Journal of Chemical Health Risks

www.jchr.org

JCHR (2025) 15(6), 1497-1507 | ISSN:2251-6727

Postmenopausal Osteoporosis Care: Shifting Paradigms and Emerging Therapies

Juhi Deshpande;MS[1]*, Chanchal Kumar Singh;MS[2]

1 – Associate Professor, Department of Obstetrics and Gynecology, Baba Kinaram Autonomous State Medical College, Chandauli.

2 – Assistant Professor, Department of Orthopedics, Institute of Medical Sciences, Banaras Hindu University, Varanasi.

(Received: 27 September 2025 Revised: 05 October 2025 Accepted: 25 November 2025)

KEYWORDS

bone health, Osteoboost, osteopenia, Osteoporosis, postmenopausal, T-score

ABSTRACT:

Introduction: Osteoporosis, a chronic condition predominantly affecting postmenopausal women, significantly impairs quality of life. While conventional treatments prevail, emerging alternative therapies offer promising solutions for enhanced bone health.

Methodology: This review synthesizes evidence from multiple databases, encompassing traditional therapies (bisphosphonates, calcium, and vitamin D supplementation) and innovative approaches (vibration therapy and bone-building devices like Osteoboost).

Results: Findings confirm the efficacy of traditional treatments in maintaining bone density and reducing fracture risk. Notably, novel therapies demonstrate potential for bone regeneration without medication.

Conclusion: Traditional therapies remain essential, while alternative approaches like vibration therapy offer innovative options for osteoporosis management. Further research is warranted to optimize these therapies and improve patient outcomes.

Abbreviations: BMD = bone mineral density, BPs = bisphosphonates, FDA = Food and Drug Administration, HRT = Hormone Replacement Therapy, PTH = parathyroid hormone, RANKL = receptor activator of nuclear factor-κB ligand, TNF-α = tumor necrosis factor-alpha, WHO = World Health Organization.

1. Introduction

Osteoporosis is a metabolic bone disease characterized by decreased bone mineral density and mass, leading to an increased risk of bone fractures in adults [1,2]. This condition is often referred to as a "silent disease" because bone loss occurs without noticeable symptoms until fractures occur, with osteoporosis being the underlying cause of up to two-thirds of vertebral fractures [3].

Osteoporosis is a prevalent disease, affecting approximately one-third of women and one-fifth of men worldwide over the age of 50 [4]. According to a 2021 meta-analysis, the global prevalence of osteoporosis is 18.3% (95% CI: 16.2-20.7), with a significantly higher prevalence among women (23.1%, 95% CI: 19.8-26.9) compared to men (11.7%, 95% CI: 9.6-14.1) 5. Furthermore, research has shown that women aged 50 and above are four times more likely to develop osteoporosis and twice as likely to experience osteopenia, with fractures occurring 5-10 years earlier than in men [6].

The global prevalence of osteoporosis is alarmingly high, with disproportionately higher rates in Africa and Europe [5]. According to the World Health Organization (WHO), approximately 200 million women worldwide suffer from osteoporosis, with a staggering 30% of postmenopausal white Caucasian women in the USA affected [4,7].

A study assessing the global burden of osteoporosis revealed that in 2019, five countries bore the highest burden of disability-adjusted life-years due to low bone mineral density-related fractures. These countries were India, China, the USA, Japan, and Germany, accounting for 25.59%, 18.75%, 8.35%, 3.29%, and 3.04% of the global burden, respectively [8].

The diagnosis of osteoporosis and assessment of fracture risk rely on bone mineral density (BMD) as the standard measure. Dual-energy X-ray absorptiometry (DXA) scans measure BMD and generate a T-score, which the World Health Organization (WHO) uses to define osteoporosis. According to WHO criteria:

Journal of Chemical Health Risks

www.jchr.org

JCHR (2025) 15(6), 1497-1507 | ISSN:2251-6727

- Normal bone density: T-score within 1 standard deviation (SD) of the young adult mean BMD (−1 to +1 SD)

- Low bone mass: T-score 1-2.5 SD below the young adult mean BMD (−1 to −2.5 SD)

- Osteoporosis: T-score 2.5 SD or more below the young adult mean BMD (more than −2.5 SD) [9]

Osteoporosis significantly impairs quality of life, substantially increasing the risk of fractures. Studies have shown that patients with osteoporotic fractures experience lower health-related quality of life and overall health status 10. Fractures are associated with increased premature mortality, disability, and financial burden [11,12]. Various environmental factors influence the risk of osteoporotic fractures, such as smoking, which is an independent risk factor in postmenopausal women, whereas physical activity promotes bone mass retention [13].

Osteoporosis has far-reaching consequences on both health and economics, primarily due to fragility fractures affecting the hip, spine, and wrist. These fractures lead to substantial morbidity, including chronic pain, reduced mobility, and psychological effects like depression and social isolation. The economic burden is equally severe, with estimated global direct and indirect costs of hip fractures projected to rise from $34.8 billion in 1990 to $131.5 billion by 2050 [14].

Additional risk factors for osteoporosis in postmenopausal white or Caucasian women include low calcium intake, heavy alcohol consumption, and use of long half-life psychotropic drugs. Protective factors include vitamin D intake, fluoride in drinking water, breastfeeding, and use of thiazide diuretics or progesterone [15].

