Vertebroplasty, Kyphoplasty, Lordoplasty, Expandable Devices, and Current Treatment of Painful Osteoporotic Vertebral Fractures

Mohamed El-Fiki

Vertebral fractures are devastating if they create neurological deficits, especially if they are unstable. Fortunately, most patients with vertebral fracture, whether inflicted by trauma, neoplasm, or osteoporosis (primary or secondary), present largely because of pain that interferes with their daily activities of living. Patients with osteoporotic fractures live less than those with femoral neck fractures. Age, sex, and racial predilections exist that favors elderly, female patients with an equal frequency in both Caucasians and Asians. Vertebral fractures are less frequent in African Americans.

One quarter of postmenopausal women suffer osteoporotic vertebral fractures. Osteoporotic vertebral fractures are multiple in up to 20% of patients and affect more than 20% of those older than 50 years, with a slight female prevalence that markedly increases when they age reach 80 years or older. Loss of height of the osteoporotic fractured vertebra may be mild (20%–25%), moderate (25%–40%), or severe (>40%). It commonly affects the thoracolumbar region, although any vertebra may be disturbed. Osteoporotic vertebral fractures are mostly wedged with anterior or mid-body shortening, and minimal posterior vertebral body curving; however, discoid biconcave or crush-like fractures also may be seen.

Osteoporotic vertebral compression fractures are increasing worldwide because of increasing longevity of the population and more a sedentary lifestyle associated with increased urbanization and more frequent use of locomotion or lifting gears. Pain on weight bearing during locomotion will limit the fractured patient’s ability to mobilize. In patients with no neurological deficits, pain management is the cornerstone of treating osteoporotic fractures through vertebral body stabilization. Prolonged bed rest together with analgesics and expensive drug management may bring about pain relief at the expense of increased consequent, dreadful, recumbent complications. Increased osteoporosis, pneumonia, pulmonary dysfunction, eating disorders, loss of independence, mental status change because of pain and the use of medications, and deep-vein thrombosis or strokes occur commonly.

It has been reported that conservative outpatient treatment would yield adequate control of pain in less than 20%–25% of patients. Early ambulation after surgery is a safeguard against multitude of complications, especially in frail, older patients after vertebral osteoporotic fractures. Minimally invasive fixation and vertebral cementing procedures deliver several advantages in this setting of pain control.

Key words
- Expandable vertebral devices
- Fractures
- Kiva
- Kyphoplasty
- Lordoplasty
- Minimally invasive spine
- Osteoporotic
- Polymethyl methacrylate
- Polyethylene terephthalate
- SpineJack
- Vertebral
- Vertebroplasty
- Vesselplasty

Abbreviations and Acronyms
- PMMA: Polymethylmethacrylate
- ODI: Oswestry Disability Index
- VAS: Visual analogue scale
Surgical Options

Three-column restoration is the gold standard of vertebral body reconstruction in cases of unstable vertebral fractures. This tactic provides immediate stabilization of unstable vertebral fractures whether traumatic, neoplastic, or osteoporotic in etiology. It may be performed through anterior, anterolateral, or posterior surgical approaches. It may be a classical open procedure, a minimally invasive approach, or a combination of both. The 3-column anterolateral spinal canal decompression through a posterior approach is more familiar to most neurosurgeons; however, open surgical fixation often fails because of the poor bone quality of osteoporotic vertebral fractures.

When pain is the presenting symptom, a percutaneous cement injection may relieve pain. The main drawback of using a cement injection (open or percutaneous) to stabilize a fractured osteoporotic vertebrae is cement leakage through the vertebral vasculature, causing a pulmonary embolism. More frequently and more neurologically devastating is leakage into the spinal canal. Maintaining the restored vertebral height and avoiding adjacent level fractures challenges neurosurgeons to master and manage.

Recent technical advances have allowed the inclusion of expandable vertebral devices into the stabilizing technique through open or minimally invasive approach in addition to enforcing the fragile shattered vertebral body with different cementing materials.

Minimally Invasion Procedures

Minimally invasive procedures are appealing to most patients and offer decreased hospitalization time, smaller incisions, immediate pain relief, early mobilization, and often lower costs. The hazards involved are overshadowed by the benefits achieved. Both vertebroplasty and kyphoplasty may be performed as percutaneous outpatient procedures in adequately equipped centers with significant, swift, painless early ambulation.

Vertebroplasty. Vertebroplasty is a reasonable minimally invasive option in the treatment of osteoporotic vertebral compression fractures. It may create immediate pain relief and stabilization of progressive kyphosis deformity induced by the discrepancy of anterior and posterior osteoporotic vertebral dimensions. Restoration of anterior vertebral height may augment the surgical goals through—at least partial—kyphosis correction or arrest, thus mitigating the theoretical progressive mechanical stress forces responsible for pain recurrence or refracture. Radicular symptoms caused by foraminal compromise during vertebroplasty remain a risk, although they are rarely encountered.

