DENTAL CARIES IN CHILDREN AND VITAMIN D DEFICIENCY; A COMPREHENSIVE REVIEW

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Abstract:
Background: Dental caries, a prevalent health condition globally, remains a significant public health issue, particularly among preschool children. The burden of caries varies based on factors like ethnicity, socioeconomic status, and oral hygiene practices. Early childhood caries (ECC) affects vulnerable children disproportionately, with high prevalence rates in less developed countries. Intrauterine enamel defects, influenced by factors like vitamin D deficiency during pregnancy, can lead to developmental defects in offspring, increasing the risk of dental caries. Vitamin D also plays a crucial role in immune modulation and the synthesis of antimicrobial proteins, impacting oral health.
Objective: This study aimed to investigate the relationship between dental caries in children and vitamin D deficiency, determine the prevalence of vitamin D deficiency in children with dental caries, assess the impact of vitamin D deficiency on the development and progression of dental caries, and explore potential interventions to prevent or treat dental caries in children with vitamin D deficiency.
Conclusion: The research underscores the significant influence of vitamin D deficiency on childhood dental caries. It highlights the importance of adequate vitamin D intake during pregnancy to prevent enamel defects and reduce the risk of caries in children. Moreover, it discusses the immunomodulatory role of vitamin D and its impact on antimicrobial proteins, emphasizing the potential benefits of optimizing vitamin D levels for enhancing antibacterial defense against caries. The study also addresses strategies for preventing, diagnosing, and treating childhood caries, emphasizing a comprehensive approach involving home-care methods, professional dental interventions, and early carious lesion detection techniques to effectively manage and prevent dental caries in children.

Keywords: Antimicrobial proteins, Children, Dental caries, Enamel defects, Salivary flow Vitamin D deficiency

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Introduction:

Dental caries, a complex condition influenced by various factors, is a significant health concern in children globally. A recent meta-analysis conducted on children from five continents revealed that the prevalence of dental caries in primary teeth was 46.2% and in permanent teeth was 53.8%. Notably, the incidence of childhood caries is higher in developing nations compared to developed ones, likely due to disparities in personal factors such as socio-demographic status, education, nutrition, oral hygiene, and access to dental care, as well as oral environmental factors like oral microbiota composition, salivary flow rate, fluoridation levels, and dietary habits [1].

Considered an infectious and transmissible disease, dental caries is primarily caused by cariogenic bacteria, notably Streptococcus mutans and lactobacilli, present in oral biofilms. These bacteria metabolize fermentable sugars like sucrose and lactose to produce organic acids, particularly lactic acid, which can demineralize enamel when the oral pH drops below 5.5. This demineralization leads to enamel porosity, enabling deeper acid penetration and ultimately cavity formation. If untreated, caries progress, affecting the dental pulp, causing inflammation, pain, and potentially resulting in tooth loss, necrosis, and even extra-dental infections [2].

Saliva plays a crucial protective role against caries by aiding in the dilution and removal of fermentable sugars from the mouth and neutralizing oral acidity through its buffering capacity. The removal of sugars by swallowing and saliva's buffering action help counteract biofilm acids. Moreover, if saliva contains sufficient calcium and phosphorus ions, it can halt demineralization and promote remineralization processes, contributing to the maintenance of oral health [3].

Traditionally, the biological effects of vitamin D had been almost exclusively related to bone metabolism (calcium deficiency causes rickets in infants and osteomalacia in adults). Currently, it is known that most cells in the body, including odontoblasts (dentin-forming), ameloblasts (enamel-forming) and salivary glands, contain vitamin D receptors (VDR), and that the binding of vitamin D with its VDR (a nuclear transcription factor) modulates the expression of numerous coding genes (approximately 5–10% of the human genome) related not only to mineral metabolism but also to cell life cycle, immune response, and energy metabolism (genomic effects) [4].

