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Role of Vitamin D in Postoperative Recovery in Lower Limb Fracture Patients

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Abstract

Background: Vitamin D deficiency has emerged as a significant factor affecting bone healing and postoperative recovery in orthopedic patients. Lower limb fractures represent a substantial burden on healthcare systems, with recovery outcomes varying significantly among patients.

Objective: This study aimed to evaluate the role of vitamin D levels in postoperative recovery outcomes among patients with lower limb fractures, including healing time, complications, and functional restoration.

Methods: A prospective cohort study was conducted involving 180 patients with lower limb fractures requiring surgical intervention. Patients were categorized based on preoperative vitamin D levels: deficient (<20 ng/mL), insufficient (20-30 ng/mL), and sufficient (>30 ng/mL). Primary outcomes included radiographic union time, postoperative complications, and functional scores at 3, 6, and 12 months.

Results: Patients with vitamin D deficiency demonstrated significantly prolonged healing times (14.2 ± 3.8 weeks vs. 10.1 ± 2.4 weeks, $p<0.001$), higher complication rates (32% vs. 12%, $p<0.01$), and inferior functional outcomes compared to those with sufficient levels. Vitamin D supplementation in deficient patients improved recovery parameters significantly.

Conclusion: Adequate vitamin D levels are crucial for optimal postoperative recovery in lower limb fracture patients. Routine screening and supplementation should be considered as standard care protocols.

Keywords: Vitamin D, lower limb fractures, postoperative recovery, bone healing, orthopedic surgery, complications

Introduction

Lower limb fractures constitute approximately 60% of all skeletal injuries requiring surgical intervention, significantly impacting patient mobility, quality of life, and healthcare resources. The complexity of postoperative recovery in these patients involves multiple physiological processes, including inflammatory response, angiogenesis, cellular proliferation, and bone remodeling. Recent evidence has highlighted the critical role of vitamin D in these processes, extending beyond its traditional function in calcium homeostasis.

Vitamin D deficiency affects nearly one billion people worldwide, with prevalence rates ranging from 30-80% in various populations. In orthopedic patients, this deficiency may be even more pronounced due to reduced mobility, limited sun exposure, and underlying health conditions. The active form of vitamin D, 1,25-dihydroxyvitamin D3, functions as a hormone that regulates over 200 genes, many of which are involved in bone metabolism, immune function, and cellular repair mechanisms.

The relationship between vitamin D status and fracture healing has gained considerable attention in recent years. Vitamin D receptors are present in osteoblasts, osteoclasts, and chondrocytes, suggesting direct involvement in bone formation and remodeling processes. Additionally, vitamin D influences the production of growth factors, cytokines, and matrix proteins essential for optimal healing outcomes.

Despite growing awareness of vitamin D's importance, standardized protocols for assessment and supplementation in postoperative fracture care remain inconsistent across healthcare institutions. This study aims to provide comprehensive evidence regarding the impact of vitamin D status on postoperative recovery outcomes in lower limb fracture patients, potentially informing clinical practice guidelines and improving patient care.

Materials and Methods

Study Design and Population

This prospective cohort study was conducted at a tertiary care orthopedic center between January 2022 and December 2023. The study included 180 adult patients (aged 18-75 years) with acute lower limb fractures requiring surgical fixation. Inclusion criteria comprised closed or Gustilo grade I open fractures of the femur, tibia, or fibula, presenting within 48 hours of injury. Exclusion criteria included pathological fractures, multiple trauma, chronic kidney disease, liver dysfunction, malabsorption syndromes, and current use of medications affecting vitamin D metabolism.

Vitamin D Assessment and Categorization

Serum 25-hydroxyvitamin D [25(OH)D] levels were measured preoperatively using chemiluminescent immunoassay. Patients were categorized into three groups: vitamin D deficient (<20 ng/mL), insufficient (20-30 ng/mL), and sufficient (>30 ng/mL). Deficient patients received oral cholecalciferol supplementation (4000 IU daily) initiated postoperatively.

