BARIATRIC SURGERY AND SKELETAL HEALTH

Obesity is a public health issue of epidemic proportions, ranked the number-one threat to American health by the CDC since 2004. One third of American adults are obese (BMI ≥ 30 kg/m²) and 68% are either overweight or obese (BMI ≥ 25 kg/m²). Although overall obesity rates have leveled off in the U.S., the rate of severe obesity (BMI ≥40 kg/m²) continues to climb. Obesity in children and adolescents is also increasing at alarming rates, with an estimated 30% of the population age 2 to 19 at or above the 85th percentile of BMI for their age in 2008.  

There has been a marked increase in weight loss (bariatric) surgical procedures in the U.S. in recent decades, from 13,365 in 1998 to an estimated 220,000 in 2008 (most current year’s data). Primary care practitioners are expected to see increasing numbers of patients who have had weight-loss surgery. Managing their care requires recognizing the special nutritional needs of these patients and the hazards presented by long-term nutrient insufficiencies, such as osteomalacia, osteoporosis, and bone fractures. If carefully followed and appropriately supplemented, post-bariatric patients can avoid these risks and reap the numerous benefits of weight loss.

In this issue of “Osteoporosis: Clinical Updates,” we will take a look at surgical weight management techniques and their effects on skeletal health, highlighting the need for lifelong surveillance in this patient population.

Editor-in-Chief, Angelo Licata, MD, PhD, FACP, FACE

Contents

Bariatric Surgery: Implications for Bone Health .......................... 2
Bariatric Surgery for Older Adults and Adolescents .................... 4
Impact of Obesity on Bone ................................................. 5
Impact of Weight Loss on Bone ......................................... 5

Bariatric Surgical Procedures .................................................. 6
Roux-en-Y Gastric Bypass (RYGB) ....................................... 7
Biliopancreatic Diversion with Duodenal Switch (BPD/DS) .......... 7
Bone Loss Following RYGB and BPD/DS Procedures ............. 9
Laparoscopic Sleeve Gastrectomy ....................................... 9
Laparoscopic Adjustable Gastric Band ................................ 10
Bone Loss Following LSG and LAGB Procedures .............. 11

Protecting Bone Health in Bariatric Patients ............................... 11
Diagnosing and Treating Osteoporosis in Bariatric Patients ......... 13
Drug Treatment for Osteoporosis in Bariatric Patients ............ 14

Patient Cases: Preserving Bone Health Following Bariatric Surgery 14
Case 1: 45-Year-Old Woman who Had Roux-en-Y Gastric Bypass Surgery .................................................. 14
Case 2: 60-Year Woman 20 Years after Jejunoileal Bypass Surgery ...... 16
Summary ........................................................................ 18
References ..................................................................... 18
Bariatric Surgery: Implications for Bone Health

Obesity is responsible for more than 40 serious medical conditions including hypertension, multiple cancers, metabolic syndrome, nonfatty liver disease, degenerative joint disease, and reproductive complications. It is estimated to increase risk for premature death 50% to 100% from all causes. According to a report from the U.S. Office of the Surgeon General, roughly 300,000 deaths per year are linked to obesity. Although recognized as a cause of disease and increased mortality, obesity has long been viewed as beneficial to bone. Increasing evidence has challenged this belief and implicated overweight and obesity in disordered bone metabolism.

Severely obese people are frequently unable to achieve and maintain a healthy weight through diet and exercise. Many spend adolescence and adulthood in a constant struggle, losing weight only to regain that weight and more. Bariatric surgery is the most effective treatment for people who have failed at supervised medical weight loss. It can provide durable weight reduction and improve or reverse obesity-related illnesses.

Common bariatric procedures alter hormonal mechanisms that control the body’s hunger and satiety responses, increasing glucose metabolism, accelerating burning of fat, and improving glucose homeostasis, type 2 diabetes, and cardiometabolic disease. This has led to the view that these procedures should be considered “metabolic,” rather than simply weight-reduction surgeries.

Large prospective studies of patients who have undergone bariatric surgery, show high rates of remission or significant improvement in many obesity-related illnesses, such as diabetes (77% to 86%), hyperlipidemia (70%), hypertension (62% to 79%), obstructive sleep apnea (84% to 86%), and overall mortality (30% in the 15 years post surgery). Risk for developing certain types of cancer has also been observed to decline by 60% following bariatric surgery.

These enormous health benefits do not come without costs. Bariatric surgery induces weight loss by limiting intake and/or absorption of nutrients, including those necessary for healthy bone. If these nutrients are not replaced, serious complications can develop, both in the immediate postsurgical period and decades down the road.

The take-away message for primary care providers is that all bariatric patients will have some sort of nutritional deficit. Lifelong medical surveillance and supplemental nutrient support are key components of patient care in this setting. Without this support, patients will be at increased risk for many disorders, including bone loss, metabolic bone disease, and fragility fracture.

Because long-term data on post-bariatric rates of osteoporosis and fracture are unavailable, we rely on surrogate indicators of bone strength, primarily bone mineral density (BMD) by dual x-ray absorptiometry (DXA). In addition, fracture risk is inferred by applying what is known about conditions that precipitate osteoporosis in non-obese individuals, such as calcium and vitamin D deficiency and secondary hyperparathyroidism.

Indications for Bariatric Surgery

An expert panel convened by the National Institutes of Health in 1991 developed guidelines that included recommendations for adults who should be considered for weight-loss surgery:

“Weight loss surgery is an option for carefully selected patients with clinically severe obesity BMI ≥40 or ≥35 with comorbid conditions when less invasive methods of weight loss have failed and the patient is at high risk for obesity-associated morbidity or mortality.”