The connection between vitamin D insufficiency and dental caries has been a subject of investigation since the 1920s. A seminal study conducted by Mellanby and Pattison in 1928, titled "The action of vitamin D in preventing the spread and promoting the arrest of caries in children," was pivotal in establishing the correlation between vitamin D deficiency and dental caries in children. This study not only demonstrated that inadequate levels of vitamin D are linked to an increased risk of dental caries but also showed that supplementation with vitamin D, either orally or through diet, can reduce this risk [5]. Subsequent to this landmark research, numerous epidemiological studies, systematic reviews, and meta-analyses of controlled clinical trials have further explored the strong association between vitamin D deficiency and dental caries in both primary and permanent teeth among children. It has been proposed that insufficient levels of vitamin D may contribute to the demineralization of teeth, akin to its effects on bone health, by leading to decreased concentrations of calcium and phosphate ions [6].

Recent clinical investigations have indicated a notable decrease in the occurrence and severity of dental caries in children under the age of three who received continuous vitamin D supplementation, particularly during the autumn and winter months following their first year of life [7]. Additionally, research suggests that infants born to mothers with vitamin D deficiencies exhibit a higher prevalence of dental caries in their primary teeth compared to infants born to mothers without such deficiencies [8]. Furthermore, a higher maternal intake of vitamin D during pregnancy has been associated with a reduced risk of dental caries in offspring. A recent cohort study has also provided evidence supporting an inverse relationship between the risk of caries in permanent teeth among children aged 6-10 years and low prenatal levels of vitamin D [9].

Objectives:

The main objectives of this study are:

1. To investigate the relationship between dental caries in children and vitamin D deficiency.
2. To determine the prevalence of vitamin D deficiency in children with dental caries.
3. To assess the impact of vitamin D deficiency on the development and progression of dental caries in children.
4. To explore potential interventions or strategies to prevent or treat dental caries in children with vitamin D deficiency.

Prevalence, Burden and Impact of Childhood Caries:

Dental caries stands as the prevailing health condition worldwide, with recent advancements and implementations in its management offering relief in certain scenarios, though not universally.

Notably, while there has been a decline in the prevalence of dental caries in children across various age groups in western nations, the issue persists as a significant public health concern, particularly among preschool children, in both developed and developing countries. The prevalence of caries exhibits substantial discrepancies influenced by factors such as ethnicity, culture, socioeconomic status, lifestyle choices, dietary habits, oral hygiene routines, and genetic predispositions leading to enamel defects [10].

The prevalence of early childhood caries (ECC) in most developed nations remains below 15%; however, in less developed countries, this figure can soar to between 50% and 80%, reflecting disparities among disadvantaged subgroups within these regions [11]. The high incidence of caries in certain contexts may stem in part from the intergenerational impact of caregivers with relatively low educational achievements [12].

When assessing the global burden of caries, it becomes evident that young children bear the greatest load of caries across all age brackets. In 2017, the number of caries cases in primary teeth surpassed half a billion worldwide, showcasing an age-standardized prevalence rate of 46.9% and 39.3% among 1–4 and 5–9-year-olds, respectively. Caries disproportionately affects economically vulnerable children. The figures are stark; in 2019, 84.5 million new cases of caries globally were linked to sociodemographic disparities. In practical terms, this translates to an average of 2.7 fresh caries cases every second, directly tied to inequality [13].

Intrauterine enamel defects:

During embryonic development, primary teeth start forming as early as 6 weeks, and the process of enamel and dentin development begins in the second trimester and continues post-birth [14]. Vitamin D plays a crucial role in odontogenesis, with the vitamin D-VDR complex regulating gene transcription for various structural proteins produced by odontoblasts (such as dentin syaloglycoproteins and dentinphosphoproteins) and ameloblasts (including amelogenins and enamelin) that constitute the unmineralized extracellular matrix. Furthermore, vitamin D promotes the intrauterine mineralization of tooth enamel and dentin, influencing the formation of oral hard tissues. Deficiency in vitamin D can impact the development of primary and permanent teeth [15].

Research suggests that insufficient vitamin D levels during pregnancy can affect the formation and mineralization of primary teeth, leading to developmental issues like dentin hypomineralization and enamel defects (hypoplasia or hypomineralization) in offspring [16]. Enamel defects, which involve disruptions in the dental matrix, have been associated with an increased risk of dental caries in various cohort studies.