Surgical Procedures and Postoperative Care

All surgeries were performed by experienced orthopedic surgeons using standard fixation techniques appropriate for each fracture type. Postoperative protocols included standardized pain management, physiotherapy, and follow-up schedules. Patients received routine calcium supplementation (1000 mg daily) and were advised on dietary modifications.

Outcome Measures

Primary outcomes included radiographic union time, defined as cortical bridging in three of four cortices on orthogonal radiographs. Secondary outcomes comprised postoperative complications (infection, delayed union, nonunion, hardware failure), functional scores using the Lower Extremity Functional Scale (LEFS), and quality of life measures. Assessments were conducted at 6 weeks, 3 months, 6 months, and 12 months postoperatively.

Statistical Analysis

Data analysis was performed using SPSS version 28.0. Continuous variables were compared using ANOVA or Kruskal-Wallis tests, while categorical variables were analyzed using chi-square tests. Multiple regression analysis was conducted to identify independent predictors of healing outcomes. Statistical significance was set at $p<0.05$.

Results

Patient Demographics

The study population comprised 108 males (60%) and 72 females (40%) with a mean age of 42.3 ± 16.8 years. Vitamin D deficiency was present in 78 patients (43.3%), insufficiency in 64 patients (35.6%), and sufficiency in 38 patients (21.1%). Baseline characteristics were comparable among groups except for age and BMI, with deficient patients being older and having higher BMI values.

Primary Outcomes

Radiographic union times varied significantly among vitamin D groups. Deficient patients required 14.2 ± 3.8 weeks for union compared to 11.8 ± 3.1 weeks in insufficient patients and 10.1 ± 2.4 weeks in sufficient patients ($p<0.001$). Multivariate analysis confirmed vitamin D level as an independent predictor of healing time after adjusting for age, BMI, fracture type, and smoking status.

Complications

Overall complication rates were significantly higher in vitamin D deficient patients (32.1%) compared to insufficient (18.8%) and sufficient (10.5%) groups ($p<0.01$). Delayed union occurred in 15.4% of deficient patients versus 6.3% in insufficient and 2.6% in sufficient patients. Infection rates were 10.3%, 4.7%, and 2.6% respectively. No cases of nonunion were observed in the sufficient vitamin D group.

Functional Outcomes

LEFS scores at 6 months showed significant differences among groups. Sufficient vitamin D patients achieved scores of 68.4 ± 8.2 compared to 58.7 ± 12.4 in insufficient and 51.3 ± 15.6 in deficient patients ($p<0.001$). These differences persisted at 12-month follow-up, indicating sustained impact on functional recovery.

Supplementation Effects

Among the 78 vitamin D deficient patients who received supplementation, 56 (71.8%) achieved sufficient levels by 3 months postoperatively. These patients demonstrated improved healing parameters compared to those remaining deficient, with union times of 12.8 ± 3.2 weeks versus 15.9 ± 4.1 weeks ($p<0.05$).

Discussion

This study provides compelling evidence for the critical role of vitamin D in postoperative recovery following lower limb fractures. The observed association between vitamin D deficiency and prolonged healing times, increased complications, and inferior functional outcomes has significant clinical implications for orthopedic practice.

The mechanism underlying vitamin D's influence on fracture healing involves multiple pathways. Vitamin D enhances intestinal calcium absorption, promotes osteoblast differentiation and activity, and modulates inflammatory responses during the healing process. Additionally, it influences the production of bone matrix proteins including osteocalcin, osteopontin, and type I collagen, which are essential for new bone formation.

The higher complication rates observed in vitamin D deficient patients align with previous research demonstrating increased infection risk and delayed healing in deficient individuals. Vitamin D's immunomodulatory effects may contribute to these findings, as adequate levels support immune cell function and antimicrobial peptide production.

Our results regarding functional outcomes suggest that vitamin D's impact extends beyond bone healing to encompass muscle function and overall recovery. Vitamin D

receptors in skeletal muscle tissue influence muscle strength, balance, and coordination, factors crucial for rehabilitation success in lower limb fracture patients.

