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Navigating Osteoporosis: Epidemiology, Risk Factors, and the Future of Diagnosis and Therapy

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ABSTRACT

Osteoporosis is one of the most prevalent bone metabolic diseases, which is associated with the low levels of bone mineral density (BMD) and susceptibility to more fractures with an eroded microstructure. Often termed a “silent disease”, it can cause serious public health issues, especially in elderly populations. This paper attempts to fill this gap, presenting thorough information about osteoporotic disease as well as its epidemiological signup, the current forms into which osteoporosis may be classified, primary and secondary, clinical procedures, and the pharmacological advancements. It also discusses new imaging techniques and the use of artificial intelligence in fracture risk evaluation. Osteoporosis is quite a complex condition and hence the understanding of its nature will help to come up with the appropriate measures for prevention and management so as to optimize bone health and decrease the risk of fractures.

Keywords: Osteoporosis, Bone, T-score, Bisphosphonates and Biomarkers

INTRODUCTION

The term osteoporosis refers to a metabolic bone disease characterized by a reduction in bone mineral density (BMD) and an increased risk of fragility fractures due to the bones deteriorating microarchitecture (1-6). Osteoporosis is often referred to as a silent disease since its symptoms can lead to bone fractures and are sometimes difficult to identify in their early stages bone fractures caused by osteoporosis have a major effect on public health (7). An imbalance between osteoblast-mediated bone production and osteoclast-mediated bone resorption leads to

osteoporosis a prevalent age-related illness that lowers bone mineral density (BMD) and increases the risk of osteoporotic fractures (8).

Osteoporosis is basically characterized by porous bones. A pathological condition Osteoporosis is brought on by the loss of bone tissue. It is disorder that weakens bones and raises the risk of fractures eventually reducing the bone density and structural integrity. Osteoporosis mostly affects the wrists, hips and vertebrae and can cause physical disability or even death following cancer, cardiovascular disease, and stroke. As one of the top three causes of death in humans, osteoporosis is a common bone metabolic illness. Reduced bone density and deteriorating bone structure, which increase bone fragility and fracture susceptibility are the hallmarks of Osteoporosis (9-10). Figure 1. Depicts the structure of bone and bone cells with their functions.

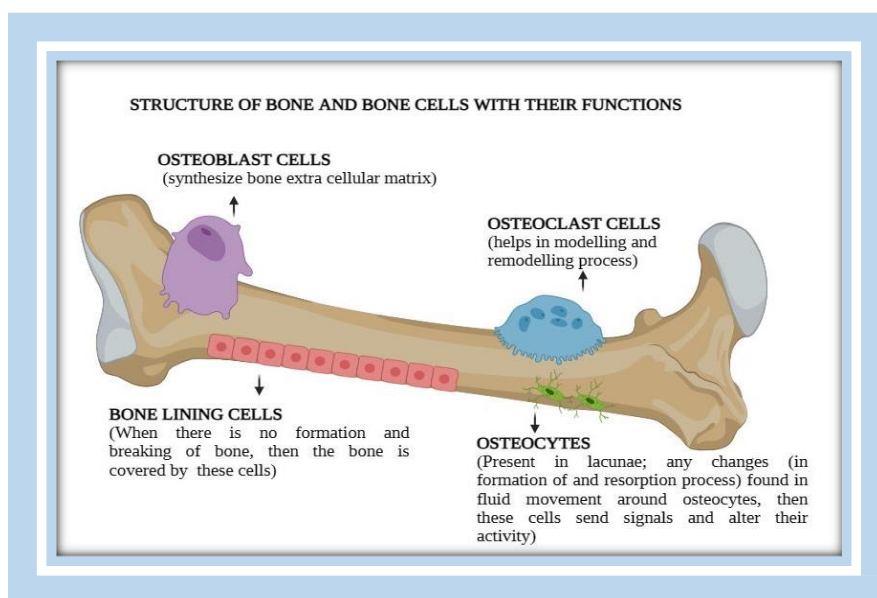


Fig 1. Structure of bone and bone cells with their functions

Bone is a dynamic physiological organ with remarkable qualities that include endocrine mechanical and metabolic functions it is a complex living tissue made up of many different cells including osteoblasts osteoclasts bone lining cells and osteocytes all of which work together to preserve the health of the bone the matrix is mineralized (11). It's crucial to maintain good bone health throughout life our bones are constantly changing and being repaired for people's general health proper bone remodeling and bone health is essential as we age a variety of biochemical markers are in charge of preserving bone homeostasis and enhancing bone health (12,13).

Osteoporosis more precisely is a condition characterized by a decrease in cortical thickness and an increase in porosity as well as a decrease in the number of trabeculae trabecular thinning and loss of connection across bones because of this bones become more fragile and brittle making them more prone to breaking (14). Osteocytes are organized compactly resembling a honeycomb inside the bone in normal circumstances bone density is a key factor in determining the risk of fracture because osteoporosis causes the walls of the honeycomb to thin and the space between the bone cells to widen this weakens the bone and increases its susceptibility to fractures even from small fragility fractures (15).

PATHOPHYSIOLOGY

PHASES OF BONE REMODELLING

The process of remodeling bones continues. The process of modeling and rebuilding bone is an ongoing, lifetime endeavor(4). There are four stages to bone remodeling: the activation, resorption, reversal, and creation phase as depicted in Figure 2. The same bone remodeling units are responsible for both bone production and resorption during the remodeling process(5). Osteocytes, osteoblasts, osteoclasts, and bone lining cells are the four main cells involved in the process. The extracellular matrix for bones is made by osteoblast cells. Cells called osteoclasts keep the physical environment in shape (modeling) and modify it to meet the needs of bodily growth and shifting environmental conditions (remodeling). The cells called osteoblasts produce the osteocytes, which are buried deep within lacunae. When there is a change in the fluid around the osteocytes, the osteocytes send signals that affect the activity of bone creation and resorption. Bone lining cells are formed by the remaining cells. These cells cover the bone when there is neither bone growth nor resorption.

