Review Article

Management of Osteoporosis in Spine Surgery

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Abstract

Osteoporosis is a burgeoning clinical problem that is characterized by decreased bone strength and density. It predisposes patients to fragility fractures and debilitating spine deformities. Several complications are associated with spine surgery in patients with osteoporosis, and there is currently no treatment algorithm to guide the spine surgeon. A multidisciplinary approach to treatment of patients with osteoporosis and spine deformity or fracture is encouraged, and preoperative planning is crucial for successful surgical outcomes. Several surgical techniques have been developed to treat osteoporosis-related deformities, including posterior instrumentation with fusion. However, achieving fixation and fusion in these patients can be difficult secondary to poor bone stock. Augmentation methods to improve pedicle screw fixation have evolved, including instrumentation at multiple levels, bioactive cement augmentation, and fenestrated or expandable pedicle screws, but their impact on clinical outcomes remains unknown. Management of osteoporosis in patients undergoing spine surgery is challenging, but with appropriate patient selection, medical optimization, and surgical techniques, these patients can experience pain relief, deformity correction, and improved function.

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As the public health burden of osteoporosis continues to increase, so too do the considerations for management of this potentially debilitating condition.[1-3] For the spine surgeon, osteoporosis presents a unique clinical challenge because it may be associated with iatrogenic instability and fracture following surgery.[4] Obtaining optimal fixation in osteoporotic bone is of utmost importance, although this technical challenge is not unique to the spine. Treating surgeons must be aware of risk factors for osteoporosis in their patient population as well as treatment algorithms, nonsurgical modalities for management, and technical surgical considerations to enhance clinical outcomes.

Many risk factors for primary osteoporosis have been identified, including increased age, tobacco smoking, sedentary lifestyle, and alcoholism.[1] Secondary osteoporosis has been linked to metabolic disorders, malabsorptive diseases, rheumatism, and hypogonadism.[1] Decreased serum vitamin D is extremely common, with reported rates ranging from 40% to 90% in adults, and is strongly associated with bone loss in patients with known osteoporosis.[5] Risk factors for hypovitaminosis D include age <50 years, tobacco use, high body mass index (≥ 30 kg/m^2), and lack of any vitamin supplementation.[6] Hypovitaminosis D has been shown to strongly correlate with fracture

Table 1

Summary of American Academy of Orthopaedic Surgeons Guidelines for Treatment of Osteoporotic Spinal Compression Fractures[2]

Strength of Recommendation	Description
Strong	Recommend against vertebroplasty for patients who present with an osteoporotic spinal compression fracture on imaging with correlating clinical signs and symptoms and who are neurologically intact.
Moderate	Suggest patients who present with an osteoporotic spinal compression fracture on imaging with correlating clinical signs and symptoms suggesting an acute injury (0-5 days after identifiable event or onset of symptoms) and who are neurologically intact be treated with calcitonin for 4 weeks.
Limited	Ibandronate and strontium ranelate are options to prevent additional symptomatic fractures in patients who present with an osteoporotic spinal compression fracture on imaging with correlating clinical signs and symptoms.
	It is an option to treat patients who present with an osteoporotic spinal compression fracture at L3 or L4 on imaging with correlating clinical signs and symptoms suggesting an acute injury and who are neurologically intact with an L2 nerve root block.
	Kyphoplasty is an option for patients who present with an osteoporotic spinal compression fracture on imaging with correlating clinical signs and symptoms and who are neurologically intact.
Inconclusive	Unable to recommend for or against bed rest, complementary and alternative medicine, or opioids/analgesics for patients who present with an osteoporotic spinal compression fracture on imaging with correlating clinical signs and symptoms and who are neurologically intact.
	Unable to recommend for or against treatment with a brace for patients who present with an osteoporotic spinal compression fracture on imaging with correlating clinical signs and symptoms and who are neurologically intact.
	Unable to recommend for or against a supervised or unsupervised exercise program for patients who present with an osteoporotic spinal compression fracture on imaging with correlating clinical signs and symptoms and who are neurologically intact.
	Unable to recommend for or against electrical stimulation for patients who present with an osteoporotic spinal compression fracture on imaging with correlating clinical signs and symptoms and who are neurologically intact.
	Unable to recommend for or against improvement of kyphosis angle in the treatment of patients who present with an osteoporotic spinal compression fracture on imaging with correlating clinical signs and symptoms.
	Unable to recommend for or against any specific treatment of patients who present with an osteoporotic spinal compression fracture on imaging with correlating clinical signs and symptoms and who are not neurologically intact.

risk, including hip and major osteoporotic fractures.[5,7] In patients undergoing spinal surgery, the rate of vitamin D deficiency has been shown to be up to 27%, whereas the association between vitamin D deficiency and pseudarthrosis has never been definitively shown.[6] One study reported that only 20% of spine surgeons routinely check metabolic panels when treating pseudarthrosis;[8] therefore, any association may be easily missed.