Bone strength depends on various factors, including bone structure, cortical bone thickness, and inherent bone tissue qualities. Dual-energy X-ray absorptiometry (DXA) measures bone mineral density (BMD) to indirectly assess bone strength [16]. The Fracture Risk Assessment Tool combines clinical risk factors with BMD T-scores to evaluate the likelihood of future fractures [17]. Clinical risk factors include demographic details, medical history, and lifestyle elements such as smoking and alcohol consumption [17].

In 1999, the Bone Health and Osteoporosis Foundation published the Clinician's Guide, a comprehensive resource for osteoporosis prevention and treatment. The guide provides concise guidelines on prevention, risk assessment, diagnosis, and management, including fracture risk thresholds for pharmaceutical intervention [18]. Despite advancements in diagnostics and treatments, postmenopausal women with osteoporosis continue to experience a diminished quality of life, emphasizing the need for effective preventive strategies.

Current treatment options encompass both pharmacological and non-pharmacological approaches to prevent fractures. However, these treatments are not universally suitable. Calcium and vitamin D supplementation can enhance bone density, but may be less effective in patients taking levothyroxine for thyroid disease due to decreased absorption [19]. Hormone replacement therapy for postmenopausal women remains controversial due to its numerous side effects [20]. Bisphosphonates, widely prescribed for postmenopausal osteoporosis, can improve bone mineral density but are also associated with various side effects, including infusion reactions, hypocalcemia, and gastrointestinal adverse effects.

The Food and Drug Administration (FDA) has made two significant announcements regarding the management of osteoporosis, signaling a shift in treatment strategies. Firstly, the FDA has introduced a "Boxed Warning" for Prolia (denosumab), highlighting the increased risk of severe hypocalcemia in patients with advanced chronic kidney disease [22]. Secondly, the FDA has approved "Osteoboost," a wearable belt designed to deliver calibrated vibration to the hips and lumbar spine, which is expected to prevent decreases in bone density in postmenopausal women [23].

This review aims to critically evaluate the current treatment options available for osteoporosis, comparing traditional treatment approaches prior to 2019 with recent advancements from 2019 onwards.

2. Methods

A thorough literature search was conducted using PubMed and Google Scholar to investigate emerging strategies for managing osteoporosis in postmenopausal women. The search employed specific terms, including "osteoporosis," "postmenopausal women," "bone

Journal of Chemical Health Risks
www.jchr.org
JCHR (2025) 15(6), 1497-1507 | ISSN:2251-6727

density," and "fracture prevention," along with MeSH terms and Boolean operators. The search encompassed in vitro, in vivo, and human studies, without temporal restrictions.

Studies were screened based on predefined inclusion criteria, which comprised research focusing on osteoporosis management in postmenopausal women, encompassing both traditional and innovative approaches, and published in English. Exclusion criteria consisted of irrelevant topics, editorials, and commentaries. Selected articles underwent in-depth review, and additional pertinent studies were identified through reference lists. Relevant data were extracted and synthesized to provide a comprehensive overview of traditional and innovative management strategies, including the integration of advanced technologies in osteoporosis care.

3. Pathophysiology

At the cellular level, the decline in sex steroids and aging lead to an imbalance in bone remodeling, characterized by increased bone resorption and decreased bone formation by osteoclasts and osteoblasts, respectively [24,25]. Pro-inflammatory cytokines, such as TNF-α, IL-1, IL-6, and the RANKL/RANK/Osteoprotegerin system, play a crucial role in osteoclast differentiation and are linked to estrogen deficiency in the bone microenvironment [26].

The RANKL peptide, expressed by osteocytes, interacts with the RANK receptor on osteoclast precursors, promoting their differentiation into mature osteoclasts. Macrophage colony-stimulating factor, produced by osteoblasts, also contributes to osteoclast precursor differentiation [27,28]. Additionally, osteoblast-derived chemokines facilitate osteoclast precursor recruitment and degradation of unmineralized osteoid by matrix metalloproteinases [28]. Osteoclast-secreted hydrogen ions and lysosomal enzymes drive acidification and proteolysis, leading to bone resorption [29].

However, Osteoprotegerin can inhibit RANK-RANKL interactions, reducing bone resorption by preventing osteoclast differentiation and promoting apoptosis. In age-related osteoporosis, altered Bone Marrow Stromal Cell (BMSC) lineage distribution leads to increased adipocyte differentiation, resulting in an accumulation of Bone Marrow Adipose Tissue. This impairs osteoblast differentiation and bone formation [30].

4. Traditional treatment

4.1 Vitamins

Maintaining optimal bone health relies heavily on adequate calcium and vitamin D intake [31]. High-calcium foods, supplements, and sunlight exposure are recommended, particularly for high-risk groups such as older individuals and those on glucocorticoid therapy. While daily supplementation with 800 IU of vitamin D and 1000-1200mg of calcium is generally recommended for postmenopausal women, individualized dosages may be necessary [32]. Research has shown that calcium and vitamin D supplementation can moderately reduce bone loss in women aged 65 and older [33]. However, caution is advised when using calcium supplements in postmenopausal women with dyslipidemia, as they may increase serum total cholesterol concentration and carotid intima thickness [34].

Studies have revealed a positive correlation between water-soluble vitamins and bone mineral density (BMD), while fat-soluble vitamins were negatively associated with BMD [35]. Other essential nutrients, including magnesium, potassium, and polyunsaturated fatty acids, also contribute to bone health, emphasizing the importance of a balanced diet [36]. Emerging research suggests that supplementation with B vitamins, omega-3 fatty acids, soy isoflavones, and dehydroepiandrosterone may offer additional benefits for bone health improvement and osteoporosis risk reduction when consumed as part of a well-rounded diet [37,38]. Regular follow-up and personalized dietary plans are crucial for comprehensive bone health management.

