Osteoporosis and the Nature of Fragility Fracture: An Overview

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The main consequence of osteoporosis is that it is a condition in which bone mass is depleted and bone structure is destroyed to the degree that bone becomes fragile and prone to fractures. For affected patients, these 'fragility fractures' are associated with substantial pain and suffering, disability and even death, along with substantial costs to society. The problems created by fragility fractures and osteoporosis are multifactorial in origin and are, therefore, a multidisciplinary problem. A first fragility fracture is often the early sign of osteoporosis, and 'secondary' prevention of fragility fractures is focused on the prevention of further fractures once an initial fracture has occurred. Nurses play a key role in education and guidance of patients with osteoporosis. This chapter will provide an overview of how osteoporosis and fragility fractures are linked, with a focus on fracture prevention.

1.1 Learning Outcomes

At the end of the chapter, and following further study, the nurse will be able to:

- Explain the basics of bone biology and its relationship to osteoporosis and fragility fractures.
- Describe the most common fragility fractures and their impact on individuals.
- Undertake fracture risk assessment and recognise and modify the fixed and modifiable risk factors using the FRAX© calculation tool.

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- Educate communities and individuals about osteoporosis diagnosis and treatment and advise on lifestyle.
- Outline the goals and benefits of osteoporosis treatment, and support individuals during treatment.

1.2 Bone Biology

The human skeleton gives structure to the body and protects organs, makes motion and mobility possible by attachment to muscles via tendons and ligaments, stores and releases minerals and, in the bone marrow, manufactures blood cells. About 80% of the skeleton is cortical (or compact) bone that forms the outer structure of the shafts of long bones. Trabecular bone (20%) is mainly present in the ends of long bones and in the centre of the vertebrae and ribs. Bone undergoes a lifelong process of replacement; mature bone is replaced with new. This regulated process of 'bone turnover' maintains a balance between bone resorption and formation to maintain skeletal integrity [1] and results in replacement of 5–10% of the skeleton each year and the total skeleton every decade [2].

Remodelling involves three types of cells; osteoblasts (bone builders), osteoclasts (bone eaters) and osteocytes, and is a continuous interaction between hormones, minerals and bone cells that is influenced by; (1) changes in calcium levels in the blood, (2) pressure/strain on the bones caused by gravity and the action of muscles and (3) hormones (oestrogen, testosterone and growth hormone).

In youth, bone formation exceeds resorption, so bone mass and strength increase. Peak bone mass is achieved between the ages of 20 and 25 years [3]. At 30–40 years, bone mass gradually decreases as bone resorption exceeds bone formation. It is estimated that, by the age of 80, total bone mass is ±50% of its peak [4]. When the balance tips towards excessive resorption, bones weaken (osteopenia) and, over time, can become brittle and at risk of fracture (osteoporosis) [5].

1.3 Osteoporosis

Osteoporosis is a common chronic systemic skeletal disease that is 'characterised by low bone mass and microarchitectural deterioration of bone tissue, with a consequent increase in bone fragility and susceptibility to fracture' [6] (see Fig. 1.1). It is a devastating disease that can lead to pain, severe disability and premature death from fracture. As bones become more porous and fragile, the more the risk of fracture is increased. Patients are often unaware they are at risk of or have osteoporosis because bone loss occurs silently and progressively without signs or symptoms until fractures occur.

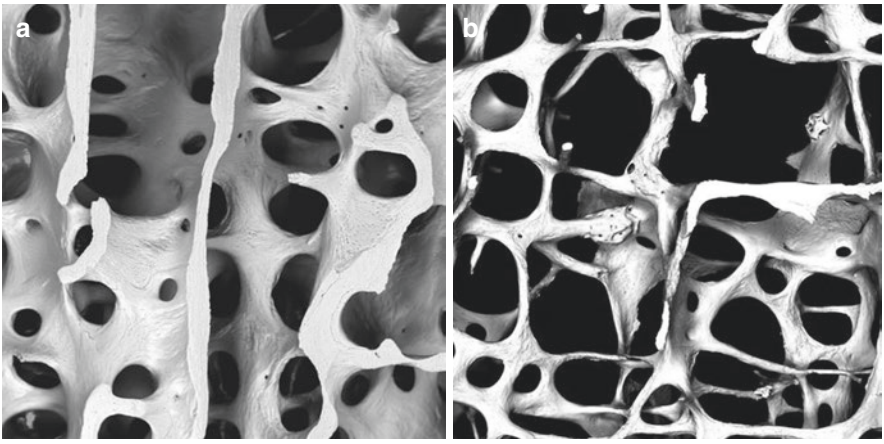

Fig. 1.1 Microscopic structure of normal and osteoporotic bone (**a**) Normal bone and (**b**) Osteoporotic bone (©Alan Boyde 2018 with permission)