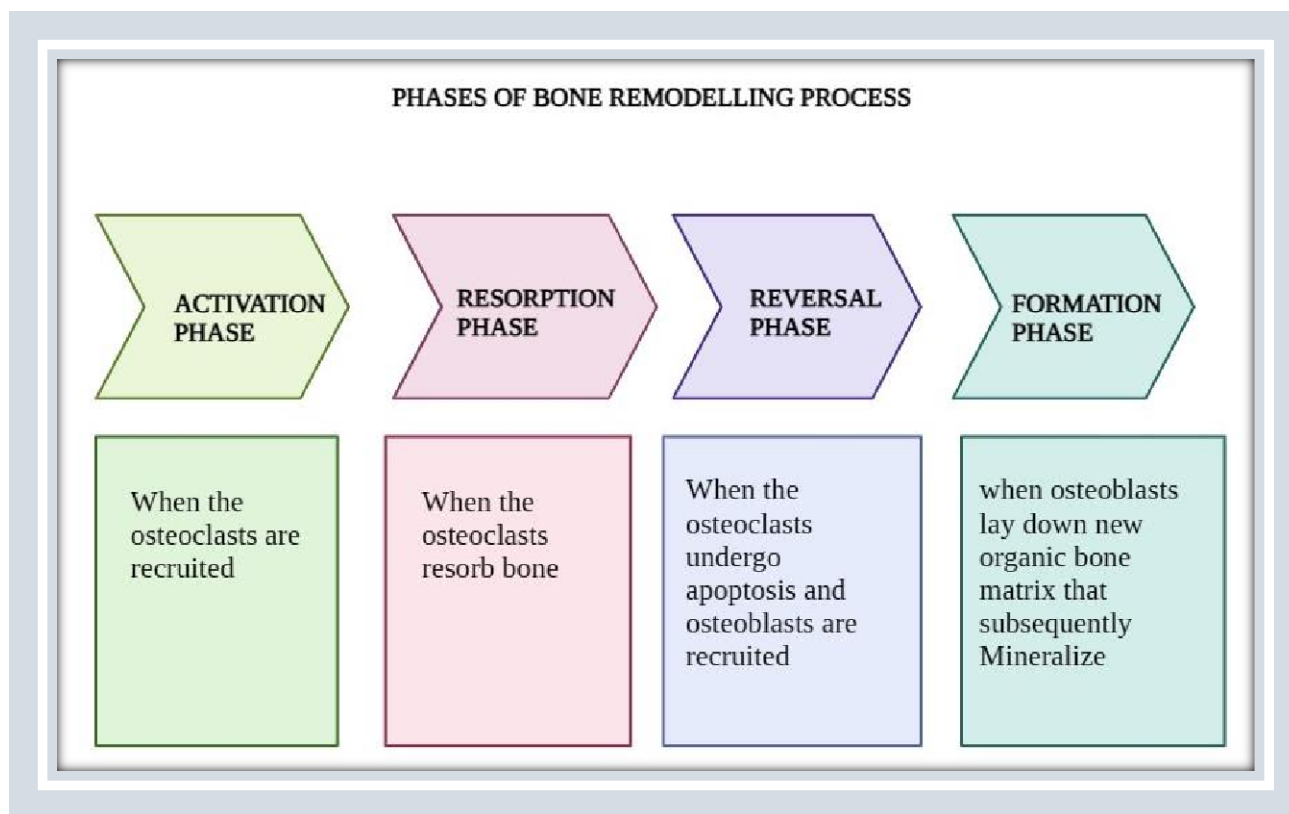


Fig 2. Phases of the bone remodelling process

Osteoporosis, or reduced skeletal mass, is caused by an imbalance between bone resorption and rebuilding. The third decade is when bone mass peaks in most people, following which bone resorption outpaces bone synthesis. Osteoporosis can result from either an acceleration of bone loss or failure to reach a normal peak bone mass (23). The actions of two principal cell types, osteoclasts and osteoblasts, which come from two separate origins, determine the balance between bone resorption and deposition. Extremely active ion channels in osteoclast cell membranes enable protons to be pushed into the extracellular space, lowering the pH in their own microenvironment. The bone mineral melts due to this pH decrease (24).

Additionally, they generate proteolytic enzymes in this milieu, such as cathepsin K, which breaks down bone matrix. Osteoblasts deposit new bone material through a poorly understood process. Whether bone is formed, preserved, or lost depends on how these two cell types interact with one another. These cells' functions are also closely related to one another (25).

EPIDEMIOLOGY

India can support 12 billion people in its population the aging of the global population has made osteoporosis prevention and management a major healthcare concern (16). One of the most incapacitating effects of osteoporosis is hip fractures for women over 50 the predicted lifetime risk of hip fracture ranges from 98 to 228 hip fracture mortality rates range from 10 to 20 which is extremely high due in part to complications following hip joint surgery and osteoporosis-related comorbidities hip fractures are also linked to significant morbidity such as decreased mobility and increasing reliance 50 of patients need assistance with everyday living and 15 to 25 end up in long-term care institutions (17). Because of rising life expectancy and an older population osteoporosis is becoming a global epidemic one in five men and one in three women over 50 are expected to suffer an osteoporotic fracture at some point in their lives according to the International Osteoporosis Foundation (18).

T - SCORE

A T-score based on BMD categorization is computed as a statistical test that calculates standard deviation SD from the mean called a T-score (19). The following bone density thresholds are used to determine an osteoporosis criterion set by the World Health Organization.

1. A T-score of 1 or -1 within 1 SD indicates normal bone density
2. A T-score ranging from 1 to 2.5 SD -1 to -2.5 SD signifies osteopenia or poor bone mass
3. A T-score of 2.5 SD or higher greater than -25 SD denotes osteoporosis (20).

T-score of -1 or greater than -2.5 osteopenia T-score of -2.5 or less osteoporosis T-score of -2.5 or less with a history of fracture extreme osteoporosis (21-22). However, there are differences in the recommendations for diagnosing osteoporosis in adolescents and young adults (Table 1). (11).

	BONE MINERAL DENSITY
INTERNATIONAL SOCIETY FOR CLINICAL DENSITOMETRY (ISCD)	CHILDREN ≥ 1 vertebral compression fractures in the absence of local disease or high energy trauma, or Clinically significant fracture history and BMD Z-score ≤ -2.0 with ≥ 2 long bone fractures up to age 10 years and/or ≥ 3 long bone fractures up to age 19 years Premenopausal Women And Men Aged < 50 Years BMD Z-score ≤ -2.0 and low-trauma fracture or secondary cause of osteoporosis
INTERNATIONAL OSTEOPOROSIS FOUNDATION (IOF)	YOUNG ADULTS age 20-50 years T- score ≤ -2.5 and low-trauma fracture or secondary cause of osteoporosis

CLASSIFICATION

Osteoporosis is classified into two main types namely primary and secondary.

1. PRIMARY OSTEOPOROSIS:

Age-related causes, such as senile osteoporosis, postmenopausal osteoporosis, and idiopathic osteoporosis, can be the primary cause of primary osteoporosis.

1.1 Senile osteoporosis:

- a. Age-related change of bone marrow mesenchymal stem cells results in the suppression of osteogenesis, or the creation of new bone, which causes excess bone loss.
- b. Age-related osteoblast dysfunction can alter the microenvironment of the bone, which can impede osteoblast differentiation and function.
- c. Endocrine dysfunctions are extremely prevalent in the senior citizen demographic.

Osteoporosis can result from hormone deficits related to estrogen, testosterone, cortisol, parathyroid, and thyroid, which are important for bone metabolism and remodeling.

d. Osteoclastic activity is affected by inactivity or lack of motion, which causes a rapid resorption of bone mass.

