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Vitamin D Deficiency and Distal Radius Fractures: A Case-Control Study

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ABSTRACT

Deficiency of vitamin D is considered a significant risk factor for fragile fractures. It is highly prevalent in South Asia despite the fact that sunlight is abundant. In the literature, there is limited data available regarding any association between deficiency of vitamin D levels and distal radius fractures (DRFs) specifically for the Pakistani population. **Objectives:** To find out the prevalence and severity of deficiency of vitamin D in patients with DRFs and to determine the association of fracture type, severity, and mechanism of injury with vitamin D levels. **Methods:** It was a case-control study that was conducted at Naseer Memorial Hospital, Azad Kashmir, consisting of 216 cases and 100 controls. Vitamin D in serum was estimated using a chemiluminescent immunoassay (Abbott Architect i2000SR). DRFs were confirmed on radiography due to a standard PA and lateral view of the wrist using a GE Optima XR220amx digital X-ray system. The AO system was used to classify the fractures. Statistical analysis of the data was done in SPSS version 23.0, while $p<0.05$ was taken as significant. **Results:** Vitamin D deficiency was significantly higher among patient's vs controls ($p<0.001$). Lower vitamin D levels correlated inversely with fracture severity ($r = -0.47$, $p<0.01$). Extra-articular fractures and low-energy trauma predominated. Female and elderly patients exhibited greater deficiency and more complex fractures. **Conclusions:** The deficiency of vitamin D is an important and independent predictor of DRFs specially in elderly female patients, and routine screening of vitamin D levels should be integrated into the fracture prevention strategy.

INTRODUCTION

Distal radius fractures (DRFs) are recorded as among the common orthopedic injuries in the world, especially in the aged group. They account for around 15–20% of all fractures and are mainly prevalent among postmenopausal women owing to the combined effect of osteoporosis, hormonal decrease, and musculoskeletal degeneration due to aging [1]. The increasing incidence of DRFs is a rising public health alarm, driven mainly by aging demographics, a decrease in the density of bone minerals, and an increased hazard of falls among older adults [2]. In South Asian countries such as Pakistan, the load of DRFs is augmented by general vitamin D deficiency, a critical yet changeable factor that influences bone health and fracture resistance [3]. Despite rich sunlight in the country, more than 80% of the Pakistani population has sub-optimal vitamin D levels, probably due to less outdoor activity, traditional practices

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of clothing, and improper diet [4]. Vitamin D plays a crucial role in the absorption of calcium, mineralization of bones, and osteoblastic function; its deficiency leads to secondary hyperparathyroidism, demineralization of the bones, and fragility fractures [5]. Globally, several authors have investigated the association of a deficiency of vitamin D with hip and vertebral fractures. However, limited research has focused on distal radius fractures, which often serve as an early sign of systemic skeletal fragility [6]. Moreover, most of the data available in the literature is from Western populations, where environmental and nutritional factors are different from those in South Asia [7-9].

Furthermore, researchers have linked vitamin D deficiency with increased fracture risk and delayed healing, but regional Pakistani studies are limited, specifically from Azad Kashmir. This gap limits planning for prevention strategies and can serve as a guide for fracture management. The study aimed to find a deficiency of vitamin D among the patients having distal radius fractures in comparison to controls and to determine any association of fracture type, severity, and mechanism of injury with vitamin D deficiency.