1.4 Epidemiology

Osteoporosis is a global problem, but the size of the problem is unclear because of the variability in assessment and awareness. In Europe, India, Japan and the USA, there are an estimated 125 million people suffering from osteoporosis. Globally, one in three women and one in five men will experience a fragility fracture resulting in a hospital visit every 3 s. In 2010, in the EU alone, 22 million women and 5.5 million men were estimated to have osteoporosis, resulting in 3.5 million new fragility fractures, comprising 610,000 hip fractures, 520,000 vertebral fractures, 560,000 forearm fractures and 1,800,000 other fractures. The economic burden was estimated at €37 billion and is still rising [7]. After hip fracture, for example, 40% of patients cannot walk independently, 80% cannot perform basic activities such as shopping independently, and 10–20% need permanent residential care [8]. The number of people living with osteoporosis in all global regions will increase dramatically in the coming decades due to ageing populations and lifestyle changes. The costs are expected to increase by 25% by 2025.

1.5 Fragility Fracture and Osteoporosis

'Fragility fractures occur as a result of "low energy trauma", often from a fall from standing height or less, that would not normally result in a fracture' [9] and they are a major public health problem; one occurs globally every 3 s, with high human and socio-economic impact, morbidity, mortality and costs. For individuals, fractures

frequently result in loss of autonomy, deterioration in quality of life and need for care. A fragility fracture may be defined as a pathological fracture that results from minimal trauma (e.g. a fall from a standing height) or no identifiable trauma at all [8]. The fracture is both a sign and a symptom of osteoporosis.

Typical fractures in patients with osteoporosis include vertebral (spine), proximal femur (hip), distal forearm (wrist) and proximal humerus [10]. Wrist fractures are the third most common type of osteoporotic fractures, accounting for up to 18% of all fractures among the elderly [11], and their impact on quality of life due to complications and impaired function is often underestimated. These distal forearm fractures are often 'the first' fragility fracture, followed by a subsequent hip or vertebral fracture.

Hip fractures are the most serious fractures. Although a woman's risk of dying from a hip fracture is high, and exceeds the lifetime risk of death from breast cancer, uterine cancer and ovarian cancer combined, the mortality risk after a hip fracture is even higher for a man. Hip fracture nearly always requires hospitalisation and is fatal in almost a quarter of all cases. For those who survive, most do not regain their pre-injury level of function, and 30% experience loss of independence. Dependency is greatly feared by patients and is costly to their family and to society [12]. If a first fragility fracture is recognised and osteoporosis treated, the risk of a future fracture can be reduced by approximately 50%, preventing the downward spiral in health and quality of life that often follows hip fracture.

Vertebral fractures are the most common manifestation of osteoporosis and are usually diagnosed when a patient presents with back pain and has a spinal X-ray that shows vertebral body fracture. Patients may have spinal fractures but never be aware of them; only 25% are clinically diagnosed as they are often asymptomatic or mildly symptomatic. Hence, although they are common, the majority do not come to attention at the time they occur, so vertebral fractures in older adults are associated with an increased mortality, often due to frailty (Chap. 2) [13]. Recognised vertebral fractures are usually treated non-surgically with a brief period of bed rest, pain medication, bracing and physiotherapy. Approximately 40% of patients develop chronic disabling pain and/or spinal deformity (kyphosis) resulting in reduced pulmonary function associated with increased risk of mortality. Vertebral fractures increase the risk of sustaining future fractures fivefold, so it is important to identify them and start treatment. If a vertebral fracture occurs when patients are already being treated for osteoporosis, therapy requires evaluation and adjustment.

