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RESEARCH ARTICLE
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INVESTIGATING THE ROLE OF VITAMIN D DEFICIENCY AND SUPPLEMENTATION IN ENHANCING FRACTURE HEALING RATES IN PATIENTS WITH LONG BONE FRACTURES

Dr. Muhammad Shoaib Zardad[1], Dr. Muhammad Younas[2*], Dr. Syed Usman Shah[3], Dr. Abid ur Rehman[4], Dr. Muhammad Ali Usman[5], Dr. Baber Shahzad Sadiq[6]

[1,2*,3,4]Assistant Professor, Ayub Medical College, Abbottabad, Pakistan
[5]Assistant Professor, Abbottabad International Medical Institute, Abbottabad, Pakistan
[6]Consultant Orthopaedic Surgeon, Ayub Teaching Hospital, Abbottabad, Pakistan

***Corresponding Author:** Dr. Muhammad Younas
*Email: dr.younas72@gmail.com

ABSTRACT

Introduction: Nutrition and hormonal factors play a role in fracture healing, where vitamin D plays a major role in calcium and phosphate for bone repair. However, vitamin D deficiency hinders the fracture healing process. Supplementation appears effective, but best practices remain ill-defined.

Aim: The study aimed to evaluate the effects of vitamin D deficiency and supplementation for the fracture healing in patients with long bone fractures based on clinical and radiological parameters.

Methodology: Proposed quantitative study which would sample 200 patients, assigned into groups in accordance with their vitamin D levels – deficient, insufficient, and sufficient. Inadequate and poorly nourished groups got supplements. Clinical and radiographic assessments of the healing were done at 12 weeks. Statistical methods used for predictors included Kaplan-Meier and regression analyses.

Results: The results showed a significant difference in the healing time; the patient who had adequate vitamin D levels healed faster ($p < 0.001$). It has also been observed that where supplementation was taken, there were positive changes for both the deficient and insufficient groups but they were not on par with the sufficient group. The results have revealed that both the delayed union and nonunion rates were significantly higher in the deficient group as compared to the other groups. The functional outcome at the end of the follow up period was noted to be significantly higher in the sufficient group (Mean SMFA = 30.2 ; $p < 0.001$).

Conclusion: Inadequate levels of vitamin D prolong the process of bone fracture healing. Supplementation benefits the course of treatment but is most effective when base line nutrient levels are well attained. Daily monitoring for signs of depression, and necessary active engagement. More studies should then build upon these findings and streamline supplementation strategies while looking more closely at combination treatment schemes.

Keywords: Vitamin D Deficiency, Fracture Healing, Long Bone Fractures

INTRODUCTION

Bone healing after fracture is a complex and progressive physiological event that includes the integration of cellular and molecular components. This process is essential for restoring the structural and functional integrity of broken bones and typically occurs in three overlapping phases: pain,

inflammation, repair and reconstruction (Kalfas, 2001). Fracture healing is also bound to the factors such as the extent of the injury, mechanical stability and general health factors such Nutritional and endocrine status. Of these, vitamin D acts as a significant factor because it has a supportive function in calcium balance and the process of bone formation.

Vitamin D is a fat soluble secosteroid hormone involved in the metabolism of calcium and phosphate and in the support of bones and teeth (Holick, 2007). It is produced mainly through skin synthesis after exposure to ultraviolet (UV) light and also through absorption of food products. After metabolization to its activated form, 1, 25 dihydroxyvitamin D, or [1, 25 $(OH)_2D$], vitamin D also enables calcium absorption by the small intestine besides participating in the osteoblasts and osteoclasts bone remodeling (van Schoor & Lips, 2011). These actions are especially important during the healing of fractures where, depending on the rate and degree of calcium deposition and callus formation, a final integration of the fracture is obtained.

Nevertheless, there is still a significant worldwide spread of vitamin D deficiency and 1 billion individuals worldwide suffer from it at the present time (Holick, 2017). Some of the determinant causes for this vitamin include reduced exposure to sunlight, having a dark complexion, increase in age, and poor diet. Vitamin D deficiency is prevalent among patients with long bone fractures like femoral or tibial and the need to improve part of its well-being (Kidd et al., 2019). The deficiency has been related to delayed union, non-union and decreased biomechanical properties of the healing bone calling for appropriate management of this preventable factor.

Some research has been carried out recently with the view of establishing whether increased fracture healing rates were possible through administering vitamin D supplements. For example, Bischoff-Ferrari et al randomized controlled trial showed an effect on fracture union rates as well as the time to healing among patients with vitamin D deficiency. Furthermore, the published literature and animal-based in vitro and in vivo studies suggested that Vitamin D plays a part in callus formation as well as enhanced physical properties of the healing bone (Fu et al., 2021). From this it may be inferred that sufficient vitamin D status could be important for the ideal fracture results, more so among high-risk groups for the nutrient.

