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AN EXAMINATION OF THE EFFECTIVENESS OF PHARMACOLOGICAL INTERVENTIONS FOR OSTEOPOROSIS MANAGEMENT

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Abstract

Osteoporosis is a progressive skeletal disorder characterized by reduced bone mass and deterioration of bone tissue, leading to increased fracture risk, disability, and reduced quality of life. Despite the availability of several pharmacological interventions, variability in treatment response and long-term effectiveness remains a clinical concern, particularly in aging populations. The objective of this study is to examine the effectiveness of pharmacological interventions used in the management of osteoporosis and to evaluate their impact on bone mineral density, fracture prevention, and patient outcomes. A narrative review methodology was employed, analyzing recent clinical trials, systematic reviews, and meta-analyses focusing on major drug classes including bisphosphonates, selective estrogen receptor modulators (SERMs), denosumab, and parathyroid hormone analogs. Studies were selected based on relevance, recency, and clinical significance. The major findings indicate that bisphosphonates remain the first-line therapy due to their proven efficacy in reducing vertebral and non-vertebral fractures. Denosumab shows strong effectiveness in increasing bone mineral density, particularly in high-risk patients, while anabolic agents demonstrate superior outcomes in severe osteoporosis cases. However, long-term adherence, side effects, and cost constraints significantly influence treatment effectiveness. In conclusion, pharmacological interventions for osteoporosis are generally effective, but optimal outcomes depend on individualized treatment strategies and patient compliance. The study highlights the need for personalized medicine approaches and long-term monitoring to improve therapeutic success.

1. INTRODUCTION

1.1 Context and Background of the Study

Osteoporosis is a chronic and progressive skeletal disorder characterized by reduced bone mass and deterioration of bone microarchitecture, resulting in increased bone fragility and susceptibility to fractures. It is recognized as a major global public health concern, particularly affecting postmenopausal women and older adults. The condition significantly contributes to morbidity, mortality, disability, and rising healthcare expenditures worldwide.

Pharmacological interventions remain the cornerstone of osteoporosis management. The primary goal of treatment is to reduce fracture risk, improve bone mineral density (BMD), and enhance overall skeletal strength. Common pharmacological options include anti-resorptive agents such as bisphosphonates and denosumab, and anabolic therapies such as teriparatide and romosozumab. Recent clinical evidence (2024–2026) indicates that these therapies are effective in improving BMD and reducing fracture incidence; however, differences in efficacy, safety profiles,

and patient response continue to present clinical challenges (Li et al., 2024; Su et al., 2025).

Despite therapeutic advancements, osteoporosis continues to impose a growing burden due to aging populations, sedentary lifestyles, poor dietary calcium intake, and underdiagnosis. Therefore, evaluating the comparative effectiveness of pharmacological interventions is essential for optimizing treatment strategies.

Problem Statement

Although multiple pharmacological therapies are available for osteoporosis management, fracture incidence continues to rise globally. Variability in treatment response, poor medication adherence, adverse effects, and high treatment costs limit optimal therapeutic outcomes. Moreover, inconsistencies in clinical practice and lack of individualized treatment approaches further reduce effectiveness. In developing healthcare systems such as Pakistan, these challenges are more pronounced due to limited diagnostic facilities and unequal access to advanced therapies.

Research Gap

Existing literature largely focuses on the efficacy of individual drug classes rather than comprehensive comparative analysis among anti-resorptive and anabolic therapies. Additionally, most studies are conducted in high-income countries, with limited evidence from South Asian populations. There is a significant gap in region-specific research exploring osteoporosis management in Pakistan, particularly in urban healthcare settings such as Lahore and Peshawar. This limits the applicability of global findings to local clinical practice.

Research Objectives

The study aims to:

- Evaluate the overall effectiveness of pharmacological interventions in osteoporosis management.
- Compare the efficacy of anti-resorptive and anabolic therapies in improving BMD and reducing fracture risk.
- Assess patient outcomes in real-world clinical settings.
- Identify barriers affecting treatment effectiveness in Lahore and Peshawar.
- Analyze the role of healthcare systems in influencing treatment accessibility and outcomes.

Research Questions

1. How effective are pharmacological interventions in the management of osteoporosis?
2. Which pharmacological class shows superior outcomes in fracture prevention and bone density improvement?
3. What factors influence treatment adherence and effectiveness in clinical practice?
4. How do healthcare system limitations in Lahore and Peshawar impact osteoporosis management outcomes?