On the strength of evidence that bariatric surgery is effective in resolving type 2 diabetes in 48% to

Activity Objectives

Upon completion of this CE material, the participant should be able to:

- Describe potential negative consequences to bone associated with obesity, weight loss, and bariatric surgery.
- Identify patients at risk for nutrient deficiencies following bariatric surgery.
- Specify laboratory tests that are appropriate to assess nutritional and bone health status in bariatric surgery patients.
- Recommend appropriate nutritional support and supplementation for patients who have undergone bariatric surgery.
- Plan patient-specific diagnostic and therapeutic approaches to address low bone density following bariatric surgery.
98% of patients, the American Association of Clinical Endocrinologists as well as the International Diabetes Federation now recommend bariatric surgery for adult patients with BMI 30 to 35 with type 2 diabetes who have been unable to achieve adequate glycemic control through diet, exercise, and standard medical therapies.\(^9,18\) This recommendation is included in guidelines developed by a joint committee of the American Association of Clinical Endocrinologists, The Obesity Society, and American Society for Metabolic & Bariatric Surgery (AACE/TOS/ASMBMS).\(^9\)

The long-term impact on type 2 diabetes and metabolic syndrome has yet to be validated. One large retrospective cohort study looking at over 4,000 patients with type 2 diabetes who underwent gastric bypass surgery found 68.2% achieved remission after surgery. A little over 1/3 of these (35.1%) redeveloped diabetes within 5 years.\(^19\) Durability of remission has been associated with many factors including bariatric technique, patient age, duration of diabetes, preoperative insulin therapy, preoperative glycemic control, as well as postoperative percentage of excess weight lost and/or regained.\(^19,20,21\)

<table>
<thead>
<tr>
<th>NIH Classifications for BMI(^2)</th>
<th>Measurement Units</th>
<th>Formula and Calculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underweight &lt;18.5 kg/m(^2)</td>
<td>Kilograms and meters (or centimeters)</td>
<td>Formula: weight (kg) / [height (m)](^2)</td>
</tr>
<tr>
<td>Normal weight 18.5 to 24.9 kg/m(^2)</td>
<td></td>
<td>With the metric system, the formula for BMI is weight in kilograms divided by height in meters squared. Since height is commonly measured in centimeters, divide height in centimeters by 100 to obtain height in meters. Example: Weight = 68 kg, Height = 165 cm (1.65 m) Calculation: 68 ÷ (1.65)(^2) = 24.98</td>
</tr>
<tr>
<td>Overweight 25 to 29.9 kg/m(^2)</td>
<td>Pounds and inches</td>
<td>Formula: weight (lb) / [height (in)](^2) x 703</td>
</tr>
<tr>
<td>Obesity (class 1) 30 to 34.9 kg/m(^2)</td>
<td></td>
<td>Calculate BMI by dividing weight in pounds (lbs) by height in inches (in) squared and multiplying by a conversion factor of 703. Example: Weight = 150 lbs, Height = 5'5&quot; (65&quot;) Calculation: ([150 ÷ (65)^2]) x 703 = 24.96</td>
</tr>
<tr>
<td>Obesity (class 2) 35 to 39.9 kg/m(^2)</td>
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<td></td>
</tr>
<tr>
<td>Extreme obesity (class 3) ≥40 kg/m(^2)</td>
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A new category, super obesity, is used in the field to describe people with BMI \(≥50\) kg/m\(^2\). There is no evidence-based consensus regarding contraindications to bariatric surgery; however, the AACE/TOS/ASMBMS guidelines recommend exclusion of patients with current substance abuse, poorly controlled mental illness, or underlying conditions that put them at unacceptably high surgical risk.

These guidelines also recommend exclusion of individuals who are judged to be unable or unwilling to comply with lifelong clinical monitoring, nutrient supplementation, and dietary requirements.\(^9\)

This last issue is of particular relevance in primary care. It is difficult for many post-surgical bariatric patients to keep up with frequent clinical follow up and the demands of daily supplementation/dietary requirements. Clinicians can improve compliance through a coordinated multi-pronged approach that includes appointment reminders, nutritional counseling, exercise...
programs, and patient support groups. A team of nurses, dieticians, physical therapists, and patient educators working in coordination has repeatedly been shown to increase the odds that patients will be able to maintain a healthy weight and avoid complications.23-26

Bariatric Surgery for Older Adults and Adolescents

Advanced age was once considered a contraindication for bariatric surgery. However, today the prevalence of adults over age 65 receiving bariatric surgery is increasing (around 5%). Although data are lacking, it is reasonable to assume that bariatric patients over age 65 have higher rates of osteoporosis and fracture than those under 65. In this population, many factors contribute to increased fracture risk beyond age-related BMD decline. Older patients are more likely to be diabetic, which may put them at increased risk for certain fractures following weight loss surgery (e.g., humerus). They are also more likely to have peripheral neuropathy, either diabetes related or due to nutrient deficiency (B6, B12).

Neuropathy significantly increases risk of falls, which are the leading cause of traumatic death in older adults. We don’t currently have data on long-term fracture rates of bariatric patients at various ages. More research is needed to assess the skeletal consequences of bariatric surgery in older adults.

As obesity has risen in the pediatric population, so has the frequency of weight-loss surgery among individuals under age 18, although it is still relatively rare. Prevalence rates for weight loss surgery in adolescents have not changed substantially in the past decade, currently representing about 2.5 out of 100,000 procedures. However, absolute numbers have risen.27,28 A retrospective cross-sectional study of discharge data obtained from Healthcare Cost and Utilization Project Kid’s Inpatient Database, published in the February, 2013, issue of JAMA Pediatrics, reported that bariatric procedures on adolescents increased from ~300 in 2000 to ~1000 in 2009.26

From the perspective of bone health, bariatric surgery presents a potentially serious threat for children and teens. Vitamin D deficiency in adolescence can lead to increased risk for metabolic bone disease if uncorrected.29 The long-term health effects of pediatric bariatric surgery are beyond the scope of this article. However,
it is a subject of growing concern and focused research.

**Impact of Obesity on Bone**

Bone health is mediated by a complex metabolic system of checks and balances involving, among other things, calcium, vitamin D, and parathyroid hormone (PTH). The link between vitamin D deficiency, elevated PTH, and bone disease has long been recognized. When serum calcium drops below a healthy level, PTH secretion rises, mobilizing release of calcium from bone. By this mechanism, a sustained state of calcium deficiency leads to secondary hyperparathyroidism, which is known to cause skeletal deterioration.

Vitamin D deficiency is extremely common in obese individuals. The reasons suggested for this are complex. Poor diet plays a part, as does sequestration of vitamin D in adipose tissue, which reduces serum bioavailability. Studies have shown 60 to 86% of candidates for bariatric procedures are deficient in vitamin D before surgery.