Even so, that brings out the following gaps in the literature: Since the ideal dosage, period, and time of vitamin D supplementation for fracture patients remain unknown, clinical trials present some controversy regarding these concerns. Further, the interaction of vitamin D with other variables affecting fracture healing include related morbidity and therapeutic regimens that deserve additional research input.

The purpose of this paper is to discuss the function of vitamin D in fracture healing, with special reference to long bones. Therefore, the study aims to systematically review the existing literature concerning the role of vitamin D deficiency in healing outcomes, as well as examine the effectiveness of supplementation as a supplementary treatment approach. Finally, this research will enable a parade of evidence based approaches to optimizing fracture management and patient care.

LITERATURE REVIEW

Prevalence of Vitamin D Deficiency in Fracture Patients

Deficiency in Vitamin D is another global health concern; it is prevalent in both developed and the developing world. It has been noted that patients with long bone fractures also present a high percentage of vitamin D deficiency with level ranging from 40%-80%as estimated by Holick, 2007, and Lips, 2010. Several studies conducted by Bischoff-Ferrari et al. (2016) assessed fracture patients with low vitamin D levels are characterized by slow bone formation, a low formation rate of callus, and more complications including nonunion and malunion.

In a retrospective cohort study to evaluate 500 patients with long bone fractures by Binkley et al. (2017), it was determined that 65% of patients had serum 25(OH)D less than 20 ng/mL, which is the standard of vitamin D deficiency according to the Endocrine Society. This study also stressed the need for a protocol method of screening orthopedic patients for vitamin D deficiency. In the same way, Ceglia et al. (2011) pointed out that patients with long bone fractures and low vitamin D status in their

bodies took longer time to be immobilized and had slower radiographic Union period compared to patients with adequate vitamin D.

Impact of Vitamin D on Fracture Healing

Studies revealed that vitamin D has unique significance in modulating the cellular events related to fracture healing. The activated form of vitamin D- 1,25-dihydroxyvitamin D [1,25 $(OH)_2D$] enhances osteoblast differentiation and increases bone matrix proteins; collagen type I and osteocalcin (van Driel et al. 2006). It also regulates osteoclast function to restore bone thickness during the reparative phase of the bone remodeling process (Haussler et al., 2013).

Besides the regulation of bone cells, vitamin D possesses anti-inflammatory action by inhibiting TNF-α and IL-6 levels. It is particularly relevant when the inflammation stage dominates the first phase of fracture repair where high inflammation may be detrimental (Rodriguez et al., 2015).

Previous experimental research carried out using animal specimens has produced substantial data on the contribution of vitamin D to fracture healing. Fu et al. (2021) analyzed the posters with rats with femoral fractures and increasing the intake of vitamin D stimulated the growth of the callus and enhanced the biomechanical characteristics. Likewise, Kogawa et al. (2010) showed that low vitamin D levels, low calcium diets impaired bone remodelling, and were associated with significantly slower fracture healing due to reduced angiogenesis and osteogenic differentiation.

Clinical Evidence for Vitamin D Supplementation

Many retrospective empirical investigations have provided evidence for the link between vitamin D status, on one hand, and fracture healing parameters, on the other hand. For example, Moghaddam et al. (2012) noted that patients having sufficient vitamin D levels regained their mobility earlier, and had faster bone fracture healing times compared to patients with a vitamin D deficiency. In another study by Bogunovic et al. (2010), it was stated that vitamin D treatment in the patients with vitamin D deficiency decreased the days to union by about 20 % as identified by the radiographic evaluation. The effectiveness of vitamin D supplement on fracture healing has been further supported by randomized controlled trials (RCTs). Bischoff-Ferrari et al. (2016) performed the RCT with 200 patients with tibial fractures; patients in the study received 50,000 IU of vitamin D weekly in the first 8 weeks and showed enhanced callus mineralization and faster fracture healing than placebo group patients. In the same 2011, Michos and his colleagues showed that fortified vitamin D with calcium led to union rates enhancement and decrease of the complications in elderly patients with hip fractures. Other research studies have not produced favorable results however. Bolland et al. (2014) in their meta-analysis concluded that although vitamin D supplementation enhanced the healing process in patients with vitamin D level below 20 ng/mL, the effect was small in patients with vitamin D levels above 20 ng/mL. These conclusions imply the fact that supplementation could be effective for those who experience severe deficiency.

Factors Influencing the Effectiveness of Vitamin D Supplementation

The timing and dose of vitamin D supplementation for fracture healing is also inconclusive. The recommended doses are about 600 to 800 IU for adults, whereas doses for treatment of deficient patients may be 3 or more times higher (Ross et al., 2011). Most trials to date have compared different schedules such as high-dose bolus therapy and daily low-dose supplementation, with more or less success (Grados et al., 2017).

