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Research Article

ARCHIVES OF NEPHROLOGY AND UROLOGY

ISSN: 2644-2833

Pattern of Bone Mineral Density at Optimal Skeletal Measurement Site among Patients on Maintenance Hemodialysis

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Abstract

Background: Chronic Kidney Disease (CKD) and Mineral-Bone Disorders (MBD) are important health problems. According to the KDIGO CKD-MBD guideline, bone loss and fracture risks are higher in CKD patients than in age-matched controls throughout all the stages, with the highest incidence among dialysis patients. Bone densitometry (BMD) is a preferred method for diagnosing osteopenia/osteoporosis. Interpreting bone densitometry in End-Stage Renal Disease (ESRD) patients requires careful assessment.

Aim of the study: To determine the pattern of bone mineral density in optimal skeletal measurement sites in patients of both genders on maintenance hemodialysis using the DEXA method.

Methods: This cross-sectional study was carried out in the Nephrology department of Dhaka Medical College Hospital from October 2020 to October 2021. A total of 60 ESRD patients (Group A, 30 male and Group B, 30 female patients) fulfilling the selection criteria were included in this study. All the subjects were evaluated clinically, and relevant data were recorded in a structured questionnaire. Bone Mineral Densitometry (BMD) test was done in every study population. Laboratory data was collected after measuring serum calcium, phosphate and iPTH levels. Statistical analysis of the clinical, densitometric and laboratory data was obtained using window-based computer software devised with Statistical Packages for Social Sciences (SPSS-23). Results were expressed in various tables.

Results: The mean age of group A (male) was 43.24±10.92 years, and group B (female) was 41±12.6 years. The mean BMI was significantly higher in females (27.19±5.98 kg/m2) than in males (23.71±4.42 kg/m2). The mean duration of dialysis was higher in males than females. The mean total BMD value expressed as gm/cm2 was almost similar, 1.04±0.22 (g/cm2) in group A and 1.05±0.18 (g/cm2) in group B, and no statistically significant ($p>0.05$) difference was observed between two groups. Considering conventional BMD sites (lumbar spine, left hip), 28(46.7%) patients had normal bone mass, 22(36.7%) patients had osteopenia, out of which 13(43.3%) were male and 9(30.0%) were female. Total 10(16.6%) patients had osteoporosis, out of which 4(13.4%) male and 6(20.0%) female. The difference between the two groups was insignificant ($p>0.05$). While considering left forearm BMD, it was found that 33.3% of males had osteopenia and 66.7 % of males had osteoporosis; on the other hand, in females, 20 % had osteopenia, and 53 % had osteoporosis. Regarding the skeletal site, the mean Total T score differences in the left hip (neck, G.T, inter) were statistically significant ($p<0.05$) between males and females. According to the Z score, low bone density was also higher in males; the

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Citation: Dr. Madhabi Karmaker, Dr. Samira Khatun, Dr. Farnaz Nobi, Dr. Shanjida Sultana Juthy, Dr. Khaleda Akhter. Pattern of Bone Mineral Density at Optimal Skeletal Measurement Site among Patients on Maintenance Hemodialysis. Archives of Nephrology and Urology. 9 (2026): 01-10.

Received: January 19, 2026
Accepted: January 28, 2026
Published: February 04, 2026

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DOI:10.26502/anu.2644-2833109

prevalence of low bone density (Z score <-1) was between 20 and 40 %, while 13.3% to 20% in females. Again, the Z score below the expected range for age (Z score <-2.0) was between 13.3% to 80 % in males and 13.3% to 40 % in females. The mean calcium and phosphate level difference was not statistically significant between male and female patients, but the iPTH level was higher in male patients. Different Correlations between BMD of measurement sites and laboratory and clinical parameters, expressed as a coefficient of correlation (r), were also found in male and female patients, with better correlation of skeletal sites in female patients.

Conclusion: Regardless of limitations, this study showed reduced bone mass in HD patients and different reductions of bone mass in different skeletal sites (both central and peripheral) in male and female patients.

Keywords: Bone mineral density; Dual X-Ray absorptiometry; End-Stage renal disease; Maintenance hemodialysis; Osteopenia; Osteoporosis.

