CHAPTER **44**

OSTEOPOROSIS: Surgical Considerations

Emily A. Hermes, DPM

The medical profession today is ever changing with incessant advances in screening protocols and advanced diagnostic imagery, many of which are currently being utilized for bone and joint health. Despite these continuous advances, the incidence of osteoporosis is perpetually prevailing. This poses unique challenges for all bone and joint surgeons, leading to an appreciable inflammation in cost and coinciding laundry list of residual complications (1-4). The purpose of this article is to provide physicians with a proficient knowledge base for not only identifying osteoporosis, but additionally encouraging adeptness in applying current treatment strategies in the operative setting.

DIAGNOSIS

Radiography

The diagnosis of osteoporosis can be made by using conventional radiography as well as through the measurement of bone mineral density (BMD). Despite the development of newer, highly accurate and precise quantitative diagnostic imaging techniques, such as dual x-ray absorptiometry (DXA) and quantitative computed tomography (QCT), osteoporosis is still most commonly diagnosed by conventional radiography. According to the literature, this is typically a late diagnosis because a substantial amount of bone loss (~30%) must occur before it can be detected on x-ray images. Ultimately, conventional radiography is poor in sensitivity and accuracy for the diagnosis of early bone loss and leads to a need for further, more extensive tests. Findings of generalized osteoporosis typically include cortical thinning and increased radiolucency (5) (Figure 1).

More specific to changes occurring in the lower extremity, in 1983, Jhamaria and associates described a five-grade osteoporosis classification system based on a calcaneal index that accounts for the trabecular pattern of the calcaneus (6). Over time it has been perceived that the use of this system in clinical practice has been limited by poor interobserver reliability due to flaws and redundancies, which led Pande and associates to generate a more concise three-grade index that can be used with more consistency and accuracy (7) (Figure 2).

In 1959, Lockhart and associates described the calcaneus as a cancellous, weightbearing bone with a high percentage of trabeculae (95%) that occur in two arches intersecting at right angles. These arches correspond to the compression and tensile stresses produced in the bone during weightbearing, affording it strength (8). As metabolic changes occur and bone density diminishes over time, it is particularly evident in the trabecular pattern of weightbearing bones on radiographs and either of the above mentioned indices can be utilized to determine the degree of osteoporosis (5, 8).

DXA

Approximately 60-70% of bone strength is related to BMD, which can be measured by various means. DXA was introduced in 1987 and currently represents the most widely-used method for diagnosing osteoporosis in a clinical setting (5). Measurements can be made at all skeletal sites where osteoporotic fractures occur, including the calcaneus; however most reads are taken at the lumbar spine and the hip, which does not always paint an accurate picture of the bones in the foot.

DXA results are presented as an overall BMD that is determined by taking the bone mineral content (expressed in grams) and dividing it by the area (cm^2). One also receives a "standard deviation" by means of a T-score and a Z-score.

Figure 1. Cortical thinning and increased radiolucency seen on plain radiograph.

Figure 2A. Modified calcaneal index based on trabecular patterns. Grade III (normal): all compression and tensile trabeculae are visible and prominent.

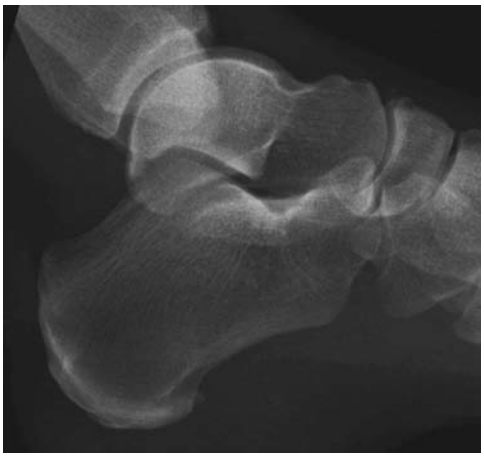

Figure 2B. Grade II (early osteoporosis): secondary tensile and the secondary compression trabeculae are completely resorbed.

