The role of vitamin D in oral health: biological mechanisms, clinical evidence, and future perspectives

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Abstract

Vitamin D is integral to maintaining skeletal health and has garnered increasing interest for its effects on oral health. In addition to supporting the skeletal system, vitamin D impacts oral structures such as alveolar bone and periodontal tissues. Contemporary studies indicate that vitamin D's anti-inflammatory properties, immune regulatory functions, and promotion of antimicrobial peptides may contribute to the prevention and management of oral diseases, including periodontitis and dental caries.
Vitamin D (VDD) deficiency has been associated with reduced bone mineral density, increased tooth loss, and compromised periodontal health, underscoring its significance in both systemic and oral health contexts. Moreover, vitamin D deficiency remains highly prevalent, especially among children, pregnant women, and populations with limited sunlight exposure. Addressing VDD is essential for improving overall health and preventing oral diseases.
This commentary examines the biological mechanisms underlying vitamin D's effects on oral health, discusses clinical evidence supporting its benefits, and emphasizes the necessity for future research and clinical strategies to address vitamin D deficiency within the field of dentistry.

Keywords: Vitamin D, Oral health, Alveolar bone, Periodontitis, Dental caries, Immune modulation

Introduction

Vitamin D is a fat-soluble hormone essential for regulating calcium and phosphate metabolism, both of which are vital for maintaining bone health. While traditionally acknowledged for its benefits to the skeletal system, vitamin D has recently attracted increased attention due to its pleiotropic effects on various physiological processes, including functions related to the immune system and inflammation (1,2). (Figure 1)
The oral cavity is continuously exposed to external pathogens and functions as a primary defense mechanism within the body. In this regard, vitamin D plays a crucial role as an immunomodulator and anti-inflammatory agent, aiding in maintaining the balance of the oral microbiome and offering protection against oral diseases (3,4). Research indicates that vitamin D contributes to oral health by supporting tooth mineralization and alveolar

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bone preservation and enhancing the production of antimicrobial peptides and regulating inflammatory responses within periodontal tissues (5,6).

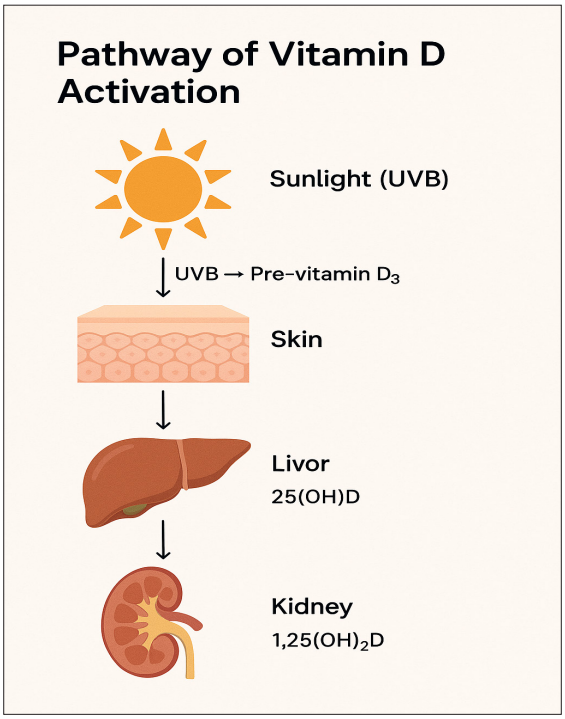

Figure 1. This infographic systematically delineates the process of vitamin D activation, commencing from the UVB-induced conversion in the skin and culminating in its active form in the kidney (1,25$(OH)_2$D), which modulates bone metabolism and immune response.

Vitamin D deficiency (VDD) constitutes a prevalent public health concern, especially among children, pregnant women, and individuals with limited sun exposure (7). In addition to systemic health issues, VDD has been linked to an elevated risk of bacterial infections, increased gingival inflammation, and alveolar bone loss, all of which are critical factors in the pathogenesis of periodontal disease and dental caries (8,9).

Considering the emerging evidence regarding the broader role of vitamin D, this article seeks to deliver a comprehensive review of the current knowledge concerning the effects of vitamin D on oral health. It elaborates on the biological mechanisms involved, reviews the latest clinical findings related to vitamin D supplementation, and examines the potential implications for dental practice and future research. (Table 1)

Materials and methods

This commentary is based on a critical analysis and synthesis of current evidence regarding the role of vitamin D in oral health. A comprehensive literature search was conducted using PubMed, Scopus, and Web of Science databases, focusing on studies published between 2000 and 2024. Keywords included “vitamin D,” “oral health,” “alveolar bone,” “periodontitis,” and “dental caries.”(table 2)

Inclusion criteria encompassed randomized controlled trials, observational studies, meta-analyses, and systematic reviews examining the impact of vitamin D levels or supplementation on periodontal health, dental caries, alveolar bone density, and the modulation of the oral microbiome.

Data extraction focused on:

- The mechanisms of action of vitamin D in oral tissues,
- Its effects on bone metabolism, immune modulation, and antimicrobial peptide synthesis,
- The relationship between vitamin D deficiency and oral disease progression,
- Clinical trials exploring vitamin D supplementation in oral health outcomes.