The incidence of vertebral compression fractures (VCFs) secondary to osteoporosis is estimated to be approximately 20% in patients older than 70 years, yielding a potential 700,000 insufficiency fractures annually.[9] Most VCFs respond well to nonsurgical management. A recent meta-analysis has shown that calcitonin is efficacious in reducing acute pain associated with these fractures.[10] In addition, the American Academy of Orthopaedic Surgeons Clinical Practice Guidelines (CPGs) recommend that patients who present with an acute osteoporotic spinal compression fracture (0 to 5 days after onset of symptoms) and are neurologically intact should be treated with a 4-week course of calcitonin. The CPGs state that evidence on the use of bracing, bed rest, complementary/alternative medicines, or opioids for pain relief is inconclusive[2] (Table 1). In select, neurologically intact patients with VCFs, the CPGs provide a limited recommendation in favor of kyphoplasty but strongly recommend against vertebroplasty,[2] whereas a recent meta-analysis has suggested that vertebroplasty may have some benefits in this population.[11] In patients undergoing surgical treatment of VCF with decompression and/or fusion with instrumentation, the presence of multiple comorbid conditions is not uncommon, and often presents clinical challenges to prolonged general anesthesia. Because degenerative spondylolisthesis and

spinal stenosis are frequently diagnosed in the elderly patient population, surgical management of these conditions often occurs in patients who also have incidental findings of chronic or healed VCF.[12] All of these factors are important considerations when evaluating a patient for surgical treatment of any spinal condition.

Screening and Prevention

The World Health Organization (WHO) recommends that all perimenopausal and postmenopausal women and patients with known metabolic bone disease or a high number of osteoporosis risk factors undergo bone mineral density (BMD) screening.[13] Before elective spinal surgery, these patients should have a dual-energy x-ray absorptiometry (DEXA) and metabolic laboratory evaluation. DEXA is the standard of care for assessment of BMD, and the frequency of DEXA scan follow-up varies based on the initial DEXA measurements and associated risk factors, such as chronic corticosteroid use, diphosphonate use, or the presence of fractures.[1,3] Recent evidence has suggested that measurement of Hounsfield units on CT of the lumbar spine correlates with BMD and may be a useful screening and diagnostic tool for osteoporosis,[14] especially given that preoperative lumbar CT is routinely obtained in many of these patients. Laboratory evaluation should include serum alkaline phosphatase, osteocalcin concentration, and measurement of collagen cross-link degradation products in urine, which is useful as a marker for bone turnover.[13] It is also important to rule out other metabolic disorders as a cause of secondary osteoporosis before initiating treatment. Other useful, routine laboratory tests include 25-OH vitamin D, which is the metabolically active circulating form and the only metabolite recommended to evaluate the vitamin D status of patients, although reference standards can vary based on the assay method.[15] Calcium and phosphate levels can also provide insight on any potential secondary causes of osteoporosis.[13]

Prevention is the most important principle in the management of osteoporosis and cannot be overemphasized.[13] In adult patients undergoing elective spine surgery or deformity correction, the surgeon must recognize risk factors for osteoporosis that may adversely affect surgical outcomes and consider referral for preventive strategies. Adequate caloric intake, appropriate dietary calcium and vitamin D intake, and resistance exercise are methods of increasing peak bone mass.[13] Cigarette smoking should be discouraged or discontinued completely, and patients should be counseled to consume alcohol only in moderation.[16] The National Osteoporosis Foundation screening recommendations are summarized in Table 2.

Table 2

Summary of National Osteoporosis Foundation Screening Recommendations for Patients Based on Age and Risk Factors

Bone Mineral Density Recommended
Women aged ≥65 years and men aged ≥70 years
Postmenopausal women and men aged 50–69 years based on risk factor profile
All patients with a fragility fracture
Vertebral Imaging Recommended
Women >70 years and men ≥80 years
Women aged 65–69 years and men aged 75–79 years if bone mineral density is ≤−1.5
Postmenopausal women and men aged 50–69 years with a low energy fracture, previous height loss ≥4 cm, prospective height loss ≥0.8 cm, or recent/long-term treatment with glucocorticoids

Adapted from the National Osteoporosis Foundation: *Clinician's Guide to Prevention and Treatment of Osteoporosis*. http://nof.org/files/nof/public/content/file/950/upload/523.pdf. Accessed February 19, 2015.