Figure 2C. Grade I (osteoporosis): attenuation of primary tensile and compressile trabeculae. There may be complete disappearance of the tensile trabeculae in severe cases (7).

The T-score refers to peak of bone mass and is calculated as the difference between the BMD of the patient and that of a healthy 30-year-old of the same sex and ethnicity. The World Health Organization (WHO) has based their Osteoporosis Severity Classification on the T-score (Table 1). The Z-score is the difference between the patient's results and the mean of age- sex- and ethnicity-matched controls. This score is normal if above -2 deviations from the mean, which indicates significant bone deterioration.

One limitation of the DXA image is that it is 2D; thus not a true representation of volumetric density. This is particularly a disadvantage when evaluating children whose bones grow markedly in size as they grow because the image is size-dependent. The advantages of DXA include high precision, relatively low cost, and low radiation dose (5).

Table 1

WORLD HEALTH ORGANIZATION OSTEOPOROSIS SEVERITY CLASSIFICATION

Normal	T-Score >1
Osteopenia	T-Score -1 to -2.5
Osteoporosis	T-Score <2.5
Severe Osteoporosis	T-Score <2.5 (with radiological evidence of one or more fractures)

QCT

QCT is a newer technique that acquires data on the entire object of interest as a series of stacked slices, or spiral CT scans. Unlike DXA, it is able to analyze volumetric density giving the BMD of the entire bone as well as a separate analysis of trabecular or cortical components. It is also able to generate 3D images, which have better reproducibility, reduced partial volume effects and reduced motion artifacts (9). Materials of large atomic number and material density present with higher X-ray attenuation and appear brighter in CT images. The disadvantages to QCT include high radiation dose, poor precision, increased cost, high degree of operator dependence, and limited access to the scanners (5).

Quantitative Ultrasound

Quantitative ultrasound may also be used to evaluate BMD through waves that are affected by the elasticity and structure of the material they are passing through and can potentially yield information on bone fragility. Theory suggests that broadband ultrasound attenuation is determined by bone

density and bone microarchitecture, whereas speed of sound is influenced by the elasticity of bone and bone density, both of which are measured with this technique. As stated earlier, not only does the calcaneus show early evidence of metabolic changes secondary to its trabecular bone content, it is also easily accessible and fairly flat, resulting in decreased repositioning error. Advantages of this method are the small modality, ability to make quick measurements, no ionizing radiation utilization, and low cost compared to DXA and QCT. It is also safe for children (5).

PERIOPERATIVE MEDICATIONS/SUPPLEMENTS

Metabolites

Calcium phosphate is the building block for bone, thus methods to improve its delivery and diminish loss are desired especially in a surgical fixation situation. Adequate daily calcium intake is necessary to reduce the risk of osteoporosis and to decrease fracture risk once diagnosed. Daily intake and upper limit (UL) recommendations are based on age and sex with it being recommended that one does not exceed the UL of calcium per day (Table 2). Excessive calcium intake can lead to constipation, development of calcium kidney stones, and inhibition of the absorption of iron and zinc from food (10).

Vitamin D is also essential for bone quality and successful healing as calcium absorption is dependent on an adequate level of the active form of vitamin D. Supplements are typically not necessary because vitamin D is available in fortified milk, foods such as fish and egg yolks, and sunlight exposure. In general, one only needs 10-15 minutes of sunlight exposure to maintain an adequate vitamin D level (10).

In a study evaluating metabolic efficiencies in patients with nonunions, typically levels of vitamin D, calcium excretion, and thyroid stimulating hormone (TSH) were abnormal. In a subset of the patients, resolution of nonunion was demonstrated with the correction of these lab values. Another important finding is that in addition to supplementing an osteoporotic surgical patient with metabolites, medications that will hinder bone quality and health, such as steroids, antacids, antiepileptics, and nonsteroidal anti-inflammatory drugs need to be identified. Tobacco and carbonated beverages are also contraindicated for bone health and quality (11).

