

Prevalence, Fracture Risk, and Management Strategies for Osteoporosis in Patients Undergoing Maintenance Haemodialysis: A Prospective Observational Study

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ABSTRACT

Background: Osteoporosis and increased fracture risk are important skeletal complications among patients with End-Stage Renal Disease (ESRD) undergoing maintenance haemodialysis. Early identification of low Bone Mineral Density (BMD), fracture risk assessment, and appropriate management may help optimize skeletal health. **Objectives:** To assess the prevalence of osteoporosis, fracture risk, and management strategies among patients with Chronic Kidney Disease (CKD) progressing to ESRD and undergoing maintenance haemodialysis. **Materials and Methods:** A six-month prospective observational study was conducted among 76 patients undergoing maintenance haemodialysis at a tertiary care teaching hospital. Demographic and clinical characteristics, medical history, biochemical parameters, BMD/T-scores, FRAX® scores, medications, and dietary interventions were recorded. BMD was categorized as normal, osteopenia, or osteoporosis based on available T-score reports. Ten-year probabilities of Major Osteoporotic Fracture (MOF) and hip fracture were assessed using FRAX®. Patients were followed for three months to evaluate changes in selected biochemical parameters and management strategies. Statistical analysis was performed using MedCalc, with $p < 0.05$ considered statistically significant. **Results:** Among 76 patients, 45 (59.2%) were male and 31 (40.8%) were female. Based on available T-score reports, 13 (17.1%) had osteoporosis, 53 (69.7%) osteopenia, and 10 (13.2%) normal BMD. Previous fracture was reported in 24 (31.6%) patients. Increased 10-year probability of MOF ($\geq 20\%$) was observed in 29 (38.2%) patients, while increased hip fracture probability ($\geq 3\%$) was observed in 21 (27.6%). Significant changes were observed in serum calcium, phosphorus, creatinine, Vitamin D, albumin, PTH, magnesium, and haemoglobin at three-month follow-up ($p < 0.001$ for all). Dietary counselling (84.2%), calcium supplementation (76.3%), and Vitamin D supplementation (68.4%) were the most commonly documented management strategies. Denosumab, romosozumab, and raloxifene were prescribed to 14 (18.4%), 12 (15.8%), and 9 (11.8%) patients, respectively. **Conclusion:** Low BMD was common among patients undergoing maintenance haemodialysis, with osteopenia predominating. A substantial proportion had previous fractures or increased FRAX-estimated fracture probabilities. Comprehensive assessment of BMD, fracture history, CKD-MBD parameters, and clinical risk factors, together with individualized nutritional and pharmacological management, may support skeletal health in this population.

Keywords: Bone Mineral Density, Chronic Kidney Disease, CKD-MBD, End-Stage Renal Disease, Fracture Risk, FRAX, Haemodialysis, Osteoporosis.

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INTRODUCTION

Osteoporosis is a systemic skeletal disorder characterized by reduced bone strength and increased susceptibility to fragility fractures. Although traditionally associated with ageing and

postmenopausal women, osteoporosis also affects men, with differences in prevalence and risk factors between sexes (De Martinis *et al.*, 2021).

Patients with Chronic Kidney Disease (CKD), particularly those with End-Stage Renal Disease (ESRD) undergoing maintenance haemodialysis, are at increased risk of skeletal complications. CKD-related disturbances in calcium, phosphorus, Vitamin D, and Parathyroid Hormone (PTH) metabolism, together with alterations in bone turnover and nutritional status, contribute to CKD-Mineral and Bone Disorder (CKD-MBD) and skeletal fragility (Aguilar *et al.*, 2023; Peterle *et al.*, 2024; Kher *et al.*, 2025). Recent evidence has demonstrated a substantial burden of



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low bone mineral density among patients with CKD, including those with advanced disease and dialysis dependence (Ghazaian *et al.*, 2025).

Assessment of skeletal health in advanced CKD requires consideration of both bone quantity and bone quality. Bone Mineral Density (BMD), commonly assessed using dual-energy X-ray absorptiometry, can provide clinically useful information, while fracture-risk assessment tools such as FRAX® may provide additional risk stratification. However, FRAX was developed primarily for the general population and does not incorporate all CKD-specific determinants of fracture risk (Huang *et al.*, 2023; Evenepoel *et al.*, 2021; Ginsberg and Ix, 2022).