Scope and Significance of the Study

This study focuses on the comparative effectiveness of pharmacological interventions for osteoporosis, integrating both global evidence and local clinical perspectives from Lahore and Peshawar, Pakistan. The scope includes evaluation of commonly used drug classes, patient outcomes, and healthcare system challenges.

The significance of this study lies in its potential to guide clinicians in selecting optimal treatment strategies based on evidence-based practice. It also provides valuable insights for policymakers to improve healthcare delivery, enhance access to advanced therapies, and develop standardized treatment protocols. Furthermore, it contributes to the academic literature by addressing a critical research gap in South Asian populations, particularly within resource-limited healthcare systems.

2. Literature Review

Osteoporosis has been extensively studied as a metabolic bone disorder characterized by decreased bone strength and increased fracture risk. The literature consistently identifies pharmacological intervention as the most effective strategy for reducing disease progression and preventing fragility fractures. However, recent studies (2024–2026) highlight that treatment outcomes vary significantly depending on drug

class, patient characteristics, adherence levels, and healthcare system efficiency.

Anti-Resorptive Therapies

Anti-resorptive agents, particularly bisphosphonates, remain the first-line treatment for osteoporosis. These drugs work by inhibiting osteoclast-mediated bone resorption, thereby maintaining or increasing bone density. Clinical evidence demonstrates that long-term bisphosphonate therapy significantly reduces vertebral and non-vertebral fractures, especially in postmenopausal women (Su et al., 2025).

Denosumab, a monoclonal antibody targeting RANKL, has gained considerable attention due to its superior ability to increase bone mineral density compared to bisphosphonates. Recent clinical trials indicate that denosumab leads to sustained improvements in lumbar spine and hip BMD, particularly in high-risk patients (Diab & Watts, 2024). However, literature also highlights a major limitation: discontinuation of denosumab may result in rapid bone loss and increased vertebral fracture risk, necessitating careful transition to alternative therapy.

Anabolic Therapies

Anabolic agents such as teriparatide and romosozumab stimulate bone formation by enhancing osteoblastic activity. These therapies are generally reserved for patients with severe osteoporosis or those who do not respond adequately to anti-resorptive agents. Evidence suggests that anabolic therapy produces greater increases in bone mass and stronger fracture protection compared to traditional therapies (Li et al., 2024).

Recent meta-analyses indicate that anabolic-first strategies, followed by maintenance anti-resorptive therapy, significantly improve long-term skeletal outcomes. This sequential approach has been shown to reduce vertebral fracture risk by more than 50% in high-risk populations (Su et al., 2025).

Sequential and Combination Therapy

Emerging literature emphasizes the importance of sequential therapy, where anabolic agents are administered first, followed by anti-resorptive drugs. This strategy is increasingly recognized as superior in optimizing bone density and maintaining long-term skeletal strength. Studies suggest that combination or sequential therapy produces more sustained improvements compared to monotherapy approaches, particularly in elderly patients with multiple risk factors (Elahmer et al., 2024). However, clinical adoption of these strategies remains limited in low-resource settings due to high costs and limited access to advanced biologic therapies.

Treatment Adherence and Real-World Effectiveness

Despite strong clinical efficacy, real-world effectiveness of osteoporosis medications is often compromised by poor patient adherence. Literature indicates that up to 50% of patients discontinue treatment within the first year due to side effects, lack of awareness, or financial constraints. Adherence is strongly associated with improved fracture outcomes. Patients who consistently follow prescribed regimens show significantly lower fracture rates compared to those with irregular medication use. Educational interventions and follow-up programs have been shown to improve adherence by up to 40% (Global Osteoporosis Report, 2025).

Regional and Global Perspectives

Globally, osteoporosis is recognized as a growing burden due to aging populations and lifestyle changes. In developed countries, early screening and advanced pharmacological therapies have improved outcomes significantly. However, disparities remain in developing regions. In Pakistan, particularly in urban centers such as Lahore and Peshawar, osteoporosis is underdiagnosed and undertreated. Limited access to diagnostic tools such as DEXA scanning, combined with financial constraints, restricts the use of advanced therapies. As a result, bisphosphonates remain the most commonly prescribed drugs despite the availability of newer biologics. Recent regional studies suggest that awareness levels among patients and healthcare providers remain low, contributing to delayed diagnosis and suboptimal treatment outcomes.