It is important to identify patients with increased fracture risk. Nurses can play a key role in assessing risk factors while obtaining a medical history when patients attend for hospital treatment following a fracture. Investing in fracture risk assessment and education for risk reduction is an important potential intervention. Following assessment of risk factors and lifestyle change education, measures can be taken to impact on modifiable risk factors and meet the individual's need for information and education.

1.5.1 Risk Factors

Risk factors for osteoporosis and fracture can be divided into two categories. Fixed risk factors (listed in Box 1.1) cannot be modified but help to identify patients with high fracture risk [14].

Box 1.1: Fixed Risk Factors for Osteoporosis [15]

Age: from 50 years, fracture risk increases, with doubling of risk for every decade thereafter because bone mineral density decreases and other risk factors such as falling or comorbidities increase.

Female gender: women are more at risk of developing osteoporosis due to menopausal decrease in oestrogen. Women have a lower peak bone mass than men.

Family history of osteoporosis: having a parent with a hip fracture at any time in their lives is associated with an increased risk of fracture (independent of bone mineral density).

Previous fracture: doubles the risk of a second fracture in both men and women.

Ethnicity: Caucasian and Asian people have a higher incidence of osteoporosis and fractures of the hip and spine.

Menopause: osteoclasts are more active, and bone loss increases due to decrease in oestrogen levels following menopause or oophorectomy.

Long-term glucocorticoid therapy: increases bone loss and impairs bone formation and calcium absorption and muscle weakness can increase the risk of falling.

Rheumatoid arthritis: inflammatory cytokines and impaired mobility increase bone loss.

Primary/secondary hypogonadism in men: rapidly increases bone loss due to normal ageing or following orchidectomy or androgen deprivation therapy.

Secondary risk factors: disorders and medications that make the bone more fragile and/or effect balance (increasing risk of falling). Also including immobility, inflammatory bowel diseases, eating disorders and endocrine disorders.

Most modifiable risk factors (listed in Box 1.2) directly impact on bone biology and result in a decrease in bone mineral density, but can also increase the risk of fracture independently of their effect on bone itself. Nurses can educate and guide patients towards healthier lifestyles to reduce these risk factors.

Box 1.2: Modifiable Risk Factors for Osteoporosis [14]

Alcohol: Excessive alcohol consumption (>2 U daily) increases the risk of a fracture by 40% due to direct adverse effects on osteoblasts and parathyroid hormone levels (regulates calcium metabolism); associated with poor nutritional status (calcium, protein and vitamin D deficiency) [15].

Smoking: The exact mechanism is unknown, but increased fracture risk is reported when there is a history of cigarette smoking [16].

Low body mass index (BMI): Regardless of age, sex and weight loss, BMI <20 kg/m^2 is associated with a twofold increased risk of fracture compared to people with a BMI of 25 kg/m^2.

Poor nutrition: Inadequate intake of calcium, vitamin D or both will influence calcium-regulating hormones; deficiency of either calcium or vitamin D will result in impaired calcium absorption and lower concentration of circulating calcium; parathyroid hormone (PTH) secretion is stimulated, increasing PTH levels and leading to an increase in bone remodelling, significant loss of bone and increased risk of fracture.

Vitamin D deficiency: Vitamin D plays an essential role in calcium absorption; it is made in the skin when exposed to the sun's ultraviolet rays (10–15 min a day is usually sufficient); food sources (see Chap. 8) or supplemental sources of vitamin D are beneficial [17].

Eating disorders: Due to poor nutrition and vitamin D deficiency and obtaining a lower peak bone mass in early adulthood.

Oestrogen deficiency: Accelerates bone loss and reduces the build-up of bone mass; related to both hormone imbalance (e.g. menopause) and nutritional factors.

Insufficient exercise: Due to sedentary lifestyle (e.g. women who sit down for > 9 h/day are 50% more likely to fracture a hip than those who sit for <6 h/day); bone remodelling is regulated by mechanical load; load-bearing physical activity and muscle activity; placing tension and torsion on bone is detected by osteocytes.

Low dietary calcium intake: (See Chap. 8.)

Frequent falls: Factors that increase risk of falling (see Chap. 3).