Introduction

Bone mineral disorder is a common complication in end-stage renal disease (ESRD), especially in patients on maintenance hemodialysis. Accelerated bone loss from abnormal turnover leads to a high prevalence of metabolic bone diseases, including osteomalacia, adynamic bone disease, osteitis fibrosa, and osteoporosis. Secondary hyperparathyroidism, metabolic acidosis, and chronic inflammation further worsen bone health in these patients [1-4]. Osteoporosis, a skeletal disorder marked by reduced bone strength and higher fracture risk, is common in ESRD patients [5]. Bone mineral density (BMD), measured at sites such as the lumbar spine and femoral neck, is essential for diagnosing osteoporosis. Studies show its prevalence in up to 80% of ESRD patients at the mid-radius, 47% at the hip neck, and less than 30% at the lumbar spine [6]. The fracture risk in ESRD patients is reported to be over four times higher than in the general population [7]. Timely evaluation of bone mineral disorders in ESRD patients is crucial. The link between bone mineral density (BMD) and bone turnover in this population is influenced by parathyroid hormone (PTH) levels, impacting both cortical and trabecular bone. The International Society for Clinical Densitometry advises forearm BMD measurement in hyperparathyroidism, as cortical bone is primarily affected by ESRD [7, 8]. Dual-energy X-ray absorptiometry (DEXA) is the preferred method for measuring BMD due to its precision, accuracy, short scan time, and low radiation exposure [9]. Commonly assessed sites include the lumbar spine, proximal femur, and forearm, with results reported as BMD, T-scores, or Z-scores. Forearm measurements are particularly useful, as radius BMD may better predict fracture risk in ESRD patients than lumbar spine assessments [10]. While BMD testing cannot differentiate between bone disease types, T-scores and Z-scores are vital for osteoporosis evaluation. The Z-score, which compares BMD to an age- and gender-matched population, is especially relevant for CKD patients and is recommended by the International Society for Clinical Densitometry [7]. Various factors influence BMD in ESRD patients. Prolonged dialysis duration, vitamin D deficiency, amenorrhea in women, and exposure to medications with adverse effects on bone health contribute to reduced BMD [11,12]. Additionally, protein-energy wasting correlates with lower BMD, while higher body mass index (BMI) and physical activity appear protective against bone loss [13]. Although DEXA scans are widely used, technical limitations in CKD patients, such as interference from aortic calcifications and vertebral osteosclerosis, may impact results [14]. To overcome these limitations, assessments at multiple sites, including the hip and distal forearm, are recommended for CKD patients [15]. Given the high prevalence of bone disorders in ESRD patients and the limitations of current diagnostic tools, assessing BMD at optimal skeletal sites is crucial. The revised KDIGO CKD-MBD guidelines recommend BMD testing in CKD patients with evidence of bone disorders to guide treatment decisions [16]. This study aims to evaluate the pattern of bone mineral density, identify osteopenia and osteoporosis, determine the optimal measurement site, assess gender differences, and explore associations with laboratory and clinical parameters in maintenance hemodialysis patients using the DEXA method.

Methodology and Materials

This cross-sectional observational study was conducted in the Department of Nephrology, Dhaka Medical College and Hospital, Dhaka, over 12 months from October 2020 to September 2021. The study included end-stage renal disease (ESRD) patients undergoing maintenance hemodialysis (MHD). A purposive sampling technique was used to recruit participants. The study was approved by the Research Review Committee (RRC) of the Department of Nephrology and the Ethical Review Committee (ERC) of Dhaka Medical College. Informed consent was obtained from all participants. Sixty patients meeting the inclusion criteria were recruited from the nephrology department at Dhaka Medical College and Hospital. Participants were divided into two groups based on gender: Group A (males) and Group B (females). Patients were instructed to attend the dialysis center on their scheduled hemodialysis day. Blood samples for biochemical testing were collected prior to the start of dialysis through the arterio-venous fistula.

Inclusion Criteria

ESRD patients of both genders aged 18-55 years.

Patients on MHD for ≥6 months.

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DOI:10.26502/anu.2644-2833109

Exclusion Criteria

Patients with a history of bone mineral disorders, fractures, malignancy, or parathyroidectomy.

Patients treated with estrogen, calcitonin, bisphosphonates, teriparatide, corticosteroids, or androgens.