1.2 Postmenopausal osteoporosis:

It was primarily brought on by insufficient estrogen.

a. Cytokines (Interleukin-1, Interleukin-17, Interleukin-6, Interleukin-7, Tumour Necrosis Factor- α) engage on estrogen receptors to generate inflammation brought on by a shortage of estrogen. This effectively inhibits osteoblasts and promotes osteoclasts.

b. The activator receptor of nuclear factor-kappa-B ligand (RANKL) is required for the myeloid precursor stage of osteoclast formation. Lack of estrogen has an impact on RANKL, which inhibits the development of osteoclasts and causes osteoporosis.

1.3 Idiopathic osteoporosis

Males suffering from idiopathic osteoporosis may exhibit no symptoms at all or exhibit indications of a potential fracture. There are no particular clinical observations related to men who have idiopathic osteoporosis. However, observational research indicates that males with idiopathic osteoporosis typically have somewhat smaller bodies than average(61). Extremely uncommon, typically brought on by genetic alterations (80).

2. SECONDARY OSTEOPOROSIS:

This type of osteoporosis arises from secondary reasons, such as continuous use of certain medications (such as corticosteroid medication) or various medications used in the treatment of disorders.

- Hyperparathyroidism
- Hypogonadism
- Inflammatory conditions (such as rheumatoid arthritis) Dementia; insufficient amounts of vitamin D; renal disease (history of kidney stones); cardiovascular disease; diabetes mellitus; Cushing syndrome, anorexia and malabsorption syndrome (19).

RISK FACTORS

Numerous risk factors for osteoporosis, such as nutrition and lifestyle choices, have been linked to research findings; however, certain risk factors cannot be changed. (Fig 3)

MODIFIABLE RISK FACTORS	NON- MODIFIABLE RISK FACTORS
• Poor nutrient absorption • Insufficient exercise • Loss of weight • Cigarette smoking • Alcohol intake • Air pollution • Stress	• Fall history • Gender • Age • Ethnic background: White • Past fracture variables related to reproduction (family history of osteoporosis)

Fig 3. Risk factors of Osteoporosis

DIAGNOSIS

Medical interviews, physical examinations, imaging (such as radiographs, dual-energy X-ray absorptiometry (DXA), magnetic resonance imaging (MRI), etc.), blood and urine tests, and differential diagnosis with other diseases are used to diagnose OP. Because DXA only offers a two-dimensional antero-posterior projection of the lumbar spine, structural defects such osteophytes and vertebral deformities linked to compression fractures may have an impact on specific BMD measurements (72). This could result in a large underestimation of OP hazards due to an overestimation of BMD. REMS, or radiofrequency echo-graphic multi-spectrometry, is a cutting-edge, non-ionizing technique for evaluating bone mineral density. It is affordable, portable, and radiation-free. REMS analyzes raw radiofrequency ultrasound signals—which are typically lost in traditional B-mode imaging—obtained from an echo-graphic scan of the proximal femur and lumbar spine to offer detailed tissue property data (20).

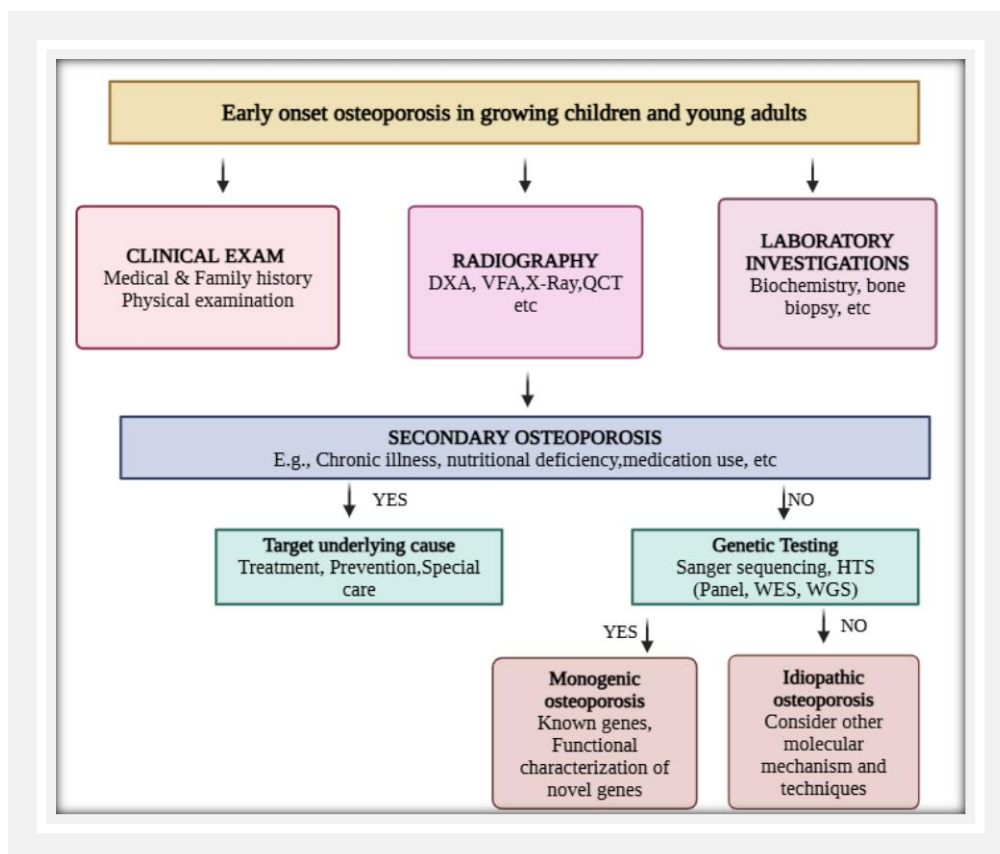


Fig 4. Flowchart showing the diagnostic workup of a growing child or young adult with suspected early onset of osteoporosis.

ALTERNATIVE METHODS OF DIAGNOSING OSTEOPOROSIS AND FRACTURE RISK

DXA is the most widely used and advised method for measuring BMD. Other test methods exist, however not all of them are accepted by healthcare systems as means of diagnosing osteoporosis.

QCT: Quantitative Computed Tomography, measures the hips and spine

Peripheral QCT: The tibia and forearm are measured using QCT

REMS: (Radiofrequency Echo-graphic Multi Spectrometry) technique

QUS: Measures the heel or finger using sound waves in QUS (Quantitative Ultrasound) (73).

SCREENING TOOLS FOR OSTEOPOROSIS

These tools can moderately predict the risk of osteoporosis (74-76).