Low bone mineral density (BMD), one of the most important indicators of fracture risk, is both a fixed and modifiable risk factor determined by a wide range of factors, including family history, age and lifestyle. Prevention of osteoporosis starts in youth by gaining a sufficient peak bone mass; it is estimated that a 10% increase in the peak bone mass of children reduces the risk of an osteoporotic fracture during adulthood by 50%. Children should be encouraged to exercise and play outside and should be given vitamin D supplements (within national guidelines) alongside a healthy diet with sufficient calcium intake. When an individual is diagnosed with osteoporosis, prevention is no longer about gaining a higher bone mass but preventing fractures. Treatment of osteoporosis consists of prescription of specific anti-osteoporosis medication and calcium and vitamin D supplements in combination with healthy lifestyles.

Nurses can play a key role in fracture prevention by identifying patients at risk, educating patients about healthy diet, recommending adequate uptake of vitamin D, encouraging regular weight-bearing activity and supporting smoking cessation and alcohol consumption reduction.

Diagnosis and treatment of osteoporosis include; (1) case finding, (2) risk evaluation, (3) differential diagnosis of secondary osteoporosis, (4) therapy/treatment and (5) follow-up.

1.5.2 Diagnosis

All nurses who provide care to older people and those who have already sustained a fragility fracture should be aware of the possibility of their patients having osteoporosis and an increased risk of a next fracture (Table 1.1). They must know how to assess and modify the risk factors, why and how osteoporosis is diagnosed and how to ensure that proper referrals are made to other members of the multidisciplinary team.

Patients who have been diagnosed with this chronic condition need support in developing coping strategies. Most newly diagnosed patients are afraid of sustaining another fracture and feel vulnerable, sometimes leading to a paralysing fear of falling. Patients with advanced osteoporosis often experience decreased ability to perform activities of daily living and suffer from chronic back pain along with depression, loss of self-esteem, disability and increasing physical dependence. Nurses can advocate and educate by helping patients to maintain function and improve quality of life [18] and can refer patients to national osteoporosis associations for further information and support.

1.5.3 Case Finding

Case finding involves opportunistically identifying patients with osteoporosis when they present with a first fracture, using the fracture (a risk factor itself) as the starting point. This is the first step towards identifying those patients most urgently in need of fracture prevention through one of two approaches:

- *Primary prevention*: preventing the first fracture by identifying patient risk factors and starting treatment; often in primary healthcare settings where there may be a lack of structured or organised programmes.
- *Secondary prevention*: preventing a second fracture after the first; assessment and treatment is performed in hospitals using structured programmes such as fracture liaison services (FLS) (Chap. 3) and often initiated in the emergency department (ED).

1.5.4 Risk Evaluation

Bone mineral density (BMD) is a measure of bone strength estimated by dual-energy X-ray absorptiometry (DXA). Low BMD is the strongest risk factor for

fracture. Clinical diagnosis of osteoporosis is based on BMD measurements and the presence of fractures [19]; BMD is transformed into a T-score, which reflects the number of standard deviations (SD) above or below the mean in healthy young adults. The thresholds for each bone category are shown in Table 1.1.

The DXA scan gives an *estimation* of bone strength by measuring the BMD in g/cm^2 in an area of the lumbar spine (L1–4), the proximal femur and hip with little or no radiation exposure (20 μSv). Every decrease of 1 SD increases the risk of a fracture approximately twofold [20]. The cortical and trabecular structures of the bone are also associated with fragility fractures, highlighting that fracture risk is not only about BMD but must be approached as multifactorial. DXA measurements can be negatively influenced by failing to position the patient properly, recent ingestion of barium for abdominal investigation, presence of vertebral fractures in the L1–4 region, hip prostheses, degenerative skeletal problems and severe arterial calcifications.

As vertebral fractures are often asymptomatic, it is essential to identify them during assessment. Most DXA scanners can also perform an additional investigation of the spine at the same time, Vertebral Fracture Assessment (VFA). The results are methodically assessed according to the Genant classification (Table 1.2). The presence of a vertebral fracture is always a sign of impaired bone strength, a predictor of a next fracture and an indication for treatment. Vertebral fractures can also be identified by X-ray when VFA is inconclusive or not available.

Another way to estimate the risk of fracture is by using the FRAX© calculation tool, a validated web-based risk assessment tool in the form of a questionnaire (12 questions) that calculates the 10-year risk of fracture based on individual risk factors with or without a known BMD. FRAX© is integrated into many national guidelines, is available in multiple languages, is easy and quick to use and is available to any healthcare professional through a website and mobile applications. It can assist in targeting patients needing intervention and can be used by all [21].