A recent randomized clinical trial demonstrated that high-dose vitamin D supplementation during pregnancy (2400 IU/day from the 24th week of pregnancy to 1 week post-partum) was associated with a reduced risk of enamel defects in children. Children born to mothers who received high-dose vitamin D supplementation showed a lower prevalence of enamel defects in both primary and permanent teeth compared to those whose mothers received the standard dose (400 IU/day). This indicates that prenatal supplementation with high doses of vitamin D could serve as a preventive measure to decrease the occurrence of enamel defects and, consequently, the risk of childhood dental caries [17].

In essence, as vitamin D plays a vital role in tooth development, a deficiency during pregnancy might lead to enamel defects and an increased susceptibility to dental caries. Therefore, monitoring and controlling vitamin D levels before conception and throughout pregnancy and post-delivery could be crucial in reducing the risk of enamel defects in primary teeth [18].

Antimicrobial proteins:

Vitamin D plays a crucial role as a regulator of the immune system, impacting both the innate and adaptive arms of immunity. Within the adaptive immune system, vitamin D influences various human immune cells such as B and T lymphocytes, monocytes, dendritic cells, and neutrophils through its interactions with the Vitamin D Receptor (VDR) [19]. By modulating the activities of these cells, vitamin D helps in regulating the production of cytokines, enzymes like acid phosphatase and hydrogen peroxide, and prevents the overexpression of inflammatory cytokines. Moreover, in the innate immune system, vitamin D is involved in enhancing the production of antimicrobial proteins (AMPs) by barrier and immune cells, especially in the mucosal lining of the gastrointestinal tract [20].

The vitamin D-VDR complex plays a pivotal role in controlling the transcription of genes encoding specific AMPs, leading to the synthesis of antimicrobial peptides like cathelicidin, β2-defensin, and hepcidin [21]. Cathelicidin, in particular, exhibits antimicrobial and antiendotoxin properties by disrupting bacterial cell membranes due to its cationic and amphiphilic nature. Additionally, it has chemotactic properties and contributes to cellular autophagy. These AMPs, including cathelicidin, are crucial components of the innate immune system's defense against various oral bacteria, including those implicated in causing dental caries [22].

Historically, the association between dental caries and Streptococcus mutans has been well-documented, with numerous studies showing a correlation between increased colonization of Streptococcus mutans and the development of caries in children. Furthermore, research has indicated a link between levels of salivary antimicrobial proteins and alterations in the composition of streptococci within dental plaque [23].

Clinical investigations focusing on saliva samples from school children have revealed that individuals with vitamin D deficiency had significantly lower levels of cathelicidin in their saliva compared to those with normal vitamin D status. Moreover, children without dental caries exhibited notably higher concentrations of cathelicidin in their saliva than those with caries. This suggests that maintaining optimal levels of vitamin D may enhance innate antibacterial defenses and potentially improve resistance against dental caries. Some researchers have even proposed utilizing AMPs, including cathelicidin, for the prevention and treatment of dental caries, highlighting the potential therapeutic applications of these peptides [24].

Salivary disfunction:

Numerous research studies have demonstrated a strong and positive association between the levels of 25-hydroxyvitamin D (25(OH) D) in serum and saliva among both young children and adults. This correlation suggests that examining the levels of 25(OH) D in saliva could serve as a non-invasive alternative to traditional serum testing, reflecting changes in circulating 25(OH) D levels. Moreover, investigations utilizing microradiography have identified salivary glands as key targets for vitamin D, given the presence of vitamin D receptors (VDR) within them, indicating their susceptibility to the genomic effects of vitamin D [25].

Experimental research has further revealed that the secretion of fluids and electrolytes from salivary glands is directly influenced by vitamin D levels. Notably, a deficiency in vitamin D has been linked to reduced salivary flow and alterations in its composition, particularly in terms of decreased calcium ion levels. While these findings have primarily been observed in animal models, they offer valuable insights into how vitamin D impacts the quantity and quality of salivary flow, with potential implications for human health [26].