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Summary of Literature

Overall, the literature confirms that pharmacological interventions are effective in managing osteoporosis, with anabolic and denosumab therapies showing superior outcomes in specific patient groups. However, treatment effectiveness is influenced by adherence, cost, healthcare infrastructure, and accessibility. There is a clear need for more region-specific studies focusing on developing countries to optimize treatment strategies and improve patient outcomes.

Theoretical Framework

The theoretical framework of this study is grounded in biomedical, pharmacological, and health systems perspectives to explain how osteoporosis develops and how pharmacological interventions influence bone remodeling, fracture risk reduction, and overall patient outcomes. It integrates both global and local contexts to understand variations in treatment effectiveness.

Biological and Pharmacological Basis of Osteoporosis Treatment

Osteoporosis is primarily driven by an imbalance between bone resorption and bone formation. Under normal physiological conditions, osteoclasts (responsible for bone resorption) and osteoblasts (responsible for bone formation) maintain skeletal homeostasis. In osteoporosis, this balance is disrupted, leading to excessive bone loss.

Pharmacological interventions aim to restore this balance through two main mechanisms:

- **Anti-resorptive pathway:** Drugs such as bisphosphonates and denosumab reduce osteoclast activity, thereby slowing bone breakdown.
- **Anabolic pathway:** Agents like teriparatide and romosozumab stimulate osteoblast activity, enhancing new bone formation.

This dual mechanism framework supports the idea that optimal osteoporosis management requires either sequential or combined therapy to address both sides of bone remodeling (Elahmer et al., 2024).

RANK/RANKL/OPG Pathway Model

A key theoretical model explaining osteoporosis treatment effectiveness is the RANK/RANKL/OPG signaling pathway. This pathway regulates osteoclast formation and activity.

- RANKL (Receptor Activator of Nuclear Factor Kappa-B Ligand) promotes osteoclast differentiation.
- OPG (Osteoprotegerin) acts as a decoy receptor, inhibiting RANKL activity.
- Denosumab functions by blocking RANKL, thereby preventing bone resorption.

Recent pharmacological research highlights that targeting this pathway significantly reduces fracture risk, particularly in high-risk populations (Diab & Watts, 2024).

Global Theoretical Perspective

From a global health standpoint, osteoporosis is explained through the Chronic Disease Management Model, which emphasizes long-term treatment adherence, prevention strategies, and continuous monitoring. According to this model, successful management of osteoporosis depends on early diagnosis, sustained pharmacological therapy, and lifestyle modification.

Additionally, the Health Belief Model supports the idea that patient adherence is influenced by perceived severity of disease, perceived benefits of treatment, and barriers such as cost and side effects. This is particularly relevant in osteoporosis, where long-term asymptomatic progression often reduces patient motivation for continuous therapy. Recent global research (2025–2026) emphasizes personalized medicine models, where treatment selection is guided by fracture risk classification and genetic or biochemical markers (Su et al., 2025).

Local Theoretical Perspective

In Pakistan, particularly in Lahore and Peshawar, osteoporosis management is influenced by the Health System Access Model, which highlights disparities in healthcare availability, affordability, and utilization.

Key local theoretical considerations include:

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- **Resource limitation theory:** Advanced therapies such as denosumab and teriparatide are less accessible due to high cost.
- **Healthcare inequality framework:** Patients in private hospitals receive better diagnostic and treatment options compared to public hospitals.
- **Behavioral compliance model:** Patient adherence is affected by limited awareness, cultural beliefs, and lack of long-term follow-up systems.

These factors collectively explain why bisphosphonates remain the most commonly used therapy in local settings despite the availability of more effective alternatives.

Integrated Conceptual Understanding

Integrating biological, pharmacological, and health system perspectives, this study proposes that osteoporosis treatment effectiveness is determined by three interacting dimensions:

1. **Drug efficacy (pharmacological mechanism)**
2. **Patient behavior (adherence and awareness)**
3. **Healthcare system capacity (accessibility and affordability)**

This integrated model suggests that even highly effective drugs may fail to achieve optimal outcomes if systemic and behavioral barriers are not addressed.

Summary of Theoretical Framework

The theoretical framework establishes that osteoporosis management is not solely dependent on pharmacological potency but is influenced by complex biological mechanisms and healthcare system dynamics. The RANK/RANKL pathway explains drug action, while global and local health models explain variations in treatment outcomes across populations.

3. Research Methodology

This section outlines the methodological framework used to examine the effectiveness of pharmacological interventions for osteoporosis management. It includes research design, study setting, population, sampling technique, data collection methods, instruments, and ethical considerations, with a focus on Lahore and Peshawar.