Medical Optimization

Because a patient who has sustained a fragility fracture often initially presents to the spine surgeon, he or she is optimally suited to initiate appropriate workup and referrals for medical management of osteoporosis.[8] However, a large gap exists between the number of patients who sustain fragility fractures and those who receive appropriate treatment of osteoporosis.[8] Based on the WHO definition, any patient who sustains a fragility fracture is assumed to have underlying osteoporosis, and one study showed that women with one or more vertebral fractures had a 1.23-fold greater age-adjusted mortality rate.[17,18]

The Fracture Risk Assessment tool is useful for predicting the risk of fragility fractures. It is an algorithm developed by the WHO that can be used to calculate the probability of hip fracture and any fragility fracture.[18] Treatment of osteoporosis should be considered for patients with low BMD (a T-score of −1.0 to −2.5) and either a 10-year risk of hip fracture ≥3%, or a 10-year risk of any osteoporotic fracture ≥20%.[18] A recent survey of spine surgeons highlighted a high level of discomfort with medical management of osteoporosis, but failed to sufficiently explain the discordance between the number of patients identified and

Table 3

Medical Optimization Strategies to Prevent and Manage Osteoporosis

Supplement/Drug	Dosage	Timing	Expected Outcome	Comments and Complications
Calcium	1,000 mg for men aged 50–70 years; 1,200 mg for women aged >51 yr and men aged >71 yr	Daily	Improvement in bone mass	Used to prevent osteoporosis, complications: NR
Vitamin D	NOF: 800–1000 IU for men and women aged >50 yr	Daily	Improvement in bone mass	Used to prevent osteoporosis, complications: NR
Diphosphonates	Varies	Varies	Increased bone mass, reduction in fracture risk	Used to treat osteoporosis, complications: dysphagia, gastric ulceration, renal impairment, osteonecrosis of jaw, subtrochanteric femur fracture
Parathyroid hormone	20 μg subcutaneous injection	Daily	Increased BMD, reduction in fracture risk	Used to treat osteoporosis, complications: cramping, nausea, dizziness, possible increased risk of osteosarcoma
Estrogen replacement	Varies	Varies	Reduction in fracture risk, maintenance of BMD	Used to treat osteoporosis, complications: possible increased risk of MI, CVA, PE, DVT, breast CA
Raloxifene	60 mg	Daily	Reduction in vertebral fracture	Used to treat osteoporosis, complications: increased risk of DVT
Calcitonin	200 IU intranasal	Daily	Reduce vertebral fracture	Used to treat osteoporosis, complications: rhinitis, epistaxis, hypersensitivity reaction
Denosumab	60 mg subcutaneous injection	Every 6 months	Improvement in BMD for postmenopausal women at high risk of fracture	Used to treat osteoporosis, complications: back/extremity pain, infection, osteonecrosis of jaw, pancreatitis

BMD = bone mineral density, CA = cancer, CVA = cerebrovascular accident, DVT = deep vein thrombosis, MI = myocardial infarction, NOF = National Osteoporosis Foundation, PE = pulmonary embolism

those appropriately treated.[8] Therefore, it is not unreasonable to consider prompt referral to primary care providers or endocrine specialists for partial or complete management of osteoporosis before any planned surgical procedure.

In the United States, several classes of drugs have been approved for the prevention and management of osteoporosis, including calcium, vitamin D, diphosphonates, parathyroid hormone (teriparatide), selective estrogen receptor modulators and/or hormone replacement, and calcitonin (Tables 3 and 4). The US FDA recommends that postmenopausal women diagnosed with osteoporosis should receive 1,500 mg of calcium and 400 IU of vitamin D daily, while the National Osteoporosis Foundation recommends 800 to 1,000 IU of vitamin D daily for adults older than age 50 years.[5] However, there is scant literature to support the use of calcium and vitamin D supplementation in the perioperative period for patients undergoing spinal surgery. Evidence suggesting improved lumbar fusion with the addition of dietary calcium supplementation has been reported in an animal model,[19] but no studies have evaluated clinical outcomes for the use of these supplements in patients undergoing spine surgery. Interestingly, one study evaluated patients after lumbar spinal stenosis decompression and fusion and reported postoperative improvement in vitamin D status without supplementation, and postoperative 25-OH vitamin D results correlated with surgical outcomes. The authors postulated that improvements in walking ability and nutritional status have a positive effect on postoperative vitamin D status.[20]

