The Interface Between Maternal Vitamin D Status and Early Childhood Caries: A Comprehensive Review from Saudi Arabia

Dr. Fatma Zahra Gamal Mohamed Ahmed, BDS* Hassan Mohamed Hassan Al- Amri** Sarah Gamal Mohamed Ahmed, BSC***

ABSTRACT

This comprehensive review examines the complex link between maternal vitamin D deficiency (VDD) and the development of Early Childhood Caries (ECC) in Saudi Arabia. Both conditions present significant public health challenges in the region. The evidence reveals concerning statistics: up to 93.8% of pregnant Saudi women exhibit suboptimal vitamin D levels. Meanwhile, ECC affects 60-95% of preschool children across various regions of Saudi Arabia. Through analysis of current literature, this review establishes that maternal VDD during pregnancy disrupts proper tooth mineralization and enamel formation in developing fetuses. This disruption potentially increases their susceptibility to ECC. The review highlights how cultural practices limiting sun exposure, inadequate dietary intake, and socioeconomic factors contribute to both conditions. Based on these findings, we recommend a multi-faceted intervention approach. This includes implementing systematic vitamin D screening and supplementation programs for pregnant women; establishing comprehensive early childhood oral health initiatives; introducing water fluoridation systems where feasible; and developing culturally sensitive public health education campaigns. Future research should focus on longitudinal studies examining the direct causal relationship between maternal VDD and ECC in the Saudi population. At the same time, policy efforts should prioritize integrating maternal vitamin D status monitoring into prenatal care protocols and expanding access to preventive dental services for young children.

Keywords: Vitamin D deficiency; Early Childhood Caries; preschool children; water fluoridation

INTRODUCTION

Vitamin D deficiency (VDD)[1-3] and Early Childhood Caries (ECC)[4-6] represent two significant public health challenges in Saudi Arabia. These conditions potentially share a complex biological and social relationship that warrants careful examination. Despite the country's abundant sunshine, paradoxically high rates of VDD persist among Saudi women, particularly during pregnancy. This occurs due to various cultural, behavioral, and environmental factors. This deficiency happens at a critical time when maternal vitamin D status can significantly influence fetal development. This development includes tooth mineralization and enamel formation (mineralization of the outer tooth layer)[1-3].

Concurrently, Saudi Arabia faces a considerable burden of ECC, particularly among young children. Recent epidemiological studies suggest prevalence rates of ECC ranging from 60% to 95% among preschool children in various regions of the country. This marks it as one of the highest rates globally[7-13]. ECC results from the interaction of several factors. These include cariogenic microorganisms (bacteria that cause tooth decay), improper feeding practices with fermentable carbohydrates, and various social factors. Clinically, ECC manifests in multiple ways. These manifestations include pain, infections, abscesses, chewing difficulties, and malnutrition. Children may also experience growth delays, gastrointestinal issues, and sleep disturbances. In severe cases, hospitalization may be required. ECC also disrupts school attendance, diminishes quality of life, and imposes a burden on caregivers[14,15].

The potential relationship between maternal vitamin D status during pregnancy and early childhood oral health outcomes represents an emerging area of research interest. Several studies have investigated these issues separately within the Saudi context. However, there is a compelling need to examine their potential interaction and combined impact on child health outcomes. Understanding this relationship is crucial for developing effective preventive strategies and public health interventions.

This review aims to synthesize current evidence regarding maternal VDD and its potential relationship with ECC in Saudi Arabia. Specifically, it examines the prevalence and risk factors of both conditions. It explores their biological and social connections and evaluates existing preventive approaches. By analyzing these

* Faculty of Dentistry,6th October University for Modern Sciences and Arts (MSA)
6th October City, Egypt.
Pediatric Dentistry Professional Diploma
Leeds Training College, England, UK, Lead Researcher
Pediatric Dentist, RAM Medical Company Center in Eastern Province
Khobar, KSA.
E-mail: nogagamal@hotmail.com
** Epidemiology Diploma
College of Public Health
Imam Abdulrahman Bin Faisal University, Dammam, KSA
*** Drug Design and Discovery Lab, Helmy Institute for Medical Sciences
Zewail City of Science, Technology and Innovation, Giza
Egypt, Biomedical Sciences Program, University of Science and Technology
Zewail City of Science, Technology and Innovation, Giza, Egypt.

interconnected health challenges, this review seeks to inform evidence-based interventions and policy recommendations tailored to the Saudi context. It also identifies critical gaps in current knowledge that warrant further investigation.