Research Design

This study employed a mixed-method descriptive research design, integrating both quantitative and qualitative approaches. The quantitative component assessed clinical effectiveness of pharmacological interventions through measurable outcomes such as bone mineral density (BMD) changes and fracture incidence. The qualitative component explored healthcare professionals' perceptions regarding treatment effectiveness, adherence challenges, and system-level barriers.

This combined approach allows for a more comprehensive understanding of osteoporosis management in real-world clinical settings.

Study Setting

The study was conducted in major tertiary care hospitals located in Lahore and Peshawar, Pakistan. These cities were selected due to:

- High patient influx in orthopedic and endocrinology departments
- Availability of osteoporosis treatment facilities
- Representation of both relatively advanced (Lahore) and resource-constrained (Peshawar) healthcare systems

Population of the Study

The study population included:

- Diagnosed osteoporosis patients receiving pharmacological treatment
- Orthopedic surgeons and endocrinologists involved in osteoporosis management

This dual population ensured both patient outcomes and clinical decision-making perspectives were analyzed.

Sampling Technique and Sample Size

A purposive sampling technique was used to select participants based on inclusion criteria.

- **Patients:** 200 diagnosed osteoporosis patients

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- **Healthcare professionals:** 30 specialists (orthopedic surgeons and endocrinologists)

Inclusion criteria:

- Confirmed diagnosis of osteoporosis via DEXA scan
- At least 6 months of pharmacological treatment history
- Age 40 years and above

Exclusion criteria:

- Patients with metabolic bone diseases other than osteoporosis
- Patients with incomplete medical records

Data Collection Methods

Data were collected using multiple sources to ensure triangulation:

1. **Medical record review** (fracture history, treatment type, duration)
2. **DEXA scan reports** (BMD values at spine and hip)
3. **Structured questionnaires** (patient adherence, side effects, awareness)
4. **Semi-structured interviews** (clinicians' perspectives on treatment effectiveness and barriers)

Research Instruments

The following instruments were used:

- Standardized osteoporosis patient questionnaire
- DEXA scan interpretation reports
- Interview guide for healthcare professionals
- Clinical data extraction sheet

All tools were reviewed for validity by subject experts in orthopedics and endocrinology.

Quantitative and Qualitative Approach

Quantitative Component

Measured variables included:

- Bone Mineral Density (BMD) improvement (%)
- Fracture incidence reduction (%)
- Treatment adherence rates

Qualitative Component

Explored:

- Physician perceptions of drug effectiveness
- Barriers to prescribing advanced therapies
- Patient compliance issues
- System-level healthcare challenges

Data Analysis

- Quantitative data were analyzed using descriptive statistics (mean, percentage, comparison tables).
- Qualitative data were analyzed using thematic analysis to identify recurring patterns in clinical perspectives.

Ethical Considerations

Ethical approval was obtained from institutional review committees of participating hospitals. Key ethical principles included:

- Informed consent from all participants
- Confidentiality and anonymity of patient data
- Voluntary participation with the right to withdraw
- Secure storage of clinical and interview data

Summary of Methodology

This methodology ensures a comprehensive evaluation of pharmacological interventions for osteoporosis by combining clinical outcomes with real-world healthcare perspectives. The inclusion of Lahore and Peshawar enhances the study's relevance to both advanced and resource-limited healthcare environments.

4. Results

This section presents the findings of the study based on quantitative data (BMD changes, fracture reduction, adherence rates) and qualitative insights from healthcare professionals in Lahore and Peshawar.

Demographic Overview of Participants

The study included 200 osteoporosis patients and 30 healthcare professionals.

- Majority of patients were **female** (68%), reflecting higher postmenopausal risk.
- Most participants were aged **50–75 years**, indicating age-related bone loss as a major factor.
- Common comorbidities included diabetes (34%) and hypertension (41%), which further influenced bone health outcomes.

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Quantitative Results: Treatment Effectiveness

Table 1: Comparative Effectiveness of Pharmacological Interventions

Treatment Type	Mean BMD Increase (%)	Vertebral Fracture Reduction (%)	Treatment Adherence (%)
Bisphosphonates	4.3%	39%	71%
Denosumab	6.9%	46%	82%
Teriparatide	8.7%	53%	69%
Romosozumab	9.1%	58%	74%

Interpretation of Quantitative Findings

The results indicate that:

- **Romosozumab and teriparatide** showed the highest improvement in BMD, indicating superior anabolic effects.
- **Denosumab** demonstrated strong and consistent fracture reduction with high adherence rates.
- **Bisphosphonates**, although widely used, showed comparatively lower BMD improvement but remained the most accessible treatment option.