Antiresorptive agents, including diphosphonates, can be initiated with the goal of improving peak bone mass and reducing the risk of fracture.[16]

Table 4

Common Pharmacologic Interventions for Osteoporosis in Postmenopausal Women

Drug Name	Type	Route	Average Dose	Duration of Treatment	Level of Evidence
Alendronate	Diphosphonate	PO	10 mg/d or 70 mg/wk	3–5 yr if low risk of fracture	I
Risedronate	Diphosphonate	PO	IR: 5 mg/d or 35 mg/wk ER: 35 mg/wk	3–5 yr if low risk of fracture	I
Zoledronic acid	Diphosphonate	IV	5 mg/yr	3–5 yr if low risk of fracture	I
Ibandronate	Diphosphonate	PO/IV	PO: 350 mg/mo IV: 3 mg/3 mo	3–5 yr if low risk of fracture	II
Denosumab	RANKL inhibitor	SQ	60 mg/6 mo	Unknown	I
Teriparatide	Recombinant parathyroid hormone	SQ	20 ug/d	Unknown	II
Raloxifene	Selective estrogen receptor modulator	PO	60 md/d	Unknown	II

ER = extended release, IR = immediate-release, IV = intravenous, PO = by mouth, RANKL = receptor activator of nuclear factor-κ B ligand, SQ = subcutaneous injection

Two types of diphosphonate drugs are available for use in the United States: nitrogen-containing and simple (ie, non-nitrogen–containing) drugs. The nitrogen-containing diphosphonates (eg, alendronate, risedronate, pamidronate, ibadronate) function via inhibition of osteoclast farnesyl pyrophosphate synthase, thereby disrupting osteoclastic bone resorption. The non-nitrogen–containing diphosphonates (eg, tiludronate, clodronate, etidronate) form a toxic adenosine triphosphate analog that induces osteoclast apoptosis.[21] Diphosphonates can be dosed on a schedule that ranges from daily to yearly, depending on the drug being used, and controversy exists on the optimal duration of treatment. Typically, improvements in bone density are monitored via reductions in biochemical markers of bone turnover (eg, serum N-terminal propeptide of type I collagen or C-terminal telopeptide) because routine measurement of BMD is not recommended. Alendronate has been shown to reduce the risk of vertebral fractures in postmenopausal women by 47%.[22]

The effects of diphosphonate therapy on spine fusion have been studied. Animal models have suggested that formation of the fusion mass may be impeded by diphosphonate use, but a recent systematic review identified one clinical trial that did not show any adverse healing effects from diphosphonate therapy.[23] These benefits are not without risks, however, and the complications associated with diphosphonate use have been well documented. Atypical subtrochanteric femoral fractures and osteonecrosis of the jaw are the most devastating complications, but disruptions in calcium homeostasis have also been described.[24] Patients who require dental procedures should undergo these procedures before initiation of diphosphonate therapy. Because of these risks, significant controversy on the use of these drugs still exists, and there is currently no consensus on the ideal management of osteoporosis with these medications.[25]

Intermittent recombinant 1-34 parathyroid hormone (teriparatide) is approved in the United States for treatment of patients with high risk of fracture who are postmenopausal (women), have primary or hypogonadal osteoporosis (men), or have glucocorticoid-induced osteoporosis. In a study of postmenopausal patients with osteoporosis and degenerative spondylolisthesis that was treated surgically, Ohtori et al[26] showed that the rate of bony union in patients who received teriparatide was 82%; this rate was statistically superior to that of patients who received diphosphonate therapy. In a separate study, the authors showed that the rate of pedicle screw loosening in this population was also significantly lower in the teriparatide group than in the diphosphonate group.[27] However, based on evidence that the use of teriparatide is associated with an increased risk of sarcoma in rat models, the US FDA requires all packaging to carry a black-box warning that describes this risk. Teriparatide is contraindicated in patients with Paget disease because of the risk of osteosarcomatous transformation.[28] Teriparatide is generally

more expensive than diphosphonates, but analyses performed in Europe have suggested that it is a cost-effective therapeutic option when compared with no treatment or diphosphonate therapy.[29] Although the use of teriparatide appears beneficial, its use in the perioperative setting for patients undergoing spine surgery remains largely unknown, and any adjustments to the treatment regimen should be performed in coordination with an endocrinologist.

Denosumab is a human monoclonal antibody that inhibits receptor activator for nuclear factor kappa-B ligand (RANKL), thereby inhibiting osteoclast resorption of bone. The drug is administered by subcutaneous injection every 6 months, and monitored for effect via serum markers of bone turnover. Denosumab has been shown in clinical trials to have a significant correlation with reductions in serum markers of bone turnover and increases in BMD in postmenopausal women.[30] It is also of interest to orthopaedic and spine surgeons because the side effect profile is generally less substantial than the profiles of diphosphonates.