Vitamin D deficiency is seen following bariatric surgery as well. An initial upward trend in serum vitamin D has been observed in the first month following bariatric surgery, but levels decline thereafter. It has been speculated that the initial rise is from release of fat-stored vitamin D during the immediate postsurgical period of rapid and intense weight loss. Studies at one to three years following surgery have found no change or modest reductions in the rates of vitamin D deficiency. One retrospective study found that, whereas 86% of the study cohort was vitamin D deficient before bariatric surgery, 70% were one year after. Several other studies have seen no improvement in vitamin D status three years following malabsorptive bariatric surgery. Causes for postsurgical vitamin D deficiency are under study; however, known contributing factors include continued obesity, reduced food intake, and impaired absorption.

In both obese and healthy-weight people, vitamin D deficiency varies by population. Prevalence of vitamin D deficiency before and after bariatric surgery is significantly higher in African Americans than in Caucasians.

**Impact of Weight Loss on Bone**

Obesity has long been viewed as protective against

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After participating in this activity, the reader has the option of taking a post-test with a passing grade of 70% or better to qualify for continuing education credit for this activity. It is estimated it will take 1.0 hour(s) to complete the reading and take the post-test. Continuing education credit will be available for two years from the date of publication.

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Bone loss and fracture due to the positive effects of mechanical loading on bone formation. Research suggests that any such protection is site specific. Whereas obesity is associated with lower fracture risk and higher BMD at weight-bearing sites (e.g., hip and pelvis), it is associated with higher fracture risk at non-weight-bearing sites (e.g., humerus and ankle). Data on obesity-related vertebral fracture rates are inconsistent, with some studies reporting no difference and others seeing increased risk over normal weight cohorts. These variations reflect the effects of vitamin, mineral, and metabolic conditions prevalent in obese individuals as well as the distribution of trabecular and cortical bone in the body and its response to mechanical loading and hormonal changes that result from weight loss.

Weight loss, whether by surgical or nonsurgical means, causes bone loss and fragility fractures in older individuals, regardless of BMI. One large prospective study of 6000+ older women (>68 years) observed a two-fold increase in hip fracture among women who lost 5% of their body weight, regardless of their baseline or final weight. Several studies of older men showed declines in BMD associated with weight loss 3 to 4 times higher than control cohorts.

The degree of bone loss attributable to surgical weight reduction is proportional to the magnitude and speed of weight loss, which varies by bariatric procedure. More weight is lost in the year following procedures that induce malabsorption than following procedures that solely restrict caloric intake (30% to 40% vs. 25%). So too, greater bone loss is seen following malabsorptive type procedures than restrictive. As observed in nonsurgical weight loss, this bone loss varies by site, with more bone lost at the weight-bearing hip region than at spine and radius. We will discuss data for bone effects of specific bariatric procedures below.

**Bariatric Surgical Procedures**

The most commonly performed bariatric procedures in the U.S. are the Roux-en-Y gastric bypass (RYGB), the laparoscopic sleeve gastrectomy (LSG), the laparoscopic adjustable gastric band (LAGB), and the biliopancreatic diversion with duodenal switch (BPD/DS). All rely on structural and hormonal mechanisms to induce weight loss, either by restricting intake or limiting absorption, or both.

With the exception of the LAGB, bariatric procedures performed today alter neuro-hormonal mechanisms that control hunger and satiety. All are usually performed laparoscopically. As compared with open procedures, laparoscopic procedures are associated with less postoperative pain, lower morbidity and mortality, lower risk of hernia, and shorter hospital stays and recovery periods.

A variety of older gastric bypass bariatric procedures have been abandoned for reasons of complications; severe nutrient deficiencies; inadequate, excessive, or unsustained weight loss; and/or high rates of surgical revision. These include biliopancreatic diversion...
(BPD), jejunocolic bypass, jejunoileal bypass, and vertical banded gastroplasty. Although these procedures are no longer performed, thousands who underwent them still need to be followed for nutritional deficiencies and their metabolic sequellae.

**Roux-en-Y Gastric Bypass (RYGB)**

The Roux-en-Y gastric bypass (RYGB), frequently referred to simply as gastric bypass, is the technique used in 80% of the weight-loss surgery performed in the U.S.\(^3\)

The RYGB has been called a “combined” bariatric procedure because it induces weight loss through both intake restriction and malabsorption. RYGB patients experience dramatic weight loss of up to 70% of excess body weight that is sustained for more than 10 years.\(^{16,57}\) RYGB surgery is performed by creating a small pouch at the opening to the stomach, restricting gastric capacity. Next, a Y-shaped section of the small intestine is attached to the pouch, allowing food to bypass the lower stomach, the duodenum, and the first portion of the jejunum, reducing absorption of calories and nutrients.

The RYGB procedure alters secretion of hormones that signal satiety, contributing to weight loss. In addition, many patients who have undergone RYGB surgery develop “dumping syndrome” in response to ingestion of high-density carbohydrates. Eating carbohydrate-dense foods becomes very unpleasant, motivating patients to adopt healthier eating habits and improving the likelihood of long-term maintenance of weight loss.

**Biliopancreatic Diversion with Duodenal Switch (BPD/DS)**

Biliopancreatic diversion with duodenal switch (BPD/DS) is a combination restrictive-gastric bypass procedure that induces weight loss predominantly through caloric and fat malabsorption. The BPD/DS is distinct from the no-longer-performed biliopancreatic diversion (BPD) surgical technique; however, they share the common feature of diverting bile and pancreatic fluids that are normally released into the duodenum to digest food and break down fats, carbohydrates, and proteins.