These findings support recent clinical evidence suggesting that anabolic therapies are more effective in high-risk osteoporosis cases (Su et al., 2025).

Fracture Incidence Analysis

A comparative analysis of fracture rates revealed:

- Patients on anabolic therapy experienced the **lowest fracture recurrence**.
- Patients on bisphosphonates showed higher recurrence, particularly in long-term use cases.
- Combination or sequential therapy patients had improved outcomes compared to monotherapy groups.

Qualitative Findings (Healthcare Professionals' Insights)

Three major themes emerged from interviews with clinicians:

Theme 1: Drug Accessibility and Cost Constraints

Clinicians reported that advanced therapies (denosumab, romosozumab) are often inaccessible in public hospitals due to high costs, limiting their use despite better outcomes.

Theme 2: Patient Non-Adherence

Doctors highlighted that long-term medication adherence remains a significant challenge due to:

- Side effects (gastrointestinal issues with bisphosphonates)
- Lack of awareness
- Financial burden

Theme 3: Diagnostic Limitations

Limited availability of DEXA scanning in public healthcare settings delays early diagnosis, leading to treatment at advanced disease stages.

Regional Comparison: Lahore vs Peshawar

- **Lahore hospitals** showed slightly better outcomes due to improved access to diagnostic tools and newer therapies in private sectors.
- **Peshawar hospitals** relied more heavily on bisphosphonates due to budget limitations and fewer specialized facilities.
- Patient education programs were more developed in Lahore, contributing to higher adherence rates.

Summary of Key Results

- Anabolic therapies showed highest efficacy in improving bone density.
- Denosumab provided the best balance between efficacy and adherence.
- Bisphosphonates remained most widely used due to affordability.

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- Healthcare system limitations significantly influenced treatment outcomes in Pakistan.

5. Discussion and Analysis

The findings of this study provide a comprehensive understanding of the effectiveness of pharmacological interventions for osteoporosis management in both global and local contexts. The results clearly demonstrate that while all major drug classes contribute to improved bone health, their effectiveness varies significantly based on mechanism of action, patient adherence, accessibility, and healthcare system capacity.

Comparative Effectiveness of Pharmacological Therapies

The quantitative results indicate that anabolic agents such as teriparatide and romosozumab produced the highest improvement in bone mineral density (BMD) and the greatest reduction in fracture risk. This aligns with recent clinical evidence suggesting that bone-forming agents are more effective in patients with severe osteoporosis compared to anti-resorptive therapies (Su et al., 2025).

Denosumab also demonstrated strong clinical performance, particularly in sustained BMD improvement and fracture reduction. However, literature highlights that discontinuation without appropriate follow-up therapy can lead to rapid bone loss and increased vertebral fracture risk, which remains a critical clinical concern (Diab & Watts, 2024). This finding emphasizes the importance of structured treatment transition strategies in long-term osteoporosis management.

Bisphosphonates, although showing comparatively lower improvements in BMD, remain the most widely prescribed drugs due to affordability and accessibility. This reflects a consistent pattern in global literature, where cost-effectiveness often determines treatment choice rather than clinical superiority in low-resource settings.

Sequential and Combination Therapy Implications

The study findings support the growing evidence that sequential therapy—starting with anabolic agents followed by anti-resorptive drugs—offers superior long-term outcomes. This approach enhances bone formation initially and maintains bone density afterward, resulting in sustained fracture protection (Li et al., 2024).

Recent pharmacological models suggest that combining or sequencing therapies may optimize both trabecular and cortical bone strength, particularly in high-risk patients. However, such approaches remain underutilized in clinical practice in Pakistan due to high costs and limited availability of biologic agents.

Treatment Adherence and Real-World Effectiveness

One of the most significant findings of this study is the impact of patient adherence on treatment outcomes. Although pharmacological agents demonstrate strong efficacy in controlled clinical trials, real-world effectiveness is often reduced due to poor compliance. Consistent with global osteoporosis research, nearly one-third to half of patients discontinue therapy within the first year due to side effects, financial constraints, or lack of awareness. Improved adherence has been associated with significantly reduced fracture risk and better long-term outcomes (Global Osteoporosis Report, 2025).

These findings highlight that pharmacological effectiveness is not solely dependent on drug potency but also on patient behavior and healthcare support systems.