Data Collection and Measurements

Demographic and clinical data were collected using a standardized questionnaire, which included sociodemographic details (age, sex), clinical parameters (height, weight, body mass index [BMI], and duration of hemodialysis), and laboratory investigations. Laboratory parameters, including serum calcium, phosphate, and intact parathyroid hormone (PTH), were measured from blood samples collected before the scheduled hemodialysis session. Blood samples were drawn from the arterio-venous fistula using standard procedures. Bone mineral density (BMD) was assessed using dual-energy X-ray absorptiometry (DXA) at the lumbar spine (L1-L4), femoral neck, and total hip, which are considered optimal skeletal measurement sites for patients with chronic kidney disease (CKD). DXA scans were conducted using Hologic Discovery technology. BMD results were expressed as grams per square centimeter (g/cm²), T-scores, and Z-scores according to the World Health Organization (WHO) criteria for osteoporosis classification [17]. The Modification of Diet in Renal Disease (MDRD) equation was used to calculate the estimated glomerular filtration rate (eGFR) [18]. For the DXA scan, participants were advised to avoid taking calcium supplements or medications containing calcium for 24 hours before the test. On the test day, participants were asked to remove any metallic objects and wear clothing without zippers or hooks to prevent interference with the X-ray findings. During the DXA procedure, participants lay on a padded platform while the scanner passed a thin, invisible beam of low-dose X-rays with two distinct energy peaks through the examined bones. The DXA machine used specialized software to calculate and display BMD values, with results shown on a computer monitor as high-quality images. The procedure took 15 to 30 minutes, and participants could resume their usual activities immediately after the test. Height and weight measurements were taken using a stadiometer and a weight scale, respectively. All data were recorded and analyzed systematically.

Statistical Analysis

Data was analyzed in the statistical package for the social sciences (SPSS) version 23. Collected data was sorted, maintained with accuracy and preserved for statistical analysis, which was done with the help of an experienced statistician. Continuous data was expressed as a mean±SD. Comparisons Unpaired T-test was used to compare the groups. Statistical significance was expressed as a p-value <0.05. The correlation was determined by Pearson's correlation coefficient (r). The greater the absolute value of r, the stronger the relation and the sign of r (positive or negative) indicates the nature of the relation. The study showed an r-value of 1 perfect correlation, 0.7 to 1.0=strong correlation, 0.4 to 0.7=moderate correlation, 0.01 to 0.2=negligible correlation and 0.00 = no association.

Results

The study included 60 patients divided equally into Groups A and B (n=30). Group A had a slightly higher mean age (43.24±10.92 years) than Group B (41±12.6 years. Group B had a significantly higher mean BMI (27.19±5.98 kg/m²) than Group A (23.41±4.42 kg/m², p=0.006) (Table 1). The pie chart in Figure 1 shows that hypertensive nephropathy (30%) and glomerulonephritis (25%) were the most prevalent causes of ESRD. 52% of patients were asymptomatic, 33% had generalized bone pain, 8% had low back pain, and 7% experienced joint pain (Figure 2). Table 2 showed no significant differences in lumbar spine and left hip BMD (p=0.529). For the left forearm, normal BMD was higher in Group B (26.7% vs. 0%, p=0.008), while osteopenia was higher in Group A (33.3% vs. 20%). Tables 3 and 4 showed that the mean BMD values and densitometric T-scores for the lumbar spine, left hip, and left forearm were comparable, with no significant differences observed. In contrast, the total left hip T-score was significantly lower in Group A (-1±1.1) compared to Group B (-0.4±1.1, p=0.039) (Table 5). Group A had lower mean T-scores at the left forearm, especially in the middle region (p=0.043), with no significant differences in other regions (Table 6). Among male patients, 12 (40.0%) had total lumbar spine Z scores <-1, and 4 (13.3%) had Z scores <-2, compared to 6 (20.0%) and 4 (13.3%) female patients, respectively. For the total left hip, 16 (53.3%) male patients had Z scores <-1, and 2 (6.7%) had Z scores <-2, while 6 (20.0%) female patients had Z scores <-1, with none having Z scores <-2 (Table 7). Tables 8 and 9 presented the correlations of BMD among different sites, ranging from r = 0.139 to r = 0.967 in males and r = 0.044 to r = 0.981 in females. The strongest correlations were observed between MID with Inter and Ultra: r = 0.493 and 0.846 in males and r=0.514 and 0.873 in females. Table 10 highlighted that iPTH levels were significantly higher in Group A (169.98±55.99 pg/ml) compared to Group B (141.75±50.96 pg/ml, p=0.049). In Table 11, BMI showed a significant positive correlation with hip (r=0.447, p=0.009) and forearm BMD (r=0.459, p=0.006). iPTH was significantly negatively correlated with hip (r=-0.420, p=0.009) and forearm BMD (r=-0.350, p=0.042). Duration of hemodialysis was negatively correlated with lumbar spine (r=-0.496, p=0.002), hip (r=-0.365, p=0.039), and forearm BMD (r=-0.451, p=0.007). Table 12 showed significant correlations where age negatively correlated with forearm BMD (r=-0.604, p=0.002). BMI positively correlated

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DOI:10.26502/anu.2644-2833109

with lumbar spine (r=0.480, p=0.013) and hip BMD (r=0.582, p=0.003). iPTH negatively correlated with hip (r=-0.416, p=0.035) and forearm BMD (r=-0.588, p=0.002). Duration of hemodialysis negatively correlated with lumbar spine (r=-0.447, p=0.009), hip (r=-0.350, p=0.042), and forearm BMD (r=-0.472, p=0.005).

