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Full Length Research Article

# PRE- AND POST-HEMODIALYSIS CHANGES IN BONE MINERAL METABOLISM AND ELECTROLYTES IN CHRONIC KIDNEY DISEASE PATIENTS: A PAIRED COMPARATIVE STUDY

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**ABSTRACT**
Chronic kidney disease (CKD) has been associated with abnormalities in the mineral metabolism of bone and serum biochemical abnormalities, especially in hemodialysis patients. These abnormalities result in renal osteodystrophy and higher numbers of clinical complications. Monitoring bone mineral and selected biochemical parameters is essential for effective management. A paired pre–post comparative study with a control group was conducted among 15 CKD patients receiving maintenance hemodialysis and 20 age- and sex-matched healthy controls. Blood samples were collected from CKD patients before and after a single hemodialysis session, while controls were sampled once. Serum calcium (Ca), phosphorus (Phos), alkaline phosphatase (ALP), vitamin D, sodium ($Na^+$) and potassium ($K^+$) were measured using the appropriate biochemical tests. Data were analysed statistically using ANOVA, paired t-tests, and Pearson's correlation; $p < 0.05$ was considered significant. Hemodialysis patients showed significantly lower serum calcium and higher phosphorus and ALP levels compared with controls ($p < 0.05$). Vitamin D levels were reduced in dialysis patients but not statistically significant ($p = 0.067$). Sodium and potassium levels were significantly lower in CKD patients and showed further reduction post-dialysis ($p < 0.05$). Pre-dialysis ALP showed a significant negative correlation with calcium levels ($r = -0.577$, $p = 0.024$), while post-dialysis trends were similar but weaker and not statistically significant. Hemodialysis significantly affects bone mineral metabolism markers and serum electrolytes in patients with CKD. These findings highlight the importance of routine biochemical monitoring for optimal management and the prevention of complications.

**Keywords:** Chronic Kidney Disease, Hemodialysis, Bone Mineralization, Phosphorus, Vitamin D

## INTRODUCTION

Chronic kidney disease (CKD) is a widespread global medical condition with increasing prevalence, primarily in developing countries. End-stage renal disease (ESRD) patients require the life-saving procedure of hemodialysis when their kidney function deteriorates (Thurlow *et al.*, 2021; Atere *et al.*, 2021; Diniz *et al.*, 2022). Hemodialysis therapy significantly affects patient quality of life by altering renal function and the metabolism of vital minerals, such as calcium, phosphorus, and vitamin D, which support bone health (Holick *et al.*, 2011; James *et al.*, 2020).

The development of bone mineralization disorders occurs frequently among patients with chronic kidney disease, particularly those receiving dialysis for long periods. Secondary hyperparathyroidism, renal osteodystrophy, and vascular calcification develop due to kidney failure, which disrupts electrolyte regulation and alters bone metabolism (Chan *et al.*, 2017). Dialysis patients experience increased morbidity and mortality because of bone turnover marker imbalances that drive conditions like ALP (Kalantar-Zadeh *et al.*, 2021; Bello *et al.*, 2022). The process of hemodialysis affects the total mineral content of the blood, including calcium, phosphorus, and vitamin D, as well as bone remodelling markers. Dialysis patients experience severe phosphorus and calcium disorders, particularly because they commonly develop both hyperphosphatemia and hypocalcemia (Ketteler *et al.*, 2017; Gaitonde, 2017). Clinical outcome improvement requires routine monitoring of key markers, such as ALP, because elevated ALP levels have been associated with reduced survival in hemodialysis patients, according to Jorge *et al.* (2018) and Damera *et al.* (2021).