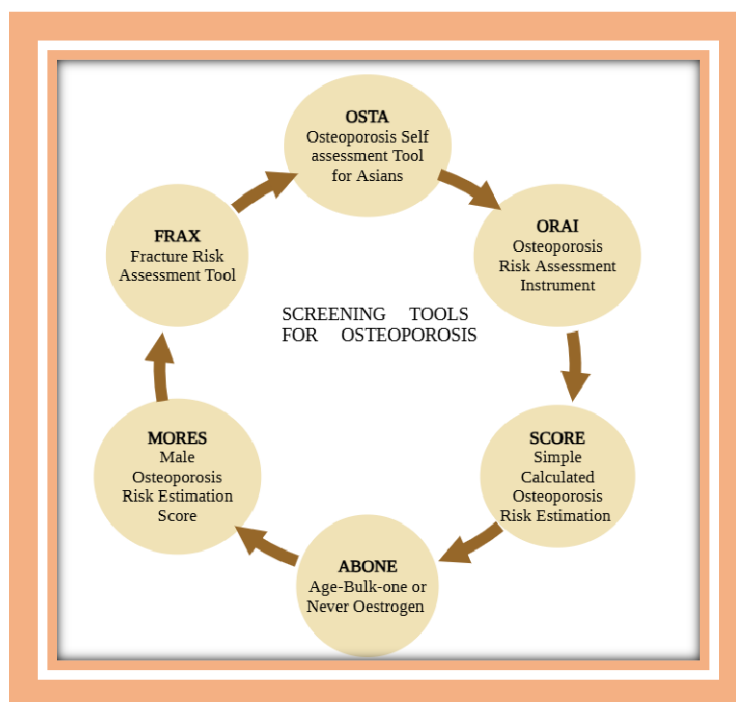


Fig 5. Screening tools for osteoporosis

BONE MARKERS:

Bone turnover biomarkers (BTMs) are byproducts of bone remodeling that can be found in blood or urine and are used as gauges of the rate of bone turnover. Osteoprolin (HYP), pyridoxine, deoxypyridinoline (DPD), tartrate-resistant acid phosphatase 5b (TRAP 5b), carboxy-terminal cross-linked telopeptide of type 1 collagen (CTX-1), and amino-terminal cross-linked telopeptide of type 1 collagen (NTX-1) are markers of bone resorption.

BTMs are indicative of the overall rate of bone turnover, hence their specificity is restricted. Compared to DXA tests, BTM levels respond noticeably and quickly to changes in turnover rate, which makes them extremely useful for clinically monitoring therapy response and adherence in osteoporosis patients from the onset of treatment.

The International Osteoporosis Foundation (IOF) and International Federation of Clinical Chemistry (IFCC) have recommended serum P1NP and CTX-1 as reference markers for bone formation and resorption, respectively, for use in fracture risk prediction and monitoring of osteoporosis treatment, even though all BTMs can shift in response to osteoporotic disease processes (77).

DIGITAL HEALTH IN FRACTURE RISK ASSESSMENT AND OSTEOPOROSIS IDENTIFICATION

The most evident use of digital health specifically for osteoporosis is in fracture risk assessment tools like the FRAX online calculator. Enhancing Digital Health and FLS Models
Currently, there are over 35 nations with at least 225 FLS (statistics from the International Osteoporosis Foundation).

Reminders, risk assessments, and education are examples of digital health solutions that can lower the incidence of secondary fractures while raising BMD tests and osteoporosis treatment initiation.

The MedCert FLS App is a secure cloud platform that complies with HIPAA (Health Insurance Portability and Accountability Act of 1996) and uses software to manage patients with fragility fractures in participating providers across the United States. It introduced a digital "5i" step approach to patient care.

More recently, NHSX and Open Medical Ltd. collaborated to create the cloud-based patient management system known as e-Trauma software. Data quality was enhanced by the use of organized granular data sets and cloud-based, learning natural language processing algorithms. A new digital FLS model of care was created by processing this intricate data.

SMARTPHONE-BASED ELECTRONIC MOBILE APPLICATIONS

The field of mobile health, or mHealth, is constantly developing and may be a useful addition to other medical technology. Everyday living involves the usage of mobile applications (apps), with over 100,000 available apps having a health care focus.

DIGITAL HEALTH-SUPPORTED PATIENT EDUCATION

The Activating Patients at Risk for Osteoporosis (APROPOS) project designed and assessed a multimodal, patient-centered, personalized, video-based behavioral intervention to encourage patients to seek osteoporosis diagnosis and treatment(78).

PHARMACEUTICAL ELECTROSPINNING AND 3D PRINTING SCAFFOLD DESIGN FOR BONE REGENERATION

Some of the most significant biomaterials used in bone tissue engineering are metals and alloys, polymers, and ceramics, as well as derived composite materials. The rise in osteoporotic fractures around the world is driving research in bone tissue engineering to find new, improved solutions for both the biomaterials used in designing bone scaffolds and the anti-osteoporotic agents capable of promoting bone regeneration(79).