The findings of this review hold significant implications. These implications affect public health policy, clinical practice, and future research directions in Saudi Arabia and similar Gulf Cooperation Council (GCC) countries. In these countries, comparable cultural and environmental factors influence both vitamin D status and oral health outcomes.

MATERNAL VDD IN SAUDI ARABIA

Prevalence rates among pregnant women

VDD is prevalent among pregnant women in Saudi Arabia. Many show insufficient vitamin D levels, which are vital for maternal health and fetal development. A study in Riyadh found that 50% of pregnant women had VDD (defined as serum levels <50 nmol/L). An additional 43.8% had insufficient levels (50-74 nmol/L). This resulted in 93.8% of women with suboptimal vitamin D levels. Only 6.3% had adequate vitamin D levels. Just 8.1% met the recommended daily intake (≥600 IU/day) (2). Another study involving 515 pregnant women found that 82.5% had VDD during their first trimester[16].

Addressing these issues through public health initiatives and education is crucial to improving maternal and neonatal health outcomes in the region.

Risk factors specific to the Saudi population

Factors contributing to this high prevalence include limited sun exposure due to cultural practices, dietary insufficiencies, and lack of supplementation (2). A study of 221 pregnant women in Saudi Arabia found that 46.2% had insufficient vitamin D, 40.3% had sufficient levels, and 13.6% were deficient, with risk factors including age, dark skin, hyperglycemia, anemia, malabsorption, genetic mutations, limited sun exposure, middle-income status, poor dietary habits, obesity, and low milk consumption[17]. A review of 12 studies highlights a widespread VDD among Saudi women, attributed to factors such as decreased cutaneous synthesis, low dietary intake, impaired activation in the liver or kidneys, and resistance to vitamin D action. Interestingly, lifestyle, dietary habits, education, and income did not significantly predict serum levels of vitamin D. VDD worsens during pregnancy, likely due to higher fetal nutritional demands, with many mothers and neonates showing suboptimal levels at delivery. The findings underscore the need for screening and interventions beyond relying solely on sunlight exposure[18]. A study of 578 Saudi women in early pregnancy found that 81% were diagnosed vitamin D deficient, with predictors including high indoor activity, multiparity, poor cholesterol levels, and living in West Riyadh, while factors such as increased physical activity, sun exposure, and higher education were protective against deficiency[19]. In a systematic review, the prevalence of VDD among Saudi women of reproductive age was high, at 77.4%, due to insufficient sunlight exposure and low dietary intake[20].

Impact on maternal and child health outcomes

VDD during pregnancy has been associated with adverse maternal outcomes and an increased risk of pregnancy complications. Current evidence highlights that VDD during pregnancy is linked to adverse outcomes. These include gestational diabetes mellitus (GDM), pre-eclampsia (high blood pressure during pregnancy), and cesarean delivery. Other complications include postpartum depression, preterm birth, and low birth weight (LBW)[21,22].

A meta-analysis of 27 studies showed that VDD raised GDM risk by 26%. Insufficient and deficient levels were also linked to higher risk. Optimal vitamin D levels (40-90 nmol/L) were associated with a lower GDM risk in a U-shaped pattern[23]. Another analysis of 15 studies involving 40,788 participants and 1,848 cases found that each 10 nmol/L increase in vitamin D lowered GDM risk by 2%, with the highest levels linked to a 29% reduced risk[24].

A study of 351 U.S. pregnant women found that 20% had vitamin D insufficiency in the first trimester. Higher vitamin D levels improved linear fetal growth but not weight or head circumference. Levels <40 nmol/L were linked to a significantly higher risk of preterm birth, while second-trimester vitamin D levels had no impact on fetal growth or pregnancy outcomes[25].

However, one study found that 86.4% of pregnant women in Saudi Arabia had VDD, but this was not associated with adverse pregnancy outcomes except for a higher rate of miscarriage (26). Additionally, VDD during pregnancy is linked to adverse health outcomes like preeclampsia, LBW, and increased risk of osteoporosis (fragile bones due to decreased bone density)[27,28].

