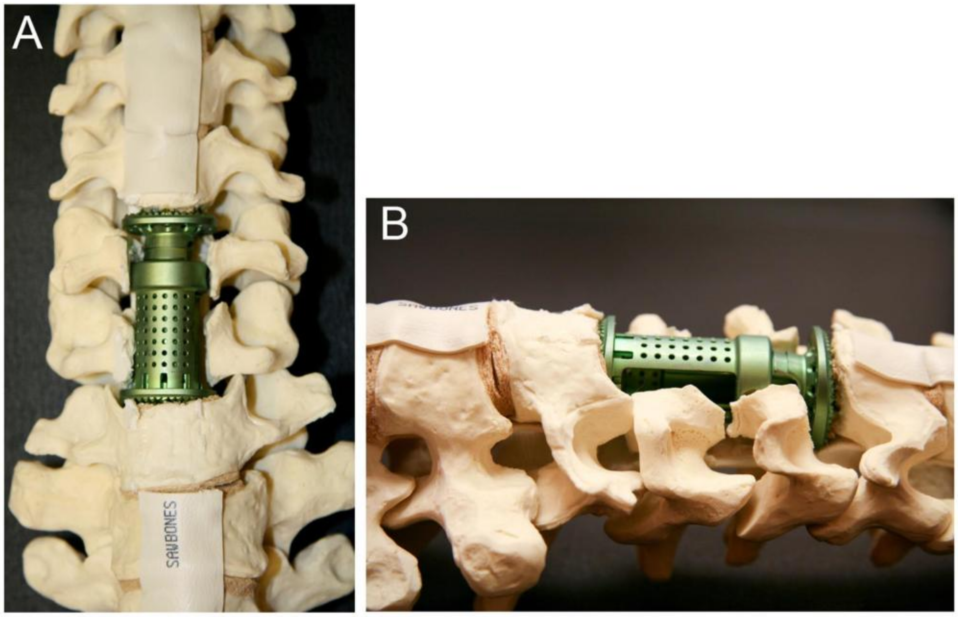

Fig. 11. Model depicting anterior reconstruction using the Synex expandable cylindrical cage. (A) Anteroposterior view; (B) lateral view.

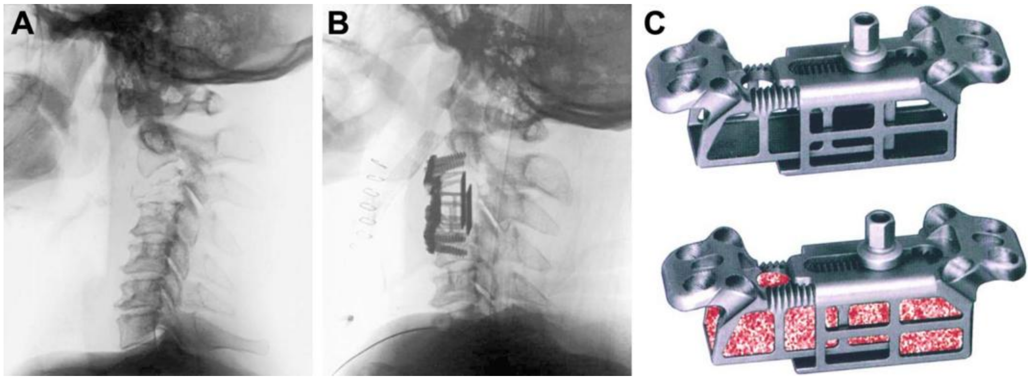

Fig. 12. Anterior reconstruction after a C3 corpectomy for squamous cell carcinoma metastasis. (A) Preoperative lateral plain radiograph showing C3 vertebral body destruction with kyphotic deformity. (B) Postoperative lateral plain radiograph showing placement of the Telescopic Plate Spacer (TPS) device into the C3 corpectomy defect. (C) Illustration of the TPS device, which can be expanded to fit the size of the corpectomy defect and can be filled with bone graft. [(A, B) From Liu JK, Apfelbaum RI, Chiles BW III, Schmidt M. Cervical spinal metastasis: anterior reconstruction and stabilization techniques after tumor resection. Neurosurg Focus 2003;15(5):E2; with permission. (C) From Interpore Cross International, Irvine, CA; with permission.]

Fig. 13. Anterior distraction device (ADD). The wings negate the need for an anterior cervical plate.

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Table 1. Listing of the different cage constructs and fusion rates found at follow-up

Construct	Author	Time of follow-up fusion evaluation	Fusion outcome
Titanium Mesh Cage (TMC)	Chuang et al. (2008)	12 months	100% All 9 patients still living showed fusion on CT (8 deceased)
Synex Expandable Cervical Cage (ECC)	Auguste et al. (2006)	Mean 22 months	100% fusion on cervical radiographs
Telescopic Plate Spacer (TPS)	Coumans et al. (2002)	12 months	100% All 9 patients still living showed fusion on CT and no movement on flexion-extension radiographs (3 deceased)
Anterior Distraction Device (ADD)	Schenke and Eif (2005)	1 month	No fusion rate listed; stated that x-rays at follow-up showed good results 4/42 patients (9.5%) required re-operation for screw loosening
Cervilift Expandable Cage	Arts and Peul (2008)	N/A	Only two patients; fusion rates not available

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