Table 1: Distribution of study patients by demographic and clinical parameters (n=60)

Variable	Group A (n=30)	Group B (n=30)	*p* value
	Mean±SD	Mean±SD	
Age (years)	43.24±10.92	41±12.6	0.488^{ns}
Height (cm)	158.6±5.5	155.8±5.9	0.063^{ns}
Weight (kg)	60.0±12.0	62.8±14.9	0.423^{ns}
BMI kg/m^2	23.41±4.42	27.19±5.98	0.006^{s}
Duration of dialysis (months)	39.4±31.2	31.3±18.7	0.246^{ns}

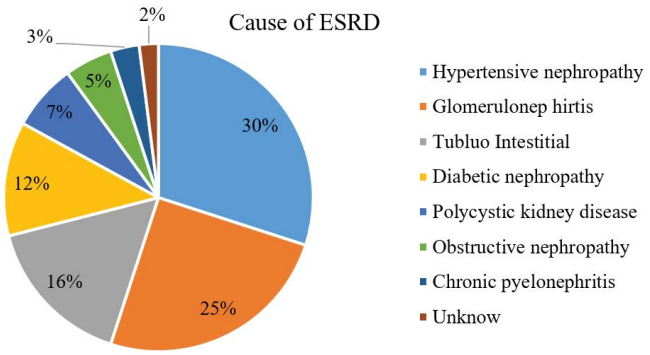

Figure 1: Pie chart of the causes of ESRD patients

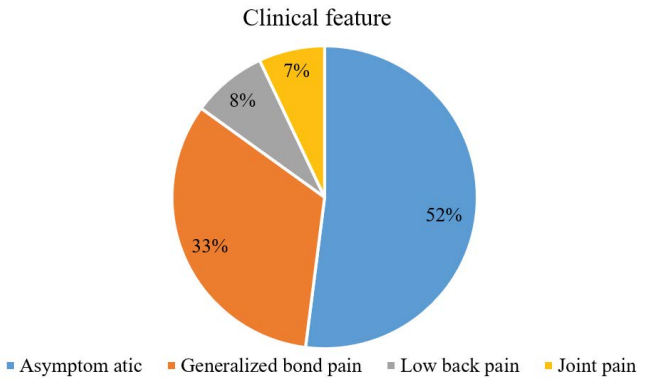

Figure 2: Pie chart of the clinical features of bone disease among study populations.

Table 2: Number and percentage of normal bone, osteopenia and osteoporosis on the basis of T-score in study patients (n=60

Bone mineral density (BMD)	Group A (n=30)		Group B (n=30)		Total (n=60)		*p* value
	n	%	n	%	n	%	
Lumbar Spine & Left hip							
Normal (T-score > -1)	13	43.3	15	50	28	46.7	0.529^{ns}
Osteopenia (T-score -1.1 to -2.5)	13	43.3	9	30	22	36.7	
Osteoporosis (T-score <-2.5)	4	13.4	6	20	10	16.6	
Left Forearm							
Normal (T-score > -1)	0	0	8	26.7	8	13.3	0.008^{s}
Osteopenia (T-score -1.1 to -2.5)	10	33.3	6	20	16	26.7	
Osteoporosis (T-score <-2.5)	20	66.7	16	53	36	60	

s=significant, ns= not significant

Table 3: Mean BMD (g/cm2) in study patients (n=60)

BMD (g/cm^2)	Group A (n=30)	Group B (n=30)	*p* value
	Mean ± SD	Mean ± SD	
T. Lumbar Spine	1.04±0.22	1.05±0.18	0.815^{ns}
Total Left hip	0.94±0.17	0.99±0.16	0.215^{ns}
T. Left Forearm	0.50±0.14	0.44±0.09	0.062^{ns}

Table 4: Mean densitometric data (T-score) at lumbar spine in study patients (n=60).