The relationship between VDD and osteoporosis in Saudi women is complex. While one study found no significant correlation between vitamin D levels and bone mineral density[29]. However, another reported a high prevalence of osteopenia (reduced bone mass) at 40% and osteoporosis at 18% in women over 40[30]. A study of 119 neonates in Saudi Arabia found no clear connection between maternal vitamin D levels and LBW. However, mothers of babies with normal birth weight had higher vitamin D levels. This underscores the need for more research to create guidelines for managing VDD during pregnancy[31]. However, other studies indicated that maternal VDD during pregnancy increases the risk of LBW in neonates[32,33]. Moreover, a study at King Abdulaziz University Hospital found high VDD rates in both mothers (90.5%) and infants (86%), with a strong link between maternal and cord blood vitamin D levels, indicating that infants of deficient mothers are more likely to have VDD[34].

ECC IN SAUDI ARABIA

Prevalence of ECC in Saudi Arabia and GCC countries

ECC constitutes a major oral health problem in the GCC countries, with a high prevalence compared to developed nations[35]. In Saudi Arabia, studies have reported ECC prevalence rates ranging from 62% to 84% among children under six years old. The mean decayed, missing, and filled teeth (dmft) scores range between 3.0 and 7.1[10]. The dmft index is a standard measure used to quantify the extent of dental caries in an individual.

A systematic review estimated the prevalence of ECC among Saudi children aged 5 to 7 years at 84%[9]. In a recent meta-analysis in Saudi Arabia, the dmft index was 4.14, with an average prevalence of 75.43 % in primary dentition[36]. Recent studies in Saudi Arabia reveal that dental caries affect 86% of primary teeth and 65% of permanent teeth[8].

In Riyadh, one study found 72.6% ECC prevalence in children aged 36 to 71 months, with a dmft score of 4.13, influenced by socioeconomic factors, feeding practices, and oral hygiene[37]. Another study in North Riyadh found a 76% ECC prevalence, with exclusively breastfed children having lower odds (68.1% vs. 83.6%, $p = 0.001$), recommending breastfeeding and good oral hygiene for preschoolers[38]. In Dawadmi, the prevalence of ECC among preschool children was reported at 96.6%[7].

The prevalence of ECC in GCC countries is high, with an average dmft of 5.14 and a prevalence rate of 80.95% [39]. In Qatar, a study reported an ECC prevalence of 89.2% among children aged four to five years; 15.6 % of the examined children had ECC and 73.6 % had severe ECC[40]. In the United Arab Emirates (UAE), studies have reported ECC prevalence rates of 83% in five-year-old children and 74% in children aged four to six years[35]. These studies highlight the widespread nature of ECC in Saudi Arabia, emphasizing the need for targeted preventive measures and public health interventions to address this issue.

Risk factors specific to Saudi Arabia

Factors include improper feeding practices, inadequate oral hygiene, and maternal VDD. These rates are higher in regions with extreme heat, such as the central and eastern provinces, where limited sun exposure exacerbates maternal VDD.

Dietary Habits and Feeding Practices: High consumption of sugary foods and beverages is widespread in GCC countries. This significantly increases the risk of ECC. The risk is due to frequent intake of fermentable carbohydrates (sugars that can be broken down by oral bacteria), especially in liquid form. Prolonged bottle feeding, particularly at night, exacerbates this issue. It exposes teeth to sugars for extended periods. This allows oral bacteria to produce acids that erode tooth enamel[41]. Among primary school children in Al-Baha, Saudi Arabia, daily consumption rates were 26.1% for sweets, 17.1% for carbonated beverages, and 4.3% for energy drinks[42]. Several studies support these findings, indicating that up to 75% of Saudi children consume soft drinks and fruit juices in feeding bottles[43-45].

Oral Hygiene Practices: Inadequate oral hygiene among children in these regions leads to plaque accumulation, creating an environment conducive to caries development. Lack of regular tooth brushing and improper cleaning techniques exacerbate the problem[46]. Oral hygiene practices in the Saudi populationtypically begin later than the recommended time for starting teeth cleaning. Studies indicate that approximately 40% of preschool children in Riyadh do not brush their teeth[47].

Socioeconomic Factors: Lower socioeconomic status, parental education levels, and limited access to dental care are significant risk factors. Parents' lack of awareness about proper oral health practices and the importance of early dental visits contributes to higher ECC rates[37]. Mothers with higher education levels are more likely to have children with better oral hygiene habits[48]. However, a general lack of awareness about the importance of preventive dental care leads to delayed dental visits, which often occur only when children experience pain[4]. Finally, access to dental care and utilization are critical issues. A significant proportion of children do not attend regular dental check-ups, and visits to the dentist are usually prompted by severe dental problems rather than as a preventive measure[49].