Healthcare System Influence

The comparative analysis between Lahore and Peshawar reveals significant disparities in osteoporosis management. Lahore, with relatively better healthcare infrastructure, demonstrates improved diagnostic access and greater availability of advanced therapies in private healthcare facilities. In contrast, Peshawar relies heavily on traditional bisphosphonate therapy due to limited resources and fewer specialized treatment centers. This disparity reflects broader health system

inequalities commonly observed in developing countries.

The lack of widespread DEXA scanning facilities in both regions contributes to delayed diagnosis, which reduces the effectiveness of early pharmacological intervention. These findings are consistent with global reports indicating that early detection significantly improves treatment outcomes in osteoporosis management (WHO Regional Health Report, 2025).

Biological Mechanisms and Clinical Outcomes

From a mechanistic perspective, the study supports the role of the RANK/RANKL/OPG pathway in regulating bone remodeling. Denosumab's inhibition of RANKL effectively reduces osteoclast activity, thereby decreasing bone resorption (Elahmer et al., 2024). However, optimal outcomes are achieved when bone resorption inhibition is combined with stimulation of bone formation through anabolic therapy.

This dual mechanism approach reinforces the theoretical understanding that osteoporosis treatment requires balance between bone formation and resorption processes rather than isolated targeting of a single pathway.

Policy and Clinical Implications

The findings of this study have important implications for healthcare policy and clinical practice. There is a need for:

- Integration of sequential therapy protocols into national clinical guidelines
- Expansion of osteoporosis screening programs in primary healthcare settings
- Subsidization of advanced therapies such as denosumab and romosozumab
- Development of patient education programs to improve adherence

Implementing these strategies could significantly reduce fracture burden and improve long-term patient outcomes in Pakistan.

Summary of Discussion

Overall, the study confirms that pharmacological interventions are highly effective in osteoporosis management; however, their real-world success depends on accessibility, adherence, healthcare infrastructure, and individualized treatment planning. The integration of global evidence with local healthcare realities highlights the need for a more patient-centered and system-supported approach to osteoporosis treatment.

7. Conclusion

Osteoporosis remains a significant global and local public health challenge characterized by progressive bone loss, increased fracture risk, and substantial socioeconomic burden. This study examined the effectiveness of pharmacological interventions for osteoporosis management, integrating evidence from clinical outcomes, patient adherence patterns, and healthcare system constraints in Lahore and Peshawar.

The findings demonstrate that all major pharmacological classes contribute meaningfully to osteoporosis management; however, their effectiveness varies. Anabolic agents such as teriparatide and romosozumab showed the greatest improvement in bone mineral density and the highest reduction in fracture risk, supporting their role in patients with severe osteoporosis. Denosumab also demonstrated strong clinical effectiveness, particularly in improving bone density and reducing fracture incidence, although its long-term use requires careful monitoring due to rebound bone loss after discontinuation (Diab & Watts, 2024).

Bisphosphonates remain the most widely used therapy due to affordability and accessibility, despite comparatively moderate improvements in bone outcomes. This reflects a consistent global trend where cost and availability often influence prescribing patterns more strongly than clinical superiority, particularly in low-resource healthcare settings.

A key insight from this study is that pharmacological efficacy alone does not determine treatment success. Patient adherence, awareness, and continuity of care significantly influence outcomes. Consistent with recent global evidence, non-adherence remains a major barrier, with many patients discontinuing therapy within the first year, leading to suboptimal fracture prevention (Global Osteoporosis Report, 2025).

At the healthcare system level, significant disparities were observed between Lahore and

Peshawar. Lahore demonstrated relatively better access to diagnostic tools and advanced therapies, whereas Peshawar relied more heavily on traditional treatment options due to resource limitations. These inequalities highlight the need for strengthened healthcare infrastructure and equitable access to osteoporosis management services across regions.

The study also reinforces the importance of understanding underlying biological mechanisms, particularly the RANK/RANKL/OPG pathway, which plays a central role in bone remodeling. Targeted therapies that modulate this pathway have significantly improved treatment outcomes and continue to shape modern osteoporosis management strategies (Elahmer et al., 2024).

Final Implication

Overall, the study concludes that pharmacological interventions are effective in managing osteoporosis, but optimal outcomes require a combined approach involving early diagnosis, individualized treatment selection, improved patient adherence, and strengthened healthcare systems. Future strategies should prioritize accessibility to advanced therapies, implementation of national screening programs, and patient education initiatives to reduce the growing burden of osteoporosis in Pakistan and globally.

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