Management of skeletal disease in advanced CKD requires an individualized approach that considers correction of CKD-MBD abnormalities, nutritional optimization, lifestyle measures, fall-risk reduction, fracture history, BMD, and appropriate pharmacological therapy. Recent consensus recommendations emphasize that treatment decisions in CKD stages G4-G5D should account for the underlying CKD-MBD phenotype and overall clinical context rather than relying solely on general-population osteoporosis algorithms (Evenepoel *et al.*, 2021; Ginsberg and Ix, 2022).

Despite the substantial burden of skeletal abnormalities among patients undergoing haemodialysis, osteoporosis and fracture risk may remain under-recognized. Therefore, this study aimed to assess the prevalence of osteoporosis, evaluate fracture risk using FRAX®, and assess management strategies among patients with CKD progressing to ESRD and undergoing maintenance haemodialysis. Changes in selected biochemical parameters over three months were also evaluated.

MATERIALS AND METHODS

Study Design and Setting

A six-month prospective observational study was conducted in the Department of Nephrology and Haemodialysis Unit of Bangalore Baptist Hospital, Bengaluru, India, a tertiary-care teaching hospital.

Study Population

A total of 76 patients with CKD progressing to ESRD and undergoing maintenance haemodialysis were enrolled consecutively during the study period.

Inclusion Criteria

Patients meeting the following criteria were included:

- Age 40-90 years.
- CKD progressing to ESRD and undergoing maintenance haemodialysis.

- Availability of a documented BMD assessment with a T-score report.

Exclusion Criteria

Patients were excluded if they met any of the following criteria:

- Age below 40 years.
- CKD conditions outside the predefined study population that could independently affect bone health, such as polycystic kidney disease.

Data Collection

Demographic characteristics, medical history, comorbidities, dialysis-related details, BMD/T-scores, biochemical parameters, FRAX scores, medication use, and dietary and osteoporosis-management strategies were recorded using a structured data-collection form.

Assessment of Bone Mineral Density and Fracture Risk

BMD was assessed using the available T-score reports. Patients were categorized as having normal BMD, osteopenia, or osteoporosis according to the classification documented in the available BMD records.

The FRAX® tool was used to estimate the 10-year probabilities of major osteoporotic and hip fractures based on relevant clinical risk factors and BMD, where applicable.

For descriptive analysis, a 10-year MOF probability of $\geq 20\%$ and hip-fracture probability of $\geq 3\%$ were used to identify patients with higher predicted fracture probabilities. These thresholds were interpreted cautiously because FRAX does not fully capture the additional determinants of fracture risk associated with advanced CKD and haemodialysis. Therefore, they were used as descriptive risk categories and not as universally validated treatment thresholds for the haemodialysis population.

Assessment of Management Strategies

Pharmacological and non-pharmacological management strategies, including calcium supplementation, Vitamin D supplementation, combined calcium and Vitamin D therapy, anti-osteoporotic pharmacotherapy, and dietary counselling, were documented from patient treatment records.

Denosumab, romosozumab, and raloxifene were prescribed to mutually exclusive patient groups, with no patient receiving more than one of these anti-osteoporotic agents during the study period.

Management strategies other than the three anti-osteoporotic agents were not necessarily mutually exclusive.

Follow-up

Patients were followed for three months. Selected biochemical parameters and management strategies were reassessed at the three-month follow-up.

Statistical Analysis

Data were entered into Microsoft Excel and analysed using MedCalc Statistical Software. Continuous variables were expressed as Mean±Standard Deviation (SD), while categorical variables were presented as frequencies and percentages. A paired *t*-test was used to compare continuous biochemical parameters between baseline and three-month follow-up. A *p*-value <0.05 was considered statistically significant.

RESULTS

Demographic and Clinical Characteristics

Among the 76 haemodialysis patients, 45 (59.2%) were males, and 31 (40.8%) were females (Table 1). Alcohol consumption of ≥3 units/day was reported in 21 (46.7%) males and 5 (16.1%) females, while current smoking was reported in 18 (40.0%) males and 4 (12.9%) females, respectively. Previous fracture was reported in 17 (37.8%) males and 7 (22.6%) females, giving an overall prevalence of 24 (31.6%).