Balloon Kyphoplasty. Balloon kyphoplasty, or the use of a balloon to inflate the compressed vertebra and enable thicker bone cement to maintain the restored height with less incidence of cement leakage, was developed as an alternative percutaneous minimally invasive, cement-enforced, low-cost procedure from percutaneous vertebroplasty in which more than 90% of patients experienced pain relief and a significant average correction of 11° and 13° of segmental and vertebral kyphotic angles were maintained. Lordoplasty was more significantly useful than kyphoplasty in restoring and maintaining the anatomic reduction and kyphotic deformity after 3 months.

The introduction of 6 bipedicular cannulas is necessary for each single fractured level. Classically, the proximal and distal intact vertebrae are injected under fluoroscopic control with 1–2 mL each of the viscous cement that is allowed to harden through 4 pedicular cannulas. The properly viscous cement should not drop from the injecting syringe. When the cannulas in the hardened, injected vertebrae above and below are forced into lordosis and the kyphotic osteoporotic vertebra height is restored. The reducing position of the cannulas is kept in place with a cross bolt, whereas the remaining 2 cannulas at the fracture level deliver the polymethyl methacrylate (PMMA) cement into the collapsed vertebra that is left to harden in the corrected position. The 6 injection cannulas are then removed. Lordoplasty does not address the problem of leakage outside the vertebral body injected. It may even increase it because 6 injection cannulas are used. The authors stressed that a high cement viscosity and a wide-bore injection cannula would decrease leakage during this cost-effective procedure.

The Case for Expandable Vertebral Devices

Variable reduction devices have been used. Technologically advanced, specific tools facilitate the innovative minimally invasive insertion within the osteoporotic fractured vertebral bodies. A vertebral body cement container may be a balloon (kyphoplasty), a porous vessel balloon (vesselplasty), titanium expandable support (SpineJack; VEXIM SA, Balma, France), or coil filled system (Kiva; Benvensine Medical, Inc., Santa Clara, California, USA). Expandable vertebral devices theoretically increase stiffness and decrease cement leakage and adjacent level fractures. Short operative and radiologic exposure time, brief hospital stay,
and early return to painless daily activity are cost-effective and appealing to most patients who sustain an osteoporotic fracture.

**Vesseloplasty**

Instead of filling a contained cavity in balloon kyphoplasty or a created reduction space in lordoplasty; vesselplasty percutaneous insertion of a “porous” polyethylene terephthalate collapsed container creates the hollowness volume inside the osteoporotic collapsed vertebral body for cement injection. Thus, it decreases complications of leakage and permits permeation of the cement into the vertebral body to increase stability. Viscosity, injection time, and filling of the vessel need to be observed simultaneously under image intensifiers. Vesselplasty also decreases the incidence of future collapse.1,18,19

**Spine Jack**

The most commonly used is the percutaneous titanium expandable device “Spine Jack,” which was more statistically able to reduce mechanically compressed vertebral bodies in an experimental anatomical study.20 In another study, 27 patients with thoracolumbar fractures were managed with the device showed significantly improved pain visual analogue scale (VAS) to more than 50% of the preoperative value in the first 24 hours postoperatively. VAS decreased further during 1-year follow up. Kyphosis correction and vertebral height restoration also were significantly maintained in anterior, middle, and posterior vertebral bodies.21

The spine jack is a device that offers the ability to rebuild the original contour of a nonfused shattered vertebra that is still mobile and to reform the appropriate anatomic framework of the vertebral shape and height. The insertion instruments include a blunt and a threaded guidewire, a working cannula, a reamer, a template, and a cannula plug system. The main advantage is endplate restoration. Inclusion of an endplate support theoretically decreases the incidence of progressive collapse with time. Usually 2 implants ensure adequate height restoration, which will alleviate pain, reclaim function, and permit early mobilization besides comfortable return of daily activities. A pedicle diameter of 5 mm is mandatory for safe proper insertion. The Spine Jack titanium implants are of 3 variable dimensions to accommodate variable vertebral morphologies. Statistically significant height restoration was maintained 3 months after insertion. Reduced incidence of adjacent fractures also was statistically much less than that observed for verteoplasty or balloon kyphoplasty.20,21

In the paper recently published in WORLD NEUROSURGERY, Lin et al. reported that the use of a Spine Jack expandable device in patients older than 60 years with osteoporotic vertebral fractures was better than vertebroplasty. This result confirmed a previous cadaveric study.20 The device was reported to help expand the vertebral fracture.21 Similar results were reported with the use of another device based on a same principle to cut down the incidence of leakage of PMMA into epidural space in about 10% of cases.22,23

**The Kiva System**

Another percutaneous device (Kiva) was suggested to decrease the incidence of cement leakage in certain types of osteoporotic vertebral compression fractures.21 The Kiva system uses a coil to scaffold cylinder-shaped, injected cement into the collapsed vertebral body. KIVA was suggested to be superior to balloon kyphoplasty and vertebroplasty in decreasing the incidence of intracanal cement leakage and maintaining the correction of kyphotic angle. PMMA leakage, when it occurred, was mainly outside the spinal canal. With the Kiva, operative time was less than other devices. The Kiva system VAS for pain was significantly superior to balloon kyphoplasty. No difference was noted in Oswestry Disability Index (ODI) scores or in the incidence of cement leak. Both procedures maintained vertebral body height for the 6-month duration of the study.24 Meanwhile, the Kiva device significantly reduced the Gardner angle24 and was associated with less adjacent-level fractures (although nonsignificant).