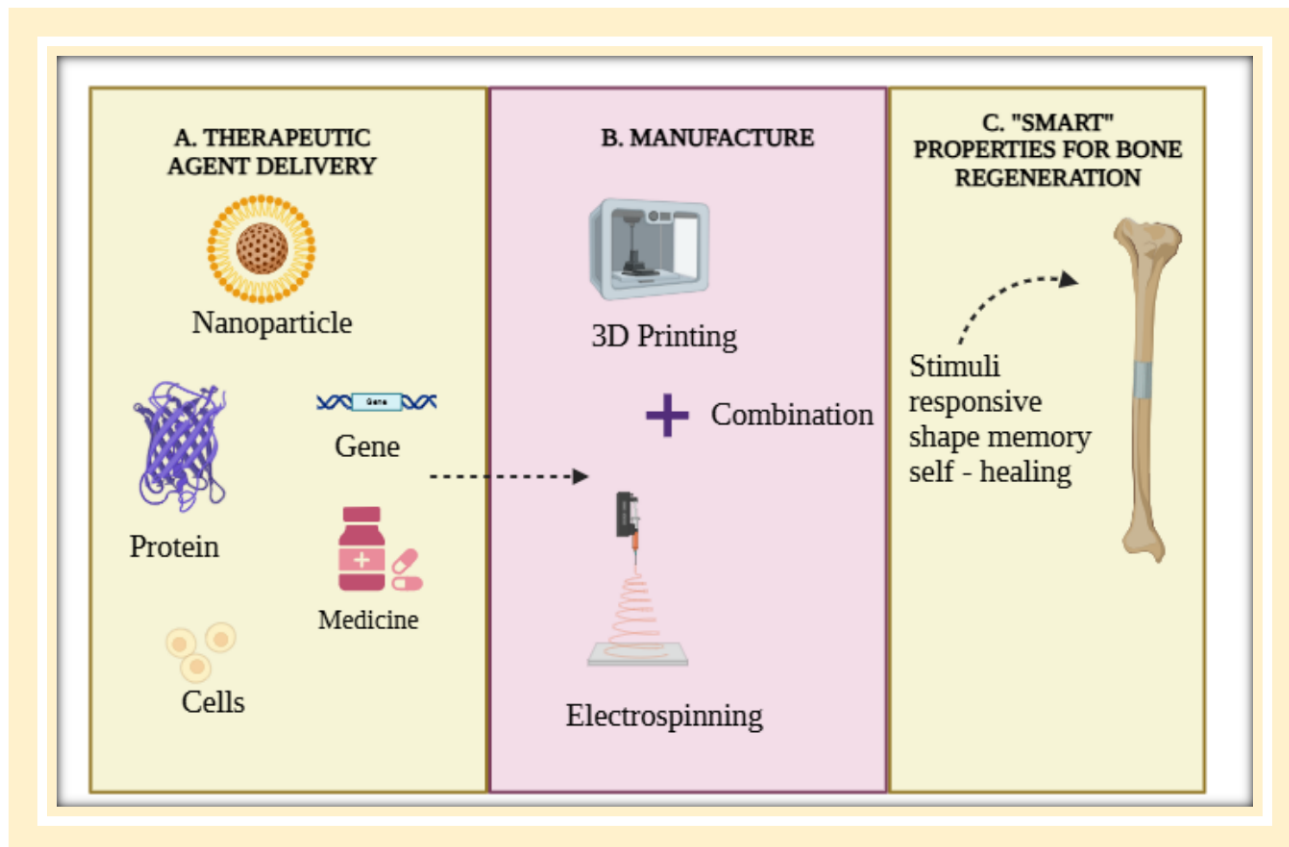


Fig 6. Pharmaceutical electrospinning and 3d printing scaffold design for bone regeneration

TREATMENT

Non – Pharmacological Treatment

Calcium

Supplementing with calcium may help slow the decrease of bone mineral density, particularly in those who are weak in the mineral. Doses vary depending on a person's age, sex, and other factors (68).

S.NO	AGE	DAILY REQUIREMENT
1.	0-6 Months	200 mg
2.	7-12 Months	260 mg
3.	1-3 Years	700 mg
4.	4-8 years	1000 mg
5.	9-18 years	1300 mg
6.	19-50 years	1000 mg
7.	Female age 51 – 70 years	1200 mg
8.	Male age 51-70 years	1000 mg
9.	Males and females over 70 years	1200 mg

Vitamin D

An 800–1,000 international units (IU) per day dose of vitamin D supplementation was linked to a decreased incidence of fractures, according to a 2022 analysis of 32 research. The disorder known as osteoporosis makes bones brittle and porous. Because vitamin D is involved in bone formation and remodeling, it may be able to help prevent osteoporosis (69).

S.NO	AGE	RECOMMENDED DAILY AMOUNT
1.	0-12 Months	400 IU/10 micrograms
2.	1-18 Years	600 IU/15 mcg
3.	19- 70 years	600 IU/15 mcg
4.	71 years and older	800 IU/20 mcg

INNOVATIVE EXERCISE PROGRAMS AND THEIR IMPACT ON BONE DENSITY

It is recommended to examine whether BMD can be increased or maintained through combined exercise and group exercise programs that include weight-bearing activities, running, low-impact loading, high volume exercise, muscle strength, and simulated functional tasks (70).

VIBRATION THERAPY:

Our body's bones respond to stress by growing new ones to support the area that is being strained. Osteoblasts are a particular type of bone-forming cell that cause this. Because of this special characteristic, performing weight-bearing exercises (such as walking or stair-stepping) or resistance training close to the osteoporotic bone is one of the most effective strategies to increase bone density in that location. Vibration treatment aims to increase bone density in areas of the body with lower bone density by simulating the mechanical forces brought on by activity.

This can be accomplished by having a person stand on an oscillating platform while a machine produces vibrations that enter the body at various frequencies and intensities. These vibration signals' dynamic quality aids in simulating the kinds of forces that normally prompt osteoblasts to start forming new bone in a given region (71).

Pharmacological Treatment:**a. New drug classes****Anabolic Agents:**

The treatment of osteoporosis patients, particularly those who are at extremely high risk of fracture, has been completely transformed by anabolic therapy (27). Anabolic drugs improve other properties of bone in addition to increasing bone mass by directly encouraging the production of new bone, therefore lowering the incidence of fractures(28). The normalization of bone mass and microarchitecture is the preferred method of treating osteoporosis in order to avoid fractures. Teriparatide, a biosynthetic human parathyroid hormone 1–34, was authorized as the first anabolic therapy for osteoporosis in the USA and the EU. Teriparatide's anabolic effects on bone boosts bone strength, diameter, mass, and structural integrity(29).

By promoting osteoblasts and suppressing osteoclasts' resorptive activity, strontium ranelate can rebalance bone turnover in favor of the development of more elastic and resistant bone, providing quick and long-lasting protection against the risk of fractures (30).

Cathepsin K Inhibitors:

An enzyme of the cysteine protease family, cathepsin K (CatK) is involved in several important functions, such as the breakdown of collagen 1 and elastin during bone resorption. Variations in CatK levels are linked to a number of pathological diseases, mainly those that affect

the bones and cartilage breakdown, including osteoporosis, osteoarthritis, and pycnodysostosis (linked to CatK deficiency) (related with CatK overexpression).

More recently, there has been a significant association found between enhanced CatK secretion and tumor growth, hypersensitivity pneumonitis, Wegener granulomatosis, berylliosis, and vascular inflammation. Because of the vast range of illnesses in pharmaceutical companies have shown a great deal of interest in the creation and validation of active site-specific inhibitors in recent decades, which involves CatK (31).

S.NO	CATEGORY	DRUG	GENERIC NAME	DOSAGE FORM	ACTION PATHWAY	SIDE EFFECTS	REF
1.	Bisphosphonates	Actonel Atelvia	Risedronate	Tablet, film-coated	Risedronate is a pyridine-based bisphosphonate that inhibits bone resorption caused by osteoclasts 2	Heartburn, diarrhea, indigestion; stomach pain; back pain, joint pain,muscle pain; or flu-like symptoms.	32,33
2.		Boniva	Ibandronate	Oral Injection	Ibandronate inhibits osteoclast activity and reduces bone resorption	Headache Fever, tiredness Back pain, bone pain	34,35
3.		Binosto Fosamax	Alendronate	Tablet	A bisphosphonate which inhibits bone resorption via actions on osteoclasts or on osteoclast precursors; decreases the rate of bone resorption, leading to an indirect increase in bone mineral density	Headache, nausea, vomiting, constipation	36,37

4.		Aclast, Zometa Reclast	Zoledronic acid	Injection	Nitrogen- containing bisphosphonate that inhibits osteoclast function and prevents bone resorption	fever, chills, body aches, flu symptoms; severe joint, bone, or muscle pain.	38,39
5.	Hormone therapy	Duavee	Bazedoxifene And conjugate estrogens	Tablet	Bazedoxifene decreases bone resorption and reduces biochemical markers of bone turnover to the premenopausal range	Memory problems, confusion, unusual behavior;	40,41
6.		Evista	Raloxifene	Tablet	Raloxifene is a selective estrogen receptor modulator that acts as both an estrogen agonist and antagonist via differential effects on the tissue- specific estrogen receptors	Leg cramps Joint pain Hot flushes	42,43