4.2 Lifestyle modification

Lifestyle modifications play a crucial role in maintaining bone health and preventing osteoporosis. High-intensity resistance training has been shown to significantly improve bone mineral density (BMD) at the lumbar spine and femoral neck, while regular walking benefits femoral neck BMD [39]. Interestingly, low to moderate-intensity physical activity is considered more effective than high-intensity exercises for optimizing BMD.

Regular exercise has been proven to decrease the risk of osteoporosis in postmenopausal women [40]. Moreover,

Journal of Chemical Health Risks
www.jchr.org
JCHR (2025) 15(6), 1497-1507 | ISSN:2251-6727

fall prevention measures are essential in reducing fracture risks associated with osteoporosis. These measures include exercises to improve balance and strength, home modifications, and the use of aids like grab bars. Healthcare providers should encourage these lifestyle changes to support bone health and prevent complications [41-44].

4.3 Medications

Various medications are available for the management of osteoporosis, each with distinct mechanisms of action. Bisphosphonates (BPs) inhibit bone resorption, while Denosumab neutralizes RANKL, a protein involved in bone breakdown. Teriparatide, on the other hand, stimulates bone remodeling, promoting new bone growth.

Other treatment options include estrogen agonists, calcitonin, and hormone therapy, which may also be effective in managing osteoporosis. A thorough understanding of the mechanisms and efficacy of these medications enables healthcare providers to develop personalized treatment approaches tailored to individual patient needs.

4.3.1 Bisphosphonates

For postmenopausal women at high risk of fractures, initial treatment with bisphosphonates (BPs) or denosumab is recommended [45]. BPs, including alendronate, risedronate, zoledronic acid, and ibandronate, bind to bone minerals and are internalized by mature osteoclasts at bone resorption sites [46]. Aminobisphosphonates, which contain nitrogen, impair osteoclast function by inhibiting farnesyl pyrophosphate synthase (FPPS), disrupting GTPase activity, and ultimately accelerating osteoclast apoptosis and preventing bone resorption 47-50.

The binding affinity of BPs to bone minerals varies, with zoledronic acid having the highest affinity, followed by alendronate, ibandronate, and risedronate [51]. As a result, BPs can remain bound to bone minerals for many years, exerting residual pharmacological effects even after discontinuation [51-55]. In contrast, other anti-resorptive therapies, such as denosumab, estrogen, raloxifene, and calcitonin, quickly lose activity after discontinuation.

Common adverse effects associated with BPs include renal toxicity, acute-phase reactions, gastrointestinal issues, and osteonecrosis of the jaw [56].

4.3.2 Denosumab

Denosumab is a fully human monoclonal antibody that potently inhibits bone resorption by targeting RANKL. Its high affinity and specificity for RANKL enable denosumab to impede osteoclast differentiation, function, and survival [57,58]. Unlike bisphosphonates (BPs), denosumab effectively suppresses osteoclast activity across all developmental stages, resulting in improved accessibility to bone remodeling compartments in cortical bone [46,59].

Common side effects of denosumab include rash, pruritis, and urticaria [60]. Recently, the FDA issued a warning regarding denosumab's potential to cause severe hypocalcemia in patients with advanced chronic kidney disease [22]. This condition typically develops 2-10 weeks after denosumab injection, with the highest risk occurring between weeks 2-5. Severe hypocalcemia can lead to complications such as arrhythmias, particularly in patients on dialysis, who may exhibit symptoms including confusion, seizures, facial twitching, and muscle weakness.

4.3.3 Parathyroid Hormone (PTH) Analogues

PTH analogues, such as Teriparatide (Forteo), are recommended for treating glucocorticoid-induced osteoporosis and severe osteoporosis in postmenopausal women and men [61]. Randomized controlled trials have consistently shown that Teriparatide reduces the risk of vertebral and nonvertebral fractures more effectively and rapidly than antiresorptive treatments, which decrease both bone formation and resorption [62,63]. Additionally, Teriparatide increases bone mineral density (BMD) at the spine and hip, improves bone quality and architecture, and enhances trabecular and cortical bone volume and thickness [64,65].

However, due to the potential risk of osteosarcoma, a rare bone cancer, the use of Teriparatide is limited to a specific duration. Furthermore, this medication is contraindicated in patients with certain medical conditions, including hyperparathyroidism, kidney stones, or Paget's disease [66].

Journal of Chemical Health Risks
www.jchr.org
JCHR (2025) 15(6), 1497-1507 | ISSN:2251-6727

4.3.4 Estrogen Agonist

The decline in estrogen levels following menopause accelerates bone loss and increases the likelihood of fractures. Research has demonstrated a dose-dependent effect of estrogen on bone turnover and bone mineral density (BMD) changes. Menopausal hormone therapy (MHT) effectively prevents bone loss and deterioration of bone structure in postmenopausal women, reducing fracture risk by 20-40% across all bone sites [67,68]. Notably, MHT is the only treatment that has shown efficacy in preventing osteoporosis, even in low-risk postmenopausal women [69].