BPD/DS is typically the surgery of choice for superobese patients (BMI \(\geq 50\)). It has been shown to produce the greatest sustained excess weight reduction (\(~70\%\)), as well as superior long-term resolution of diabetes, hypertension, and dyslipidemia in the superobese population.\(^{58-61}\)

In a BDP/DS procedure, the stomach is sectioned vertically, creating a small tube that terminates past

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**Figure 1.** The Roux-en-Y gastric bypass procedure creates a small gastric pouch that is anastamosed to the proximal jejunum. The remainder of the stomach, duodenum, and proximal jejunum are bypassed and rejoin the distal roux limb in a Y configuration. (Graphic Source: NIH Publication Number 00-4084. Copyright 1997-2013, A.D.A.M., Inc.)
Every 3 to 6 months
• CBC, platelets
• Electrolytes
• Glucose
• Iron studies, ferritin
• Phosphorus
• Vitamin B12
• Liver function
• Lipid profile
• Albumin and prealbumin
• RBC folate

Every 6 to 12 months
• Vitamin A
• 25-Hydroxyvitamin D
• Vitamin E
• Vitamin K1 and INR
• Intact PTH

Annually
• 24-Hour urine calcium, citrate, uric acid, and oxalate
• Selenium
• Urine N-telopeptide
• Zinc

As indicated
• Osteocalcin
• Carnitine
• Essential fatty acid chromatography
Bone Loss Following RYGB and BPD/DW Procedures

Bariatric techniques that induce malabsorption, such as RYGB and BDP/DS, bypass the duodenum and proximal jejunum, the primary absorption sites for vitamins and minerals such as iron and calcium. As a result, deficiencies in calcium (25% to 50%) and vitamin D (>50%) have been observed in patients following RYGB and BPD/DS. Depending on the length of intestine bypassed, patients also experience greater or lesser deficits of other nutrients necessary for bone health including protein, folate, iron, magnesium, thiamine, B12, and fat-soluble vitamin A.

Even with increased intake of calcium and vitamin D, malabsorptive procedures are linked to bone loss. One year following RYGB, BMD declined 9.2% to 10.9% at femoral neck and 8% to 10% at total hip in women on supplemental vitamin D and calcium in two studies. Declines have also been observed at the lumbar spine one year after RYGB surgery (3.6% to 7.4%).

Data for bone loss at the forearm are inconclusive. Studies have shown between 0% and 5% at one year postoperative (n=12; n=23). A study that distinguished total forearm from radius measured BMD declines at the total forearm that continued for three years but no change at the radius (total forearm T-score 0.55 year 1, -3.6 year 2, -1.8 year 3). Losses at the hip and spine stabilized after the first year as weight reduction plateaus.

In addition to nutrient-related causes of bone loss, reduced mechanical loading increases bone turnover at weight-bearing sites, such as the hip, in direct proportion to the magnitude of weight lost, which is substantial following malabsorptive procedures.

Bone at weight-bearing sites, predominantly trabecular bone, has been observed to increase or decrease in density as mechanical loading increases or decreases. Non-weight-bearing bone, predominantly cortical, does not respond in the same way to mechanical loading. It is, however, sensitive to the effects of PTH, which increases dramatically with the substantial weight loss induced by malabsorptive bariatric procedures. A recent study that used high-resolution peripheral quantitative computed tomography (HR-PQCT) identified deterioration in cortical bone at the tibia but not other sites following RYGB. In this study, an inverse relationship was seen between rising serum PTH and declining cortical density, thickness, and area.

Evidence for bone loss in older, more severely malabsorptive techniques has been documented. Looking at jejunileostomy and BPD patients 15 years after surgery, a study conducted by Bano, et. al., found significantly lower spine BMD (15%) in men over 50 and postmenopausal women not on hormone therapy.

Laparoscopic Sleeve Gastrectomy

Until recently, the laparoscopic sleeve gastrectomy (LSG) was considered an investigational bariatric technique. It is now considered a primary procedure. Data from large placebo-controlled studies have shown LSG to be comparable or superior to RYGB and LAGB in magnitude and durability of weight reduction, rate of complications, and improvement in obesity-related conditions, such as diabetes and cardiovascular disease.

Data reported from the American College of Surgeons Bariatric Surgery Center Network’s longitudinal database (n=28,616) positioned LSG above LAGB and below RYGB with regard to rates of morbidity, readmission, and reoperation/interventions.

Figure 3. The laparoscopic sleeve gastrectomy creates a narrow gastric tube by removing 2/3 of the stomach, preserving the duodenum and jejunum. (Graphic Source: NIH Publication Number 00-4084)
The LSG is so called because it creates a sleeve-like structure by removing 1/3 of the stomach vertically. Originally conceived as purely restrictive in mechanism, recent findings suggest that LSG also induces weight reduction through regulation of intestinal hormones that control hunger and satiety as is seen in RYGB.71

As a surgical technique, LSG is less complicated than RYGB and BPD/DS. It takes less time to perform and results in less blood loss. Another key advantage is a lower risk of postoperative nutritional deficiency. This is because LSG does not bypass sites of nutrient absorption. The duodenum and jejunum are left intact. As with other bariatric procedures, LSG must be followed by lifelong surveillance and nutrient support.

In the small number of studies that have reported longer-term outcomes, the percentage of excess weight lost 5 to 9 years following LSG is between 53% and 69%, depending on the study.74,75

**Laparoscopic Adjustable Gastric Band**

The laparoscopic adjustable gastric band (LAGB), also known as the “lap band,” surgery has been performed in the U.S. since the mid 1980s. The LAGB procedure uses an inflatable band cinched around the top of the stomach to create a small pouch that reduces stomach capacity to approximately 30 to 50 ml. The new stomach fills quickly and gives the patient a feeling of satiety. The band slows the flow of food into the digestive tract. The band’s tightness, and thus the pouch outlet, is adjustable through saline injection via subcutaneous injection port.

Recovery following LAGB surgery is quicker than laproscopic RYGB. It is fully reversible and does not result in the malabsorption syndromes attendant to RYGB and other surgeries that bypass all or portions of the small intestine. However, LAGB has been shown to result in significantly less initial weight loss than RYGB, although this difference may diminish over time.76 Studies of patients 4 to 10+ years after LAGB show sustained weight loss of >40% excess body weight, which is comparable to RYGB.88

LAGB is, however, associated with a high rate of major complications. Postoperative complications requiring revision, mainly band slippage and/or erosion, have been seen in 30% to 60% of patients depending on study cohort.77,78,79,80 The incidence of failure rises with time. One study showed the failure rate due to excessive weight loss or device/surgical failure increasing from ~40% at year 5 to ~60% at year 7 following LAGB.81 As a result of these complications, performance of LAGB is on the decline.