The existing corrective treatments for these imbalances fail to yield satisfactory results for dialysis patients who primarily need assistance in resource-constrained settings. Untreated electrolyte disruptions result in cardiovascular complications together with higher patient mortality rates, according to Fox *et al.* (2022). Therefore, treatment strategy evaluations combined with monitoring bone mineralization biochemical markers should be fundamental to minimizing the negative impacts of dialysis therapy. This research evaluates the effects of hemodialysis on bone mineral metabolism markers by measuring serum calcium, phosphorus, vitamin D, and ALP levels in dialysis patients compared with control subjects. The study results would deliver essential knowledge about hemodialysis management for CKD patients by demonstrating the necessity of consistent bone mineralization marker observation for better care.

## MATERIALS AND METHODS

### Study Design and Setting

The study assessed the effects of hemodialysis on bone mineralization indices in CKD patients using a paired pre–post comparative study. The study was conducted between January and August 2023 at Federal Medical Centre (FMC) Owo, Ondo State, Nigeria. The study enrolled 35 participants. A study was conducted on fifteen (15) hemodialysis patients (aged 20–60 years) undergoing regular hemodialysis treatment and twenty (20) age- and sex-matched healthy individuals as controls.

### Ethics approval and consent to participate

Ethical approval was obtained from the Federal Medical Centre,

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Owo IRB (FMC/OW/380/VOL.CLXXVII/177), and informed consent was obtained from all participants. Although no direct intervention was provided, participants benefited from biochemical evaluation of bone mineral parameters, and results were shared with clinicians for appropriate patient management.

**Criteria for Participant Selection**

- **Inclusion Criteria**: Hemodialysis patients with a minimum of 6 months of dialysis history, aged 20–60 years, and no history of malignancy or major systemic illness.
- **Exclusion Criteria**: Pregnant or lactating women, individuals with severe comorbidities such as cancer, liver failure, and active infections, and those with secondary hyperparathyroidism or other conditions affecting bone metabolism were excluded from the study.

**Sample Collection**

Five milliliters (5mL) of Blood samples were collected in the hemodialysis patients before the start of dialysis and after a single dialysis at the end of the session. Control participants provided fasting blood samples once also. Blood samples were kept at 4°C and processed within 2 hours of collection. The study also obtained information regarding participant demographics as well as comorbidities alongside dialysis background which included duration of dialysis treatment and dialysis modality type.

**Biochemical Analysis**

Standard laboratory procedures were used to measure the serum levels of calcium, phosphorus, vitamin D and ALP. Serum calcium, sodium, potassium and phosphorus were analyzed using the colorimetric technique on automated analyzer (Beckman Coulter AU680, USA) (Alpern *et al.*, 2012). Serum vitamin D was measured by the enzyme linked immune-sorbent assay (ELISA) technique (Melsin ELISA Kit, USA) (Holick *et al.*, 2011). The serum ALP was measured using the standard enzymatic assay (Randox Laboratories Ltd, UK) (Damera *et al.*, 2021).

**Statistical Analysis**

IBM SPSS Statistics version 25.0 (SPSS Inc., Chicago, USA) was used for statistical analysis. Data distribution was assessed using the Shapiro–Wilk test. Continuous variables were summarized as mean ± standard deviation for normally distributed data and median (interquartile range) for non-normally distributed variables, while categorical variables were presented as percentages. One-way analysis of variance (ANOVA) was used to compare mean values of calcium, sodium, potassium, phosphorus, vitamin D, and ALP among the pre-dialysis, post-dialysis, and control groups. Where appropriate, post hoc tests were performed for pairwise comparisons. Correlations between calcium, A, and vitamin D levels in hemodialysis patients were assessed using Pearson correlation coefficient. Statistical significance was set at $p < 0.05$.

**RESULTS**

The sociodemographics of the 35 subjects are shown in Figure 1. The 15 pre-dialysis CKD patients and 20 healthy controls, matched for age and sex, had the following characteristics. The CKD patients were aged on average 49.93 ± 16.89 years, while the controls were aged on average 50.13 ± 13.87 years. Systolic and diastolic blood pressures were significantly lower in the dialysis group compared to controls (109.81 ± 19.84 mmHg vs 153.67 ± 33.99 mmHg; and 73.48 ± 12.08 mmHg vs 101.33 ± 15.52 mmHg). BMI was slightly higher in CKD patients than in controls (25.98 ± 6.92 vs 25.55 ± 3.81).

