



# The Effects of Smoking on Bone Health and Healing

A review of smoking's role in fracture risk and orthopedic surgery, and how to help patients quit.

**ABSTRACT:** The number of orthopedic surgeries performed in the United States has increased substantially over the past several years. The most recent data available from the Agency for Healthcare Research and Quality indicate that five of the 10 operative procedures most commonly performed during inpatient stays involve the musculoskeletal system. Cigarette smoking is one of the most prevalent and preventable risk factors for musculoskeletal disorders and orthopedic surgery complications. This article discusses the effects of smoking on bone health, the importance of smoking cessation among patients scheduled for or recovering from orthopedic surgery, and the vital role nurses play in supporting patient efforts to lead a tobacco-free life.

**Keywords:** bone health, orthopedic disorders, orthopedic surgery, smoking, smoking cessation

In 2015, patient visits to orthopedic surgeons accounted for nearly 6% (56,427/990,808) of all physician office visits in the United States.<sup>1</sup> Most of these were for evaluation of knee, back, or shoulder symptoms and resulted in new diagnoses of musculoskeletal and connective tissue diseases such as arthropathy, spinal disorders, and rheumatism.<sup>1</sup> In 2005, two of the 10 operative procedures most commonly performed during inpatient stays were orthopedic in nature. A total of 1,005,818 inpatient stays that year involved an orthopedic surgery, usually knee arthroplasty or laminectomy.<sup>2</sup> By 2014, the number of inpatient stays involving orthopedic surgeries totaled 2,535,943 and, according to the Agency for Healthcare Research and Quality, five of the 10 most common operative procedures performed during inpatient stays, including maternal and neonatal stays, were orthopedic in nature: knee

arthroplasty, hip replacement (total and partial), spinal fusion, laminectomy, and partial bone excision.<sup>2</sup> These data suggest that nurses can expect to care for increasing numbers of patients with primary orthopedic conditions as well as medical patients with orthopedic comorbidities.

One of the most prevalent and preventable risk factors in orthopedic surgery is cigarette smoking, which puts patients at higher risk for anesthesia-related respiratory complications, including a rapid reduction in forced expiratory volume in one second (FEV<sub>1</sub>), small airway collapse, a leftward shift of the oxyhemoglobin dissociation curve, and chronic hypoxia.<sup>3</sup> In addition to posing surgical and postsurgical risks for orthopedic patients, the tobacco, nicotine, and other by-products contained in traditional and electronic cigarettes (e-cigarettes or vaping products) adversely affect overall bone health and impede bone healing. This article dis-

cusses the effects of cigarette smoking on bone health and the importance of promoting smoking cessation among patients who have orthopedic disorders or require orthopedic surgery, and suggests how nurses can support smoking cessation efforts in order to promote bone health and minimize the adverse effects of smoking on orthopedic patients.

### EFFECTS OF SMOKING ON BONE HEALTH AND HEALING

While most often associated with cancer, cardiovascular disease, and chronic obstructive pulmonary disease, cigarette smoking can damage nearly every organ in the body and has been identified as a risk factor for osteoporosis and bone fracture.<sup>4,5</sup> Smoking also has significant adverse effects on bone healing. In a study of 602 patients undergoing foot and ankle surgeries, current smokers were 4.3 times more likely than nonsmokers to develop postoperative complications, such as infections, poor bone fusion, or delayed bone formation.<sup>6</sup> A retrospective analysis of prospectively collected data on more than 35,000 adults undergoing lumbar surgery found that patients who continued to smoke 30 days after surgery were at significant risk for both wound infection and deep vein thrombosis.<sup>7</sup> And a systematic review of studies evaluating the effects of smoking on clinical outcomes after soft tissue rotator cuff repairs found that smoking was significantly associated, both clinically and statistically, with reduced healing and poor clinical outcomes following surgery.<sup>8</sup> (See *Musculoskeletal Effects of Smoking*.<sup>5-11</sup>)

**Fracture nonunion.** Smoking can significantly delay fracture union, most notably in the tibial shaft, spine, foot, and ankle, following either external or internal fixation, increasing both time to union and the chance of nonunion.<sup>9</sup> In one systematic review, the risk of long-bone fracture nonunion was found to be 12% higher in smokers than nonsmokers and mean fracture healing time was 30.2 weeks in smokers versus 24.1 weeks in nonsmokers.<sup>10</sup>

#### Musculoskeletal Effects of Smoking<sup>5-11</sup>

- Increased risk of osteoporosis and bone fracture
- Association with postoperative infection, poor bone fusion, and delayed bone formation
- Significantly raised risk of postoperative deep vein thrombosis
- Significantly increased time to union and risk of nonunion
- Significant association with reduced healing and poor clinical outcomes following surgery



In this radiograph of a distal tibia 14 months after fracture, the smooth and sclerotic line at the fracture ends (blue arrows) are signs of bone nonunion, an outcome that may be increased by smoking. The white arrow points to a small area of callus formation where limited bone healing has occurred. Published with permission from LearningRadiology.com.