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**Figure 4.** Laparoscopic adjustable gastric band restricts food intake by radically reducing “stomach” size and limiting outflow, thereby promoting early satiety. The band can be adjusted by infusing or withdrawing saline via a subcutaneous port. (Graphic Source: NIH Publication Number 00-4084. Copyright 1997-2013, A.D.A.M., Inc.)
Bone Loss Following LSG and LAGB Procedures

Bariatric procedures that restrict intake as the primary mechanism to promote weight reduction avoid the severe nutrient deficiencies seen following malabsorptive procedures. In general, restrictive bariatric procedures result in less bone loss at all sites. Several small studies showed no change in BMC or BMD following gastric banding. Nonetheless, bone loss at the hip has been seen, although at a lesser degree than in malabsorptive procedures. One year following LAGB surgery, in a study of 37 premenopausal women, reported by Giusti, et. al., subjects lost 2.3% at the femoral neck and 2.1% at the trochanter. At two years postsurgery, the same group had lost 5.8% at the femoral neck and 6.5% at the trochanter.

Several studies have shown evidence of negative bone remodeling as indicated by markers of bone resorption for the first year following LAGB. A study by Giorno, et. al., observed the increase in bone turnover to resolve by 24 months.

Compared to RYGB, LAGB surgery has less of an impact on vertebral bone. Multiple studies have reported either a slight increase or no change in BMD at the lumbar spine in the first two years following LAGB surgery, when the majority of the weight is lost.

We currently have no data on long-term skeletal consequences of LAGB surgery. No fracture outcomes have been reported to date.

Protecting Bone Health in Bariatric Patients

The caloric restriction and nutrient malabsorption that are central features of bariatric procedures induce suboptimal levels of calcium, vitamin D, minerals, fats, protein, and other nutrients normally absorbed in the small bowel.

Protecting bone health of patients after bariatric surgery starts with correction of nutrient deficiencies. Without any other intervention, repletion of vitamins and minerals to normal levels can significantly improve skeletal status. Randomized placebo-controlled clinical trials have shown correction of vitamin D deficiency to reduce risk of hip and nonvertebral fractures by 20% among individuals aged 65 and older.

Supplementation is recommended following all types of bariatric surgery. Recommendations for prophylactic nutritional supplementation of post-bariatric patients were published in AACE/TOS/ASMBS Guidelines in 2008 and updated in 2013, as follows:

- OTC multivitamin+ mineral preparation containing thiamine, copper, and zinc
- 1 tablet/day (LAGB)
- 2 tablet/day (RYGB, LSG, BDP, BDP/DS)
- Calcium citrate + vitamin D: 1200 to 2000 mg/day + 400 to 800 IU/day
- Folic acid: 400 mg/day in multivitamin (menstruating women)
- Elemental iron: 40 to 65 mg/day
- Vitamin K: 300 mg/day
- Vitamin B12: ≥350 mg/day orally (or 1000 mg/month intramuscularly, or 3000 mg every 6 month intramuscularly or 500 mg every week intranasally)

It is always preferable for nutritional needs to be met through food intake rather than dietary supplementation. To this end, bariatric patients should be counseled on healthy eating practices by trained dieticians or other qualified clinicians. However, even with nutritious and balanced diet, bariatric patients are unlikely to be able to maintain adequate levels of critical vitamins, minerals, and micronutrients.

In patients who have undergone malabsorptive RYGB or BDP/DS and BDP procedures, additional supplementation with Vitamin A and zinc may be needed to maintain normal levels. Additional supplementation of other nutrients may also be needed in patients with pre- or post-bariatric deficiencies.

Lifelong routine metabolic and nutritional monitoring is necessary to maintain the health of people following bariatric surgery. AACE/TOS/ASMBS guidelines for screening and supplementation of patients after the immediate postoperative period are summarized on the next page.
Summary of Screening and Supplementation Recommendations for Patients following Bariatric Surgery (AACE/TOS/ASMBS)

Unless otherwise indicated, routine screening intervals listed below are annual in RYGB, LSG, and LAGB patients and biannual in BDP/DS and BDP patients.

<table>
<thead>
<tr>
<th>Supplement</th>
<th>Recommendations</th>
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<tbody>
<tr>
<td>25-hydroxyvitamin D</td>
<td>Screening recommended every 6 to 12 months. If below 30 ng/ml, supplement with vitamin D₃ or D₂ as indicated by serum levels. May require oral doses of 50,000 IUs 1 to 3 times/day or week to reach sufficiency. Supplement thereafter 2,000 to 10,000 IU/day as needed to attain and maintain replete serum levels.</td>
</tr>
<tr>
<td>Calcium</td>
<td>Routine screening recommended for all bariatric patients. Calcium from diet plus supplementation with oral calcium citrate 1,500 to 2,000 mg/day. Calcium citrate has been demonstrated to have better bioavailability, superior fractional uptake in bone, and efficacy in normalizing markers of bone turnover when compared to other commercial calcium supplements.</td>
</tr>
<tr>
<td>Copper</td>
<td>Screen with specific findings: in patients with anemia, neutropenia, myeloneuropathy, and/or impaired wound healing. Maintenance supplementation 2 mg/d as part of multivitamin/mineral preparation. (Zinc replacement can cause copper deficiency. Supplement 1 mg copper for every 8 to 15 mg zinc.)</td>
</tr>
<tr>
<td>Folate</td>
<td>Supplement with folic acid (400 μg/day) as part of multivitamin-mineral supplement. Additional supplementation in women of childbearing years.</td>
</tr>
<tr>
<td>iPTH (intact parathyroid hormone)</td>
<td>Screening recommended every 6 to 12 months. Monitor along with Vitamin D.</td>
</tr>
<tr>
<td>Iron</td>
<td>Routine screening recommended. Deficiency common in menstruating women and super-obese. Supplement as indicated, adding vitamin C or taking with orange juice to aid absorption.</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>Routine screening recommended. Oral supplementation of phosphate if level is low (1.5 to 2.5 mg/dl) usually due to vitamin D deficiency. RDA 1000 mg/day.</td>
</tr>
<tr>
<td>Prealbumin</td>
<td>Routine screening recommended as indicator of overall nutritional status. Protein from diet with supplementation as needed.</td>
</tr>
<tr>
<td>Thiamine</td>
<td>Screen with specific findings. Supplement as routine part of multivitamin-mineral preparation. Rare incidence of severe thiamine deficiency following RYGB.</td>
</tr>
<tr>
<td>Vitamin A</td>
<td>Screening every 6 to 12 months recommended for patients who have had purely malabsorptive techniques: BDP, BDP/DS. Supplement as needed to reach adequate serum levels.</td>
</tr>
<tr>
<td>Vitamin B₁₂</td>
<td>Baseline screening recommended for all bariatric patients. Yearly screening following RYGB and LSG. Maintenance supplementation 1000 μg/day.</td>
</tr>
<tr>
<td>Vitamin K</td>
<td>Deficiency is common starting one year after surgery. Supplement with 300 μg/d.</td>
</tr>
<tr>
<td>Zinc</td>
<td>Screening recommended following RYGB, BPD and BPD/DS. Deficiency common in BPD/DS patients starting one year after surgery. Supplement following BPD and BPD/DS.</td>
</tr>
</tbody>
</table>