Densitometric data	Group A (n=30)	Group B (n=30)	*p* value
	Mean ± SD	Mean ± SD	
Total Lumbar			
T score	-0.75±1.41	-0.46±1.60	0.456^{ns}
L1			
T score	-0.78±1.28	-0.32±1.65	0.228^{ns}
L2			
T score	-0.99±1.37	-0.58±1.73	0.309^{ns}
L3			
T score	-0.67±1.26	-0.23±1.87	0.454^{ns}
L4			
T score	-0.46±1.71	-0.27±1.68	0.669^{ns}

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DOI:10.26502/anu.2644-2833109

Table 5: Mean densitometric data (T-score) at left hip in study patients (n=60)

Hip	Group A (n=30)	Group B (n=30)	*p* value
	Mean ± SD	Mean ± SD	
Total left hip			
T-score	-1±1.1	-0.4±1.1	0.039
Neck			
T score	-0.48±1.52	0.4±1.47	0.028[s]
G. T			
T score	-1.05±1.11	-0.39±1.18	0.030[s]
Inter			
T score	-1.12±1	-0.53±1.22	0.044[s]

Table 6: Mean densitometric data (T- score) at forearm in study patients (n=60).

Forearm	Group A (n=30)	Group B (n=30)	*p* value
	Mean ± SD	Mean ± SD	
Total left forearm			
T-score	3.44±1.241.24	-2.6±1.74	0.066
Ultra			
T score	-2.04±1.55	-1.06±2.68	0.080[ns]
MID			
T score	-3.54±1.65	-2.61±1.82	0.043[s]
One-third			
T score	-4.35±1.96	-3.24±2.38	0.052[ns]

Table 7: Bone densitometric data (Z score) in study patients (n=60)

Variable	Z score			
	Z <-1		Z <-2	
	N	%	N	%
Total Lumbar Spine				
Male (Group A)	12	40	4	13.3
Female (Group B)	6	20	4	13.3
Total Left hip				
Male (Group A)	16	53.3	2	6.7
Female (Group B)	6	20	0	0
Total Forearm				
Male (Group A)	6	20	24	80
Female (Group B)	4	13.3	12	40

Table 8: Correlation between BMD of individual measurement sites expressed as a coefficient of correlation (r) in group A.

Site	L1	L2	L3	L4	Neck	G. T	Inter	Ultra	MID	1/3
L1	1	0.931**	0.905**	0.715**	0.785**	0.943**	0.800**	0.502**	0.397*	0.267
L2	0.931**	1	0.931**	0.819**	0.760**	0.922**	0.799**	0.514**	0.313	0.159
L3	0.905**	0.931**	1	0.857**	0.827**	0.900**	0.725**	0.482**	0.340	0.196
L4	0.715**	0.819**	0.857**	1	0.660**	0.721**	0.561**	0.634**	0.473**	0.363*
Neck	0.785**	0.760**	0.827**	0.660**	1	0.837**	0.705**	0.346*	0.209	0.139
G.T	0.943**	0.922**	0.900**	0.721**	0.837**	1	0.830**	0.550**	0.408*	0.308
Inter	0.800**	0.799**	0.725**	0.561**	0.705**	0.830**	1	0.481**	0.493**	0.356*
Ultra	0.502**	0.514**	0.482**	0.634**	0.346*	0.550**	0.481**	1	0.846**	0.834**
MID	0.397*	0.313	0.340	0.473**	0.209	0.408*	0.493**	0.846**	1	0.967**
1/3	0.267	0.159	0.196	0.363*	0.139	0.308	0.356*	0.834**	0.967**	1

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Table 9: Correlation between BMD of individual measurement sites expressed as a coefficient of correlation (r) in group B.

Site	L1	L2	L3	L4	Neck	G. T	Inter	Ultra	MID	1/3
L1	1	0.953**	0.877**	0.830**	0.570**	0.907**	0.166	0.545**	0.077	0.093
L2	0.953**	1	0.945**	0.906**	0.596**	0.922**	0.168	0.570**	0.138	0.139
L3	0.877**	0.945**	1	0.937**	0.575**	0.877**	0.183	0.575**	0.051	0.057
L4	0.830**	0.906**	0.937**	1	0.622**	0.917**	0.060	0.529**	0.031	0.055
Neck	0.570**	0.596**	0.575**	0.622**	1	0.496**	0.264	0.260	0.455*	0.481*
G.T	0.907**	0.922**	0.877**	0.917**	0.496**	1	0.044	0.607**	0.160	0.120
Inter	0.166	0.168	0.183	0.060	0.264	0.044	1	0.422*	0.514*	0.503*
Ultra	0.545**	0.570**	0.575**	0.529**	0.260	0.607**	0.422*	1	0.873**	0.820**
MID	0.077	0.138	0.051	0.031	0.455*	0.160	0.514*	0.873**	1	0.981**
1/3	0.093	0.139	0.057	0.055	0.481*	0.120	0.503*	0.820**	0.981**	1