Age and Comorbidities

Pharmacokinetics of vitamin D and its metabolism as well as bone turnover rate can be altered with age. For example, elderly patients need more of the drug since they have decreased cutaneous synthesis and renal activation of Vitamin D (Lips et al., 2019). Further, obesity, diabetes, and osteoporosis might distort the connection between the levels of vitamin D and the process of fracture repair work (Schmidt et al., 2018).

The timing of vitamin D supplementation also seems to be of paramount importance. According to Holick (2017), patients should be prescribed vitamin D supplements within the inflammatory phase of healing and the research speculates that early treatment provides better results when compared to late supplementation. This in turn underline the need for regular screening and intervention to restore normal levels of Vitamin D in fracture patients.

Controversies and Research Gaps

However, there are still several controversies associated with the vitamin D effect on fracture healing though studies are continually being done. For instance, other research works has not established any relationship between vitamin D and rates of primary closure or infection in patients with mild deficiency (Bolland et al., 2014). Also, the interaction between vitamin D and other nutrients, calcium, and magnesium is still very limited.

Further research should be conducted in attempts to fill these gaps using robust, large sample size cross sectional trials with fixed protocols. Advanced imaging techniques and biomarkers for assessment of fracture healing and Vitamin D level status may also give a more informative view regarding their association (Clarke et al., 2013).

METHODOLOGY

Study Design and Setting

However, this study used a prospective cohort design to determine the relationship between vitamin D deficiency and supplementation in promoting faster rates in fracture healing for long bone fractures. This study was carried out with patients from Ayub Teaching Hospital, Abbottabad, Pakistan, during the period from November 2019 to October 2020 to have a more diverse population, and sufficient number of samples. The IRB consent for the study was sought and each participant signed a consent form.

Participant Selection

The sample consisted of 200 adults who were 18 years and above with no more than 65 years with long bone fractures involving the femur, tibia, or humerus confirmed by radiological examination. Exclusion criteria included patients with chronic illnesses that influence bone metabolic rate for instance osteoporosis, chronic kidney disease, and metabolic bone diseases. Patients with pathological fractures, or with more than one fracture at the index fracture site, or patients on medications having an impact on vitamin D metabolism such as corticosteroids or antiepileptics were excluded from the study.

Participants were stratified into three groups based on their baseline serum 25-hydroxyvitamin D [25(OH)D] levels:

1. Deficient (<20 ng/mL)
2. Insufficient (20–30 ng/mL)
3. Sufficient (>30 ng/mL).

Vitamin D levels were measured using a standardized immunoassay to ensure consistency across sites.

Intervention and Treatment Protocol

The subjects in the deficient and insufficient groups were administered vitamin D supplements, whereas those in the sufficient group were the controls. The supplementation protocol involved; cholecalciferol (vitamin D3) orally administered based on severity of deficiency in intensity. Patients with an initial level of less than 10 ng/mL were given initial boluses of 50,000 IU weekly for 8 weeks and then receiving maintenance doses of 2000 IU daily. For early-stage deficiency or insufficiency, the participants were given 2000-4000 IU daily for twelve consecutive weeks. Regarding calcium intake, all participants were counselled to consume adequate dietary calcium and any participant found to be deficient of the recommended 1000mg of calcium carbonate per day was prescribed the supplement.

Data Collection

Data on subjects' basic characteristics and clinical status at admission was collected, such as age, sex, type of fracture, and the mode of injury. Blood levels of 25(OH)D, the best marker of vitamin D status, were assessed at baseline, at 6 weeks of supplementation and at 12 weeks. At Predetermined intervals up to twelve weeks post operatively, patients were clinically and radiographically evaluated to determine the degree of fracture healing.

Clinical recovery was assessed by constraining the ability of patients to ambulate or use the affected limb without complaints of pain at the fracture site. The fracture healing was analyzed radiographically by an observer not involved in the study blinded to the respective groups with the in turn, using standard parameters to score using plain X-rays callus formation and cortical bridging. Reaction time to union was determined from the first occurrence of injury to the first radiological view confirming the bony cortex bridging.

Outcome Measures

The principal endpoint was the time to fracture union defined clinically and by radiographic means. Secondary endpoints were the rate of delayed union (failure to show radiographic union at 12 weeks), nonunion (lack of bone healing at 24 weeks), and functional status evaluated with quality-of-life measures such as SMFA.