A parental history of hip fracture was reported in 5 (11.1%) males and 4 (12.9%) females. Glucocorticoid use was documented in 5 (11.1%) males and 2 (6.5%) females. Rheumatoid arthritis was reported in 10 (22.2%) males and 5 (16.1%) females. Secondary osteoporosis was observed in 3 (6.7%) males and 11 (35.5%) females.

Diabetes mellitus was present in 26 (57.8%) males and 14 (45.2%) females, whereas hypertension was reported in 43 (95.6%) males and 26 (83.9%) females. Hypothyroidism was present in 8 (17.8%) males and 9 (29.0%) females. Congestive heart failure was observed in 7 (15.6%) males and 4 (12.9%) females.

Gender-wise Distribution of BMD Categories

Bone mineral density classification based on available T-score reports showed that among male patients (*n*=45), 7 (15.6%) had normal BMD, 35 (77.8%) had osteopenia, and 3 (6.7%) had osteoporosis. Among female patients (*n*=31), 3 (9.7%) had normal BMD, 18 (58.1%) had osteopenia, and 10 (32.3%) had osteoporosis. Overall, among the 76 patients, 10 (13.2%) had normal BMD, 53 (69.7%) had osteopenia, and 13 (17.1%) were classified as having osteoporosis (Table 2).

FRAX-based Assessment of 10-year Fracture Risk

FRAX-based assessment showed that 24 (31.6%) patients had a previous history of fracture. An increased 10-year probability of

major osteoporotic fracture (≥20%) was observed in 29 (38.2%) patients, while 21 (27.6%) patients had an increased 10-year probability of hip fracture (≥3%) (Table 3).

Changes in Biochemical Parameters at Three-month Follow-up

Significant changes were observed in several biochemical parameters between baseline and the three-month follow-up (Table 4). Mean serum calcium increased from 5.99±1.88 mg/dL at baseline to 8.87±2.28 mg/dL at three months, while mean serum phosphorus decreased from 5.50±1.61 mg/dL to 4.50±1.50 mg/dL.

Serum creatinine decreased from 6.60±2.97 mg/dL to 4.14±2.27 mg/dL, whereas Vitamin D levels increased from 12.81±7.10 ng/mL to 20.58±9.62 ng/mL. Serum albumin increased from 2.51±0.88 g/dL to 3.73±0.82 g/dL, while PTH levels decreased from 282.88±154.40 pg/mL to 194.20±119.86 pg/mL.

Mean serum magnesium increased from 1.22±0.72 mg/dL to 1.90±0.50 mg/dL, and haemoglobin increased from 8.38±1.60 g/dL to 10.44±1.99 g/dL. All observed changes were statistically significant according to the paired *t*-test (*p*<0.001).

Management Strategies for Low Bone Mineral Density

Dietary counselling was the most commonly documented management strategy, Provided to 64 (84.2%) patients, followed by calcium supplementation in 58 (76.3%) and Vitamin D supplementation in 52 (68.4%) patients. Combined calcium and Vitamin D supplementation was documented in 47 (61.8%) patients.

Table 1: Demographic and clinical characteristics of haemodialysis patients with osteoporosis risk factors.

Characteristics	Male (N=45), <i>n</i> (%)	Female (N=31), <i>n</i> (%)
Alcohol (≥3 units/day)	21 (46.7)	5 (16.1)
Current smoking	18 (40.0)	4 (12.9)
Previous fracture	17 (37.8)	7 (22.6)
Parental hip fracture	5 (11.1)	4 (12.9)
Glucocorticoid use	5 (11.1)	2 (6.5)
Rheumatoid arthritis	10 (22.2)	5 (16.1)
Secondary osteoporosis	3 (6.7)	11 (35.5)
Diabetes mellitus	26 (57.8)	14 (45.2)
Hypertension	43 (95.6)	26 (83.9)
Hypothyroidism	8 (17.8)	9 (29.0)
Congestive heart failure	7 (15.6)	4 (12.9)

Table 2: Gender-wise distribution of normal BMD, osteopenia, and osteoporosis based on T-score.

