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ORIGINAL RESEARCH

Evaluation of Serum Vitamin D Levels and Their Correlation with Bone Healing Time in Tibial Shaft Fractures: A Longitudinal Observational Study

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ABSTRACT

Background: Vitamin D plays a critical role in bone metabolism and mineralization, which are essential for optimal fracture healing. Deficiency in serum vitamin D may delay the bone healing process, particularly in long bone fractures like the tibia. This study aimed to evaluate serum vitamin D levels in patients with tibial shaft fractures and assess their correlation with bone healing time. **Materials and Methods:** A longitudinal observational study was conducted on 70 adult patients (aged 20–60 years) with closed tibial shaft fractures treated conservatively or surgically. Serum 25-hydroxyvitamin D levels were measured at admission. Patients were categorized into vitamin D sufficient (≥30 ng/mL), insufficient (20–29 ng/mL), and deficient (<20 ng/mL) groups. Bone healing was assessed clinically and radiographically at monthly intervals until confirmed union. Correlation analysis was performed between vitamin D status and time to union. **Results:** Out of 70 patients, 28 (40%) were vitamin D deficient, 22 (31.4%) insufficient, and 20 (28.6%) sufficient. The mean healing time was significantly longer in the deficient group (19.2 ± 2.8 weeks) compared to the sufficient group (13.5 ± 2.1 weeks) ($p < 0.001$). A strong negative correlation was found between serum vitamin D levels and bone healing time ($r = -0.62$, $p < 0.001$). Delayed union (>20 weeks) was observed in 32.1% of deficient patients compared to 5% in the sufficient group. **Conclusion:** Low serum vitamin D levels are significantly associated with prolonged bone healing time in tibial shaft fractures. These findings underscore the importance of screening and correcting vitamin D deficiency in fracture patients to promote timely bone regeneration.

Keywords: Vitamin D, tibial shaft fracture, bone healing, fracture union, 25-hydroxyvitamin D, longitudinal study, orthopedic healing.

INTRODUCTION

Vitamin D is a crucial regulator of calcium and phosphate metabolism, playing a fundamental role in skeletal development, bone remodeling, and mineralization. Its active form, 1,25-dihydroxyvitamin D, enhances calcium absorption in the intestines and promotes bone mineralization, both of which are vital for fracture healing (1,2). Tibial shaft fractures, one of the most commonly encountered long bone injuries, often require extended recovery periods, during which optimal nutritional and metabolic conditions are necessary to ensure proper bone regeneration (3,4).

Vitamin D deficiency remains prevalent worldwide, particularly in developing countries, where limited sun exposure, poor dietary intake, and increased skin pigmentation contribute to suboptimal levels (5). This deficiency has been linked to delayed fracture healing, non-union, and other orthopedic complications, as vitamin D receptors are expressed on osteoblasts and chondrocytes, cells that are central to bone repair mechanisms (6,7). Several studies have shown that insufficient vitamin D levels may impair the inflammatory, reparative, and remodeling phases of bone healing, thereby prolonging the overall healing time (8,9).

Although research has indicated a relationship between vitamin D status and bone health, there remains a lack of consensus on its direct impact on

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fracture healing duration in tibial shaft fractures, especially in the context of a longitudinal clinical evaluation (10). Given the high incidence of vitamin D insufficiency in the general population and the significant morbidity associated with delayed union, it is critical to explore this relationship in detail. This study aims to evaluate the serum vitamin D levels in patients with tibial shaft fractures and determine their correlation with the time to fracture union, providing evidence for the role of vitamin D in fracture prognosis.

MATERIALS AND METHODS

This longitudinal observational study was conductedin the Department of Orthopaedics, Sree Gokulam Medical Collegeover a period of 18 months. A total of 70 adult patients, aged between 20 and 60 years, presenting with closed tibial shaft fractures were enrolled. Patients were included if they had fresh fractures managed either conservatively with casting or surgically through intramedullary nailing. Exclusion criteria comprised open fractures, pathological fractures, metabolic bone disorders, chronic kidney or liver disease, and ongoing vitamin D supplementation.

Upon admission, a detailed clinical history was recorded, including age, sex, fracture type, and treatment modality. Blood samples were collected to measure serum 25-hydroxyvitamin D [25(OH)D] levels using a chemiluminescence immunoassay. Based on serum concentrations, patients were categorized into three groups: sufficient (≥30 ng/mL), insufficient (20–29 ng/mL), and deficient (<20 ng/mL).

Bone healing was assessed both clinically and radiologically at monthly follow-up intervals. Clinical assessment included absence of pain on weight-bearing and no tenderness at the fracture site. Radiographic healing was evaluated using standard anteroposterior and lateral views of the tibia, with union defined as the presence of bridging callus in at least three of four cortices. The time to fracture union was documented for each patient.

Data were statistically analyzed using SPSS version 26.0. Mean and standard deviation were calculated for continuous variables, while frequencies and percentages were used for categorical data. Comparisons between vitamin D groups were made using ANOVA, and Pearson correlation was applied to assess the relationship between serum vitamin D levels and healing time. A p-value <0.05 was considered statistically significant.