The effectiveness of postoperative vitamin D supplementation in improving outcomes among initially deficient patients supports the potential for intervention. However, the relatively slow normalization of vitamin D levels suggests that preoperative optimization might be preferable when feasible.

Study limitations include the observational design, potential confounding variables, and the single-center setting. Additionally, seasonal variations in vitamin D levels and compliance with supplementation were not fully controlled. Future randomized controlled trials with larger sample sizes and longer follow-up periods would strengthen the evidence base.

Clinical implications of these findings include the need for routine preoperative vitamin D screening in fracture patients, development of standardized supplementation protocols, and integration of vitamin D optimization into enhanced recovery after surgery pathways. Cost-effectiveness analyses would be valuable to support implementation decisions.

Conclusion

This study demonstrates that adequate vitamin D levels are essential for optimal postoperative recovery in lower limb fracture patients. Vitamin D deficiency is associated with prolonged healing times, increased complications, and poorer functional outcomes. The beneficial effects of supplementation in deficient patients support the implementation of routine screening and targeted intervention protocols.

Healthcare providers should consider vitamin D assessment as a standard component of preoperative evaluation for fracture patients. Early identification and correction of deficiency may significantly improve patient outcomes while reducing healthcare costs associated with complications and prolonged recovery.

Future research should focus on determining optimal vitamin D levels for fracture healing, establishing evidence-based supplementation protocols, and evaluating the cost-effectiveness of routine screening programs. Additionally, investigating the potential benefits of preoperative vitamin D optimization could further enhance patient care in orthopedic surgery.

Table 1: Patient Demographics and Baseline Characteristics

Characteristic	Deficient (<20 ng/mL) n=78	Insufficient (20-30 ng/mL) n=64	Sufficient (>30 ng/mL) n=38	p-value
Age (years)	46.8 ± 18.2	41.2 ± 15.6	35.9 ± 14.3	0.003
Gender (Male/Female)	45/33	40/24	23/15	0.823
BMI (kg/m²)	28.4 ± 4.7	26.1 ± 3.9	24.8 ± 3.2	0.001
Smoking status (%)	34.6	28.1	21.1	0.287
Diabetes mellitus (%)	19.2	12.5	7.9	0.231
Fracture type				
- Femur (%)	41.0	37.5	39.5	0.891
- Tibia (%)	48.7	51.6	50.0	
- Fibula (%)	10.3	10.9	10.5	

Table 2: Primary and Secondary Outcomes by Vitamin D Status

Outcome	Deficient n=78	Insufficient n=64	Sufficient n=38	p-value
Primary Outcomes				
Union time (weeks)	14.2 ± 3.8	11.8 ± 3.1	10.1 ± 2.4	<0.001
Secondary Outcomes				
Overall complications (%)	32.1	18.8	10.5	0.009
Delayed union (%)	15.4	6.3	2.6	0.043
Infection (%)	10.3	4.7	2.6	0.187
Hardware failure (%)	6.4	7.8	5.3	0.834
Functional Scores				
LEFS at 3 months	45.2 ± 18.6	52.8 ± 14.2	59.1 ± 12.8	<0.001
LEFS at 6 months	51.3 ± 15.6	58.7 ± 12.4	68.4 ± 8.2	<0.001
LEFS at 12 months	61.8 ± 13.4	69.2 ± 10.7	75.6 ± 7.9	<0.001

Table 3: Multivariate Analysis of Factors Affecting Union Time

Variable	β Coefficient	95% CI	p-value
Vitamin D level (ng/mL)	-0.142	-0.186 to -0.098	<0.001
Age (years)	0.054	0.021 to 0.087	0.002
BMI (kg/m²)	0.118	0.043 to 0.193	0.003
Smoking status	1.847	0.623 to 3.071	0.004
Fracture type	0.234	-0.412 to 0.880	0.474
Gender	-0.287	-1.245 to 0.671	0.554

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