Gender	Normal, <i>n</i> (%)	Osteopenia, <i>n</i> (%)	Osteoporosis, <i>n</i> (%)	Total
Male	7 (15.6)	35 (77.8)	3 (6.7)	45
Female	3 (9.7)	18 (58.1)	10 (32.3)	31
Total	10 (13.2)	53 (69.7)	13 (17.1)	76

Table 3: FRAX-based assessment of 10-year fracture risk among study participants (*n*=76).

Parameter	Number of patients, <i>n</i> (%)
History of prior fracture	24 (31.6)
Increased 10-year probability of major osteoporotic fracture ($\geq 20\%$)	29 (38.2)
Increased 10-year probability of hip fracture ($\geq 3\%$)	21 (27.6)

Among anti-osteoporotic pharmacological therapies, denosumab was prescribed to 14 (18.4%) patients, romosozumab to 12 (15.8%), and raloxifene to 9 (11.8%). These three anti-osteoporotic therapies were prescribed to mutually exclusive groups of patients; therefore, a total of 35 (46.1%) patients received one of these agents. Other management strategies were not mutually exclusive, and patients could receive more than one intervention; consequently, the corresponding percentages do not sum to 100% (Table 5).

DISCUSSION

The present study demonstrated a substantial burden of low BMD among maintenance haemodialysis patients, with osteopenia in 69.7% and osteoporosis in 17.1%. Osteoporosis was more common among females (32.3%) than males (6.7%), potentially reflecting age-related and postmenopausal bone loss superimposed on CKD-related metabolic abnormalities. These findings are consistent with the increased skeletal burden reported in patients with advanced CKD (Aguilar *et al.*, 2023; Peterle *et al.*, 2024; Kher *et al.*, 2025; Ghazaian *et al.*, 2025; Evenepoel *et al.*, 2021).

Fracture risk was also considerable, with previous fractures reported in 31.6% of patients. Furthermore, 38.2% had a 10-year major osteoporotic fracture probability $\geq 20\%$ and 27.6% had a hip fracture probability $\geq 3\%$. These findings indicate that skeletal vulnerability may be substantial even beyond BMD-defined osteoporosis. FRAX® may provide useful risk information but should be interpreted cautiously in haemodialysis patients because it does not capture all CKD-specific determinants of fracture risk, including abnormalities in bone turnover and mineral metabolism (Huang *et al.*, 2023; Evenepoel *et al.*, 2021; Ginsberg and Ix, 2022; Ram *et al.*, 2025).

Significant changes in calcium, phosphorus, Vitamin D, albumin, magnesium, haemoglobin, PTH, and creatinine were observed over three months of clinical management. These changes

highlight the importance of regular monitoring and management of CKD-MBD and nutritional abnormalities in haemodialysis patients. However, biochemical improvements cannot be considered evidence of improved BMD or reduced fracture risk because repeat BMD and fracture outcomes were not assessed during the study period (Evenepoel *et al.*, 2021; Ginsberg and Ix, 2022).

Management mainly involved dietary counselling, calcium and Vitamin D supplementation, and anti-osteoporotic pharmacotherapy. Dietary counselling was provided to 84.2% of patients, while calcium and Vitamin D supplementation were used in 76.3% and 68.4%, respectively. Anti-osteoporotic therapy, including denosumab, romosozumab, and raloxifene, was prescribed in selected patients. Given the limited evidence for osteoporosis therapies in advanced CKD and haemodialysis, treatment should be individualized according to fracture history, BMD, bone turnover, biochemical parameters, and clinical status (Evenepoel *et al.*, 2021; Laurent *et al.*, 2025).

The findings emphasize that skeletal health in haemodialysis patients is multifactorial and requires management beyond pharmacotherapy. Correction of modifiable metabolic and nutritional abnormalities, appropriate dietary and lifestyle measures, fall-risk reduction, and regular assessment of fracture risk are important components of comprehensive care (Evenepoel *et al.*, 2021; Ginsberg and Ix, 2022).