Table 10: Laboratory parameters of study population (n=60)

Laboratory parameters	Group A (n=30)	Group B (n=30)	*p* value
	Mean ± SD	Mean ± SD	
Calcium(mg/dl) (Normal 8.5-10.5 mg/dl)	8.58±1.02	8.62±0.92	0.875ns
Phosphate (mg/dl) (Normal 2.5-4.5 mg/dl)	5.0±1.43	4.62±0.95	0.246ns
Intact Parathyroid (pg/ml) (Normal 11-67 pg/ml)	169.98±55.99	141.75±50.96	0.049s

Table 11: Correlation between BMD of measurement sites, laboratory and clinical parameters, expressed as a coefficient of correlation (r) in group A

Variable	Lumbar Spine		Hip		Forearm	
	r	P	r	P	r	P
Age	0.022	0.901	-0.089	0.617	0.297	0.088
BMI	0.007	0.967	0.447**	0.009	0.459**	0.006
iPTH	0.062	0.729	-0.420*	0.013	-0.350*	0.042
Calcium	-0.116	0.512	0.180	0.309	0.160	0.366
Phosphate	-0.167	0.344	-0.004	0.981	-0.297	0.088
Ca×Po4	-0.214	0.225	0.101	0.571	0.226	0.198
Duration of hemodialysis	-0.496**	0.002	-0.365*	0.039	-0.451**	0.007

Table12: Correlation between BMD of measurement sites laboratory and clinical parameters, expressed as a coefficient of correlation (r) in group B

	Lumbar Spine		Hip		Forearm	
	r	p	r	p	r	p
Age	0.107	0.605	-0.108	0.598	-0.604**	0.002
BMI	0.480*	0.013	0.582**	0.003	0.284	0.159
iPTH	-0.031	0.880	-0.416*	0.035	-0.588**	0.002
Calcium	0.246	0.226	0.250	0.219	0.097	0.653
Phosphate	0.382	0.054	-0.157	0.444	-0.310	0.123
Ca×Po4	0.098	0.634	0.137	0.505	-0.248	0.221
Duration of hemodialysis	-0.447**	0.009	-0.350*	0.042	-0.472**	0.005