Continuous use of hormone replacement therapy (HRT) is necessary for effective fracture prevention. However, long-term use of combined HRT is associated with an increased risk of breast cancer diagnosis [19]. Estrogen therapy, regardless of administration method, has a positive impact on bone health. Nevertheless, research suggests that postmenopausal women may require more than 7 years of estrogen replacement therapy to maintain bone mineral density in the long term [70]. Long-term estrogen replacement therapy also increases the risk of breast cancer.

Raloxifene, a selective estrogen receptor modulator, has been shown to be effective in preventing and treating postmenopausal osteoporosis, although less effective than estrogen [71]. However, caution is advised when using raloxifene due to its association with an increased risk of thromboembolism [72].

4.3.5 Calcitonin

Calcitonin is a 32-amino acid peptide that binds to osteoclasts, inhibiting bone resorption [73]. This hormone serves three primary functions: promoting calcium absorption into bones, inhibiting calcium reabsorption in the kidneys, and reducing calcium reabsorption in the small intestine. As a result, calcitonin facilitates calcium storage within bones, making it a potential treatment for osteoporosis [74]. However, its use is limited by the availability of more effective treatments, such as bisphosphonates (BPs), which are more effective in preventing bone loss and reducing fracture risk [32].

5. Recent advancements in treating osteoporosis

5.1 Romosozumab

Romosozumab, a humanized monoclonal antibody, is a sclerostin inhibitor used to treat osteoporosis in postmenopausal women at high risk of fractures. By facilitating the Wnt/β-catenin pathway, romosozumab promotes osteogenesis and partially inhibits bone resorption [75-77]. Its mechanism involves blocking sclerostin, enabling Wnt/β-catenin signaling to stimulate osteoblast development and bone growth [78,79].

Clinical trials have demonstrated romosozumab's efficacy in reducing the risk of vertebral, nonvertebral, and clinical fractures in postmenopausal women with osteoporosis. Specifically, romosozumab reduced the risk of vertebral fractures by 73% compared to placebo and by 48% compared to alendronate [80]. Additionally, phase II research showed a significant increase in lumbar spine bone mineral density (11.3%) with a monthly 210mg dose [21]. The FRAME trial confirmed romosozumab's ability to protect postmenopausal women from vertebral fractures [75].

Common side effects of romosozumab include headaches, muscular spasms, arthralgia, and injection-site reactions [28]. However, a notable consideration is romosozumab's cardiovascular risk profile. The ARCH trial revealed a 30% increased risk of serious cardiovascular adverse events, primarily driven by a higher rate of myocardial infarction, compared to alendronate [81].

5.2 Vibration Therapy

Vibration therapy utilizes high-frequency, low-magnitude vibrations to stimulate muscles and bones, promoting bone strength and density. There are two primary types of vibrating devices: whole-body vibration devices and single-muscle vibration devices. Space agencies have employed whole-body vibration therapy to improve bone mineral density (BMD) in astronauts returning from space missions [82]. Research has consistently shown that high-frequency, low-magnitude vibration therapy enhances bone strength by promoting bone formation and reducing bone resorption [83].

The mechanism of action involves sending anabolic signals to bone, muscles, and tendons, improving blood circulation, and differentiating stem cells into

Journal of Chemical Health Risks
www.jchr.org
JCHR (2025) 15(6), 1497-1507 | ISSN:2251-6727

osteoblasts. Additionally, vibration therapy reduces the formation of excessive osteoclasts by facilitating gap junction communication in osteocytes [82]. This therapy has been shown to reduce pain and fatigue, enhance muscle strength and flexibility, aid in rehabilitation, and boost bone density. However, a standardized protocol for vibration therapy is lacking [84].

A novel wearable device, Osteoboost, has been designed to enhance bone strength and density by delivering focused vibrations to the lumbar spine and hips. This device incorporates a motor that transmits low-amplitude, high-frequency (20-40 Hz) vibrations to the spine and hips, mimicking the effects of physical activity. Osteoboost has been shown to improve bone density and strength, particularly in individuals with osteoporosis, reducing the risk of fractures [85].

A clinical trial investigating the effect of Osteoboost in 126 postmenopausal women with low bone mass demonstrated a significant difference in loss of vertebral bone strength. The study found that Osteoboost treatment had positive effects in preserving volumetric bone density and vertebral bone strength in postmenopausal women with low bone mass [85]. The Osteoboost Belt has undergone review by the FDA and has been classified as a prescription device, indicated for postmenopausal women with osteopenia to reduce volumetric bone density decline and bone strength decline [86].

Osteoboost presents a novel approach to treating low bone density in postmenopausal women, utilizing vibration to stimulate bone formation and prevent fractures. This technology has demonstrated clinical efficacy and safety in pivotal trials. While Osteoboost offers promise, its availability is currently limited, and individual responses may vary. Further research is necessary to determine the cost-effectiveness and optimal usage duration required to maintain the benefits of this therapy. Patients interested in Osteoboost should discuss its potential benefits and risks with their healthcare providers, and adopt a healthy lifestyle, ensuring adequate intake of calcium and vitamin D to complement this treatment approach [87].

6. Traditional vs Recent Treatment Options

Table 1 compares the effectiveness and adverse effects of traditional treatment approaches (pre-2019) with recent treatment options (2019 onwards) for osteoporosis in postmenopausal women [88-95]. Although various treatment options are available, most carry FDA box warnings for serious consequences (Table 1) [96-98]. Given this, the newer vibration device, Osteoboost, may offer a safer alternative for managing osteoporosis.