METHODS

It was a case control study was conducted from 15 September 2021 to 15 March 2022 in Naseer Memorial Hospital, Dadyal, Azad Kashmir. Approval of the study was obtained from the hospital ethical review committee (ERC) before the initiation (REF: RA05/NMH/21/081) and was conducted following the Declaration of Helsinki. All participants gave consent to participate in the study, including patients and controls, after being informed about the objectives and aims of the study. The sample size was calculated as 196 based on the prevalence of vitamin D deficiency as the primary outcome variable. The study derived the sample size by using the formula: $n=Z2 \cdot p \cdot (1-p)/d2$; where: Z=1.96(confidence level set as 95%), p=0.85 based upon the previous regional data by Jamal AB [4], and d=0.05 (margin of error). The yielded sample size was increased by 10% (n=216) to account for expected non-responses or incomplete data. Patients were identified through the orthopedic outpatient clinic. Patients with confirmed distal radius fractures (DRFs) were selected using a consecutive sampling method. Age and gender-matched healthy 100 individuals were selected from the general population to be selected as controls. Controls were selected after confirming the absence of a history of fractures, chronic illnesses affecting bone health (e.g., osteoporosis, chronic renal disease), and no vitamin D supplements for the last 6 months. The data of the patients were recorded on a proforma from the Outpatient Department, like demographic details (age, sex, comorbidities) and fracture characteristics (type, location, mechanism, and severity) for further analysis. Blood for determining the vitamin D levels was drawn from both patients and the control group, and chemiluminescent immunoassay (CLIA) was performed using Abbott Architect i2000SR analyzer, two-point calibration, and internal quality controls. Levels of vitamin D were classified as deficient if <20 ng/mL, insufficient if 20–30 ng/mL, and sufficient if >30 ng/mL [4]. Fracture assessment was done by radiographs in standard posteroanterior (PA) and lateral wrist views using a GE Optima XR220amx digital X-ray system. Fractures were classified based on location (right or left limb), intra-articular or extra-articular, mechanism of injury (classified as trauma by low energy, such as a fall from altitude or trauma by high-energy, such as a road traffic accident), and fracture type A (extra-articular), moderate B (partial articular), or severe C (complete articular). Analysis of the fractures was done to find any association between fracture type, severity, and vitamin D deficiency. Subgroup analysis was also done to establish an association between vitamin D and any specific fracture characteristic.

Data were entered in SPSS version 23.0 for analysis. Continuous variables were presented as means with standard deviation (SD), whereas variables that were categorical were presented as frequencies and percentages. Normality of distribution was determined using the Shapiro- Wilk test. Independent t and Mann-Whitney U tests were used for continuous data comparison, while categorical variables analysis was done using Fisher's exact test and Chi-square test, whereas suitable. Multivariate logistic regression was conducted to look for vitamin D deficiency predictors among fracture patients after adjusting for age, sex, and comorbidities. Pearson's correlation analysis evaluated the association between levels of vitamin D and fracture severity, while taking a p-value <0.050 as significant.

RESULTS

Two hundred and sixteen patients having distal radius fractures and 100 age- and gender matched controls were included in the study. The Shapiro–Wilk test demonstrated a nonnormal statistical distribution for serum vitamin D levels; therefore, non-parametric tests were applied where appropriate. Patients with DRF were older than controls. The median age of the control group (58.3 years, IQR 52.0–66.0) was significantly more than that of the experimental group (56.1 years, IQR 49.0–63.0; Mann–Whitney U = 9824.0, p=0.04). Sex distribution was similar between groups (female 63.9 percent vs 58.0 percent; χ^2 = 1.79, p=0.18). Diabetes mellitus (χ^2 = 5.11, p=0.02) and osteoporosis (χ^2 = 14.02, p-value less than 0.001) were significantly more common among fracture patients, while hypertension showed no group difference

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(χ^2 = 0.54, p=0.46). Baseline characteristics of the participants are shown in table 1.

Table 1: Clinical Characteristics and Demography of the Participants

Variables	Patients (n= 216), n (%)	Controls (n= 100), n (%)	Test	p-value
Age, Median (IQR), Years	58.3 (52.0–66.0)	56.1 (49.0–63.0)	Mann–Whitney U = 9824.0	0.040
Female Sex	138 (63.9%)	58 (58.0)	χ^2 = 1.79	0.180
Diabetes mellitus	54 (25.0%)	13 (13.0%)	χ^2 = 5.11	0.020
Hypertension	91 (42.1%)	38 (38.0%)	χ^2 = 0.54	0.460
Osteoporosis	72 (33.3%)	11 (11.0%)	χ^2 = 14.02	—

Extra-articular fractures were found in 58% and intra-articular fractures in 42.0%. Low-energy trauma was the main mechanism, and high-energy trauma accounted for 30%. Right-sided fractures were found in 62% of patients. Based upon the AO Classification, 47.2 % of fractures were mild (Type A), 28.2 % moderate (Type B), and 24.5% were severe (Type C). Detailed characteristics of the fractures are shown in table 2.