As shown in Table 1, serum calcium levels were significantly lower in both pre-dialysis and post-dialysis groups when compared with controls (8.5 ± 0.6 and 8.2 ± 0.7 vs. 9.3 ± 0.4, $p = 0.003$). Phosphorus levels, expressed as median (interquartile range), were significantly higher in CKD patients compared with controls ($p < 0.001$). Similarly, alkaline phosphatase levels were significantly elevated in CKD patients and are presented as median (IQR) ($p < 0.001$). Sodium and potassium levels were significantly reduced in CKD patients compared with controls ($p = 0.023$ and $p = 0.019$, respectively). Vitamin D levels, also presented as median (IQR), were lower in CKD patients but did not reach statistical significance ($p = 0.067$).

ALP levels compared to calcium levels in pre-dialysis subject showed a significant negative correlation ($r = -0.577$, $p = 0.024$) (Figure 3). However, in the post-dialysis group (Table 2), there was a moderate negative correlation between ALP and calcium ($r = -0.433$, $p = 0.107$), however, was not significant.

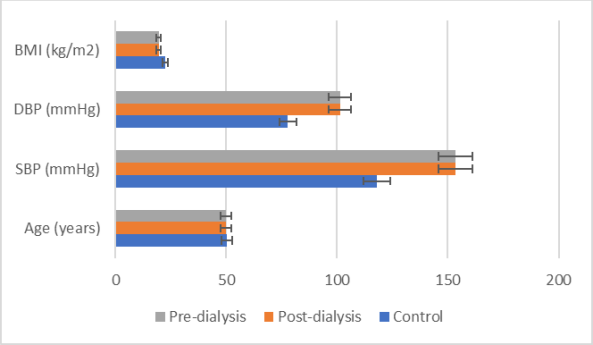


**Figure 1:** Sociodemographic characteristics of study participants

**Table 1**: Comparison of Bone Mineralization Indices and Electrolyte Levels between Pre-Dialysis, Post-Dialysis, and Control Groups

| Parameters | Pre-Dialysis Group(n=15) | Post-Dialysis Group(n=15) | Control Group(n=20) | p-value |
|---|---|---|---|---|
| **Calcium (mg/dL)** | 8.5 ± 0.6 [a] | 8.2 ± 0.7 [a] | 9.3 ± 0.4 [b] | 0.003* |
| **Phosphorus (mg/dL)** | 5.2 (4.6-6.1) | 5.5 (4.8-6.4) | 3.5 (3.2-3.9) | 0.001* |
| **Vitamin D (ng/mL)** | 25.1 (20.8-29.4) | 27.2 (22.5-31.0) | 30.5 (26.0-34.8) | 0.067 |
| **ALP (U/L)** | 125 (110-138) | 130 (115-150) | 90 (82-98) | 0.001* |
| **Sodium (Na) (mEq/L)** | 135 ± 30.0 [a] | 133 ± 40.0 [b] | 140 ± 2.0 [c] | 0.023* |
| **Potassium (K) (mEq/L)** | 4.5 ± 0.4 [a] | 4.2 ± 0.3 [a] | 4.3 ± 0.2 [b] | 0.019* |

*significant at p≤0.05

a = significantly different from control, b = significantly different from pre-dialysis, c = significantly different from post-dialysis.