Raloxifene is a selective estrogen receptor modulator that was approved for use in the United States in 2007. The drug functions by stimulating an estrogenic response in bone tissue. It improves BMD and has been used clinically with some success.[31]

Preoperative Considerations

As the average expected lifespan has increased, so too has the average age of patients undergoing spine surgery.[12] The indications for spine surgery in older adults at risk for osteoporosis are similar to those in patients without osteoporosis, including radiculopathy, myelopathy, progressive deformity, and neurogenic claudication secondary to various conditions (eg, degenerative spondylolisthesis, lumbar or cervical disk herniation, stenosis, adult kyphosis/scoliosis).[12] Although a definitive link between adult scoliosis or degenerative spondylolisthesis and osteoporosis has not been shown in the literature, older patients with degenerative spinal conditions or deformity are more likely to have osteoporosis. In a population aged >50 years that required spine surgery, the reported incidence of osteopenia was 46.1% and 41.4% for men and women, respectively, and the incidence of osteoporosis was 14.5% and 51.3% for men and women, respectively.[12] Given the advanced age of the population at risk for osteoporosis, significant comorbid conditions that increase overall surgical risk often exist.

Okuda et al[32] examined the surgical outcomes of posterior lumbar interbody fusion in patients who were younger and older than 70 years and found that patients older than 70 years had a higher rate of delayed union than did younger patients, but the overall rate of fusion was not statistically different. Patients who have undergone appropriate screening and workup for osteoporosis and are considering spine surgery should be counseled preoperatively on the risk of delayed fusion. It is also important to note that a direct link between osteoporosis and worse clinical outcomes and a correlation between clinical outcomes and decreased rates of radiographic fusion or loss of deformity correction have not been definitively proven.[32,33] If a patient undergoing fusion is on diphosphonate therapy, the surgeon must consider the possible deleterious effects of the medication on achieving fusion;[23] a discussion with the primary care provider or endocrinologist who is managing the diphosphonate therapy may be beneficial to adjust medications postoperatively. As mentioned previously, the perioperative use of selective estrogen receptor modulators remains largely unexplored and, because any evidence-based recommendations are limited, further research is needed to address the concerns related to effects on fusion.

A recent study showed that, in patients with lumbar disk herniation, a delay of ≥12 weeks in time to surgery was more likely to result in greater pain at 6 months postoperatively, suggesting that delays in surgical treatment of patients with this and other degenerative lumbar conditions may predispose patients to worse clinical outcomes.[34] Therefore, postponing elective spine procedures to allow for medical optimization of osteoporosis is controversial, and no consensus on this topic currently exists. Improvements in BMD occur over relatively longer periods of time and, in many patients, it is not reasonable to consider waiting until evidence of improved BMD has been confirmed on DEXA. Therefore, we typically initiate treatment of osteoporosis as soon as identified preoperatively (typically 4 to 6 weeks before surgery) and continue medical management in consultation with an endocrinologist postoperatively, if indicated.

In osteoporotic patients undergoing deformity correction, preoperative planning is paramount to maximize the achievable correction and construct stability. Long, full-length standing plain radiographs, with the hips and knees extended, should be obtained preoperatively to evaluate sagittal alignment parameters and establish the flexibility of the osteoporotic spine for osteotomy planning purposes. These parameters allow for accurate determination of correction and the selection of the appropriate levels for treatment.

Surgical Considerations and Techniques

All biomechanical considerations related to spine surgery, including

fatigue failure, pullout strength, and insertional torque, are directly affected by BMD.[35] In the osteoporotic spine, bone-implant failure is most commonly the result of screw pullout or cutout, and optimizing the bone-screw interface is paramount for achieving fixation.[25] However, in appropriately selected older patients (aged ≥70 years), overall fusion rates are similar to those of younger patients, and patient-reported health assessments in multiple areas improved substantially following surgery.[32]

Regardless of the type of spine surgery, specialized techniques can improve fixation and facilitate healing in the osteoporotic spine. The size of the construct, fusion technique, pedicle screw insertion method, and other augmentations are important considerations for surgical planning purposes. Table 5 lists the 10 most important surgical pearls for optimizing outcomes of spine surgery in patients with osteoporosis.