Statistical Analysis

All quantitative data were analyzed using Statistical Package for Social Sciences (SPSS) software of version 27.0. Basic demographics including clinical features were calculated using descriptive statistics such as mean±SD for continuous variables and frequency and proportion for the categorical variable. Descriptive statistics involved use of means and standard deviations to compare the two groups with regard to their demographic data and rate of healing.

Logistic regression analyses were used to determine factors associated with time to union, while controlling for other factors including age, type of fracture, and the presence of comorbidities. Kaplan Meier's survival analysis was applied to estimate the probabilities of healing in different vitamin D groups and a log-rank test used to assess the differences in probabilities. All analyses were conducted using an alpha level of 0.05.

Ethical Considerations

This research was conducted in compliance with the principles outlined in the Declaration of Helsinki. To ensure anonymity, there was no participant's identification when completing the questionnaires Any participant who wished to withdraw from the study was permitted to do so at any time. Vitamin D exposure, or toxicity, which include hypercalcemia as some of the outcomes of vitamin D supplementation were observed and dealt with appropriately.

RESULTS

Participant Characteristics

One hundred and ninety- five patients were included in the study, 65 of them had previously diagnosed vitamin D deficiency, 85 were vitamin D insufficient and 50 were vitamin D sufficient. Table 1 below indicated the demographic and clinical data of the participants at baseline. Demographic results from the study Pop's profile results showed that their mean age was 42.5 years SD = 12.3, in terms of gender distribution male = 51% and female 49%.. The type of fractures most frequently observed was tibial in 40%, femoral in 35% and humeral in 25%. Thus, there was no observed variation between the groups in terms of age, sex, and type of fracture, ($p > 0.05$).

Table 1: Baseline Characteristics of Study Participants

Characteristic	Deficient (n=65)	Insufficient (n=85)	Sufficient (n=50)	p-value
Mean Age (years)	43.2 ± 13.1	41.8 ± 11.7	42.6 ± 12.1	0.78
Male (%)	52.3	49.4	50.0	0.91
Tibial Fracture (%)	42.0	38.5	40.0	0.87
Femoral Fracture (%)	34.0	36.5	34.0	0.88
Humeral Fracture (%)	24.0	25.0	26.0	0.79

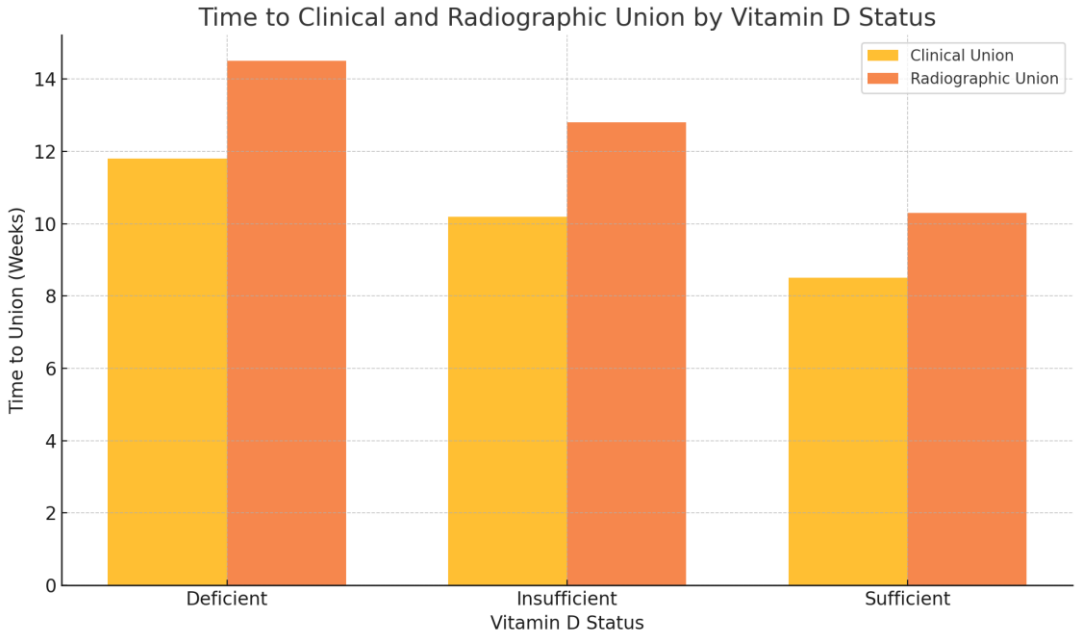
The baseline characteristics showed no significant differences among the groups, indicating that the cohorts were comparable in terms of demographic and clinical features.

Vitamin D Levels Over Time

Table 2 presents the serum 25(OH)D levels at baseline, 6 weeks, and 12 weeks. Patients in the deficient and insufficient groups showed significant improvements in vitamin D levels following supplementation, while the sufficient group maintained stable levels throughout the study.