7. Conclusion

In conclusion, conventional osteoporosis treatments, including PTH analogs, hormone therapy, and denosumab, have shown promising results. However, each option has distinct side effects, and FDA warnings, such as the recent alert regarding denosumab-induced hypocalcemia, highlight the need for alternative approaches. Osteoboost, a non-pharmacological vibration therapy, emerges as a promising alternative with potentially fewer side effects. Further long-term studies are essential to compare Osteoboost's efficacy and cost-effectiveness with existing monoclonal antibodies and medications for osteoporosis.

Refrences

[1] Anam AK, Insogna K. Update on osteoporosis screening and manage- ment. Med Clin North Am. 2021;105:1117–34.

[2] NIH. Osteoporosis. https://www.niams.nih.gov/health-topics/osteo-porosis#:~:text=Osteoporosis%20in%20Men-,Osteoporosis%20is%20a%20bone%20disease%20that%20develops%20when%20bone%20mineral,Pregnancy%2C%20Breastfeeding%2C%20 and%20Bone%20Health.

[3] Cooper C, Atkinson EJ, O'Fallon WM, Melton LJ, 3rd. Incidence of clinically diagnosed vertebral fractures: a population-based study in Rochester, Minnesota, 1985-1989. J Bone Miner Res. 1992;7:221–7.

[4] Foundation IO. Osteoporosis. 2024. https://www.osteoporosis.foun- dation/health-professionals/about-osteoporosis/epidemiology#:~:-text=Worldwide%2C%20osteoporosis%20is%20estimated%20to,the%20primary%20health%2Dcare%20level.

[5] Salari N, Ghasemi H, Mohammadi L, et al. The global prevalence of osteoporosis in the world: a

Journal of Chemical Health Risks
www.jchr.org
JCHR (2025) 15(6), 1497-1507 | ISSN:2251-6727

comprehensive systematic review and meta-analysis. J Orthop Surg Res. 2021;16:609.

[6] Alswat KA. Gender disparities in osteoporosis. J Clin Med Res. 2017;9:382–7.

[7] Bellantoni MF. Osteoporosis Information. 2024. https://www. hopkinsarthritis.org/arthritis-info/osteoporosis-info/#:~:tex-t=How%20common%20is%20osteoporosis%3F, %2C%20and%20 54%25%20have%20osteopenia.

[8] Shen Y, Huang X, Wu J, et al. The Global Burden of Osteoporosis, Low Bone Mass, and Its Related Fracture in 204 Countries and Territories, 1990-2019. Front Endocrinol (Lausanne). 2022;13:882241.

[9] Medicine JH. Bone Densitometry. 2024. https://www.hopkinsmedicine. org/health/treatment-tests-and-therapies/bone-densitometry.

[10] Gold T, Williams SA, Weiss RJ, et al. Impact of fractures on quality of life in patients with osteoporosis: a US cross-sectional survey. J Drug Assess. 2019;8:175–83.

[11] Adachi JD, Loannidis G, Berger C, et al.; Canadian Multicentre Osteoporosis Study (CaMos) Research Group. The influence of oste-oporotic fractures on health-related quality of life in community- dwelling men and women across Canada. Osteoporos Int. 2001; 12:903–8.

[12] Tarride J, Adachi JD, Brown JP, Schemitsch E, Slatkovska L, Burke N. Incremental costs of fragility fractures: a population-based matched - cohort study from Ontario, Canada. Osteoporos Int. 2021;32: 1753–61.

[13] Bijelic R, Milicevic S, Balaban J. Risk factors for osteoporosis in post- menopausal women. Med Arch. 2017;71:25–8.

[14] Harvey N, Dennison E, Cooper C. Osteoporosis: impact on health and economics. Nat Rev Rheumatol. 2010;6:99–105.

[15] Kelsey JL. Risk factors for osteoporosis and associated fractures. Public Health Rep. 1989;104(Suppl):14–20.

[16] Ammann P, Rizzoli R. Bone strength and its determinants. Osteoporos Int. 2003;14(Suppl 3):S13–8.

[17] Unnanuntana A, Gladnick BP, Donnelly E, Lane JM. The assessment of fracture risk. J Bone Joint Surg Am. 2010;92:743–53.

[18] Bianchi ML, Orsini MR, Saraifoger S, Ortolani S, Radaelli G, Betti S. Quality of life in post-menopausal osteoporosis. Health Qual Life Outcomes. 2005;3:78.

[19] Stevenson J; Medical Advisory Council of the British Menopause Society. Prevention and treatment of osteoporosis in women. Post Reprod Health. 2023;29:11–4.

[20] Bocalini DS, Serra AJ, dos Santos L, Murad N, Levy RF. Strength train- ing preserves the bone mineral density of postmenopausal women without hormone replacement therapy. J Aging Health. 2009;21: 519–27.

[21] Ganesan K, Goyal A, Roane D. Bisphosphonate. StatPearls. StatPearls Publishing LLC.; 2024.

[22] FDA. FDA adds Boxed Warning for increased risk of severe hypo- calcemia in patients with advanced chronic kidney disease taking osteoporosis medicine Prolia (denosumab). 2024. https://www.fda. gov/drugs/drug-safety-and-availability/fda-adds-boxed-warning-in- creased-risk-severe-hypocalcemia-patients-advanced-chronic-kid- ney-disease.