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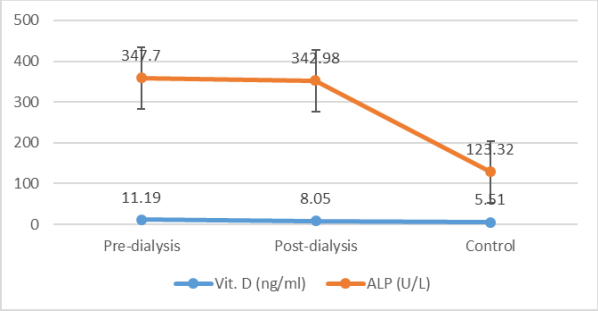


**Figure 2**: Vitamin D and ALP levels in pre-dialysis, post-dialysis and Control subjects

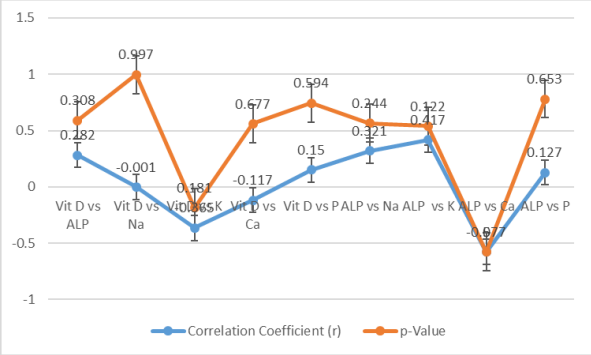


**Figure 3**: Correlation between Vitamin D and ALP with other parameters in pre-dialysis subjects

**Table 2**: Correlation between Vitamin D and ALP with other bone minerals in post-dialysis subjects

| Pairs of Variables | Correlation Coefficient (r) | p-Value |
|---|---|---|
| Vit D vs ALP | 0.035 | 0.901 |
| Vit D vs Na | -0.035 | 0.901 |
| Vit D vs K | -0.439 | 0.102 |
| Vit D vs Ca | 0.295 | 0.285 |
| Vit D vs P | 0.087 | 0.759 |
| ALP vs Na | -0.074 | 0.792 |
| ALP vs K | 0.47 | 0.077 |
| ALP vs Ca | -0.433 | 0.107 |
| ALP vs P | 0.172 | 0.539 |

## DISCUSSION

The study gives important knowledge about bone metabolism changes and electrolyte fluctuations in dialysis patients with CKD. The research demonstrates substantial impairments in the mineral levels of calcium, phosphorus, ALP activity, sodium, and potassium in dialysis-treated patients when compared to normal subjects. The results demonstrated that serum calcium levels were markedly lower in both pre-dialysis and post- dialytic groups in comparison with controls (p=0.003). This is consistent with multiple other studies that have shown depletion in calcium levels in hemodialysis patients with chronic kidney disease. Both Khan *et al.* (2016) and Damera *et al.* (2021) describe this as the consequence of renal incapacity to produce the active form of vitamin D, combined with tubular incapacity to resorb calcium maintaining a state of hypocalcaemia. Wafaa (2018), and Fox *et al.* (2022) added that dialysis solution shifts may further contribute to calcium decline during treatment. In terms of public health considerations, the results illustrates that calcium imbalance is evident in these patient populations, thus close monitoring of bone mineral homeostasis in this population on a routine basis will heighten the potential for early correction and reduce the risk of renal osteodystrophy, impending fracture incidence and cardiovascular challenges, ultimately reducing disease burden.

The study findings showed that both pre-dialysis and post-dialysis patients had significant hyperphosphatemia compared with controls ($p < 0.001$). The results are consistent with prior findings by Ketteler *et al.* (2017) and Soumya and Pratibha (2021), which reported that hyperphosphatemia is commonly observed among hemodialysis patients with chronic kidney disease. The hyperphosphatemia has been attributed to declining renal phosphate excretion and inadequate removal during dialysis sessions. However, both high pre- and post-dialysis phosphate levels could relate to considerable phosphate load intake, as well as dialysis modality in the research and standardized therapy for the CKD population (Levin *et al.*, 2017; Bello *et al.*, 2022). An interpretation across research areas suggests that persistent hyperphosphatemia during dialysis was not solely dependent on renal function but also on dialysis quality, pre-dialysis phosphate intake, and interventions. Nonetheless, persistent hyperphosphatemia is an important clinical consequence from a population of public health perspective because of its association with vascular calcification, cardiovascular risk, and even mortality. Thus, it is recommended to strengthen measures for Dietary phosphate restriction, dialysis adequacy, and long-term assessment of mineral metabolism metabolites in the CKD population.