7.		Femhrt	Ethinyl estradiol or norethindron e	Tablet	Progestins exert their effects in target cells by binding to specific progesterone receptors that interact with progesterone response elements in target genes.	Heart attack, stroke, Signs of a blood clot, pain	44,45
8.	Miscellaneous bone resorption inhibitors	Prolia	denosumab	Sub cutaneous injection	human monoclonal antibody that binds the cytokine RANKL (receptor activator of NFκB ligand), an essential factor initiating bone turnover. RANKL inhibition blocks osteoclast maturation, function and survival, thus reducing bone resorption.	Lung infection, Headache, Back pain	46,47

9.	Parathyroid hormone and analogs	Forteo	teriparatide	subcutaneous solution	the classical physiological actions of PTH on calcium and phosphate homeostasis and bone metabolism are osteoblasts, osteocytes, and renal tubular cells.	Nausea, joint pain	48,49
10.	Parathyroid hormone and analogs	Tymlos	abaloparatide	subcutaneous solution	Abaloparatide is an agonist at the PTH1 receptor (PTH1R), a G-protein-coupled receptor (GPCR) that regulates bone formation and bone turnover, as well as mineral ion homeostasis	Unusual body aches; pounding heartbeats or fluttering in your chest;	50,51
11.	Miscellaneous bone resorption inhibitors	Evenity	Romosozumab	subcutaneous solution	Inhibition of this protein allows Wnt signalling in osteoblasts to promote bone formation and allows for the inhibition of receptor activator of nuclear factor kappa-beta-ligand (RANKL) mediated bone resorption by osteoclasts	Jaw pain or numbness red or swollen gums, loose teeth, infected gums	52,52

12.	Calcitonin	Miacalcin	calcitonin injection	injectable solution	Calcitonin inhibits osteoclast-mediated bone resorption through the regulation of the number and activity of osteoclasts.	Flushing, nausea, vomiting, swelling	54,55
13.	Antacids, Minerals and electrolytes	Alka-Mints,	calcium carbonate	Oral suspension Oral tablet Chewable tablet	Calcium carbonate is a basic inorganic salt that acts by neutralizing hydrochloric acid in gastric secretions. It also inhibits the action of pepsin by increasing the pH and via adsorption.	Stomach upset, constipation	56,57
14.	Vitamins	Carlson D, Ddrops, Decara, Delta D3,	cholecalciferol (vitamin D3)	Tablets Capsules	The hormonal form of vitamin D, 1,25(OH) ₂ D, is the ligand for a transcription factor, the vitamin D receptor (VDR).	Chest pain, short breath	58,59,60

DISCUSSION

Osteoporosis continues to be a major public health concern, particularly as the world's population ages. Its quiet development frequently results in serious side effects, such as fractures that can significantly lower quality of life and raise death rates. According to epidemiological statistics, the prevalence of osteoporotic fractures is rising, especially in older individuals and postmenopausal women. This emphasizes the pressing need for efficient care, early diagnosis, and preventative techniques.

Understanding the complex nature of osteoporosis is made easier by the division of the condition into main and secondary types. Age-related and postmenopausal forms of primary osteoporosis highlight the significance of hormonal effects and age-related alterations in bone metabolism. Secondary osteoporosis highlights the significance of several medical illnesses and lifestyle variables, underscoring the necessity of thorough evaluation and treatment that takes into account individual risk profiles.

Novel therapeutic approaches that target certain biochemical pathways and anabolic substances are examples of advances in pharmacological treatments that provide new prospects for improving bone health. Adopting these treatments, however, necessitates giving certain patient characteristics, such as age, sex, and comorbidities, some thought. In addition, patient education and lifestyle changes are essential components of the comprehensive care of osteoporosis. The promotion of weight-bearing activities and a healthy diet can greatly increase bone density.

New diagnostic techniques, especially those that make use of digital health technology, are revolutionizing the way osteoporosis is diagnosed and treated. By raising awareness and promoting proactive treatment, tools like the FRAX calculator and mobile health applications may empower individuals and healthcare professionals. Osteoporosis care might become more effective and individualized as technology develops further.

CONCLUSION

To sum up, osteoporosis is a complicated and common disorder with broad effects on general health. To effectively manage this condition, a multimodal strategy that includes lifestyle modifications, early diagnosis, tailored therapy, and education is essential. Addressing the escalating osteoporosis pandemic will need ongoing research into novel treatments and diagnostic techniques. The potential to prevent fractures and improve patient outcomes will be strengthened by the integration of digital health technologies and patient-centered care models as healthcare systems adjust to these developments. By increasing knowledge and advocating for preventive measures, we can lessen the effects of osteoporosis and enhance the lives of impacted people.

S.NO	ABBREVIATION	
1.	BMD	Bone Mineral Density
2.	pH	Concentration Of Hydrogen
3.	SD	Standard Deviation
4.	ISCD	International Society For Clinical Densitometry
5.	IOF	International Osteoporosis Foundation
6.	RANKL	Receptor Of Nuclear Factor-Kappa-B Ligand
7.	DXA	Dual-Energy X-Ray Absorptiometry
8.	MRI	Magnetic Resonance Imaging
9.	REMS	Radiofrequency Echo-Graphic Multi-Spectrometry
10.	QCT	Quantitative Computed Tomography
11.	QUS	Quantitative Ultrasound
12.	BTM	Bone Turnover Biomarkers
13.	HYP	Hydroxyproline
14.	DPD	Deoxypyridinoline
15.	CTX	Carboxy-Terminal Cross-Linked Telopeptide Of Type 1 Collagen
16.	TRAP	Tartrate-Resistant Acid Phosphatase
17.	NTX	Amino-Terminal Cross-Linked Telopeptide Of Type 1 Collagen
18.	IFCC	International Federation Of Clinical Chemistry
19.	PINP	Serum Procollagen Type I P-Propeptide
20.	FRAX	Fracture Risk Assessment Tools
21.	FLS	Fracture Liaison Service
22.	APROPOS	Activating Patients At Risk For Osteoporosis
23.	HIPAA	Health Insurance Portability And Accountability Act

REFERENCES:

1. Knowledge, Attitudes, Practices, and Awareness Levels Among Indian Postmenopausal Women About Osteoporosis and Its Relationship With Sociodemographic Factors: A Cross-Sectional Study From Northern India Kale A, Khandelwal N, Rai S *Cureus* (2024)
2. Guideline for diagnostic, prevention, and treatment of postmenopausal osteoporosis Grygorieva N, Kovalenko V, Chaykivska E *Pain, Joints, Spine* (2023) 13(3) 128-15
3. Body Mass Index, Body Composition and Physical Activity as Predictors of Bone Density in Postmenopausal Osteoporotic Women S, Pascalau N, Jurjiu N
4. Exosomes: A promising new strategy for treating osteoporosis in the future S, Liang Y, Pan X *Journal of Drug Delivery Science and Technology*
5. Deep learning in the radiologic diagnosis of osteoporosis: a literature review Y, Lin J, Xu Z *Journal of International Medical Research*
6. Path analysis to identify factors influencing osteoporosis: A cross-sectional study Chen Q, Chen J, Shi J *Experimental Gerontology*
7. Formulation and assessment of penetration potential of Risedronate chitosan nanoparticles loaded transdermal gel in the management of osteoporosis: In vitro and ex vivo screening Pathak S, Sahu P, Sharma R *Carbohydrate Polymer Technologies and Applications* (2024) 7
8. Osteo18, a novel urinary proteomic signature, associated with osteoporosis in heart transplant recipients Y, Huang Q, Staessen J *Heliyon* (2024) 10(2)
9. To determine the prevalence of osteoporosis in Smokers Vijay Singh S, Bhalla R, Bhalla Assistant Professor R *International Journal of Life Sciences* (2024) 13(1)
10. Determination of Risk Factors of Osteoporosis in the Community of Post-Menopausal Age Perveen R, Shabbir A, Azad Pakistan *Journal of Health Sciences* (2023) 08-12
11. Bone fragility and osteoporosis in children and young adult Formosa M, Christou M, Mäkitie O *Journal of Endocrinological Investigation*
12. Assessing the osteoporotic risk markers in apparently healthy adults A, Dhama A, Chahal A *National Journal of Physiology, Pharmacy and Pharmacology* (2023) (0) 1
13. Prevalence of Diabetes Mellitus and Differences in Clinical Characteristics in A Population of Patients Affected by Severe Osteoporosis and Fragility Fractures Nardone I, Antonelli R, Uccioli L (2024)
14. Meta-Analysis: Effects of Smoking, Alcohol Consumption, and Low Physical Activity on Osteoporosis in Adults Fahrezi M, Ghifari A, Murti Research *Journal of Epidemiology and Public Health* (2024) (01) 25-36

15. Narrative Review on Osteoporosis: A Silent Killer Kulkarni S, Kour JOURNAL OF CLINICAL AND DIAGNOSTIC RESEARCH (2024)
16. Agrawal, A.C., Garg, A.K. Epidemiology of Osteoporosis. JOIO 57 (Suppl 1), 45–48 (2023). <https://doi.org/10.1007/s43465-023-01012-3>
17. Experiences of postmenopausal osteoporosis: a narrative review Al Zadjali F, Brooks J, Stanmore E *Disability and Rehabilitation* (2024) 46(5) 828-840
18. Expert opinion on the clinical use of calcium and vitamin D supplements in osteoporosis in Indian settings. M, M. K *International Journal of Research in Orthopaedics* (2024) 10(2) 364-368
19. Narrative Review on Osteoporosis: A Silent Killer Kulkarni S, Kour JOURNAL OF CLINICAL AND DIAGNOSTIC RESEARCH (2024)
20. Serum sclerostin levels as a diagnostic marker for osteoporosis Paranthaman M *Bioinformation* (2024) 20(1) 54-58
21. IJFANS International Journal Of Food And Nutritional Sciences Osteoporosis And Periodontal Disease: A Comprehensive Guide Gupta S, Das A, Mukherjee K(2012) 2022
22. To determine the prevalence of osteoporosis in Smokers Vijay Singh S, Bhalla R, Bhalla Assistant Professor *International Journal of Life Sciences* (2024) 13(1)
23. Varacallo MA, Fox EJ. Osteoporosis and its complications. *Med Clin North Am.* 2014 Jul;98(4):817-31, xii-xiii. [PubMed] [Reference list]
24. Blair, H.C., et al., *Osteoclastic bone resorption by a polarized vacuolar proton pump.* Science, 1989. 245(4920): p. 855-7.
25. Orwoll, E.S., *Toward an expanded understanding of the role of the periosteum in skeletal health.* J Bone Miner Res, 2003. 18(6): p. 949-54.
26. Dayanandan, A.P., Cho, W.J., Kang, H. et al. Emerging nano-scale delivery systems for the treatment of osteoporosis. *Biomater Res* 27, 68 (2023). <https://doi.org/10.1186/s40824-023-00413-7>
27. Inderjeeth, Charles A.a,b,c; Inderjeeth, Diren C.a. The use of anabolic agents in the treatment of osteoporosis: a clinical update. *Current Opinion in Endocrinology & Diabetes and Obesity* ():10.1097/MED.0000000000000867, May 17, 2024. | DOI: 10.1097/MED.0000000000000867
28. Girotra M, Rubin MR, Bilezikian JP. Anabolic Agents for Osteoporosis : What is Their Likely Place in Therapy? *Treat Endocrinol.* 2006;5(6):347-58. doi: 10.2165/00024677-200605060-00003. PMID: 17107220.
29. Brixen, K. T., Christensen, P. M., Ejersted, C., & Langdahl, B. L. (2004). Teriparatide (biosynthetic human parathyroid hormone 1-34): A new paradigm in the treatment of

- osteoporosis. In Basic and Clinical Pharmacology and Toxicology (Vol. 94, Issue 6, pp. 260–270). <https://doi.org/10.1111/j.1742-7843.2004.pto940602.x>
30. Brandi, M. L. (2010). Symposium V: Strontium Ranelate And Fragility Fractures Strontium Ranelate: The Pathophysiological Rationale. In Clinical Cases in Mineral and Bone Metabolism (Vol. 7, Issue 3).
 31. Mijanović, O., Jakovleva, A., Branković, A., Zdravkova, K., Pualic, M., Belozerskaya, T. A., Nikitkina, A. I., Parodi, A., & Zamyatnin, A. A. (2022). Cathepsin K in Pathological Conditions and New Therapeutic and Diagnostic Perspectives. In International Journal of Molecular Sciences (Vol. 23, Issue 22). MDPI. <https://doi.org/10.3390/ijms232213762>
 32. Actonel: Uses, Dosage & Side Effects Guide - Drugs.com
 33. Risedronic acid: Uses, Interactions, Mechanism of Action | Drug Bank Online
 34. Boniva: Side Effects, Dosage & Uses - Drugs.com
 35. fda, & cder. (n.d.). *BONIVA*® (*ibandronate sodium*) *INJECTION*. <https://www.fda.gov/drugsatfda>
 36. Binosto: Side Effects, Dosage & Uses - Drugs.com
 37. Alendronate: Dosage, Mechanism/Onset of Action, Half-Life - Medicine.com
 38. Aclasta IV Injection: Uses, Dosage & Side Effects - Drugs.com
 39. Zoledronic acid: Uses, Interactions, Mechanism of Action | Drug Bank Online
 40. Duavee: Uses, Dosage, Side Effects & Warnings - Drugs.com
 41. Bazedoxifene: Uses, Interactions, Mechanism of Action | Drug Bank Online
 42. Raloxifene: Uses, Interactions, Mechanism of Action | Drug Bank Online
 43. Evista: Uses, Dosage, Side Effects, Warnings - Drugs.com
 44. Femhrt: Uses, Dosage & Side Effects - Drugs.com
 45. Femhrt (norethindrone acetate/ethinyl estradiol tablets). (n.d.). <https://www.fda.gov/drugsatfda>
 46. Hanley DA, Adachi JD, Bell A, Brown V. Denosumab: mechanism of action and clinical outcomes. *Int J Clin Pract*. 2012 Dec;66(12):1139-46. doi: 10.1111/ijcp.12022. Epub 2012 Sep 12. PMID: 22967310; PMCID: PMC3549483.
 47. Denosumab (drugs.com)
 48. Teriparatide Uses, Side Effects & Warnings (drugs.com)