Table 5

Top 10 Surgical Pearls to Maximize Outcomes of Spine Surgery in Patients with Osteoporosis

Prevention of osteoporosis is the most important principle in the management of the condition.
Prompt referral to an endocrinologist for preoperative optimization is recommended.
Longer fusion constructs and avoiding constructs that start or end at the cervicothoracic or thoracolumbar junction may protect against junctional or segmental failure.
At least three fixation points above and below the apex of the deformity should be used.
Hybrid constructs (pedicle screws, hooks, wires) may improve fixation strength.
Iliac and/or sacral fixation in long fusion constructs is recommended, when feasible, to maximize stability.
Anterior column support increases load-sharing, decreases strain on constructs, and should be used whenever possible.
The direction of pedicle screw insertion affects pullout strength, and purchase in subchondral bone (eg, sacral promontory) is recommended to maximize fixation.
Undertapping increases the insertional torque and pullout strength of pedicle screws.
Hubbing of pedicle screws adversely affects pullout strength and should be avoided.

The role of instrumented versus uninstrumented spinal fusion in patients with osteoporosis has not been adequately explored. In patients with an osteoporotic spine, longer fusion constructs for surgical stabilization provide increased points of fixation and help protect against junctional or segmental failure.[25] Specific affected levels should be identified and treated, and appropriate sagittal alignment should be restored, although evidence suggests that larger deformity correction in older patients (average age, ≥60 years) increases the risk of junctional kyphosis.[25,36] The extent of fixation, including the level at which the construct ends, is critical because increased junctional strain at the termination of the construct may lead to accelerated and progressive deformity.[36] Transition points, such as the cervicothoracic and thoracolumbar junctions, should be avoided because these regions are predisposed to kyphotic collapse, especially in osteoporotic patients. Multiple points of fixation (at least three fixation points superior and three points inferior to the apex of the deformity) should be used to decrease strain at each individual fixation point.[25] Hybrid posterior constructs that use pedicle screws, sublaminar wires, and laminar hooks may increase pullout strength in osteoporotic bone and improve overall construct stability.[37]

In the setting of osteoporosis in the lumbosacral region, the use of iliac and/or sacral fixation for fusion is recommended whenever possible to reduce the risk of sacral insufficiency fractures. Adult deformity correction, in particular, requires distal pelvic fixation to increase stability and reduce pseudarthrosis and implant failure.[37] The trajectory of the sacral screws should ideally be toward the promontory to improve purchase because screws inserted in this tricortical manner have been shown to have twice the insertional torque of bicortical screws.[38] S2 alar iliac screws are another available option for protection of sacral fixation because these transiliac sacral screws may have lower implant prominence and a lower complication rate than that of traditional iliac fixation.[37]

Combined anterior-posterior interventions increase load-sharing and decrease strain on the fixation construct, which may yield increased stability. An anterior approach can be useful to optimize decompression, and decreased subsidence can be achieved by increasing the anterior interbody graft/cage cross-sectional area and placing screws in denser bone.[39] Compared with isolated posterior instrumentation, anterior column support has the advantage of increased construct stability. For patients considering anterior-posterior spine surgery, all potential complications must be discussed, although there is scant evidence available suggesting that the use of anterior column

support puts patients at an increased clinical risk for pseudarthrosis or construct failure. It is important to note that during fusion procedures in the anterior column, patients with osteoporosis may be predisposed to interbody cage subsidence secondary to decreased bone density.[32] Therefore, care must be taken to place the cage along the apophyseal ring and protect the end plate during preparation of the disk space. Differences in cage positioning or material may also predispose to subsidence because differences between the modulus of elasticity of dissimilar fusion materials may affect load distribution in the decompressed interbody space, thereby leading to increased contact pressures and ultimately subsidence of the cage.[40]

Pedicle screw positioning to optimize fixation has also been extensively studied. The bone-implant interface is the most significant contributor to failure in the osteoporotic spine, and the trajectory of pedicle screw insertion has been repeatedly evaluated as a technique to improve fixation strength. In the thoracic spine, maximum insertional torque and pullout strength may be increased by placing screws in a straight-forward direction rather than using an anatomic trajectory.[35] Insertion angled toward the subchondral bone near the end plate may not only allow for stronger fixation, but may also increase insertional torque.[25] Medially angulated pedicle screws, with a transverse connector and length of 80% of the vertebral body, have also been shown to improve pullout strength.[41] Diverging screws in the sagittal plane also increases load-bearing capability in an axial vector;[25] however, controversy exists regarding the optimal insertional torque for screw placement.[25] Several studies have suggested that screw design is more important in pullout strength than insertional torque, while others have suggested that tapping insertional torque may directly predict pullout strength.[42] Tapping insertional torque may also allow tactile feedback for optimal screw size selection and improved pullout strength.[42] However, oversizing the pedicle should be avoided because some larger screws may predispose the osteoporotic vertebrae to fracture along the thinned cortex of the pedicle.[43] The inferior portion of the pedicle provides the most robust fixation, and undertapping the pedicle screw tract increases pullout strength.[35,42] Appropriately sized and positioned pedicle screws are crucial for attaining optimal fixation in the osteoporotic spine.[42]