Geographic and Environmental Factors: The absence of centralized water fluoridation in Saudi Arabia leads to varying fluoride levels in drinking water. This affects dental health. Even in areas with relatively high fluoride levels, poor dietary habits diminish the protective effects of fluoride. Additionally, disparities exist between urban and rural areas. Children in rural regions tend to have higher caries rates. This is partly due to limited access to dental care and preventive measures[4]. Addressing these challenges requires comprehensive public health strategies that promote better dietary habits, improved oral hygiene practices, early dental visits, and consistent access to fluoridated water.

VITAMIN D-ORAL HEALTH CONNECTION

Role of Vitamin D in Tooth Development, Mineralization Enamel Formation

Vitamin D is crucial for calcium homeostasis (maintaining proper calcium levels) and bone health. It plays a significant role in tooth development. Vitamin D regulates the function of ameloblasts (cells that form enamel) and odontoblasts (cells that form dentin). These cells are essential for the formation and mineralization of enamel and dentin[50]. Prenatal VDD disrupts these processes, leading to hypocalcified dentin (insufficiently calcified tooth material), delayed tooth eruption, and enamel hypoplasia, a condition marked by defective enamel that predisposes primary teeth to caries[51,52]. Additionally, vitamin D's beneficial effects on oral health extend beyond tooth mineralization. It produces antimicrobial peptides (proteins that fight microbes) like cathelicidins and defensins. These combat cariogenic bacteria such as *Streptococcus mutans* (bacteria that cause tooth decay). Deficiency reduces this protective mechanism, increasing susceptibility to decay[53.54].

ROLE OF MATERNAL VITAMIN D IN ECC

Maternal vitamin D levels during pregnancy are vital for the dental health of children, as sufficient vitamin D is necessary for proper tooth calcification and enamel formation. Deficiency can result in enamel hypoplasia, making children more prone to ECC. One study found that children aged 12 to 35 months with deficient vitamin D levels in cord blood had a dmft score twice as high as those with adequate levels[55]. Lower prenatal vitamin D levels increase the risk of enamel hypoplasia and ECC in infants[56]. Although prenatal vitamin D supplementation did not significantly lower ECC prevalence, higher cord blood 25(OH) D levels were linked to fewer decayed primary teeth[57]. A meta-analysis of over 11,000 participants found that children of mothers with prenatal VDD (≤ 35 nmol/L) had a 1.35-fold higher risk of ECC[58].

PREVENTION AND INTERVENTION STRATEGIES

Maintain Adequate Vitamin D Levels in Pregnant Women: Evidence from supplementation trials and the National Academy of Medicine (NAM) provides guidance. The recommended serum vitamin D levels are between 20 and 40 ng/mL (50 to 100 nmol/L). Levels below 20 ng/mL are considered suboptimal. The NAM found insufficient data to determine a safe upper limit. However, they raised concerns about potential risks at levels above 50 ng/mL (125 nmol/L). These risks include fractures and certain cancers (59-61). Maintaining maternal serum 25(OH)D levels ≥ 50 nmol/L throughout pregnancy is considered optimal. Pregnant women should be encouraged to maintain adequate nutrition through a healthy, balanced diet. However, the World Health Organization (WHO) does not recommend routine measures for all pregnant women. These include oral vitamin D supplementation or screening to improve maternal and perinatal outcome[62].

Early Childhood Oral Health Programs: Management of ECC involves assessing caries risk through several models. These include the Caries-risk Assessment Tool (CAT), Caries Management by Risk Assessment (CAMBRA), the American Dental Association (ADA) model, and Cariogram. These models consider various factors. These include fluoride use, existing caries lesions, and social influences. Oral health care during pregnancy can reduce the risk of ECC in children. Pregnant women should maintain good oral hygiene, avoid sugary foods, and receive dental care.

Early infant oral health includes several practices. These include cleaning gums, using fluoride toothpaste as teeth emerge, and limiting sugar intake. Fluoride is key to caries prevention. It can be professionally applied or used in home-use toothpaste. Regular dental visits, beginning at 6 months, are essential for preventing caries. The use of pit and fissure sealants (protective coatings applied to the chewing surfaces of teeth) is also important. These measures help establish a dental home and ultimately improve long-term oral health[63].