49. Vall H, Patel P, Parmar M. Teriparatide. [Updated 2024 Feb 29]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan-. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK559248/>
50. Abaloparatide Uses, Side Effects & Warnings (drugs.com)
51. Abaloparatide: Uses, Interactions, Mechanism of Action | Drug Bank Online
52. Romosozumab Uses, Side Effects & Warnings (drugs.com)
53. Romosozumab: Uses, Interactions, Mechanism of Action | Drug Bank Online
54. Calcitonin injection Uses, Side Effects & Warnings (drugs.com)
55. Human calcitonin: Uses, Interactions, Mechanism of Action | Drug Bank Online
56. Calcium carbonate Uses, Side Effects & Warnings (drugs.com)
57. Calcium carbonate: Uses, Interactions, Mechanism of Action | Drug Bank Online
58. Vitamin D3 Uses, Side Effects & Warnings (drugs.com)
59. Bikle DD. Vitamin D: Production, Metabolism and Mechanisms of Action. [Updated 2021 Dec 31]. In: Feingold KR, Anawalt B, Blackman MR, et al., editors. Endotext [Internet]. South Dartmouth (MA): MDText.com, Inc.; 2000-. Available from: <https://www.ncbi.nlm.nih.gov/books/NBK278935/>
60. Vitamin D3: Uses, Interactions, Mechanism of Action | Drug Bank Online
61. Samson Enitan, S., Ngozi Adejumo, E., Osaigbovoh Imaralu, J., Ademola Adelakun, A., Anike Ladipo, O., & Bosede Enitan, C. (2023). Personalized medicine approach to osteoporosis management in women: integrating genetics, pharmacogenomics, and precision treatments. *Clinical Research Communications*, 6(3), 18. <https://doi.org/10.53388/crc2023018>
62. Anita Sanghani-Kerai DM, Lancashire H, Osagie L, Coathup M, Blunn G. Stem cell interventions for bone healing fractures and osteoporosis. *Curr Stem Cell Res Therapy*. 2018;13(5):369–77.
63. Arjmand B, Sarvari M, Alavi-Moghadam S, Payab M, Goodarzi P, Gilany K, et al. The prospect of stem cell therapy and regenerative medicine in osteoporosis. *Front Endocrinol (Lausanne)*. 2020;11:430.
64. Hadjiargyrou M, Komatsu DE. The therapeutic potential of microRNAs as ortho biologics for skeletal fractures. *J Bone Miner Res*. 2019;34(5):797–809.
65. Ebert MS, Neilson JR, Sharp PA. MicroRNA sponges: competitive inhibitors of small RNAs in mammalian cells. *Nat Methods*. 2007;4(9):721–6.

66. Chen, Y., Huang, Y., Li, J. *et al.* Enhancing osteoporosis treatment with engineered mesenchymal stem cell-derived extracellular vesicles: mechanisms and advances. *Cell Death Dis* 15, 119 (2024). <https://doi.org/10.1038/s41419-024-06508-w>
67. Kroupova K, Palicka V, Rosa J. Monoclonal antibodies for treatment of osteoporosis. *Drugs of Today* (Barcelona, Spain : 1998). 2023 Mar;59(3):195-204. DOI: 10.1358/dot.2023.59.3.3453905. PMID: 36847627.
68. Calcium for osteoporosis: How much to take, supplement forms, and more (medicalnewstoday.com)
69. <https://www.medicalnewstoday.com/articles/vitamin-d-osteoporosis#benefits>
70. Benedetti MG, Furlini G, Zati A, Letizia Mauro G. The Effectiveness of Physical Exercise on Bone Density in Osteoporotic Patients. *Biomed Res Int.* 2018 Dec 23;2018:4840531. doi: 10.1155/2018/4840531. PMID: 30671455; PMCID: PMC6323511.
71. Vibration Therapy and Osteoporosis: What to Know (verywellhealth.com)
72. Incidence And Risk Factors For Osteoporosis In Postmenopausal Women: A Population-Based Study, Karunakar Dodda S, Archana Rajulapati B, Rao Kolati *SInternational Journal of Academic Medicine and Pharmacy*
73. Other diagnostic tools | International Osteoporosis Foundation
74. Uemura, K., Takashima, K., Higuchi, R., Kono, S., Mae, H., Iwasa, M., Abe, H., Maeda, Y., Kyo, T., Imagama, T., Ando, W., Sakai, T., Okada, S., & Hamada, H. (2024). Assessing the utility of osteoporosis self-assessment tool for Asians in patients undergoing hip surgery. *Osteoporosis and Sarcopenia*, 10(1), 16–21. <https://doi.org/10.1016/j.afos.2024.01.003>
75. Chavda, S., Chavda, B., & Dube, R. (2022). Osteoporosis Screening and Fracture Risk Assessment Tool: Its Scope and Role in General Clinical Practice. *Cureus*. <https://doi.org/10.7759/cureus.26518>
76. Toh, L. S., Lai, P. S. M., Wu, D. B.-C., Bell, B. G., Dang, C. P. L., Low, B. Y., Wong, K. T., Guglielmi, G., & Anderson, C. (2019). A comparison of 6 osteoporosis risk assessment tools among postmenopausal women in Kuala Lumpur, Malaysia. *Osteoporosis and Sarcopenia*, 5(3), 87–93. <https://doi.org/10.1016/j.afos.2019.09.001>
77. Williams C, Sapra A. Osteoporosis Markers. 2023 May 1. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2024 Jan–. PMID: 32644732.
78. Gupta A, Maslen C, Vindlacheruvu M, Abel RL, Bhattacharya P, Bromiley PA, Clark EM, Compston JE, Crabtree N, Gregory JS, Kariki EP, Harvey NC, McCloskey E, Ward KA, Poole KES. Digital health interventions for osteoporosis and post-fracture care. *Ther Adv Musculoskelet Dis.* 2022 Mar 28;14:1759720X221083523. doi: 10.1177/1759720X221083523. PMID: 35368375; PMCID: PMC8966117.

79. Codrea CI, Croitoru AM, Baciuc CC, Melinescu A, Fica D, Fruth V, Fica A. Advances in Osteoporotic Bone Tissue Engineering. *J Clin Med.* 2021 Jan 12;10(2):253. doi: 10.3390/jcm10020253. PMID: 33445513; PMCID: PMC7827332.
80. Osteoporosis in Men. (2009).