Recent developments in pedicle screw design have also improved fixation in osteoporotic bone. Expandable pedicle screws may improve pullout strength for the management of traumatic and degenerative spinal diseases in osteoporotic patients.[44] One study found that expandable pedicle screws had a decreased risk of loosening or loss of fixation in lumbar spine fusion and may improve overall clinical outcomes.[45] However, the use of expandable pedicle screw systems has not been approved by the US FDA. Hybrid constructs (constructs that use hooks and wires) also may improve fixation secondary to relative preservation of cortical bone in the lamina.

It is often common practice for surgeons to "hub" pedicle screws to improve fixation strength. Hubbing of the pedicle screws involves seating and engaging the ventral aspect of the screw head onto the dorsal lamina cortex.[46] However, biomechanical evidence has suggested that hubbing may decrease pullout strength rather than providing a load-sharing effect.[46] Thus, hubbing pedicle screws against the dorsolaminar cortex should be avoided. The use of rod reduction devices and techniques to bring posterior rods into contact with pedicle screw heads is also ubiquitous. However, the use of these devices may decrease overall pullout strength and work energy to failure.[47]

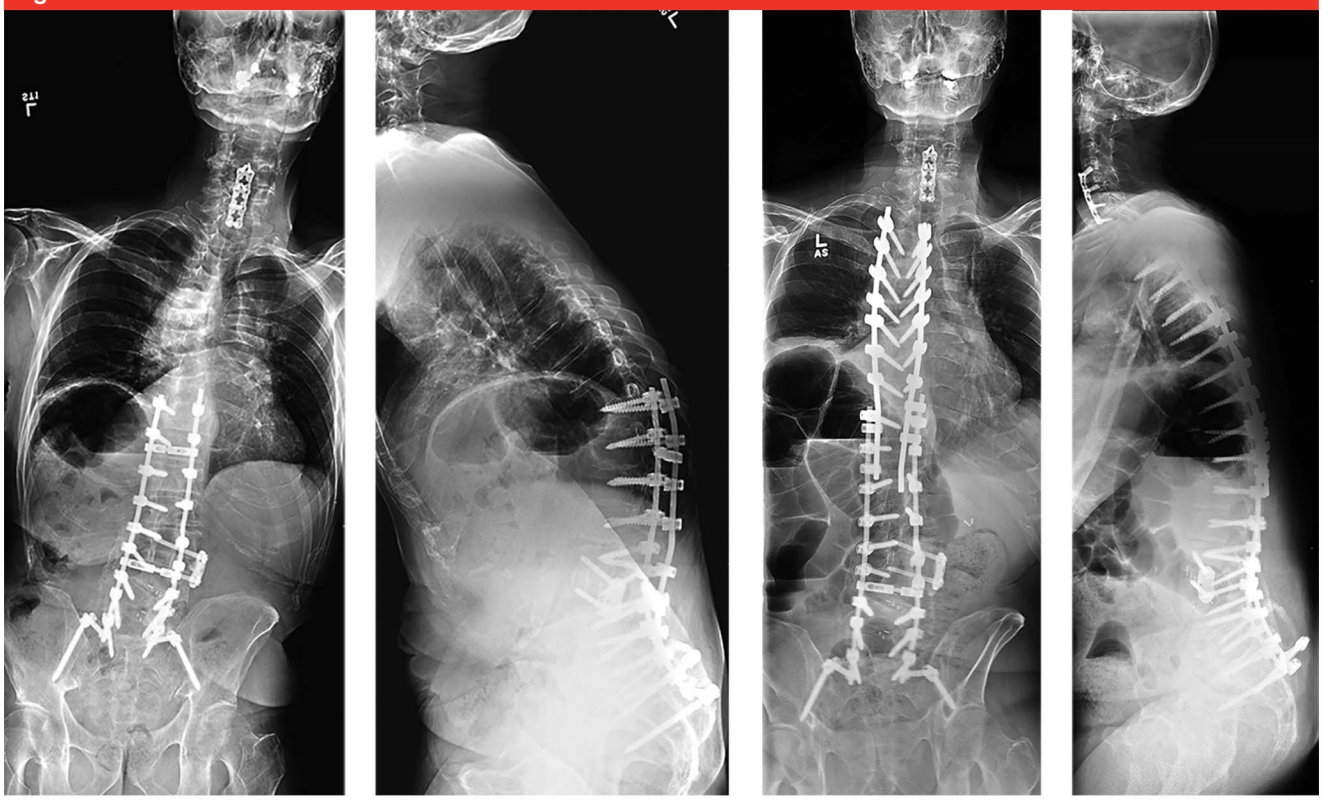
Augmentation of pedicle screws with polymethyl methacrylate (PMMA) or calcium phosphate as a method of improving fixation strength has been studied extensively.[48-51] The technique for injection of the cement and advances in screw design have a significant effect on the magnitude of the improvement in fixation. Fenestrated screws allow for the cement to be confined to the vertebral body and prevent extrusion,[48] but solid screws with retrograde cement prefilling appear to have higher pullout strength than that of cannulated or fenestrated screws.[49] PMMA augmentation increases pullout strength by 149%, with better results achieved with placement of the screw through uncured PMMA than through hardened cement.[50] In addition, decreased loss of deformity correction and a higher fusion rate have been reported with PMMA augmentation.[51]