Table 1.1 WHO criteria for clinical diagnosis of osteoporosis [19]

BMD T-score	Diagnosis
T-score ≥ −1 SD	Normal
−1 > T-score > −2.5 SD	Low bone mass/osteopenia
T-score ≤ −2.5 SD	Osteoporosis
T-score ≤ −2.5 SD with existing fracture	Severe osteoporosis

Table 1.2 Genant classification

Normal vertebra	Grade 0		
Mild fracture	Grade 1	−20–25%	Wedge, biconcave or crush
Moderate fracture	Grade 2	−25–40%	Wedge, biconcave or crush
Severe fracture	Grade 3	≥−40%	Wedge, biconcave or crush

1.5.5 Differential Diagnosis of Secondary Osteoporosis

Approximately 30% of women and 50% of men with osteoporosis have secondary osteoporosis that may be known or hidden and is caused by specific clinical conditions (Box 1.3). Treating the cause can decrease fracture risk and avoid unnecessary treatment [22], so every patient with a fragility fracture and a low BMD should have a baseline blood test for bone and mineral metabolism (calcium, phosphate, alkaline phosphatase, 25-hydroxyvitamin D, parathyroid hormone), liver and kidney function, full blood count and thyroid-stimulating hormone.

Box 1.3: Examples of Disorders Associated with Secondary Osteoporosis

- Diabetes mellitus
- Cushing's syndrome
- Hyperparathyroidism
- Hyperthyroidism
- Premature menopause
- Hypogonadism
- Celiac disease
- Inflammatory bowel disease
- Liver cirrhosis
- Rheumatoid arthritis
- Ankylosing spondylitis
- Systemic lupus erythematosus
- Anorexia nervosa

1.5.6 Treatment

Many patients are unaware they have osteoporosis until after their first fracture, but even after a fracture, it often goes untreated. This international 'treatment gap' means fewer than 20% of those who sustain a fragility fracture receive therapies to reduce the risk of fracture within the year following the fracture [23]. Treatment of osteoporosis is a combination of medication, lifestyle choices, adequate intake of calcium and vitamin D and prevention of falls.

The goal of osteoporosis medication is to *prevent fractures* (not to increase the DXA numbers). Fracture risk can be reduced by approximately 50% with optimal treatment of osteoporosis that consists of:

- Specific anti-osteoporosis medication (agreed through shared decision-making)
- Adequate intake of calcium and vitamin D (dietary or supplements)
- Attention to lifestyle factors (hand in hand with prescribed drug treatment)
- Fall prevention (when relevant)
- Follow-up (plan is known by the patient).

1.5.6.1 Medication to Reduce Fracture Risk

There are various medications used to treat osteoporosis, all having different entry points, but they all have the same goal: preventing fractures. The most common approved treatments will be considered here including:

- Bisphosphonates (alendronate, ibandronate, risedronate and zoledronic acid) (oral or intravenous)
- 'Selective oestrogen receptor modulators' (SERM) (raloxifene, bazedoxifene; oestrogen 'agonist/antagonist' drugs that act like oestrogen in bone but in the uterus and breast tissue act like an oestrogen blocker)
- Parathyroid hormone (teriparatide): stimulates (new) bone formation, resulting in increased BMD (daily subcutaneously injection)
- Monoclonal antibody (denosumab): reduces bone turnover by inhibiting the maturation of osteoclasts (subcutaneously every 6 months).

While the development of new treatments is ongoing, the most commonly prescribed are bisphosphonates which attach to bone tissue and reduce bone turnover by suppressing the activity of osteoclasts, often referred to as 'anti-resorption' therapy. The drug must be taken regularly for a minimum of 5 years initially and is combined with calcium and vitamin D supplements. Oral bisphosphonates are poorly absorbed (only approximately 1% of each dose), even with total compliance and proper administration. When administered orally, bisphosphonates must be taken according to the following instructions:

- In the morning, on an empty stomach
- At least 30 min before any food or drink
- Swallowed whole with a large glass of tap water
- The patient must remain upright for at least 30 min
- Any calcium-containing supplements must be delayed for 3–4 h.