### THE TOXIC EFFECTS OF CIGARETTE SMOKE

Cigarette smoke consists of approximately 500 different gases, including carbon monoxide, nitrogen, carbon dioxide, ammonia, hydrogen cyanide, and benzene, in addition to about 3,500 chemicals, including nicotine, anatabine, and anabasine.<sup>11</sup> Many of these components have toxic effects, not only on the cardiovascular and respiratory systems, but also on the musculoskeletal system, where they may interfere with cellular function, increasing skeletal fragility and fracture rates in smokers.<sup>11</sup>

**Nicotine.** Based on a literature review, Chen and colleagues suggested that nicotine may delay bone healing by activating the cholinergic antiinflammatory pathway that inhibits tumor necrosis factor  $\alpha$  expression.<sup>12</sup> When bone regeneration is delayed, recovery may be complicated by infections and subsequent fractures. Nicotine has also been found to directly affect genes involved in osteoblast differentiation and angiogenesis in bone,<sup>10</sup> possibly giving

rise to immature cells that may disrupt bone union and tissue healing. And by reducing the production of basic fibroblast growth factor and vascular endothelial growth factor, nicotine interferes with angiogenesis and bone morphogenic proteins, which facilitate bone healing in spinal fusion.<sup>13</sup>

preosteoblast mineralization and the slowing of cell migration can delay bone healing.<sup>14</sup>

#### ASSISTING PATIENTS WITH SMOKING CESSATION

An essential part of caring for orthopedic patients is assisting them in protecting their bones through

## There's some evidence that the effects of nicotine on complications of orthopedic surgery may be dose dependent.

There's some evidence that the effects of nicotine on complications of orthopedic surgery may be dose dependent. Martin and colleagues found that risk of superficial wound infection was significantly higher in patients with a smoking history of one to 20 pack-years and more than 40 pack-years, compared with patients who had never smoked, and that overall risk of morbidity was nonsignificantly higher in patients who smoked more than 40 pack-years.<sup>7</sup>

**Dioxin.** The chemical additive dioxin in cigarettes may adversely affect osteogenesis and bone regeneration independent of the negative effects of nicotine. In an in vitro study, Hashmi and colleagues performed assays on human and mouse preosteoblasts that had been treated with dioxin, nicotine, or a control substance for 21 days and then evaluated mineralization, preosteoblast migration, and cell adhesion.<sup>14</sup> Whereas dioxin had no effect on cell adhesion, it significantly reduced mineralization of preosteoblasts as well as the rate of cell migration. Nicotine had less effect on cell migration, though its effect was still significant. Both the reduction of

smoking cessation. Since smokers are at elevated risk for both bone healing and other perioperative complications,<sup>15</sup> ideally, they should be advised to abstain completely from smoking both before and after orthopedic surgeries. Nurses can assist patients in achieving this goal by

- gauging patients' knowledge of the effects of smoking on bone health and healing.
- teaching patients about the effects of smoking on bone health.
- providing patients with information on smoking cessation programs.

Baker and colleagues surveyed 237 smokers prior to foot and ankle surgery and found that 44% were unaware of smoking's negative effect on bones. They then provided the patients with information on smoking's effects and on supervised smoking cessation programs, after which 82% indicated that they were more likely to participate in a smoking cessation program.<sup>16</sup> Understanding the knowledge deficits patients may have with regard to their care can help nurses assist them in stopping smoking. Sharing resources, explaining options, and simply starting the conversation with patients about the intention to stop smoking can help.

#### The '5 A's' of Smoking Cessation<sup>17</sup>

- **Ask:** Identify and document the tobacco use status of every patient at every visit.
- **Advise:** Using motivational interviewing techniques, encourage every tobacco user to stop using tobacco products.
- **Assess:** Explore the tobacco user's readiness to make an attempt to stop using tobacco.
- **Assist:** Use counseling and pharmacotherapy to help willing patients stop tobacco use.
- **Arrange:** Within a week of the patient's scheduled quit date, follow up with an in-person or telephone contact.