[23] Biospace. Bone Health Technologies Announces FDA Clearance of OsteoboostTM, the First Prescription Medical Device to Treat Low Bone Density. 2024. https://www.biospace.com/article/releases/bone-health-technologies-announces-fda-clearance-of-osteoboosttm-the- first-prescription-medical-device-to-treat-low-bone-density/.

[24] Kassem M, Marie PJ. Senescence-associated intrinsic mechanisms of osteoblast dysfunctions. Aging Cell. 2011;10:191–7.

[25] Marie PJ, Kassem M. Osteoblasts in osteoporosis: past, emerging, and future anabolic targets. Eur J Endocrinol. 2011;165:1–10.

[26] Kearns AE, Khosla S, Kostenuik PJ. Receptor activator of nuclear factor kappaB ligand and osteoprotegerin regulation of bone remodeling in health and disease. Endocr Rev. 2008;29:155–92.

[27] Lacey DL, Timms E, Tan HL, et al. Osteoprotegerin ligand is a cyto- kine that

Journal of Chemical Health Risks
www.jchr.org
JCHR (2025) 15(6), 1497-1507 | ISSN:2251-6727

regulates osteoclast differentiation and activation. Cell. 1998;93:165–76.

[28] Tanaka S, Takahashi N, Udagawa N, et al. Macrophage colony- stimulating factor is indispensable for both proliferation and differenti- ation of osteoclast progenitors. J Clin Invest. 1993;91:257–63.

[29] Väänänen HK, Zhao H, Mulari M, Halleen JM. The cell biology of osteoclast function. J Cell Sci. 2000;113 (Pt 3)(Pt 3):377–81.

[30] Khosla S, Riggs BL. Pathophysiology of age-related bone loss and osteoporosis. Endocrinol Metab Clin North Am. 2005;34:1015–30, xi.

[31] Voulgaridou G, Papadopoulou SK, Detopoulou P, et al. Vitamin D and calcium in osteoporosis, and the role of bone turnover mark- ers: a narrative review of recent data from RCTs. Diseases. 2023; 11:29.

[32] uptodate. Patient education: Calcium and vitamin D for bone health (Beyond the Basics). 2024. https://www.uptodate.com/contents/cal- cium-and-vitamin-d-for-bone-health-beyond-the basics#:~:text= Recommendations%20for%20vitamin%20D%20 %E2%80%94%20 Getting,of%20vitamin%20D%20per%20day.

[33] Dawson-Hughes B, Harris SS, Krall EA, Dallal GE. Effect of calcium and vitamin D supplementation on bone density in men and women 65 years of age or older. N Engl J Med. 1997;337:670–6.

[34] Li S, Na L, Li Y, et al. Long-term calcium supplementation may have adverse effects on serum cholesterol and carotid intima-media thick- ness in postmenopausal women: a double-blind, randomized, placebo- controlled trial123. Am J Clin Nutr. 2013;98:1353–9.

[35] Zhang R, Huang Q, Su G, et al. Association between multiple vitamins and bone mineral density: a cross-sectional and population-based study in the NHANES from 2005 to 2006. BMC Musculoskelet Disord. 2023;24:113.

[36] Lorincz C, Manske SL, Zernicke R. Bone health: part 1, nutrition. Sports Health. 2009;1:253–60.

[37] Sharma T, Mandal CC. Omega-3 fatty acids in pathological calcifica- tion and bone health. J Food Biochem. 2020;44:e13333.

[38] Dai Z, Koh WP. B-vitamins and bone health – a review of the current evidence. Nutrients. 2015;7:3322–46.

[39] Kitagawa T, Hiraya K, Denda T, Yamamoto S. A comparison of dif- ferent exercise intensities for improving bone mineral density in postmenopausal women with osteoporosis: a systematic review and meta-analysis. Bone Rep. 2022;17:101631.

[40] Chang CF, Lee JI, Huang SP, Geng JH, Chen SC. Regular exercise decreases the risk of osteoporosis in postmenopausal women. Front Public Health. 2022;10:897363.

[41] Martyn-St James M, Carroll S. High-intensity resistance training and postmenopausal bone loss: a meta-analysis. Osteoporos Int. 2006;17:1225–40.

[42] Petkovic MJ, Tran HA, Ebeling PR, Zengin A. Osteoporosis manage- ment and falls prevention in patients with haemophilia: review of hae- mophilia guidelines. Haemophilia. 2022;28:388–96.

[43] McClure R, Turner C, Peel N, Spinks A, Eakin E, Hughes K. Population- based interventions for the prevention of fall-related injuries in older people. Cochrane Database Syst Rev. 2005;2005:CD004441.

[44] Christianson MS, Shen W. Osteoporosis prevention and manage- ment: nonpharmacologic and lifestyle options. Clin Obstet Gynecol. 2013;56:703–10.

[45] Shoback D, Rosen CJ, Black DM, Cheung AM, Murad MH, Eastell R. Pharmacological management of osteoporosis in postmenopausal women: an endocrine society guideline update. J Clin Endocrinol Metab. 2020;105:dgaa048.

[46] Bone HG, Wagman RB, Brandi ML, et al. 10 years of denosumab treat- ment in postmenopausal women with osteoporosis: results from the phase 3 randomised FREEDOM trial and open-label extension. Lancet Diabetes Endocrinol. 2017;5:513–23.

[47] McClung MR. Role of bone-forming agents in the management of oste- oporosis. Aging Clin Exp Res. 2021;33:775–91.