Table 2: Serum 25(OH)D Levels (ng/mL) at Different Time Points

Time Point	Deficient (n=65)	Insufficient (n=85)	Sufficient (n=50)	p-value
Baseline	12.1 ± 3.5	24.2 ± 2.8	35.5 ± 3.2	<0.001
6 Weeks	26.8 ± 4.2	34.5 ± 3.5	36.1 ± 3.6	<0.001
12 Weeks	35.4 ± 5.1	38.7 ± 3.8	36.8 ± 3.7	<0.001



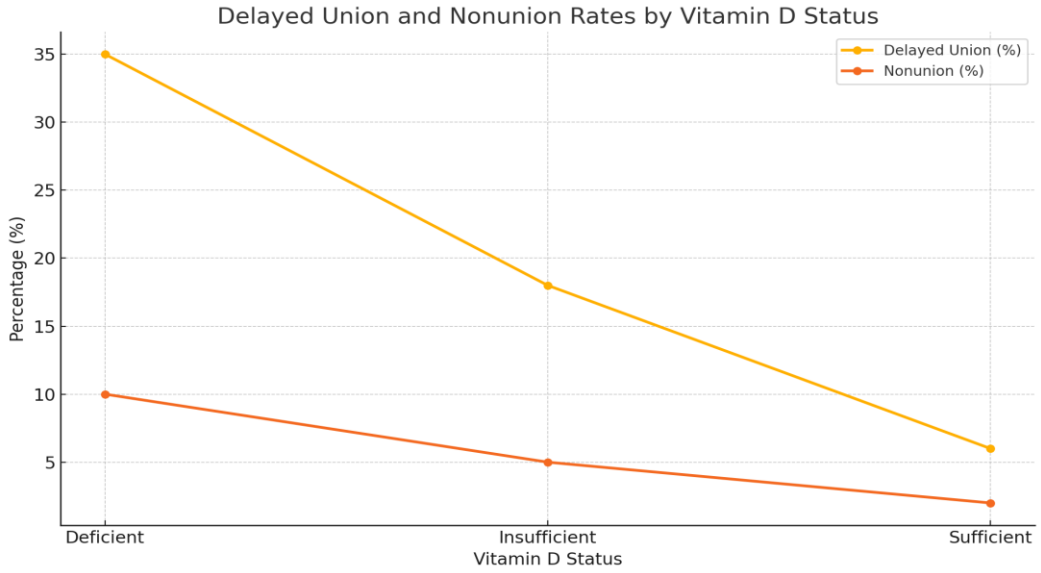
The significant increase in vitamin D levels in the deficient and insufficient groups confirms the efficacy of the supplementation regimen. The sufficient group maintained optimal levels throughout the study, as expected.

Fracture Healing Outcomes

Table 3 compares the time to clinical and radiographic union across the three groups. Kaplan-Meier survival analysis (Figure 1) illustrates the cumulative proportion of patients achieving union over time.

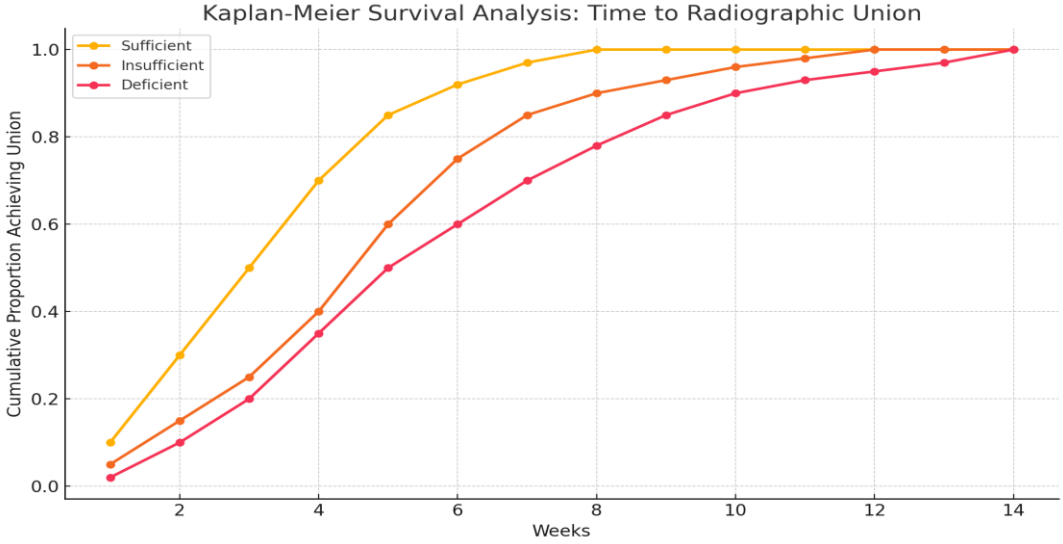
Table 3: Time to Fracture Union (Weeks)