Table 2: Characteristics of the Fractures among the Patients (n=216)

Variables	n (%)
Fracture Type	
Extra-Articular	125 (58.0%)
Intra-Articular	91 (42.0%)
Mechanism of Injury	
Low-Energy Trauma	151 (70.0%)
High-Energy Trauma	65 (30.0%)
Laterality	
Right Side	134 (62.0%)
Left Side	82 (38.0%)
AO Severity	
Type A (Mild)	102 (47.2%)
Type B (Moderate)	61 (28.2%)
Type C (Severe)	53 (24.5%)

Levels of vitamin D were significantly low in the patient group vs the control group (16.8 ng/mL, IQR 12.3–21.5 vs 31.4 ng/mL, IQR 26.0–36.8; Mann–Whitney U = 4121.5, p<0.001). Deficiency of vitamin D was found in 73.1% of patients vs 15.5% of controls; insufficiency and sufficiency distributions differed significantly (χ^2 = 112.6, p<0.001). Classification details are presented in table 3.

Table 3: Classification According to Levels of Vitamin D and Group Comparisons

Serum Levels of Vitamin D	Patients (n=216)	Controls (n=100)	χ^2	p-value
Deficient (<20 ng/mL)	158 (73.1%)	15 (15.5%)	112.6	<0.001
Insufficient (20–30 ng/mL)	43 (19.9%)	35 (35.0%)		
Sufficient (>30 ng/mL)	15 (7.0%)	50 (49.5%)		

Additional continuous comparison: Median vitamin D level in patients: 16.8 ng/mL (IQR 12.3–21.5)

Median vitamin D level in controls: 31.4 ng/mL (IQR 26.0–36.8). Mann–Whitney U = 4121.5, p<0.001

Vitamin D deficiency was found significantly more among intra-articular fractures compared with extra-articular fractures (χ^2 = 7.84, p=0.02). Fracture severity also exhibited a significant association with vitamin D status: severe fractures (Type C) had the maximum proportion of vitamin D-deficient patients, while mild fractures (Type A) had the lowest (χ^2 = 16.91, p<0.001). Low-energy trauma was strongly associated with vitamin D deficiency compared with high-energy trauma (χ^2 = 5.47, p=0.02). It was found that a significant negative correlation was present between serum vitamin D levels and AO severity grade (Pearson r = –0.32, p<0.001), indicating that lower vitamin D levels are associated with greater fracture complexity. Independent predictors of deficiency of vitamin D among fracture patients included age 60 years or older (AOR 1.78, 95 percent CI 1.20–2.64, p=0.005), female sex (AOR 1.92, 95 percent CI 1.23–2.99, p=0.004), osteoporosis (AOR 2.15, 95 percent CI 1.32–3.50, p=0.002), and low-energy trauma (AOR 1.63, 95 percent CI 1.05–2.56, p=0.03). Assessment of the model revealed acceptable calibration (Hosmer–Lemeshow p=0.42) and a moderate ability to explain the outcome (Nagelkerke R2 = 0.29), with full regression details listed in table 4.

Table 4: Multivariate Logistic Regression Detecting Predictors of Deficiency of Vitamin D

Predictor	Adjusted OR	95 percent CI	p-value
Age ≥ 60 Years	1.78	1.20–2.64	0.005
Female Sex	1.92	1.23–2.99	0.004
Osteoporosis	2.15	1.32–3.50	0.002
Low-Energy Trauma	1.63	1.05–2.56	0.030
Model fit			
Nagelkerke R^2	0.29	—	—
Hosmer–Lemeshow p	0.42	—	—

DISCUSSION

This study found that patients with DRF had vitamin D deficiency, which indicates a moderate link between serum levels of vitamin D and increased risk of fracture. This suggested its crucial role in bone integrity and making bones more prone to develop fractures. Our findings are consistent with the available regional data. Siddiqee et al. [11] and Dhibar et al. [3] found marked vitamin D deficiency in the South Asian population, with prevalence rates as high as 80%. The study findings are also in accordance with the research of Cianferotti et al. and Manoj, who found suboptimal vitamin D levels in patients having fragile fractures [9, 10]. These cross-population findings highlight a broader regional crisis. According to Siddiqee et al. and Jiang et al. Asian populations have a deficiency mainly due to behavioral and dress-related barriers to adequate