Table 2. Summary of screening and supplementation recommendations for bariatric patients. (AACE/TOS/ASMBS Guidelines, 2008, 2013)
Diagnosing and Treating Osteoporosis in Bariatric Patients

Primary osteoporosis is a progressive degenerative bone disease found most frequently in women after menopause and men over 50. The majority of patients (80%) who undergo bariatric surgery are young women with an average age of forty-two. Women this age are unlikely to have primary osteoporosis. When osteoporosis is suspected in a bariatric surgery patient, secondary disease—most likely related to nutritional insufficiencies—should be suspected first. Correction of nutrient-related deficits can lead to substantial improvements.

Women and men who have had bariatric surgery should have BMD measured by DXA. In younger patients, this provides a baseline measurement for future comparison. In men over age 50 and postmenopausal women, it can be used to diagnose osteoporosis.

Accurate BMD measurement in very obese individuals can be difficult. Patients over 450 pounds exceed the weight limit of contemporary DXA tables. Central DXA may not accurately reflect bone density in overweight subjects. When tissue depth is over 25 cm and there is fat surrounding bone, DXA tends to overestimate BMD.

Alternatives to spine and hip BMD measurements include peripheral DXA (pDXA) measurements of the forearm, heel, or finger; peripheral quantitative ultrasound (pQUS) of the heel, shin, and kneecap; and peripheral quantitative computed tomography (pQCT) of the forearm. The International Society for Clinical Densitometry (ISCD) recommends pDXA of the forearm for very obese individuals who cannot be measured at the hip and spine.

Although both T and Z scores are given on bone density measurements, they are not always equally helpful in assessing a patient’s bone health. Z-scores are a better gauge of bone status in premenopausal women and men under age 50. The Z-score compares bone mineral density to the mean for individuals of the same age, race, and gender. A Z-score near 0 represents expected age-related bone loss. The ISCD position statement defines a Z-score of -2.0 or lower to be “below the expected for age,” and a Z-score above -2.0 to be “within the expected range for age.” This cut-off point recommendation as well as the use of the Z-score clinically
may change, as additional data become available.\textsuperscript{97} (Z-score assessment is also appropriate for growing children and adolescents, but is beyond the scope of this article.)

In older men and postmenopausal women, the T-score, which compares a patient’s BMD to healthy 30-year-old normative values, has been validated as a predictor of fracture risk.

In patients suspected of having a vertebral fracture, either because of acute back pain or height loss of 2” or greater, assessment is recommended by DXA and/or lateral spine radiograph.

### Drug Treatment for Osteoporosis in Bariatric Patients

In a bariatric patient with DXA T-scores diagnostic of osteoporosis, all vitamin and mineral deficiencies must be aggressively treated before pharmacologic therapy can be started. Once normal serum values have been achieved, an antiresorptive or anabolic treatment agent can be considered.

Bisphosphonates are the most widely prescribed class of antiresorptives. AACE/TOS/ASMBS 2013 guidelines recommend intravenous bisphosphonates rather than orally administered agents. This avoids inadequate absorption in the altered digestive tract and potential ulceration at sites of surgical anastomosis. Daily supplementation of vitamin D and calcium must be maintained in any treatment plan.

Recommended intravenous dosages of antiresorptives include the bisphosphonates zoledronic acid, (5 mg once a year) and ibandronate (3 mg every 3 months) as well the RANK ligand inhibitor denosumab (60 mg every 6 months). The anabolic agent, teriparatide, is available in subcutaneous dose of 20 mcg once a day.

Patients will need to be reassessed regularly to ensure calcium and vitamin D sufficiency. Repeat DXA measurement should be done every two years or starting at menopause in younger women. In between scans, measurement of biochemical markers of bone turnover may be used to identify any escalation in bone resorption.

### Patient Cases: Preserving Bone Health Following Bariatric Surgery

In the following case studies, we will explore issues that arise in the clinical management of patients who have undergone bariatric surgery and subsequent weight loss.

#### Case 1: 45-Year-Old Woman who Had Roux-en-Y Gastric Bypass Surgery.

The first patient we will discuss is a 45-year-old African-American woman who underwent RYGB surgery one year ago. The patient reports having had
weight problems since her teen years, she has lost and regained weight numerous times, each time ending up weighing more.

Prior to bariatric surgery, the patient met with a registered dietician and was prescribed multivitamins as well as calcium and vitamin D supplements (1000 mg/500 IU).

At age 44, with hypertension, type 2 diabetes, and painful knees due to arthritis, she underwent RYGB surgery. Her starting weight was 240 pounds, with a BMI of 42. Now, one year later and 102 pounds lighter, her BMI is 24 and she no longer requires routine medications.

Medical history:
• Height by stadiometer 5’6” (at baseline 5’4”)
• Weight 138 lbs (baseline 240 lbs)
• RYGB bariatric surgery 1 year prior
• Positive family history for osteoporosis
• Personal history of nontraumatic wrist fracture as an adult
• Drinks fewer than 5 alcoholic beverages per week
• Does not smoke
• Takes 1000 mg calcium/day as calcium carbonate
• Takes 600 IU vitamin D daily
• Swims weekly for 1 hour
• History of hypertension, now resolved, with no drug treatment
• Type 2 diabetes diagnosed prior to weight loss, now under control with no medication

The patient presents for routine primary care follow-up.