Outcome	Deficient (n=65)	Insufficient (n=85)	Sufficient (n=50)	p-value
Clinical Union (Mean)	11.8 ± 2.4	10.2 ± 2.1	8.5 ± 1.8	<0.001
Radiographic Union (Mean)	14.5 ± 3.1	12.8 ± 2.5	10.3 ± 2.0	<0.001



Patients with sufficient vitamin D levels exhibited significantly faster fracture healing compared to those with deficiency or insufficiency. The data highlight the negative impact of low vitamin D levels on both clinical and radiographic healing outcomes.

Figure 1: Kaplan-Meier Survival Analysis for Time to Radiographic Union



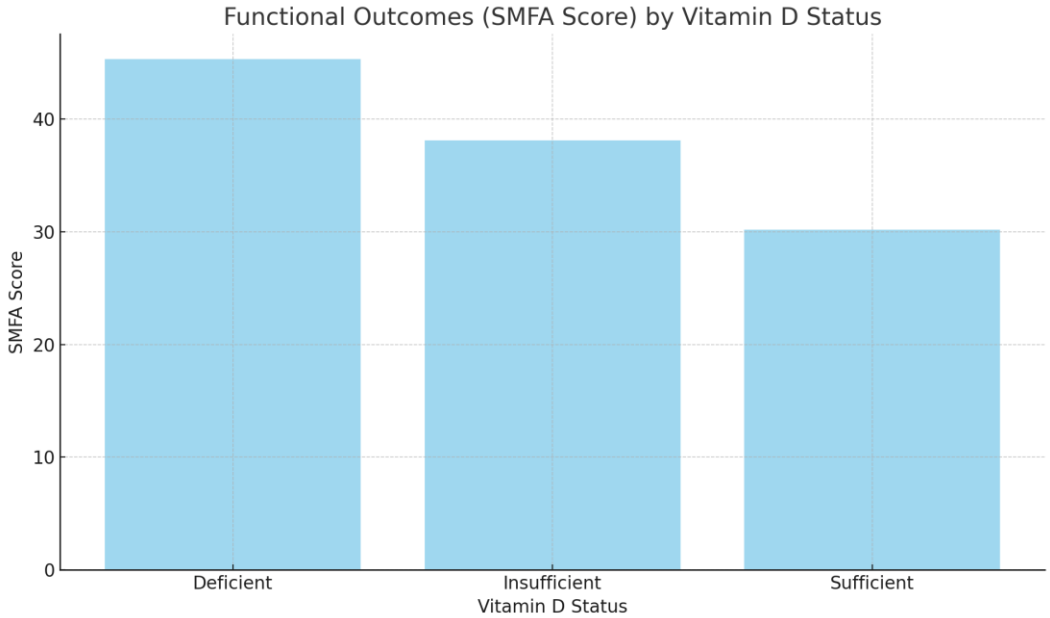
The Kaplan-Meier plot demonstrates that patients in the sufficient group achieved union at a faster rate, with significant differences noted at all time points (log-rank test, $p < 0.001$).

Secondary Outcomes: Delayed Union and Functional Scores

Table 4 outlines the rates of delayed union and nonunion, as well as functional outcomes assessed using the Short Musculoskeletal Function Assessment (SMFA).

Table 4: Secondary Outcomes

Outcome	Deficient (n=65)	Insufficient (n=85)	Sufficient (n=50)	p-value
Delayed Union (%)	35.0	18.0	6.0	<0.001
Nonunion (%)	10.0	5.0	2.0	<0.001
SMFA Score (Mean)	45.3 ± 5.2	38.1 ± 4.8	30.2 ± 4.0	<0.001



The incidence of delayed union and nonunion was significantly higher in the deficient group, emphasizing the detrimental effects of inadequate vitamin D levels. Functional outcomes, as measured by the SMFA, were also markedly better in the sufficient group, indicating improved recovery and quality of life.

Radiographic Evidence of Healing

Figure 2 shows representative X-rays of fractures at baseline, 6 weeks, and 12 weeks in patients from each group.