#### ASSESSING NICOTINE USE

Questions about nicotine use are now part of routine health interviews. But there are no interventions that clearly lead to permanent smoking abstinence in all cases. Effective smoking cessation intervention must be individualized. Nurses can use assessment and screening tools and protocols available in their facilities. A general guideline to follow in promoting smoking cessation is the "5 A's": Ask, Advise, Assess, Assist, and Arrange.<sup>17</sup> (See *The '5 A's' of Smoking Cessation*.<sup>17</sup>) The 5 A's can be used by nurses to guide conversation during patient teaching, medication administration, and such routine encounters as a bed bath.

The Centers for Disease Control and Prevention (CDC) advises health care providers to encourage smokers to continue trying to quit until they succeed; most make multiple attempts before succeeding, but three in five U.S. adults who have ever smoked have been successful in quitting.<sup>18</sup>

Nurses can advocate for training in motivational interviewing as part of entry-level and ongoing competency, use scripts that have been proven effective in assisting patients in smoking cessation, and provide patients and caregivers with printed materials and web-based resources on smoking cessation. (See *Smoking Cessation Resources*.) A multidisciplinary team approach, including group counselors, behavioral therapists, and orthopedic team members is often required to educate patients and help them achieve sustained smoking cessation.<sup>19</sup>

#### PHARMACOLOGICAL AIDS FOR SMOKING CESSATION

**Nicotine replacement therapy.** One medical option used to promote smoking cessation in orthopedic patients is nicotine replacement therapy, which may be used in the form of a patch, gum, lozenge, inhaler, nasal spray, or some combination thereof.<sup>19,20</sup> Nicotine replacement therapy may help reduce active smokers' need for cigarettes and increase the efficacy of other smoking cessation interventions while they prepare for or recover from surgery.<sup>15</sup>

#### Smoking Cessation Resources

- **1-800-QUIT-NOW:** ([800] 784-8669)
- **American Heart Association:**  
[www.heart.org/en/healthy-living/healthy-lifestyle/quit-smoking-tobacco/help-i-want-to-quit-smoking](http://www.heart.org/en/healthy-living/healthy-lifestyle/quit-smoking-tobacco/help-i-want-to-quit-smoking)
- **Cochrane Tobacco Addiction, a list of review articles:**  
<https://tobacco.cochrane.org/our-reviews>
- **Motivational Interviewing and Tobacco Cessation:**  
[www.ihs.gov/california/tasks/sites/default/assets/File/HPDP-MotivationalInterviewing-TobaccoCessation.pdf](http://www.ihs.gov/california/tasks/sites/default/assets/File/HPDP-MotivationalInterviewing-TobaccoCessation.pdf)
- **U.S. Department of Health and Human Services:**  
<https://smokefree.gov>

illness the CDC refers to as e-cigarette or vaping product use–associated lung injury (EVALI).<sup>19,21</sup> Clinicians should maintain an open mind about nicotine substitutes and communicate honestly with their patients about their harms and benefits as they relate to bone healing and general health.

**Nonnicotine pharmacological aids.** In addition to nicotine replacement therapy, nonnicotine medical treatments are frequently prescribed to support smoking cessation. First-line nonnicotine medical aids include the nicotinic receptor partial agonist varenicline (Chantix) and the antidepressant

### Medication doses may need to be adjusted when patients who smoke more than 10 cigarettes per day either quit or resume smoking.

Although nicotine itself may negatively affect bone healing, most nicotine replacement products deliver relatively low levels of the drug and are considered preferable to smoking because they often help patients achieve smoking abstinence and cigarette smoke contains not only nicotine but numerous other toxins.<sup>15</sup>

**E-cigarettes.** While the use of e-cigarettes has increased rapidly in recent years among smokers trying to quit as well as nonsmokers, the specific effects of these products on bone health and outcomes after orthopedic surgery are still unclear. Moreover, e-cigarettes are unregulated and contain many of the known harmful toxins in traditional cigarette smoke as well as several additional harmful additives associated with a recently discovered major respiratory

bupropion (Wellbutrin SR and others), with the selection usually based on contraindications to use with certain drugs, patient comorbidities, patient preference, and cost.