RESULTS

A total of 70 patients (45 males and 25 females) with closed tibial shaft fractures were included in the study. The mean age of participants was 38.6 ± 10.2 years. Based on serum 25(OH)D levels at the time of admission, 28 patients (40%) were categorized as vitamin D deficient (<20 ng/mL), 22 (31.4%) as insufficient (20–29 ng/mL), and 20 (28.6%) as sufficient (≥30 ng/mL).

The mean time to clinical and radiographic union differed significantly across the groups. Patients in the sufficient group showed an average healing duration of 13.5 ± 2.1 weeks, compared to 16.8 ± 2.4 weeks in the insufficient group and 19.2 ± 2.8 weeks in the deficient group ($p < 0.001$). The frequency of delayed union (>20 weeks) was highest in the deficient group (32.1%), followed by the insufficient group (18.2%), and lowest in the sufficient group (5%) (Table 1).

A statistically significant negative correlation was observed between serum vitamin D levels and bone healing time ($r = -0.62$, $p < 0.001$), indicating that lower vitamin D levels were associated with longer healing durations (Table 2).

Table 1: Distribution of Patients by Vitamin D Status and Mean Healing Time

Vitamin D Status	Number of Patients (%)	Mean Healing Time (weeks)	Delayed Union (%)
Deficient (<20 ng/mL)	28 (40.0%)	19.2 ± 2.8	32.1%
Insufficient (20–29)	22 (31.4%)	16.8 ± 2.4	18.2%
Sufficient (≥30)	20 (28.6%)	13.5 ± 2.1	5.0%

Table 2: Correlation Between Serum Vitamin D Levels and Bone Healing Time

Parameter	Correlation Coefficient (r)	p-value
Vitamin D vs. Healing Time	-0.62	<0.001

These findings clearly suggest that lower serum vitamin D levels are associated with increased time to union and a higher likelihood of delayed healing (Table 1, Table 2).

DISCUSSION

This study highlights a significant association between serum vitamin D levels and the duration of bone healing in patients with tibial shaft fractures. Patients with lower vitamin D levels demonstrated notably prolonged healing times and a higher incidence of delayed union, consistent with previously reported evidence linking vitamin D deficiency with impaired bone repair processes (1,2).

Vitamin D facilitates calcium and phosphate homeostasis, which are crucial for callus formation and mineralization during fracture healing. It exerts its action through vitamin D receptors expressed on osteoblasts, promoting osteogenic differentiation and bone matrix production (3,4). The negative correlation observed in this study (r = -0.62) confirms that lower serum 25(OH)D levels are strongly associated with

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delayed fracture healing, a trend similarly reported in earlier clinical and experimental research (5,6).

Our findings are consistent with those of Brinker et al., who reported that hypovitaminosis D is prevalent among patients with non-union fractures and that supplementation may enhance healing outcomes (7). Furthermore, a prospective study by Doetsch et al. noted delayed callus formation in patients with low vitamin D levels following long bone fractures (8). Similar delays in radiographic union have also been observed by Cho et al., who reported that vitamin D deficiency was independently associated with increased healing time in surgically treated tibial fractures (9).

Despite advances in surgical techniques and fixation devices, nutritional status remains a modifiable factor in fracture management. In our study, patients with sufficient vitamin D levels healed significantly faster than those who were deficient, echoing the conclusions of Holick and colleagues, who emphasized vitamin D sufficiency as essential for optimal bone remodeling and repair (10). Moreover, Barker et al. demonstrated that preoperative correction of vitamin D deficiency in fracture patients could reduce recovery time and complications (11).

Notably, a substantial percentage of the study population (71.4%) fell into the deficient or insufficient category, suggesting that subclinical vitamin D deficiency remains widespread among orthopedic trauma patients, particularly in regions with limited sun exposure or dietary intake (12). This aligns with the findings of Mithal et al., who reported high prevalence rates of hypovitaminosis D in South Asian countries, underscoring the public health significance (13).

Additionally, fracture healing involves a cascade of molecular events, including inflammation, angiogenesis, and matrix remodeling, all of which can be negatively influenced by low vitamin D levels (14). Studies in animal models have demonstrated that vitamin D deficiency delays chondrocyte hypertrophy and mineralization, crucial steps in the endochondral ossification pathway (15).

The strength of this study lies in its prospective longitudinal design and standardized follow-up intervals for radiographic assessment. However, certain limitations should be acknowledged. Serum calcium and parathyroid hormone levels were not assessed, which could have provided additional insights into mineral metabolism. Moreover, the lack of interventional comparison limits conclusions on the effectiveness of supplementation.

CONCLUSION

In conclusion, this study reinforces the evidence that adequate serum vitamin D levels are essential for timely fracture healing. Routine screening and early correction of vitamin D deficiency in patients with tibial shaft fractures may serve as a cost-effective strategy to optimize healing outcomes and reduce the risk of delayed union.

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