Bisphosphonates

Bisphosphonates are one of the most common medical augmentations to bone healing and quality. They are a class of synthetic bone antiresorptive agents that influence bone metabolism, however the mechanism of action is not yet fully understood. It is known that bisphosphonates are strong inhibitors of osteoclast-medicated bone resorption, inhibiting both cell function and inducing early apoptosis. Bisphosphonates have a very high affinity for hydroxyapatite crystals, which allows the ability to localize and accumulate on bone mineral surfaces, particularly at sites of high bone turnover. Ultimately, bisphosphonates cause limitation of catabolic breakdown of bone and callus formation is enhanced; thus likely to accelerate stability and healing in a surgical and/or fracture setting. That being said, it must be considered that in theory, the use of bisphosphonates may result in a nonunion secondary to the inhibition of osteoclastic activity that hinders fracture remodeling and healing potential. The results on nonunions associated with bisphosphonate usage are diverse and varied throughout literature, which is likely due to factors that are uncontrolled in the studies such as comorbidities and type/duration of bisphosphonate used (12, 13).

Table 2

DIETARY REFERENCE INTAKES FOR CALCIUM

Age	Mg/Day	Tolerable Upper Intake Level (mg/day)
0-6 Months	200	1,000
6-12 Months	260	1,500
1-3 Years Old	700	2,500
4-8 Years Old	1,000	2,500
9-18 Years Old	1,300	3,000
19-50 Years Old	1,000	2,500
Males 51-70 Years Old	1,000	2,000
Females 51-70 Years Old	1,200	2,000
>70 Years Old	1,200	2,000

Although a very popular medical augmentation in the treatment of osteoporosis, bisphosphonates do carry a risk of osteonecrosis of the jaw. The absolute risk is low, however it is difficult to manage when it does occur. The exact mechanism of the development of osteonecrosis associated with bisphosphonate usage is unknown but it is the strong inhibition of osteoclast function that can lead to the inhibition of normal bone. Because bisphosphonates are preferentially deposited in bone with high turnover rates, the mammalian jaws are at increased risk due to the ability to turnover at a high rate in order to maintain biomechanical competence (11, 13, 14). To date, there have been no reported cases of bisphosphonate-associated complications within bones outside the craniofacial skeleton (15, 16).

With steroid use, the current guidelines are that patients taking the equivalent dose of prednisolone 7.5 mg per day or more for more than three months, should be considered for skeletal protection with a bisphosphonate (13). There are limited studies that looked at elective surgery and bisphosphonate usage, however one study of distal radial fractures in patients with osteoporotic bone and plate fixation shows that the early initiation of bisphosphonate treatment did not affect time to radiographic union or clinical outcomes (12).

Teriparatide

After bisphosphonates, Teriparatide is the second most common therapeutic intervention in cases of osteoporosis. Teriparatide, a recombinant human parathyroid hormone injection, enhances both osteoblastic and osteoclastic activity. Osteoblasts are more enhanced than osteoclasts; thus fracture stability is increased and bone healing is promoted. The most commonly reported side effects with this injection are nausea, leg cramps, and dizziness and there is a small chance of the development of osteosarcoma (17, 18).

SURGICAL FIXATION

It is important to recognize that medical augmentation, as discussed earlier, is just as important as the structural augmentation in cases of healing and bone quality and when used together offer the most benefit. Traditional methods of augmentation in osteoporotic bone include: dual plating, polymethylmethacrylate usage, joint replacement, and locked plating (11).

Locked Plating

Locked plating has revolutionized care of osteoporotic bone by improving screw purchase and expanding fracture fixation capabilities; however it is not the stand alone solution in all cases. The fixed angle construct with multiple points of fixation improves the efficiency, security, and longevity of the screws placed into osteoporotic bone (11).