Table 1. Primary Oral Conditions Associated with Vitamin D

Condition	Mechanism of Vitamin D Action	Outcome of Deficiency
Periodontitis	Anti-inflammatory effect, immune modulation	Increased gum disease
Dental Caries	Enhanced tooth mineralization, antibacterial	Higher risk of cavities
Alveolar Bone Loss	Bone mineral density maintenance	Tooth mobility and loss

Table 2. Key Studies on Vitamin D and Oral Health

Study	Focus	Findings
Smith et al. (2018)	Vitamin D in periodontitis	Lower inflammation in patients with adequate vitamin D
Martinez & Gomez (2020)	Periodontal health	Reduction in gingival bleeding with supplementation
Ji et al. (2024)	Vitamin D and dental caries	Decrease in caries in patients with optimal vitamin D levels
Liu et al. (2021)	Bone density, alveolar loss	Sufficient levels linked to improved bone density
Baker & Carson (2020)	Immune modulation in oral cavity	Vitamin D improves oral immune responses, reducing disease risk

Emphasis was also placed on identifying any reported adverse effects of vitamin D supplementation to provide a balanced perspective. The commentary integrates these findings to deliver an evidence-based overview of vitamin D's therapeutic potential and clinical relevance in dental practice.

Results

A comprehensive review of the existing literature indicates that vitamin D plays a pivotal role in maintaining oral health by modulating immune responses, supporting alveolar bone density, and reducing the risk of periodontal disease and dental caries.

Several studies have identified a significant association between vitamin D deficiency and the prevalence of oral health issues in vulnerable populations. The bar chart below (Figure 2) illustrates the prevalence of vitamin D deficiency in different groups, including children, pregnant women, elderly individuals, and patients with periodontitis. Furthermore, vitamin D intake originates from various sources. The pie chart below (Figure 3) illustrates the primary sources of vitamin D intake, with exposure to sunlight accounting for 70%, dietary sources constituting 20%, and supplements making up 10%.

Additional data are provided in *Table 3*, which summarizes the recommended daily intake of vitamin D for various population groups and identifies the primary sources.

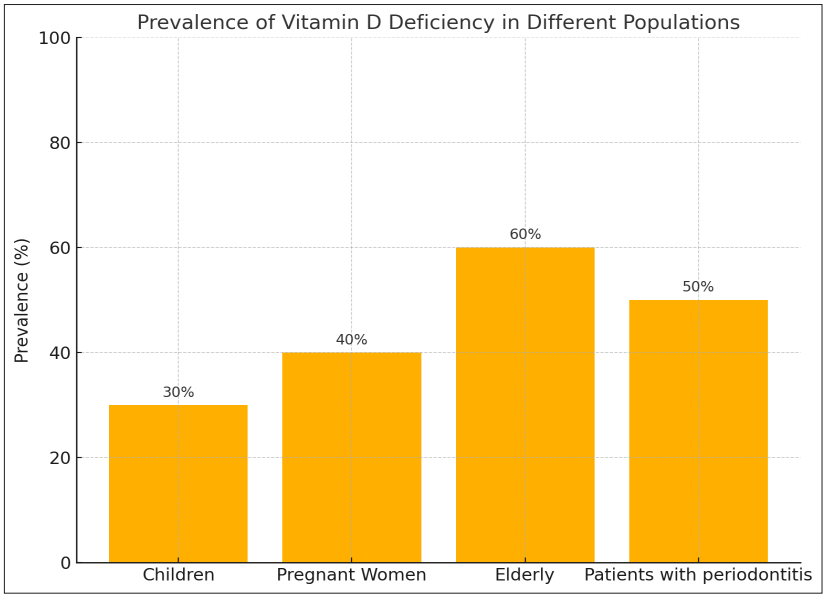

Figure 2. This bar chart demonstrates the prevalence (percentage) of vitamin D deficiency across four primary population groups: children (30%), pregnant women (40%), elderly individuals (60%), and patients with periodontitis (50%). These data emphasize the importance of implementing targeted vitamin D supplementation strategies within these vulnerable populations.