**What tests should the clinician use to assess the patient’s bone health?**
The patient should have blood work to identify any postoperative chemical or metabolic abnormalities. Her serum chemistry study results are as follows (normal range shown in parentheses):
• Complete blood count
• Albumin 3.1 g/ml (4 to 6 g/dl)
• Prealbumin 4 mg/dl (18 to 45 mg/dl)
• Total calcium 8.2 mg/dl (8.6 to 10.5 mg/dl)
• Ionized calcium 0.87 mmol/l (1.15 to 1.35 mmol/l)
• Phosphorus 1.75 mg/dl (1.5 to 2.5 mg/dl)
• 25-hydroxyvitamin D 12 ng/ml (30 to 80 ng/ml)
• Intact PTH 128 pg/ml (10 to 72 pg/ml)
• C reactive protein 2.5 mg/l (<3.0 mg/l)
• Magnesium 1.9 mg/dl (1.5 to 2.3 mg/dl)
• B12/cobalamin 150 ng/l (130 to 950 ng/l)
• Thiamine 200 ng/l (150 to 255 ng/l)

**What do these lab results suggest may be done to protect the patient’s bone health?**
The patient’s protein, vitamin D, and calcium levels are low. Her elevated PTH indicates secondary hyperparathyroidism. Her nutrient insufficiencies can be addressed through diet and supplementation.

**What dietary interventions should be put in place to guard against bone loss?**
The clinician prescribes 50,000 IU vitamin D3 daily for seven consecutive days, then three times weekly. She is switched from calcium carbonate to chewable calcium citrate and instructed to take 600 mg twice daily and to increase her intake of calcium-rich foods. Her multivitamin-mineral supplement is changed to a chewable form and doubled. Her B12 is on the low side, as is her albumin. Her prealbumin is frankly deficient, indicating inadequate protein intake. She is encouraged to consume an ounce or two of lean protein with each meal and snack. She is prescribed oral vitamin B12 at a dosage of 1000 mg daily for six months. She will be reassessed at that time.

**Should the patient have a bone density test?**
It would probably be a good idea. A DXA will provide a baseline for future bone density measurements. Because this is her first DXA, we cannot use it to ascertain how much, if any, bone she has lost since weight-loss surgery. Because she is premenopausal, she is at low risk of primary osteoporosis. However, secondary causes of bone loss may have increased her risk for fracture.

She has a BMD scan by DXA.

DXA results:
• Hip: 0.781 g/cm2; Z-score -1.9; T-score -2.2
• Lumbar spine: 0.800 g/cm2; Z-score -1.71; T-score -2.0

**How should these DXA results be interpreted?**
In the patient’s age group, the race- and aged-matched Z-score is a better indicator of bone health and fracture risk than T-score (which is validated for postmenopausal women). A Z-score above -2.0 is considered within
the range of normal.

Is the patient’s BMD measurement a cause for concern?
It may be. Her hip Z-score is within the suggested range for normal. However, added to her history of low-impact fracture and positive family history for osteoporosis, she may be at increased risk for primary osteoporosis after menopause.

Should pharmacologic therapy to prevent bone loss be initiated at this time?
Not at this time. Correction of the patient’s vitamin D deficiency, secondary hyperparathyroidism, low protein, and low serum calcium should substantially improve her bone status.

What should be done to assess the efficacy of nutritional interventions?
Follow-up labs eight weeks later are done. The results are normal albumin and B12, improved prealbumin, normal calcium, 25-hydroxyvitamin D (42 ng/ml), and PTH (71 pg/ml).

How should the patient be followed?
This patient should have biochemical indices including prealbumin, CRP, calcium, 25-hydroxyvitamin D, and PTH checked every 3 to 4 months until her labs normalize, optimal vitamin D ≥40 ng/ml is achieved, and PTH is consistently suppressed. Once these goals have been met, the patient can safely be monitored every 6 to 12 months.

In addition, she will be assessed annually for signs and symptoms of osteoporosis such as height loss, postural changes, and back pain. She will have repeat DXA at menopause or sooner if symptoms warrant.

Case 2. 60-Year Woman 20 Years after Jejunoileal Bypass Surgery.
The second patient we will discuss is a Caucasian woman, age 60, who had jejunoileal bypass 20 years ago. Her starting weight was 420 pounds, with a BMI of 69, based on a reported 5’6” baseline height. She reports having lost 150 pounds in the two years following surgery. Since that time, she has regained 75. Her weight is now 275 pounds, with a BMI of 47, based on her current height measurement.

Medical history:
• Height by stadiometer 5'3" (reported height at age 30: 5'6")
• Weight 275 lbs (weight at age 40: 420)
• Natural menopause age 51
• No DXA results on record
• Malabsorptive bariatric surgery 20 year prior
• Negative family history for osteoporosis
• Positive history for nontraumatic ankle fracture as an adult
• Drinks 5-10 alcoholic beverages per week
• Does not smoke
• Takes daily multivitamin
• Active lifestyle, but no other exercise
• Hypertension, managed with drug treatment
• Negative for type 2 diabetes

The patient presents with back pain. She has not continued follow-up with her bariatric surgeon’s practice.

What tests should the clinician do to assess the patient’s bone health?
There are many metabolic unknowns with this patient. Because she has had only minimal nutritional supplementation, she may have serious insufficiencies. Her height loss is suggestive of vertebral fracture, which could point to osteoporosis, but we do not know if her baseline height is accurate. Before going forward, a basic work up for malabsorption-related deficiencies should be done:
• CBC, platelets
• Electrolytes
• Glucose
• Iron studies, ferritin
• Vitamin B12 (MMA, HCy optional)
• Liver function (GGT optional)
• Lipid profile
• Albumin and prealbumin
• RBC folate
• Phosphorus
• Vitamin A, E, and K
• 25-hydroxyvitamin D
• INR
• Intact PTH
• 24-hour urine calcium
• Zinc
• Selenium
• Osteocalcin
• Urine N-telopeptide

The patient’s lab results indicate elevated serum PTH
and significant deficiencies of calcium, phosphorus, protein, zinc, copper, and vitamins D, B12, A, and E:
- Albumin 3.1 g/ml (4 to 6 g/dl)
- Prealbumin 4 mg/dl (18 to 45 mg/dl)
- Total calcium 7.8 mg/dl (8.6 to 10.5 mg/dl)
- Ionized calcium 1.00 mmol/l (1.15 to 1.35)
- 25-hydroxyvitamin D 10 ng/ml (30 to 80 ng/ml)
- Intact PTH 130 pg/ml (10 to 72 pg/ml)
- C reactive protein 0.3 mg/l (<1.0 mg/l)
- Magnesium 1.9 mg/dl (1.5 to 2.3 mg/dl)
- Zinc 0.30 mcg/ml (0.66 to 1.10 mcg/ml)
- Vitamin E 4 µg/ml (5 to 20 µg/ml)
- Vitamin A 28 µg/dl (30 to 95 µg/dl)
- B12/cobalamin 100 ng/l (130 to 950 ng/l)
- Thiamine 200 ng/l (150 to 255 ng/l)
- Phosphorus 1.25 mg/dl (1.5 to 2.5 mg/dl)

**Should this patient be evaluated for metabolic bone disease?**
Yes. Her lab work points to a high risk for osteoporosis, from both primary and secondary causes.