Far-Cortex Locking (FCL) Screws

Despite the many benefits of the locking plate technology in osteoporotic bone, a few complications exist; such as coronal shear fractures, delayed diagnosis of nonunions, and stiff fixation constructs. The FCL screws have been shown to decrease plate construct stiffness without losing screw purchase in osteoporotic bone; thus potentially improving callus response. These are locking screws that have a reduced diameter shaft and lock into the plate as well as into the far cortex of the diaphysis. The reduced screw shaft diameter is significant in that it allows for elastic flexion of the screw and induces parallel interfragmentary motion for facilitation of fracture healing by callus formation. In one study, the use of FCL screws in place of standard locking screws reduced the axial stiffness of a diaphyseal plating construct by 88% while retaining strength (18-21).

Dual Plating

Dual plating is a technique that utilizes plates inserted at 90° or 180° to one another. This is an historic treatment for femoral fractures that allows for multiple screws to be inserted in varied angles and directions, improving screw fixation mechanics, especially by neutralizing rotational and bending forces (22-24). A disadvantage is excessive periosteal stripping and soft tissue dissection with excessive devascularization to allow for adequate access (11).

Polymethylmethacrylate (PMMA)

PMMA is a useful tool to assist in screw and/or nail strength and fixation, even in osteoporotic bone. Although PMMA can augment screw fixation, it is an unnatural method that does not allow for remodeling or incorporation. Thus, if the bone does not heal and the PMMA and associated necrotic bone had to be removed, this would be deleterious to an elderly osteoporotic patient. In addition, the heat generation during the curing process can kill off local osteocytes and ultimately result in delayed local healing. PMMA is also difficult to remodel and remove if necessary (25).

Calcium Sulfate and Calcium Phosphate Cement

Calcium sulfate and calcium phosphate cements are advantageous in that unlike PMMA, they are resorbable and provide immediate fracture stability. Both are osteoinductive materials that improve pullout strength (12, 25).

PEDIATRIC CONSIDERATIONS

Osteoporosis is increasingly being noted at all ages and is now a relevant problem in young patients. Children can be diagnosed with either primary osteoporosis (an intrinsic skeletal defect) or secondary osteoporosis (the results of other diseases and/or treatment). Secondary osteoporosis is the most common form. Typically, pediatric osteoporosis presents as fractures with minimal trauma or chronic bone pain. There are no long-term studies with large numbers of pediatric patients looking at establishing the safety and efficacy of drugs in the therapy of osteoporosis, even for calcium and vitamin D supplements. Current recommendations for children with osteoporosis include beginning with the simplest and safest treatment: calcium and vitamin D (Table 2). Bisphosphonates are typically reserved for severe cases and Teriparatide is not typically recommended since the pharmacological stimulation of bone formation during the growing age might increase the risk for osteocarcoma (26).

REHABILITATION

Patients with soft bone typically benefit from immediate weightbearing and mobility to avoid further disuse osteoporosis, deconditioning, and immobility. One study looking at 168 postmenopausal women showed at the 2-year mark that those in the placebo group had a 2.5% loss of bone at the distal tibia whereas those taking calcium and increasing exercise had only 1% bone loss. Those taking calcium tablets alone had 1.6% bone loss and those supplementing with only milk powder had a 1.5% loss (27). Another study looked at two small groups of women who were 69.2 ± 3.5 years of age and were all talking calcium plus vitamin D. These women either participated in exercise classes for 1 hour 3 times per week or did no exercise, and at 32 weeks, the exercise groups showed a significant improvement in bone density compared to those not exercising. Although research is scarce, these improvements in bone density with supplementation and exercise should encourage perioperative supplementation and exercise. This may help to "build up" bone density and improve fixation. Early return to activity is key when managing osteoporotic patients postoperatively.

SUMMARY

Osteoporosis may present a dilemma for the foot and ankle surgeon, however it is important to recognize that there are a myriad of options when it comes to diagnosis and treatment. There are many different imaging modalities available to assist in early diagnosis of osteoporosis, which will ultimately lead to early treatment. Both medical and structural treatment options are available and continue to improve with time. In addition, early return to activity is important and should be considered in preoperative planning.

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