The consequences of vitamin D deficiency on salivary flow are twofold: firstly, it leads to a decrease in salivary flow, compromising its buffering capacity against organic acids and, consequently, its protective role against dental caries. Secondly, as salivary flow serves as a carrier of essential minerals crucial for ongoing tooth remineralization, a deficiency in vitamin D results in a significant reduction of these minerals in saliva, impeding the remineralization process and heightening the risk of caries in both primary and permanent dentition [27].

Current recommendations from reputable health organizations advocate for adequate vitamin D supplementation, particularly in specific populations. For instance, the US Endocrine Society recommends a daily oral cholecalciferol supplementation of 1500–2000 IU for pregnant women, ideally initiated early in pregnancy [28]. Similarly, the American Academy of Pediatrics, the US Endocrine Society, and the ESPGHAN suggest that children aged 0–1 and 1–18 years should consume a minimum of 400 and 600 IU/day of vitamin D, respectively. Hence, newborns are advised to begin a daily oral cholecalciferol supplement of 400 IU promptly after birth, continuing throughout the first year to ensure adequate vitamin D levels. Children and adolescents who fail to meet the recommended dietary allowances for vitamin D, even with fortified foods, should consider a daily oral cholecalciferol supplement of 600 IU. Notably, individuals at heightened risk of vitamin D deficiency may require higher daily intake levels [30].

Prevention, Diagnosis and Treatment for Childhood Caries:

According to recent research, oral hygiene maintenance and dietary modification are considered the primary home-care methods for preventing caries [31]. However, many children find it challenging to incorporate these tasks into their daily routines, as evidenced by the current high burden of caries. In addition to home-care methods, professional dentistry techniques such as fluoride application on smooth tooth surfaces and sealant application to pits and fissures have proven efficacy in preventing caries. Dentists also recommend alternative strategies like xylitol, amorphous calcium phosphate, silver diamine fluoride, systemic fluoride, and behavioral-based interventions for caries prevention [32].

Detection of initial dental caries typically involves visually and tactically inspecting the dental hard tissue for cavities. However, accurately diagnosing visible enamel decay requires further examination in a dental surgery setting with optimal illumination and saliva control. It is essential for the child to cooperate during examinations, as probing may inadvertently damage the enamel. Dental radiographs, particularly Bitewing radiographs, are useful for identifying clinically unidentified lesions in both dentine and enamel [33]. Over the past two decades, several novel methods for detecting early carious lesions have emerged. Common diagnostic aids include laser fluorescence and electric caries meters, while newer non-invasive techniques like Quantitative Light-induced Fluorescence, DIAGNOdent, Fibre-optic Transillumination, and Electrical Conductance are also being explored. Despite promising results, further evidence is needed to validate the diagnostic accuracy of these non-invasive techniques before widespread adoption in clinical practice. Early detection of carious lesions is crucial for effective caries management, as it helps identify caries-active patients and those at risk of future caries [34].

The treatment of childhood caries varies depending on the disease progression, the child's age, the level of cariogenic bacteria in the biofilm, as well as the child's social, behavioral, dental, and medical history. Vitamin D3 is essential for regulating calcium and phosphorus absorption and maintaining skeletal and dental tissues. A deficiency in vitamin D3 can lead to delayed teeth eruption and abnormal calcification of enamel and dentin, making teeth more susceptible to caries. Supplements can help maintain optimal vitamin D levels, reducing the risk of early carious lesions [35].

Conclusion:

In conclusion, this research article highlights the significant impact of vitamin D deficiency on dental caries in children. The study emphasizes the relationship between vitamin D deficiency and the prevalence, development, and progression of dental caries. It also explores the potential interventions, such as high-dose vitamin D supplementation during pregnancy, to prevent enamel defects and reduce the risk of childhood dental caries. Furthermore, the article discusses the role of vitamin D in immune modulation and its effect on antimicrobial proteins, as well as the importance of adequate vitamin D intake for oral health. The prevention, diagnosis, and treatment of childhood caries are also addressed, emphasizing the need for a comprehensive approach involving home-care methods, professional dental interventions, and early carious lesion detection techniques to effectively manage and prevent dental caries in children.

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