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sunlight [11, 12]. This study used AO classification to quantify the fracture severity and determine the correlation, and applied the regression analysis. The study found that extraarticular fractures and low-energy trauma were more prevalent in patients with a deficiency of vitamin D, which suggests that vitamin D deficiency deteriorates bone elasticity, and minor mechanical stress can damage bone integrity. These findings are in accordance with the research of Sahni et al. and Pilz et al. who also established that vitamin D deficiency leads to fragile fractures by weakening bone microarchitecture and mineralization [7, 13]. We also found a moderate inverse correlation of vitamin D and fracture severity, which also supports the biomechanical role of vitamin D in maintaining the strength of the bone. Our study indicated a gender difference in deficiency of vitamin D. Women, particularly those who had menopause, had a higher prevalence of deficiency of vitamin D and had complex fractures. Similar trends have been reported by Prietl and fellows, Lips et al. who have postulated that this difference is related to estrogen deficiency, lower muscle mass, and reduced calcium absorption in females [14, 2]. This necessitates targeted screening and supplementation programs in women over 50 years of age. In this study, age was found to be a critical predictor. The study observed a moderate negative correlation between vitamin D levels and age, which is similar to the recordings of LeBoff et al. who also documented limited outdoor exposure in adults with old age [15]. This study also confirmed that age ≥ 60, female gender, osteoporosis, and low-energy trauma are all independently related to deficiency of vitamin D, which is consistent with the findings of Fu et al. [16]. Comorbidities like hypertension and diabetes were prevalent among the patients in our study, but no statistically significant correlation with vitamin D levels was determined in our study. This suggested that deficiency of vitamin D acts as an independent risk factor and not as a mediator through systemic disease [17]. Similar findings were documented by Gatt et al. who also concluded that vitamin D influences bone repair and immune modulation independent of metabolic comorbidities [18]. The findings in this study have a very powerful public health impact. The finding of a high incidence of vitamin D deficiency despite plentiful sunlight suggests a cultural and behavioral etiology, mainly limited exposure to sunlight and low vitamin D intake in the diet among the Pakistani population. Similar deficiencies have been recognized across Europe, where vitamin D deficiency is a pandemic [19]. These findings are augmented by the recommendations of Rutigliano et al. and Holick, who emphasized region-specific supplementation and fortification of diet [8, 20].

Although this study is the first of its kind in the region but had many shortcomings. It was a single-center study, which does not represent the entire Pakistani population. Furthermore, diet and sunlight exposure time, which are the major reasons for vitamin D status, were not controlled. Physical activity, socioeconomic status, and genetic predisposition were also not evaluated. Blood samples were obtained after the injury, and acute inflammation could have influenced the serum levels of vitamin D. Nevertheless, the strength of the study is that detailed fracture classification was done, we included a control group, and biochemical assessment was done using CLIA. Therefore, it is recommended that routine vitamin D screening be incorporated in fracture prevention strategies, especially for elderly women and in patients presenting with low-energy trauma. Future longitudinal and interventional studies should be conducted to determine whether vitamin D supplements can reduce fracture incidence or improve healing results in DRF patients.

CONCLUSIONS

The study found that deficiency of vitamin D is an important and independent predictor of distal radius fractures specially in elderly female patients, and routine screening of vitamin D levels should be integrated in the fracture prevention strategy. Overall, this study has provided evidence that deficiency of vitamin D is a significant and modifiable predictor of fracture severity. Addressing this deficiency could play a key role in modifying the rising burden of osteoporosis-related fractures in Pakistan.

Authors' Contribution

Conceptualization: FN
Methodology: JJ, AM, A, FN
Formal analysis: AM, A, FN
Writing and Drafting: AM, FR, MR, FN
Review and Editing: JJ, AM, FR, MR, A, FN

All authors approved the final manuscript and take responsibility for the integrity of the work

Conflicts of Interest

All the authors declare no conflict of interest.

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