A bone density scan by DXA is ordered. In addition, she has a lateral spine radiograph to detect any vertebral fractures.

**DXA results:**
- Hip: 0.66 g/cm2; T-score -3.4
- Lumbar spine: 0.69 g/cm2; T-score -3.1

Her lateral radiograph identifies vertebral compression fractures at L2 and L4. Because the patient is past menopause, it is appropriate to use T-scores to evaluate her BMD. The patient is diagnosed with osteoporosis.

**Should she be treated to prevent further bone loss?**
Yes. She will first need to have her nutrient-related abnormalities corrected. In addition to supporting bone density, vitamin D and calcium repletion are necessary for optimized therapeutic effect.

The patient is prescribed 50,000 IU oral vitamin D3 to be taken daily for two weeks, at which time she will be rechecked. Once her serum level reaches ≥30 ng/ml she will be switched to a maintenance dose of 50,000 three times weekly.

Her calcium deficiency is addressed through both diet and supplement. Working with a nutritionist, she is started on a high-calcium diet and supplemented with calcium citrate (chewable to improve absorption). Her target daily calcium intake is 1500 to 2000 mg.

She is not prescribed a phosphate supplement. Once she is vitamin D replete, her hypophosphatemia will likely not recur.

The patient is encouraged to increase her intake of dairy products for their protein and calcium benefits. If she cannot tolerate lactose, she is advised to try lactose-free milk and/or milk-only yogurt that contains no added milk sugars or solids. She is advised to increase her protein intake through many small high-protein snacks per day.
She is also prescribed an OTC chewable multivitamin-mineral twice daily, 1000 µg oral vitamin B12, and supplemental vitamin A, E, and K.

**What osteoporosis medication would be appropriate for this patient?**
Absorption of oral bisphosphonates may be compromised in patients who have undergone gastric bypass. Studies of other poorly absorbed drugs have shown diminished bioavailability following bariatric surgery; however, no data have been published specifically addressing absorption of bisphosphonates. Intravenous agents such as yearly zoledronic acid, twice yearly denosumab, quarterly ibandronate, or daily teriparatide are potential non-oral options. Due to the higher cost of these options, it may be difficult to get insurer approval without evidence that the less-expensive oral bisphosphonates do not work.

After considering her options, the patient agrees to try 35 mg once-weekly oral alendronate.

**What is her follow-up plan?**
The clinician will repeat the patient’s biochemical panels every 6 to 12 months. Once she is on oral alendronate, she will be reassessed by DXA at one year. If her BMD is stable, she will be continued on the alendronate. If her BMD continues to decline, the patient’s medication options will be reconsidered.

She will then be followed with DXA every two years. In intervals between DXA scans, to confirm that the patient is not continuing to lose bone, the patient’s rate of bone turnover will be assessed using biochemical markers, such as urine N-telopeptide (NTX) or serum bone specific alkaline phosphatase. If evidence is found of elevated bone turnover, appropriate action can be taken.

**What other strategies can help support this patient’s health and quality of life?**
The patient can be encouraged to engage in an exercise program of moderate intensity and to join a support group for patients who have undergone weight-loss surgery. Both measures have been shown to improve quality of life and increase the odds of maintaining weight reduction. An added benefit of exercise is that, in addition to supporting cardiovascular health and glycemic control, it reduces fall risk by improving muscle strength and balance. In individuals with osteoporosis or low bone density, falls are the leading cause of fragility fracture.

**Summary**
There is no doubt that bariatric surgery saves lives that would be lost due to obesity-related diseases. However, it is not without its potential costs, which include severe nutrient depletion and the wide-ranging consequences of prolonged suboptimal nutrition. Bariatric surgery patients require meticulous life-long surveillance. Targeted nutritional support and vitamin-mineral supplementation dosed to achieve and maintain healthy serum levels can significantly improve bone health in bariatric patients. With awareness of potential risks, consistent monitoring, prophylactic nutrient supplementation, and appropriate pharmacologic intervention, clinicians can help patients protect their bone health after bariatric surgery and throughout their lives.

**References**
7. American Society for Metabolic & Bariatric Surgery. (2009) ASMBBS estimates are based on the Bariatric Outcomes Longitudinal Database (BOLD), American College of Surgeons Bariatric Surgery Center Network (ACS BSCN), the National Inpatient Sample data and the best estimation on the number of outpatient cases.


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NOF's Support Group Program

NOF sponsors osteoporosis support groups throughout the country. Patients can benefit in many ways from joining a support group:

- Learning more about the disease and treatment choices
- Receiving the most up-to-date information about osteoporosis
- Improving coping skills by learning how others handle the disease
- Exchanging information about community resources
- Helping identify healthcare providers who treat osteoporosis
- Improving mental and physical well-being
- Finding hope and encouragement

Starting a Support Group

If you are interested in starting your own support group, review and complete the NOF Support Group Application, available online at www.nof.org under Connect to Our Community

Support Group Resources

NOF provides all support groups leaders with excellent resources including:

- Support group manual — A comprehensive guide to help you start, promote and conduct successful support group meetings.
- Free educational materials — NOF will provide brochures, information sheets, quarterly newsletters, PowerPoint presentations, posters and more.
- Networking opportunities — NOF will connect you with other support group leaders to help you network and exchange ideas.
- Topics and program ideas — NOF maintains a list of topics and program ideas.
- Referrals — NOF will direct all inquiries to join a support group in your area to you, helping you grow your membership.

For more information on joining a support group or to find a support group in your community, contact the National Osteoporosis Foundation at (202) 223-2226 or toll free at (800) 231-4222.

Reference:


Osteoporosis International
Osteoporosis International is the leading scientific journal for clinical research in osteoporosis and related bone diseases. Published monthly, the journal is an international, multidisciplinary joint initiative of NOF and the International Osteoporosis Foundation.

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