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Discussion

Bone mineral density (BMD) abnormalities are a significant complication in patients with chronic kidney disease (CKD), particularly those undergoing maintenance hemodialysis (MHD). CKD-mineral and bone disorder (CKD-MBD) leads to complex alterations in bone metabolism, characterized by imbalances in calcium, phosphorus, vitamin D, and parathyroid hormone (PTH) levels. These changes not only contribute to low BMD but also increase the risk of fractures and reduce quality of life [19]. This cross-sectional study was conducted to determine the prevalence of osteopenia and osteoporosis, to compare BMD measurement scores at different skeletal sites between males and females, and to identify the optimal site for measuring BMD in dialysis patients. This study found that the mean age was slightly higher in Group A (43.24±10.92 years) compared to Group B (41±12.6 years). Similarly, the mean height was greater in Group A (158.6±5.5 cm) than in Group B (155.8±5.9 cm). However, Group B had a higher mean weight (62.8±14.9 kg) than Group A (60.0±12.0 kg). Despite these differences, the age, height, and weight variations between the groups were not statistically significant ($p>0.05$). Comparable findings were reported by Anwar et al. (2020) and Antunes et al. (2020), who observed significantly higher ($p<0.05$) mean age, height, and weight in male subjects, supporting the trends in this study [20-21]. Additionally, Chuang et al. (2020) and Nakanishi et al. (2018) noted higher mean ages, which could be attributed to geographical, racial, ethnic, or genetic factors influencing their populations [22-23]. In our study, the mean BMI was significantly higher ($p<0.05$) in Group B (27.19±5.98 kg/m²) compared to Group A (23.41±4.42 kg/m²). This observation aligns with Antunes et al. (2020) and Anwar et al. (2020), although Chuang et al. (2020) reported higher BMI in males [21, 22]. In this study, we observed a higher mean duration of dialysis in group A (39.4±31.2 months) compared to group B (31.3±18.7 months), though the difference was not statistically significant ($p>0.05$) (Table I). Similar findings have been reported in previous studies, with Orlic et al. (2010) highlighting dialysis duration as a risk factor for bone loss in dialysis patients [24]. Our results align with those of Anwar et al. (2020), Yamaguchi et al. (1996), Nakai et al. (2001), and Nakanishi et al. (2018) [20, 26, 23]. Additionally, dialysis duration has been shown to affect bone mineral density (BMD) in both men and women [27]. Among our patient cohort, 30% had hypertensive nephropathy, 25% had glomerulonephritis, 16% had tubulointerstitial/analgesic nephropathy, 12% had diabetic nephropathy, 7% had polycystic kidney disease, 5% had obstructive nephropathy, 3% had chronic pyelonephritis, and 2% had an unknown cause. Regarding clinical symptoms, 52% were asymptomatic, 33% reported generalized bone pain and body aches, 7% had joint pain, and 8% experienced low back pain (Figures 1 & 2). In the present study, we observed that 28 (46.7%) patients had normal bone mineral density (BMD) at conventional measurement sites, including 13 (43.3%) males and 15 (50%) females. Osteopenia was detected in 22 (36.7%) patients, with 13 (43.3%) males and 9 (30%) females, while osteoporosis was found in 10 (16.6%) patients, consisting of 4 (13.4%) males and 6 (20%) females. The differences between the groups were not statistically significant ($p>0.05$). Only 8 (13.3%) patients exhibited normal bone density when examining BMD at the left forearm. Among males, 20 (66.7%) had osteoporosis, while 10 (33.3%) had osteopenia. In females, 16 (53%) had osteoporosis and 6 (20%) had osteopenia. The findings indicated a higher incidence of bone loss in males than females, particularly in the peripheral skeletal sites as opposed to the axial sites. In alignment with these results, Anwar et al. (2020) observed that osteopenia was more prevalent in females at the lumbar spine, while males had more osteopenia at the hip in ESRD patients [20]. Similarly, Sit et al. (2007) reported osteopenia/osteoporosis at the lumbar spine (82.8%) and femoral neck (64.3%) without significant differences between sexes [28]. Orlic et al. (2010) found greater bone loss in females and significant loss in peripheral skeletal sites [24]. Other studies identified high prevalence rates of osteoporosis, particularly in the mid-radius, hip, neck, and lumbar spine, with variability observed between hemodialysis and peritoneal dialysis patients [4, 29]. Factors such as dialysis duration, elevated iPTH, hormones, and BMI may contribute to these outcome differences. Our study found that the mean total BMD (g/cm²) was comparable between the two groups 1.04±0.22 in Group A and 1.05±0.18 in Group B with no statistically significant difference ($p>0.05$, Table III). Orlic et al. (2010) reported lower BMD in females across all measurement sites, with the highest values in the hip and lumbar spine [24]. Similarly, previous studies confirmed lower BMD in females [20], while Grzegorzewska and Młot-Michalska (2007) observed better BMD preservation in male HD patients [30]. In our study, the mean total lumbar T-score was observed to be -0.75±1.41 in Group A and 0.46±1.60 in Group B. Similarly, the mean total T-score for the left hip was -1±1.1 in Group A and -0.4±1.1 in Group B, with a statistically significant difference between the groups ($p=0.039$). However, the mean total T-score in the left forearm was -3.44±1.74 in Group A and -2.6±1.74 in Group B, but the difference was not statistically significant ($p=0.066$). A study by Orlic et al. (2010) also reported significantly lower T-scores in the hip among female patients, while no significant difference was noted in the forearm, except at the mid-forearm (-2.3±1.9 vs -1.4±1.7, $p=0.01$) [24]. Orlic et al. (2010) also suggested using the Z-score for assessing bone density in CKD patients, aligning with ISCD recommendations that a Z-score ≤-2.0 is considered "below the expected range for age" [24]. However, the Osteoporosis Work Group proposed defining low bone density in CKD patients as a

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DOI:10.26502/anu.2644-2833109