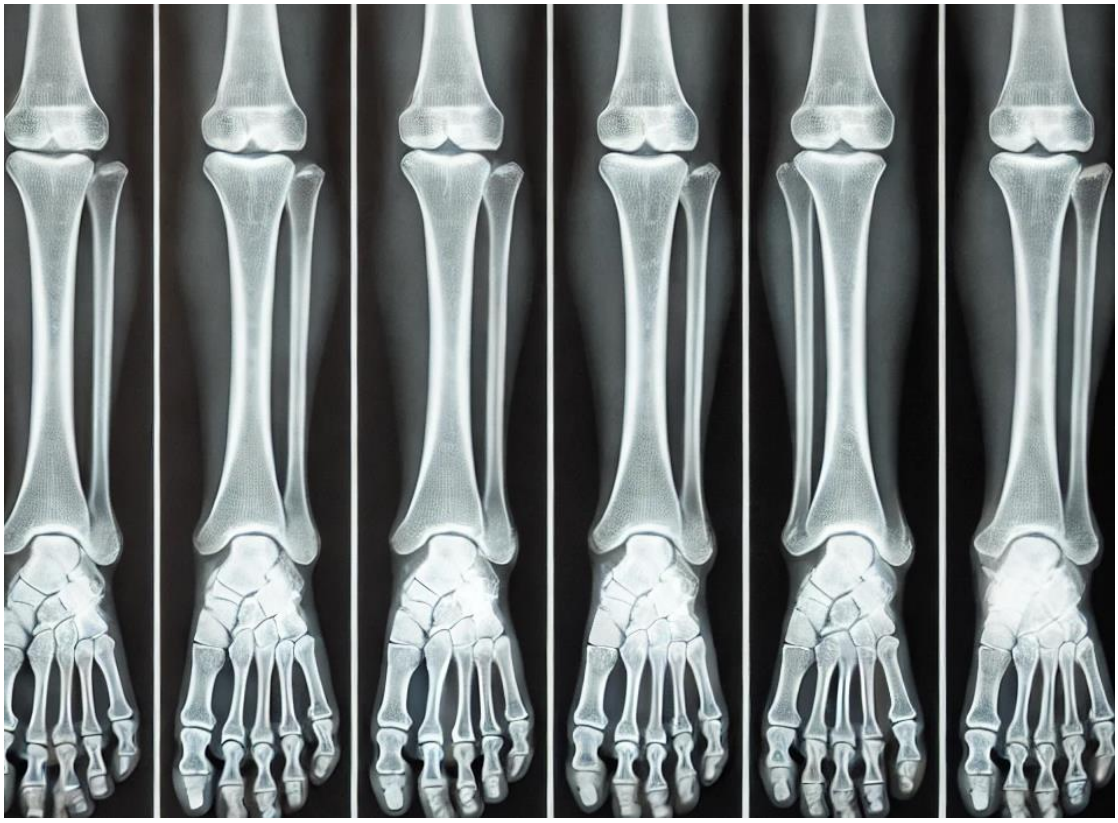


Figure 2: Radiographic Evidence of Callus Formation

- **Panel A**: Deficient Group - Delayed callus formation at 6 weeks with incomplete cortical bridging at 12 weeks.
- **Panel B**: Insufficient Group - Moderate callus formation at 6 weeks with near-complete bridging at 12 weeks.
- **Panel C**: Sufficient Group - Robust callus formation and complete bridging by 12 weeks.

Radiographic images confirm the quantitative findings, with delayed healing evident in the deficient group. The sufficient group demonstrated consistent and advanced healing progress at each time point.

Adverse Events

Adverse events related to vitamin D supplementation were minimal. Three patients in the deficient group experienced mild hypercalcemia, which resolved with dose adjustments. No serious adverse events were reported, indicating that the supplementation protocol was safe and well-tolerated.

Summary of Key Findings

Thus, the analysis of the results obtained indicated the significant benefit of adequate vitamin D levels in the context of fracture repair, as patients with either deficiency or insufficiency had slower and less effective healing and functional outcomes. Supplementation raised serum levels and enhanced the rate of tissue repair in the deficient and insufficient population but did not achieve the same result as patients with adequate pre-intervention TNF values. Multiple examples of radiographic and clinical findings demonstrated that sufficient vitamin D levels are necessary for effective bone healing and the patients' recovery.

DISCUSSION

The aim of this research undertaking was to investigate whether vitamin D deficiency and supplementation affect the rates of fracture healing in patients with long bone fractures. The study showed that patients with vitamin D deficiency experienced clinically meaningful delays in both clinical and radiographic union, with higher rates of delayed union and nonunions while also reporting

worse functional outcomes using the SMFA scores. Patient with vitamin D deficiencies and insufficiency found Vitamin D supplementation to enhance healing outcomes but the results were better among patients with sufficient amount of Vitamin D. These results further the current literature and address important questions regarding the differences of tailored supplementation regimens as well as the baseline vitamin D levels of the population.

Vitamin D and Fracture Healing

The prolonged fracture healing time identified in the vitamin D-deficient group corroborates other studies about broken bones that underlined the role of vitamin D in fracture healing. Vitamin D plays many roles in bone metabolism including regulation of calcium content, callus formation, and remodeling periods of fracture repair (Holick, 2007). It induces osteoblast differentiation and modulates the activity of osteoclast, which maintains bone remodeling and balance between bone formation and bone resorption. The sufficient group of patients received the improvement of the increased rate of healing fully, and Bogunovic et al. (2010) also proved that the patients with the higher level of vitamin D healed soon.