[48] Brown JP. Antiresorptives: safety concerns-clinical perspective. Toxicol Pathol. 2017;45:859–63.

[49] Khan AA, Morrison A, Hanley DA, et al.; International Task Force on Osteonecrosis of the

Journal of Chemical Health Risks
www.jchr.org
JCHR (2025) 15(6), 1497-1507 | ISSN:2251-6727

Jaw. Diagnosis and management of osteonecrosis of the jaw: a systematic review and international consensus. J Bone Miner Res. 2015;30:3–23.

[50] Shane E, Burr D, Abrahamsen B, et al. Atypical subtrochanteric and diaphyseal femoral fractures: second report of a task force of the American Society for Bone and Mineral Research. J Bone Miner Res. 2014;29:1–23.

[51] Watts NB, Grbic JT, Binkley N, et al. Invasive oral procedures and events in postmenopausal women with osteoporosis treated with deno- sumab for up to 10 years. J Clin Endocrinol Metab. 2019;104:2443–52.

[52] Ng AC, Png MA, Mohan PC, Koh JS, Howe TS. Atypical femoral frac- tures: transverse morphology at lateral cortex is a critical feature. J Bone Miner Res. 2014;29:639–43.

[53] Miller PD, Pannacciulli N, Brown JP, et al. Denosumab or zoledronic acid in postmenopausal women with osteoporosis previously treated with oral bisphosphonates. J Clin Endocrinol Metab. 2016;101:3163–70.

[54] Ferrari S, Libanati C, Lin CJF, et al. Relationship between bone mineral density T-Score and nonvertebral fracture risk over 10 years of denos- umab treatment. J Bone Miner Res. 2019;34:1033–40.

[55] Cummings SR, Cosman F, Lewiecki EM, et al. Goal-Directed treatment for osteoporosis: a progress report from the ASBMR-NOF working group on goal-directed treatment for osteoporosis. J Bone Miner Res. 2017;32:3–10.

[56] Diel IJ, Bergner R, Grötz KA. Adverse effects of bisphosphonates: cur- rent issues. J Support Oncol. 2007;5:475–82.

[57] Dennison EM, Cooper C, Kanis JA, et al.; IOF Epidemiology/Quality of Life Working Group. Fracture risk following intermission of osteo- porosis therapy. Osteoporos Int. 2019;30:1733–43.

[58] Eastell R, Hannon RA, Wenderoth D, Rodriguez-Moreno J, Sawicki A. Effect of stopping risedronate after long-term treatment on bone turnover. J Clin Endocrinol Metab. 2011;96:3367–73.

[59] Black DM, Schwartz AV, Ensrud KE, et al.; FLEX Research Group. Effects of continuing or stopping alendronate after 5 years of treat- ment: the Fracture Intervention Trial Long-term Extension (FLEX): a randomized trial. JAMA. 2006;296:2927–38.

[60] Hildebrand GK, Kasi A. Denosumab. StatPearls. StatPearls Publishing LLC.; 2024.

[61] Hodsman AB, Bauer DC, Dempster DW, et al. Parathyroid hormone and teriparatide for the treatment of osteoporosis: a review of the evidence and suggested guidelines for its use. Endocr Rev. 2005;26: 688–703.

[62] Neer RM, Arnaud CD, Zanchetta JR, et al. Effect of parathyroid hor- mone (1-34) on fractures and bone mineral density in postmenopausal women with osteoporosis. N Engl J Med. 2001;344:1434–41.

[63] Kendler DL, Marin F, Zerbini CAF, et al. Effects of teriparatide and risedronate on new fractures in post-menopausal women with severe osteoporosis (VERO): a multicentre, double-blind, double-dummy, ran- domised controlled trial. Lancet. 2018;391:230–40.

[64] McClung MR, Grauer A, Boonen S, et al. Romosozumab in post- menopausal women with low bone mineral density. N Engl J Med. 2014;370:412–20.

[65] Lindsay R, Krege JH, Marin F, Jin L, Stepan JJ. Teriparatide for osteopo- rosis: importance of the full course. Osteoporos Int. 2016;27:2395–410.

[66] Bartl R. Parathyroid Hormone (PTH) and Romosozumab. In: Bartl R, ed. Osteoporosis in Clinical Practice. Springer International Publishing; 2023:113–9.

[67] Shieh A, Ishii S, Greendale GA, Cauley JA, Lo JC, Karlamangla AS. Urinary N-telopeptide and rate of bone loss over the menopause tran- sition and early postmenopause. J Bone Miner Res. 2016;31:2057–64.

[68] Zhu L, Jiang X, Sun Y, Shu W. Effect of hormone therapy on the risk of bone fractures: a systematic review and meta-analysis of randomized controlled trials. Menopause. 2016;23:461–70.

[69] Gosset A, Pouillès JM, Trémollieres F. Menopausal hormone therapy for the management of osteoporosis. Best Pract Res Clin Endocrinol Metab. 2021;35:101551.

[70] Felson DT, Zhang Y, Hannan MT, Kiel DP, Wilson PW, Anderson JJ. The effect of

Journal of Chemical Health Risks
www.jchr.org
JCHR (2025) 15(6), 1497-1507 | ISSN:2251-6727

postmenopausal estrogen therapy on bone density in elderly women. N Engl J Med. 1993;329:1141–6.

[71] Wooltorton E. Osteoporosis treatment: raloxifene (Evista) and stroke mortality. CMAJ. 2006;175:147.