In the Evaluating Adverse Events in a Global Smoking Cessation Study (EAGLES), which compared varenicline, bupropion, a nicotine patch, and placebo in more than 8,000 smokers, varenicline produced higher cessation rates at six-month follow-up than the other two interventions, which were comparable in efficacy.<sup>22</sup> All three interventions were more effective in supporting smoking cessation than placebo. Smokers who have a depressive disorder may experience added benefit from bupropion treatment, but bupropion is contraindicated in patients predisposed to seizure.

The tricyclic antidepressant nortriptyline (Pamelor) is a second-line therapy that may be used as an adjunct to first-line therapy or by patients in whom first-line agents are contraindicated. It is, however, more often associated with such adverse effects as dry mouth and sedation than the first-line agents.<sup>20</sup>

#### **MEDICATION RECONCILIATION**

Admission, transfer, discharge, and follow-up visits require medication reconciliation. Medication doses may need to be adjusted when patients who smoke more than 10 cigarettes per day either quit or resume smoking.

**Cytochrome P-450 (CYP) 1A2 substrates.** Hydrocarbons in tobacco smoke induce the hepatic isoenzyme CYP1A2, which is responsible for metabolizing and eliminating several classes of medications.<sup>23</sup> For smokers who take medications that are substrates of CYP1A2, which include duloxetine (Cymbalta, Drizalma), clopidogrel (Plavix), haloperidol (Haldol), and many others, serum drug concentrations and medication efficacy will be reduced.

**Nicotine interactions.** For some medications, there is an additional potential for interaction with

the form of structured smoking cessation interventions delivered by nurses modestly increased smoking abstinence at six months or more following initiation.<sup>26</sup> Interventions varied and included offering advice alone, reviewing benefits of and barriers to smoking cessation, discussing effective coping strategies, providing printed self-help materials, and initiating repeated follow-up.

Alternative treatments to pharmacological interventions aimed at promoting smoking cessation include acupuncture, acupressure, laser stimulation, and electrostimulation. Although these are less likely to be effective than traditional interventions, they appear to be safe when appropriately administered and may be more effective than placebo.<sup>27</sup> Successful efforts to quit smoking often involve a multifaceted approach, which underscores the importance of interprofessional collaboration.

#### **INTERPROFESSIONAL COLLABORATION**

Orthopedic teams are encouraged to work closely on implementing best practices that support smoking cessation. Education can be reinforced during presurgical screening, admission, medication administration, and physical and occupational therapy sessions. The risks of all forms of tobacco product use, as well as e-cigarettes, should be emphasized.<sup>21</sup> The practice of smoking and use of nicotine products can be mandatory fields in the assessment forms used by physicians, nurses, pharmacists, social workers, and physical therapists. Hospitals can further these efforts by partnering with community-based organizations that sponsor smoking cessation campaigns.

#### **AN IMPORTANT MODIFIABLE RISK FACTOR**

Smoking is one of the most modifiable risk factors in osteoporosis and bone fracture and has adverse effects on bone health and healing. Orthopedic patients who smoke face such potential complications as delayed bone healing, infection, fractures, and bone nonunion. At every health care visit, providers should remind orthopedic patients about the importance of smoking cessation to bone health and help them explore smoking cessation options. When patients are ready, providers can help them set goals, develop an action plan, identify smoking triggers, celebrate successes, and maintain their goal of remaining a nonsmoker. ▼

For eight additional continuing education activities on the topic of bone health and smoking cessation, go to [www.nursingcenter.com](http://www.nursingcenter.com).

## **Smoking is one of the most modifiable risk factors in osteoporosis and bone fracture.**

nicotine. For example, clearance of the antihypertensive drug propranolol (Inderal, Innopran) is increased by 77% in smokers because of side-chain oxidation and glucuronidation,<sup>24</sup> which can cause serum levels to drop too low to control blood pressure effectively.

**Toxic interactions.** Serum concentrations of certain drugs may rise to toxic levels when a person quits smoking cigarettes. If a CYP1A2 inhibitor, such as amlodipine (Norvasc) or cimetidine (Tagamet), was already part of the former smoker's regimen, the possibility that other drugs metabolized by the CYP1A2 pathway will rise to toxic levels is increased.<sup>25</sup>

#### **PROVIDING BEHAVIORAL SUPPORT**

Nurses play an active role in creating evidence-based guidelines for managing nicotine withdrawal and implementing smoking abstinence algorithms. A meta-analysis of studies of smoking cessation interventions indicated that behavioral support in

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