Certainly, serum ALP levels in the dialysis cohort were also significantly higher than controls ($p < 0.001$). This, by and large, is agreed to denote a higher remodelling rate in the renal osteodystrophic CKD population (Jorge *et al.*, 2018; Shantouf *et al.*, 2019). Evidence from others, such as Regidor *et al.* (2018) and Bello *et al.* (2022), also supports this idea, implicating high ALP levels as predictors of CKD-related adverse bone outcomes and increased mortality rates in dialysis patients. Similarly, although other studies have identified a marked discrepancy in ALP levels, it is believed this may be due to age differences, the duration of dialysis, and the use of 'bone-affecting' medications such as vitamin D analogues and phosphate binders. It also, from a public health point of view, demonstrates the significant importance of assessing bone markers regularly in a CKD population to prevent fractures, optimise bone status, and alleviate future demand on health services.

There were significant decreases in sodium and potassium concentrations in both the pre-dialysis and post-dialysis patients compared to the controls (p=0.023 and p=0.019, respectively). These findings are supported by the work of Seethalakshmi *et al.* (2020) and Santos and Peixoto (2020), which found that in hemodialysis, circulating potassium levels can be maintained at safe levels while sodium levels are moderated by diffusion through the dialysis membrane. Numerous other studies show variability in sodium levels following dialysis (Obiagwu *et al.*, 2023; Bitewlign *et al.*, 2025), which could be due to variables such as dialysate composition, dialysis duration, and patient hydration status;

however, the general trend remains evident, confirming dialysis as the therapy correcting potentially life-threatening abnormalities. From a public health viewpoint, this would call for frequent monitoring of electrolytes for dialysis units to prevent life-threatening cardiac arrhythmias secondary to hyperkalaemia and to adjust dialysis prescription accordingly for safer maintenance.

Compared to the controls, the dialysis patients also showed lower vitamin D levels but the difference was not statistically significant ($p = 0.067$). This was also documented by Holick *et al.* (2011) and Patel and Singh (2019) who demonstrated that vitamin D deficiency is present in the majority of those with CKD because of a deficiency in the renal conversion of 25-hydroxyvitamin D to the active hormone. Such a deficiency might be worsened with less sunshine, diet and the effects of metabolic derangement of dialysis. The investigation of ALP with calcium levels in pre-dialysis patients showed a statistically significant negative connection through correlation analysis ($r = -0.577$, $p = 0.024$). The results indicate that high bone turnover leads to calcium depletion in pre-dialysis patients so early bone mineralization management is necessary (Ketteler *et al.*, 2015). The moderate relationship between ALP and calcium levels measured following dialysis treatment ($r = -0.433$, $p = 0.107$) failed to reach statistical significance as alternative factors potentially affect calcium metabolism.

**Limitation of the Study**

This study is limited by a small sample size and single-centre design, which may restrict generalisability of the findings. In addition, the pre–post assessment was based on a single dialysis session without long-term follow-up, limiting evaluation of chronic biochemical changes. Potential confounding factors such as dietary intake, dialysis adequacy, and medication use were also not fully controlled.

**Conclusion**

Hemodialysis greatly changes the calcium and phosphorus homeostasis and electrolyte status in CKD patients. Some markers, such as calcium, phosphorus, ALP, vitamin D, sodium and potassium, remain abnormal and persist throughout the hemodialysis process. Therefore, regular monitoring of mineral and electrolyte parameters are important in early detection and correction of abnormalities to improve clinical outcome.

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