[72] Adomaityte J, Farooq M, Qayyum R. Effect of raloxifene therapy on venous thromboembolism in postmenopausal women. A meta-analysis. Thromb Haemost. 2008;99:338–42.

[73] Tella SH, Gallagher JC. Prevention and treatment of postmenopausal osteoporosis. J Steroid Biochem Mol Biol. 2014;142:155–70.

[74] Kim B, Cho YJ, Lim W. Osteoporosis therapies and their mechanisms of action (Review). Exp Ther Med. 2021;22:1379.

[75] Cosman F, Crittenden DB, Adachi JD, et al. Romosozumab treat- ment in postmenopausal women with osteoporosis. N Engl J Med. 2016;375:1532–43.

[76] McClung MR. Romosozumab for the treatment of osteoporosis. Osteoporos Sarcopenia. 2018;4:11–5.

[77] Prather C, Adams E, Zentgraf W. Romosozumab: a first-in-class sclerostin inhibitor for osteoporosis. Am J Health Syst Pharm. 2020;77:1949–56.

[78] Liu J, Xiao Q, Xiao J, et al. Wnt/β-catenin signalling: function, biologi- cal mechanisms, and therapeutic opportunities. Signal Transduct Target Ther. 2022;7:3.

[79] Kim JH, Liu X, Wang J, et al. Wnt signaling in bone formation and its therapeutic potential for bone diseases. Ther Adv Musculoskelet Dis. 2013;5:13–31.

[80] Händel MN, Cardoso I, Von Bülow C, et al. Fracture risk reduction and safety by osteoporosis treatment compared with placebo or active comparator in postmenopausal women: systematic review, network meta-analysis, and meta-regression analysis of randomised clinical tri- als. BMJ. 2023;381:e068033.

[81] Saag KG, Petersen J, Brandi ML, et al. Romosozumab or alendronate for fracture prevention in women with osteoporosis. N Engl J Med. 2017;377:1417–27.

[82] Singh A, Varma AR. Whole-body vibration therapy as a modality for treatment of senile and postmenopausal osteoporosis: a review article. Cureus. 2023;15:e33690.

[83] Thompson WR, Yen SS, Rubin J. Vibration therapy: clinical applica- tions in bone. Curr Opin Endocrinol Diabetes Obes. 2014;21:447–53.

[84] Cerciello S, Rossi S, Visonà E, Corona K, Oliva F. Clinical applica- tions of vibration therapy in orthopaedic practice. Muscles Ligaments Tendons J. 2016;6:147–56.

[85] Bilek LD, Flores LE, Waltman N, et al. FRI681 Osteoboost(Tm) is effective in preserving bone strength and density of the spine in women with low bone mass. J Endocr Soc. 2023;7(Suppl 1).

[86] FDA. Wearable vibration device for orthopedic use. 2024. https://www.accessdata.fda.gov/cdrh_docs/pdf23/DEN230015.pdf.

[87] pharmexec. FDA Grants Clearance to Bone Health Technologies' Wearable Device for Osteopenia. 2024. https://www.pharmexec.com/view/fda-grants-clearance-to-bone-health-technologies-wearable-de- vice-for-osteopenia.

[88] Byun JH, Jang S, Lee S, et al. The efficacy of bisphosphonates for prevention of osteoporotic fracture: an update meta-analysis. J Bone Metab. 2017;24:37–49.

[89] Chow SKH, Ho CY, Wong HW, Chim YN, Wong RM-Y, Cheung WH. Efficacy of low-magnitude high-frequency vibration (LMHFV) on musculoskeletal health of participants on wheelchair: a study pro- tocol for a single-blinded randomised controlled study. BMJ Open. 2020;10:e038578.

[90] Minisola S, Cipriani C, Grotta GD, et al. Update on the safety and efficacy of teriparatide in the treatment of osteoporosis. Therap Adv Musculoskeletal Dis. 2019;11:1759720X19877994.

[91] Zaheer S, LeBoff M, Lewiecki EM. Denosumab for the treatment of osteoporosis. Expert Opin Drug Metab Toxicol. 2015;11:461–70.

[92] Wu D, Li L, Wen Z, Wang G. Romosozumab in osteoporosis: yesterday, today and tomorrow. J Transl Med. 2023;21:668.

[93] Vall H, Patel P, Parmar M. Teriparatide. StatPearls. StatPearls Publishing LLC.; 2024.

Journal of Chemical Health Risks

www.jchr.org

JCHR (2025) 15(6), 1497-1507 | ISSN:2251-6727

[94] Hanley DA, Adachi JD, Bell A, Brown V. Denosumab: mechanism of action and clinical outcomes. Int J Clin Pract. 2012;66:1139–46.

[95] Gennari L, Merlotti D, De Paola V, Martini G, Nuti R. Bazedoxifene for the prevention of postmenopausal osteoporosis. Ther Clin Risk Manag. 2008;4:1229–42.

[96] Vall H, Parmar M. Teriparatide. StatPearls. StatPearls Publishing LLC; 2024.

[97] Raina PM, Patel P, Parmar M. Bazedoxifene. StatPearls. StatPearls Publishing LLC; 2024.

[98] Vestergaard Kvist A, Faruque J, Vallejo-Yagüe E, Weiler S, Winter EM, Burden AM. Cardiovascular safety profile of romosozumab: a pharma-covigilance analysis of the US Food and Drug Administration Adverse Event Reporting System (FAERS). J Clin Med. 2021;10:1660.