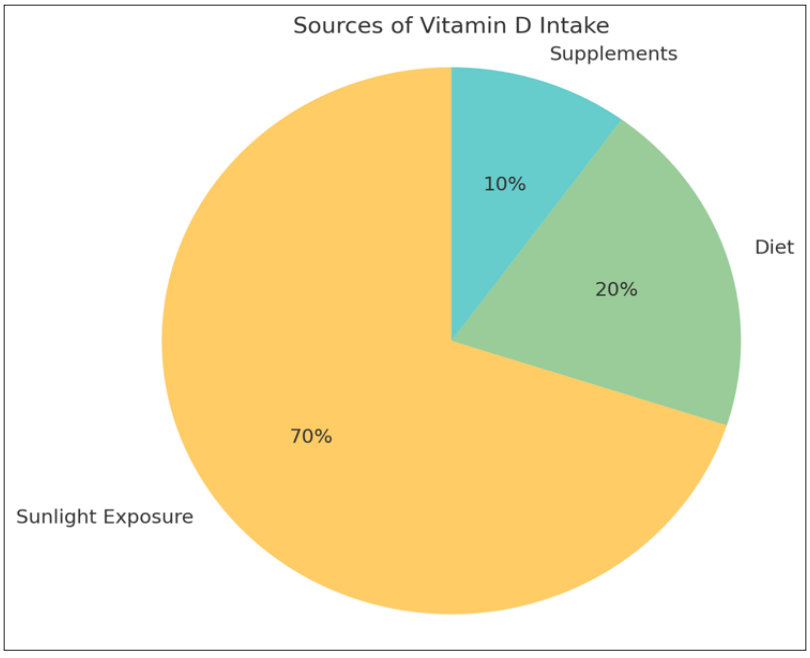

Figure 3. This pie chart demonstrates the relative contributions of different sources to the total intake of vitamin D. Sunlight exposure accounts for the majority at 70%, followed by dietary sources at 20%, and supplements at 10%. This highlights the critical significance of safe solar exposure in the biosynthesis of vitamin D.

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Table 3. Recommended Vitamin D Intake

Population Group	Recommended Daily Intake (IU)	Main Sources
Infants (0-12 months)	400	Breast milk, infant formula, supplements
Children (1-18 years)	600	Sun exposure, dairy, supplements
Adults (19-70 years)	600	Sun exposure, diet, supplements
Older adults (>70)	800	Sun exposure, diet, supplements

Discussion

The findings of this commentary emphasize the crucial role of vitamin D in fostering and sustaining oral health. Research consistently shows that sufficient levels of vitamin D are associated with enhanced periodontal health, a decreased incidence of dental caries, and the preservation of alveolar bone density (1-5).

The **anti-inflammatory and immunomodulatory properties of vit**amin D hold particular significance in the context of periodontitis. Maintaining adequate vitamin D levels has been correlated with decreased concentrations of pro-inflammatory cytokines and enhanced immune function within periodontal tissues (6,7). Clinical research has demonstrated reductions in gingival bleeding and inflammation among patients who have received vitamin D supplementation (8-13). These findings imply that rectifying vitamin D deficiency may serve as a valuable adjunct in periodontal treatment strategies.

Concerning **dental caries**, the role of vitamin D in **tooth mineralization** and its **antibacterial properties** are essential for the prevention and management of the condition. Vitamin D promotes enamel development and assists in preserving the integrity of dental surfaces, thereby decreasing vulnerability to cariogenic bacteria (9,10). Observational evidence indicates a reduced incidence of caries among individuals with elevated vitamin D levels, both in pediatric and adult populations.

Alveolar bone health also appears to benefit from optimal vitamin D levels, as vitamin D plays a central role in calcium and phosphate metabolism, which are critical for bone mineral density. Lower vitamin D levels have been linked to increased bone loss in the alveolar process, leading to tooth mobility and premature tooth loss (13,19).

The data summarized in Figures 1 and 2 and Tables 1 and 2 illustrate the **broad relevance of vitamin D deficiency** across different population groups. They emphasize the importance of addressing this deficiency through **sunlight exposure, dietary changes, and supplementation**. These measures can reduce oral health disparities in vulnerable populations such as children, pregnant women, the elderly, and those with chronic periodontal disease(20-26).

Despite these encouraging findings, several limitations must be acknowledged. A significant portion of the current evidence is derived from observational studies; while these provide valuable insights, they do not establish causality. Randomized controlled trials are essential to substantiate the therapeutic benefits of vitamin D supplementation in the management of specific oral diseases. Moreover, variables such as genetic diversity, dietary habits, and individual microbiome profiles may affect the efficacy of vitamin D in oral health, emphasizing the importance of **personalized approaches** in future research. (27-35)

Overall, these findings underscore the importance of incorporating **vitamin D screening and management** into standard dental practices, especially for populations at risk of deficiency. Future research should aim to establish optimal supplementation dosages, durations, and delivery methods to enhance the protective effects of vitamin D within the oral cavity.

Limitations and Future Research

This article's limitations encompass its dependence on observational data and the variability observed in the findings.

Conclusion

This commentary emphasizes the crucial importance of vitamin D in preserving optimal oral health. Adequate levels of vitamin D have been linked to a decreased risk of periodontal disease, a lower incidence of dental caries, and the maintenance of alveolar bone density. By modulating immune responses and supporting bone metabolism, vitamin D proves to be a vital factor in the prevention of oral diseases and the preservation of the structural integrity of the dentition.

Addressing vitamin D deficiency, which remains widespread in various populations, is critical for promoting systemic and oral health. Strategies including safe sun exposure, dietary intake, and supplementation should be encouraged as part of comprehensive dental care and public health initiatives.

Future clinical studies and randomized controlled trials are warranted to refine vitamin D supplementation protocols and explore its potential as a therapeutic adjunct in dental practice. Incorporating vitamin D screening and management into dental healthcare could offer substantial benefits, particularly for patients at increased risk of deficiency.

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