Z-score ≤-1.0 [31]. In this present study, low bone density (Z<-1) was detected in 40% of males and 20% of females at the lumbar spine, 53.3% of males and 20% of females at the hip, and 20% of males and 13.3% of females at the forearm. A Z-score below the expected range (Z<-2) was observed in 13.3% of both sexes at the lumbar spine, 6.7% of males and 20% of females at the hip, and 80% of males and 40% of females at the forearm. These findings indicate a higher prevalence of low bone mass at peripheral sites, particularly in males, aligning with T-score findings and Orlic et al.'s (2010) study [24]. Previous studies have established a correlation between BMD measurements at different skeletal sites. This study's correlation ranged from r=0.139 to r=0.967 in males and r=0.044 to r=0.981 in females. The strongest correlation was observed between MID, Inter, and Ultra sites, with better axial-appendicular correlation in females. These findings align with previous research by Orlic et al. (2010) [24]. The distribution of laboratory parameters in our study across the patient groups revealed no significant difference in mean calcium levels, with values of 8.58±1.02 mg/dl for group A and 8.62±0.92 mg/dl for group B (p>0.05) (Table 10). This finding aligns with previous studies by Nakanishi et al. (2018), Antunes et al. (2020), Chuang et al. (2020), and Orlic et al. (2010) [21-24]. Similarly, while group A had a higher mean phosphate level (5.0±1.43 mg/dl versus 4.62±0.95 mg/dl in group B), no statistical significance was observed (p>0.05), consistent with Nakanishi et al. (2018) and Orlic et al. (2010) [23-24]. Regarding iPTH, group A had a significantly higher mean value (169.98±55.99 pg/ml) compared to group B (141.75±50.96 pg/ml) (p<0.05), especially in males, in line with Nakanishi et al. (2018) [23]. However, Orlic et al. (2010) found significantly higher iPTH levels in females [24]. This study investigated the correlation between bone mineral density (BMD) at different measurement sites and clinical and laboratory parameters, with the correlation coefficient (r) used to express the relationship. In Group A, a significant positive correlation was found between body mass index (BMI) and BMD at the hip (r=0.447; p=0.009) and forearm (r=0.459; p=0.006). Additionally, intact parathyroid hormone (iPTH) showed a significant negative correlation with BMD at the hip (r=-0.420; p=0.009) and forearm (r=-0.350; p=0.042). Duration of hemodialysis also had a significant negative correlation with the lumbar spine (r=-0.496; p=0.002), hip (r=-0.365; p=0.039), and forearm (r=-0.451; p=0.007). In Group B, age was negatively correlated with forearm BMD (r=-0.604; p=0.002), while BMI had a positive correlation with the lumbar spine (r=0.480; p=0.013) and hip (r=0.582; p=0.003). iPTH was negatively correlated with BMD at the hip (r=-0.416; p=0.035) and forearm (r=-0.588; p=0.002). Furthermore, the duration of hemodialysis negatively correlated with the lumbar spine (r=-0.447; p=0.009), hip (r=-0.350; p=0.042), and forearm (r=-0.472; p=0.005). These findings are consistent with previous studies reporting similar associations between BMD and various parameters [22-24]. Additionally, studies by Urena et al. (2003) and Lechleitner et al. (1994) noted a negative correlation between iPTH and BMD at different sites [27,32]. However, some studies, like Ambrus et al. (2011), did not find a correlation between iPTH and BMD at the lumbar spine, while Gerakis et al. (2000) reported no significant differences in vertebral BMD among different types of renal osteodystrophy [33-34].

Limitations of The Study

Every hospital-based study has limitations, and the present study is no exception. The limitations of the present study are mentioned.

- It was a cross-sectional study using only one method (DEXA) on a relatively small number of patients from one selected hospital in Dhaka city.
- All patients in this study received twice-weekly hemodialysis using the same dialysis solution. However, the adequacy of dialysis for individual patients was not measured.

Conclusion and Recommendations

This study highlights a high prevalence of osteopenia and osteoporosis (60%) among patients on maintenance hemodialysis, with a greater burden observed in males. The significant reduction in bone mineral density (BMD) was predominantly noted at appendicular sites, particularly the hip, and the strongest correlation was found between hip (inter) and forearm (MID) measurements in both groups. These findings emphasize the necessity of comprehensive skeletal assessments to improve the diagnosis and management of chronic kidney disease-mineral and bone disorder (CKD-MBD). Given the observed pattern of BMD loss, we recommend that DEXA scans be performed at multiple skeletal sites, including the distal forearm, to enhance the detection and monitoring of bone health in CKD-MBD patients. Further multicenter studies with larger sample sizes are needed to validate these findings. Long-term research utilizing DEXA alongside advanced imaging techniques such as peripheral quantitative computed tomography (pQCT) is warranted to improve BMD assessment and guide targeted interventions for better skeletal outcomes in this high-risk population.

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Citation: Dr. Madhabi Karmaker, Dr. Samira Khatun, Dr. Farnaz Nobi, Dr. Shanjida Sultana Juthy, Dr. Khaleda Akhter. Pattern of Bone Mineral Density at Optimal Skeletal Measurement Site among Patients on Maintenance Hemodialysis. Archives of Nephrology and Urology. 9 (2026): 01-10.