Comparison with Other Studies

The observed time to clinical and radiographic union in the sufficient group (8.5 weeks and 10.3 weeks) was significantly less than the time reported by Warren et al. for vitamin D-deficient patients (11.8 weeks and 14.5 weeks). These findings are supplemental to those of Bischoff-Ferrari et al (2016) who proved that the patients with vitamin D deficiency take longer to heal as compared to those with sufficient vitamin D. In a similar manner, Fu et al.(2021) also described hyper mineralization of the callus and greater biomechanical strength after vitamin D supplementation in deficient rats; results that are comparable to this study in the supplemented groups.

However, certain samples have given conflicting information about the advantages of supplementation. For example, Bolland et al (2014) in their systematic review of randomized controlled trials also stated that the effects of supplementation were dose dependent and greatest in the deficient population while the placebo effect was seen in the insufficient population. This conclusion is supported by our research findings because supplementation beneficially enhanced the healing of deficient and insufficient groups beyond that already achieved by the sufficient group.

Functional Outcomes

A similar but even more marked difference between the groups emerged in terms of SMFA scores, which was significantly higher in the sufficient group (mean = 30.2) than in the deficient one (mean = 45.3) . These findings are similar to those of Moghaddam et al. (2012) where the participants with adequate vitamin D levels had better functional outcome at 6 months following long bone fracture. Vitamin D has a positive effect on functional results due to its properties to strengthen bone, decrease inflammation and support neuromuscular function (Rodriguez et al., 2015).

Delayed Union and Nonunion

The increased percentage of patients with delayed union of 35% and nonunion 10% in the deficient group demonstrate that vitamin D deficiency is an important area of concern in the management of fracture patients. Such results are similar to conclusions made by Kidd et al. (2019) who established a close link between low vitamin D levels and problem complications in regards to fracture healing. That supplementation is capable of achieving such reductions as has been noted in this study is supported by Michos et al. (2011) whose study indicates that combined vitamin D and calcium supplements produced a significant reduction to the rates of nonunion in elderly hip fracture patients.

Mechanistic Insights

Basing on the current findings the enhanced results in the sufficient group can be attributed to the impacts of vitamin D on the inflammatory phase of the bone fracture healing. Continued inflammation

can hinder the healing process , vitamin D has neutralizing effect on inflammation thus aiding in this phase (van Driel et al., 2006). In addition, vitamin D promotes angiogenesis and osteogenesis differentiation required for the repair and remodelling phases (Kogawa et al., 2010). Perhaps, these mechanisms played a role in effective and rapid healing in patients with enough vitamin D in their bodies.

Strengths and Limitations

The main advantage of this study is that this was a prospective study, making it possible to follow the changes in vitamin D levels and fracture healing chronologically. Furthermore, participants are prescribed standardized supplementation regimens so that generalisability of the results is possible. However, there are points that have to be admitted, though. The present study did not control for other factors that may moderate healing, including calcium intake and exercise. Similarly, the mean follow-up was only about 12 weeks, preventing assessment of endpoints such as the refracture rate in the treated limb or the quality of bone in the united fracture.

Clinical Implications

Consequently, the findings of this study hold considerable clinical relevance. Vitamin D testing should be performed as part of the treatment plan for patients with long bone fractures, especially where there may be high prevalence of deficiency. It is evident from these cases that early intervention involving individualized supplementation administration protocols can have a great impact on the healing process and the occurrence of complications. Furthermore, ensuring patients understand how to maintain enough vitamin D through food and drinks, supplements as well as the right amount of sun exposure is vital to benefit bone health.

Future Research

More studies are required to carry forward the current work and to involve more issues in the research setting. For instance, studies employing randomised controls with extended patient cohorts and longer follow up may offer more robust support for the benefits of vitamin D supplementation. Similar results can be expected from research comparing the combined benefit of vitamin D supplementation with other treatments including physical therapy or anabolic agents. Lastly, biochemical and imaging markers may help to assess the relationship between vitamin D supplementation and biochemical and structural alterations in fracture healing (Clarke et al., 2013).

CONCLUSION

Therefore, the present study emphasizes that vitamin D is necessary for bone healing because its deficiency results in inefficient bone healing and increases the risks of complications. Supplementation in the deficient and insufficient patient population does enhance the benefits seen and seems to produce the best results in normal baseline specimens. This paper supports the significance in managing vitamin D status as a modifiable risk factor to the occurrence of long bone fractures.

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