Proper follow-up improves adherence and compliance with treatment and facilitates monitoring of the treatment goal - fracture prevention. At the start of treatment, patients must be aware of the duration, the goal and benefits, for how long the medication must be taken and from whom to seek support when problems such as side effects occur. Many patients fail to persist with their treatment, and many others experience a suboptimal response due to unintentional poor compliance or impaired absorption. Approximately 50% of all patients who start treatment stop within the first year [24]. It is important to check regularly that patients are following the instructions and are continuing to take their treatment properly. Despite the wishes of most patients to measure the effect of the treatment short term, it is not recommended to make periodic measurements of BMD by DXA because BMD changes as a result of osteoporosis treatment occur slowly and the magnitude of measurement error with DXA is similar to the short-term change in response to treatment. An alternative approach is to measure biochemical markers of bone turnover in blood or urine samples. These show large and rapid changes in response to osteoporosis treatment, allowing detection of a significant treatment response within a few months.

Another factor in poor compliance is fear of side effects. In oral treatments, gastrointestinal complaints are a common reason for patients to stop the treatment without talking to their health practitioner. It is important that patients report side effects so that further treatment options can be discussed. A rare, but feared, side effect is osteonecrosis of the jaw (ONJ); the risk can be reduced by good oral hygiene and regular dental care.

All patients will have an individual treatment plan through life depending on the significance of their fracture risk, the type of medication and lifestyle changes. The duration of the different therapies varies, and there is no uniform recommendation that applies to all patients. After a period of treatment, re-evaluation of the risk should be performed, consisting of DXA, VFA (or X-ray of the spine) and fracture risk assessment. Treatment of osteoporosis is sometimes difficult for patients to understand, meaning that treatment plans sometimes fail. Patients need to know from diagnosis that osteoporosis is a chronic condition but that treatment duration is limited (bisphosphonates treatment is 3–5 years). Good understanding of diagnosis and fracture risk is important because patients can then make informed choices regarding treatment and lifestyle changes. Adherence and compliance are often low due to lack of knowledge, lack of guidance, invalid values and beliefs regarding therapies, side effects and the fact that patients do not 'feel' the benefits of the treatment, i.e. not having a fracture.

Nurses play a key role in improving compliance and adherence through specific nursing interventions including:

- Education about the treatment goal and benefits
- Education about the prescribed drug regimen and recognising significant adverse reactions
- Instructing the patient to report side effects
- Advising patients on how to properly administer the medication
- Assessing and supporting compliance and adherence
- Informing and recording for how long patients have to take their medication
- Scheduling fracture risk re-evaluation
- Advising on lifestyle modification regarding diet and exercise
- Advising on good oral hygiene and regular dental care
- Advising on prevention of falls (see Chaps. 2 and 3)
- Referring patients to national osteoporosis associations for support.

1.5.7 Suggested Further Study

To effectively provide care to patients with or at risk of fragility factures, it is essential that nurses have extensive and up-to-date knowledge of osteoporosis, its prevention and management. Individual further study should be conducted using the following:

- Talk to patients and their families about the impact of sustaining a fragility fracture due to osteoporosis. Reflect on these conversations, and search for evidence-based literature about improving care and outcomes.
- Expand knowledge by taking an online course, and use this to assess knowledge and performance anually.

- Read and make notes from books, articles and national or international guidelines on osteoporosis and fracture prevention. The following are examples, but many other options exist.

Online Courses

https://nos.org.uk/for-health-professionals/professional-development/e-learning-and-training/ — an interactive training course enabling any clinician to improve their knowledge and ability to deliver excellent healthcare to people with, or at risk of, osteoporosis and fragility fractures

https://www.cme.nof.org/BoneSource™ - NOF's professional programme, promotes excellence in clinical care for all healthcare professionals involved in the prevention, diagnosis and treatment of osteoporosis

Example Websites

www.capturethefracture.org/
www.iofbonehealth.org
www.nos.org.uk
www.nof.org

Suggested Reading

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1.5.8 How to Self-Assess Learning

- Discuss within the local team if national guidelines for osteoporosis treatment and prevention and fragility fracture prevention are implemented correctly
- Conduct peer-review sessions within the team identifying how team performance impacts on patient outcomes and develop action plans for how practice can be improved
- Undertake assessments contained within online courses listed above.

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