**Other Expandable Devices**

Anterior expandable devices were found to be statistically more capable of maintaining reduction when applied to tuberculosis-induced vertebral collapse followed for a prolonged period of time.25,26

**Hybrid Combinations**

Circumferential reduction was suggested for unstable fractures with anterior expandable device coupled with posterior instrumentation to maintain reduction and kyphotic angle. Nevertheless a rather high rate of postoperative endplate impaction of the device was noted.27 The use of a reduction device with posterior instrumentation in burst fractures was associated with significantly more height and anatomical restoration of the affected body.28 This finding may support further the use of a stabilizing device. Percutaneous short segment internal fixation adjuvant to percutaneous kyphoplasty showed significantly better pain control as measured by VAS and better functional status as measured by ODI scores than percutaneous kyphoplasty alone when patients were followed for 2 years. Kyphotic angle correction was significantly better in the percutaneous instrumented kyphoplasty group than the kyphoplasty-only group. More refractures and adjacent level fractures were noted in the kyphoplasty-only group.29

**Complications of Minimally Invasive Percutaneous Vertebral Corrections**

In addition to potential rare sensitivity reactions to cementing substances, cement leakage, failure to maintain reduction, and adjacent vertebral fractures are the main limitations30 with resultant conceivable instability.31 It is common to have osteoporotic fractures adjacent to the levels operated either as the result of altered dynamics or increased stiffness of the cemented spine or the natural course of osteoporosis. Adjacent-level fractures, however, were more common in a control group than in patients who underwent balloon kyphoplasty.2 Surgeons thrive to decrease complication through improving the technique and delivery of the cementing and supporting equipment.

**Cementing Materials**

Several cementing materials have been tried. The most popular are PMMA, calcium phosphate, and hydroxyapatite. The osteoconductive calcium phosphate and hydroxyapatite are appealing PMMA-replacement materials to avoid PMMA stiffness–related complications such as adjacent-level fractures. Whether the results of different cement materials are comparable is not known and is beyond the core of this Perspective. The 10-year
follow up of calcium phosphate cement kyphoplasty in traumatic fractures indicated minimal cement resorption of 22% with maintained kyphotic angle correction. An animal model confirmed that calcium phosphate cement remodeling was not predictable. The authors did not recommend its use for percutaneous vertebroplasty and were dissatisfied with the sheep model they used.32 Not only were adjacent-level fractures thought to be increased but also refractions of the same augmented vertebra after vertebroplasty as the result of cement fragmentation was reported in an 84-year-old severely osteoporotic patient 10 months after his insufficient PMMA augmentation of his D12 vertebra.33

**Volume of Cement injected**
The effective volume of PMMA injected was suggested to be 4–6 mL.34 Lesser volumes may be considered ineffective, whereas larger volumes may leak outside the confines of the vertebral collapse with increased incidence of neurologic complications.35 Many cases of cement leakage were observed (10%); however, only 1% were symptomatic.

**Bipedicular or Unipedicular Injection**
Whether bipedicular injection is required or unipedicular injection is sufficient was also studied in a meta-analysis study of 559 vertebral osteoporotic fractures in 440 pooled patients. Unipedicular injection was favored because VAS, ODI, cement leakage, and adjacent vertebral fractures were not significantly different with shorter time of radiologic exposure.17,36,37 Radiofrequency also was used to enhance the cement viscosity to decrease leakage. The radiofrequency augmented kyphoplasty authors used 2.9–5 mL of cement with significant height restoration and pain relief with less than 5% leakage incidence, but with a case of kyphoplasty adjacent fracture.38 It is noted that the Kiva system entails a unipedicular pass whereas the Spine Jack necessitated a bipedicular access.

**CONCLUSIONS**
Minimally invasive percutaneous procedures for cementing vertebral osteoporotic fractures are appealing to patients. Early ambulation and immediate pain control is achieved. Percutaneous expandable vertebral devices to support the endplate and decrease cement leakage are currently more efficient. Unipedicular cement delivery may be desirable. Cementing materials may be further improvised to be more compatible with physical and mechanical properties of normal bone to decrease the incidence of adjacent level fractures.

**REFERENCES**


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