Although vertebroplasty for management of VCFs is not currently recommended in the American Academy of Orthopaedic Surgeons CPGs, an emerging body of evidence suggests that there may be a role for this technique.[11] In theory, prophylactic vertebroplasty may reduce the rate of junctional failure by reducing the stiffness encountered between the end of the construct and the adjacent level.[52] Thus, vertebroplasty may also be useful for preventing further kyphosis adjacent to longer segmental constructs.

Complications

Early postoperative complications (<3 months) in older patients with poor bone quality include pedicle fractures and compression fractures, with an overall reported rate of 13%[53] (Figure 1). Late complications

Figure 1



AP (**A**) and lateral (**B**) radiographs of the spine demonstrating vertebral body compression fracture at T10, pedicle screw pullout, and proximal junction kyphosis in a 74-year-old man with Parkinson disease and degenerative scoliosis. One year prior to referral, the patient underwent lumbar decompression and T10 to ilium posterior spinal fusion with pedicle screw instrumentation and interbody fusions at L2-3, L3-4, and L4-5. He presented with worsening back pain, progressive kyphosis, and increasing difficulty maintaining an upright posture. Postoperative AP (**C**) and lateral (**D**) radiographs of the spine. Revision surgery was performed with correction of the proximal junction kyphosis. The posterior spinal fusion with instrumentation was extended to T3 using domino connectors at T10-T11.

(>3 months) include pseudarthrosis with instrumentation failure, adjacent level degeneration, screw loosening, progressive kyphosis at the cephalad portion of the construct, and compression fractures.[53] Subsidence and disk space collapse have been reported in patients treated with interbody fusion procedures,[32] although the effect of these complications on clinical outcomes has not been fully elucidated. Delayed union as well as prolonged hospitalization and intubation in osteoporotic patients have also been described, but no direct comparison examining the incidence of these complications between osteoporotic and non-osteoporotic patients has been made in the literature. Figure 1 demonstrates the risks of fixation failure inherent in spine surgery in patients with osteoporosis.

Summary

Osteoporosis is rapidly becoming a significant healthcare burden, and the complications associated with the condition require prompt recognition and appropriate treatment. Medical therapies are aimed at preventing the disease, maximizing BMD, and, with regard to the spine, preventing further deformity or fracture. In patients with osteoporosis, spine surgery presents a difficult challenge, and a multidisciplinary approach is encouraged for medical optimization and preparation of patients for whom surgery is indicated. Preoperative planning is imperative for the success of the procedure, and the treating surgeon must be aware of potential complications and pitfalls. Multiple techniques can be used to improve fixation and construct stability, and the literature continues to evolve as additional clinical evidence is reported. Despite the challenges inherent in this patient population, with appropriate patient selection and surgical techniques, spine surgery can

provide pain relief, deformity correction, and improved function.

References

Evidence-based Medicine: Levels of evidence are described in the table of contents. *Evidence-based Medicine:* Levels of evidence are described in the table of contents. In this article, references 10, 22, and 23 are level I studies. References 11, 20, 26, 27, 31, and 34 are level II studies. References 4, 12, 45, and 53 are level III studies. References 6, 7, 14, 24, 32, 36, 44, 51, and 52 are level IV studies. References 8, 9, and 37 are level V expert opinion.

References printed in **bold type** are those published within the past 5 years.

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