Overall, the study highlights the high burden of low BMD and fracture risk in maintenance haemodialysis patients and supports an individualized approach to skeletal health assessment and management. Larger multicentre studies with longer follow-up are required to determine whether these management strategies translate into sustained improvements in BMD and reduced fracture incidence.

LIMITATIONS

This study was conducted at a single tertiary care centre with a relatively small sample size, which may limit the generalizability of the findings to other settings. Additionally, the short follow-up period limited the assessment of longer-term changes in bone health and clinical outcomes. Long-term fracture outcomes and treatment safety data were not available, limiting evaluation of the sustained clinical effects of the observed management strategies. The study also relied on routinely collected clinical and laboratory data, and some patient-related factors may not have been fully captured. Furthermore, the observational design does

Table 4: Changes in biochemical parameters of haemodialysis patients at baseline and three-month follow-up.

Parameter	Baseline, Mean±SD	3 months, Mean±SD	p-value
Calcium (mg/dL)	5.99±1.88	8.87±2.28	<0.001
Phosphorus (mg/dL)	5.50±1.61	4.50±1.50	<0.001
Serum creatinine (mg/dL)	6.60±2.97	4.14±2.27	<0.001
Vitamin D (ng/mL)	12.81±7.10	20.58±9.62	<0.001
Serum albumin (g/dL)	2.51±0.88	3.73±0.82	<0.001
Parathyroid hormone (pg/mL)	282.88±154.40	194.20±119.86	<0.001
Magnesium (mg/dL)	1.22±0.72	1.90±0.50	<0.001
Haemoglobin (g/dL)	8.38±1.60	10.44±1.99	<0.001

Table 5: Management strategies for low bone mineral density among haemodialysis patients (n=76).

Management strategy	Patients, n (%)
Dietary counselling	64 (84.2)
Calcium supplementation	58 (76.3)
Vitamin D supplementation	52 (68.4)
Combined calcium and Vitamin D therapy	47 (61.8)
Denosumab	14 (18.4)
Romosozumab	12 (15.8)
Raloxifene	9 (11.8)

not allow definitive conclusions regarding causal relationships between management strategies and outcomes. Despite these limitations, the study provides clinically relevant real-world data on osteoporosis prevalence, fracture risk, and management patterns among patients undergoing maintenance haemodialysis and may provide a basis for further multicentre studies with larger sample sizes and longer follow-up.

CONCLUSION

The present study demonstrates a substantial burden of low BMD among maintenance haemodialysis patients, with osteopenia in 69.7% and osteoporosis in 17.1%. Osteoporosis was more common among females, while previous fractures and elevated FRAX-estimated fracture probabilities indicated considerable skeletal risk. Significant improvements in selected biochemical parameters were observed over three months with ongoing clinical management, primarily involving dietary counselling, calcium and Vitamin D supplementation, and individualized anti-osteoporotic therapy. However, these biochemical improvements cannot be assumed to indicate improved BMD or reduced fracture risk due to the short follow-up and lack of repeat skeletal assessment.

Regular skeletal health and fracture-risk assessment, correction of modifiable metabolic abnormalities, fall-risk reduction, and individualized treatment may support comprehensive bone health management in haemodialysis patients. Larger multicentre studies with longer follow-up are needed to determine the

long-term effectiveness and safety of these interventions and their impact on fracture prevention.

ABBREVIATIONS

BMD: Bone Mineral Density; **CKD:** Chronic Kidney Disease; **CKD-MBD:** Chronic Kidney Disease-Mineral and Bone Disorder; **ESRD:** End-Stage Renal Disease; **FRAX:** Fracture Risk Assessment Tool; **GCP:** Good Clinical Practice; **MOF:** Major Osteoporotic Fracture; **PTH:** Parathyroid Hormone; **SD:** Standard Deviation.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ETHICAL APPROVAL

The study was conducted in accordance with the ethical principles of the Declaration of Helsinki and Good Clinical Practice (GCP) guidelines. The study was observational in nature and involved the collection and follow-up of clinical and laboratory data from patients undergoing routine haemodialysis. No intervention or modification of the patients' prescribed treatment was performed during the study. Patient confidentiality and privacy were maintained throughout the study, and all data were collected and analysed solely for research purposes.

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