Fluoride Application: Fluoride is well-established in its role in preventing dental caries. Topical applications, such as fluoride varnish, have been shown to reduce caries incidence in children[64,65]. However, in Saudi Arabia, the absence of water fluoridation and limited public awareness hinder the effectiveness of such preventive measures. Implementing biannual fluoride varnish applications, especially for high-risk populations, could significantly improve dental health outcomes

Encourage Healthy Dietary Habits: Healthy diets, rich in lean proteins and vegetables, support dental health, while unhealthy eating habits, such as frequent sugar and juice consumption, are major risk factors for ECC[66,67]. Breastfeeding is recommended for infants, but parents should be aware that combining breastfeeding with other carbohydrates can increase the risk of tooth decay[68]. A balanced diet for children includes several components. These include drinking enough water and eating a variety of foods. Recommended foods include whole grains, fruits, vegetables, protein, and low- fat or fat-free dairy. Children should limit sugary snacks and balance food intake with physical activity. This helps maintain a healthy BMI (body mass index) and supports normal growth[69]. Raising public awareness is crucial. People should understand the connection between frequent carbohydrate consumption and caries. They should also be aware of the risks of excessive intake of simple carbohydrates, saturated fats, and sodium[68].

CONCLUSION AND RECOMMENDATIONS

The high prevalence of both maternal VDD and ECC in Saudi Arabia represents an urgent public health concern requiring immediate attention. The evidence demonstrates that maternal VDD (affecting up to 93.8% of pregnant women) may contribute to improper tooth mineralization and increased ECC susceptibility, which currently affects 60-95% of preschool children in the country. This relationship is particularly concerning in the Saudi context, where cultural and environmental factors such as limited sun exposure due to hot weather, traditional clothing like abayas and neqabs, indoor lifestyles, inadequate dietary intake, and insufficient preventive dental care create a perfect storm of risk factors.

We recommend implementing a comprehensive three-tier intervention strategy to address these interconnected challenges. First, maternal health services should incorporate routine vitamin D screening and supplementation programs during pregnancy, with targeted education about safe sun exposure and dietary sources of vitamin D. Despite the WHO's lack of universal recommendations for vitamin D screening, integrating these practices into a tailored public health framework can improve outcomes and reduce healthcare costs. Screening programs should also include secondary and tertiary prevention strategies to mitigate complications arising from untreated VDD and ECC.

Second, oral health initiatives should focus on early prevention by establishing "dental homes" for children by age one, implementing community-wide water fluoridation programs where feasible, and regular application of fluoride varnish in clinical settings. The implementation of water fluoridation in Saudi Arabia must address several region-specific challenges, including the significant variability in natural fluoride levels across different regions (ranging from 0.00 to 6.20 ppm), requiring customized approaches rather than a one-size-fits-all strategy. Success will depend on sufficient funding allocation, enhanced intersectoral collaboration between the Ministry of Health and the Ministry of Environment, Water, and Agriculture, and the establishment of robust monitoring systems to maintain optimal fluoride levels (0.6-0.8 ppm as recommended by the MOH) while preventing dental fluorosis. Third, public health campaigns should be culturally tailored to address both issues simultaneously, emphasizing the importance of maternal vitamin D status for children's oral health and providing practical guidance for maintaining optimal levels while respecting cultural practices.

Key stakeholders who should be actively involved in implementing these recommendations include: (1) policymakers from the Ministry of Health, particularly the Oral Health Department and Maternal and Child Health divisions, who can incorporate VDD screening into prenatal care protocols; (2) healthcare providers, including obstetricians, pediatricians, and dental professionals, who require training to effectively screen for and manage both conditions; (3) the Council of Cooperative Health Insurance to ensure coverage for preventive dental services and vitamin D supplementation; (4) educational institutions and teachers who can integrate oral health education into school curricula; and (5) community leaders and religious figures who can help address cultural barriers to sun exposure and promote preventive health practices.

The integration of preventative healthcare measures into Saudi Arabia's Vision 2030 health objectives provides an opportunity to institutionalize these initiatives. For example, workplace wellness programs can incorporate vitamin D screening, particularly in industries where employees have limited exposure to sunlight. Public health campaigns should emphasize the importance of safe sun exposure and dietary sources of vitamin D while respecting cultural practices. Enhanced prevention strategies, such as fluoride varnish applications and early dental visits for children, should complement vitamin D-related interventions to comprehensively tackle ECC. By embedding these practices within national health goals, Saudi Arabia can address the dual burdens of VDD and ECC, improve public health outcomes, and align with the nation's long- term objectives of reducing healthcare expenditures and enhancing population wellness.

Future Directions: Future research should prioritize conducting longitudinal cohort studies in Saudi Arabia to establish direct causal relationships between maternal vitamin D levels during pregnancy and subsequent ECC development in children. These studies should comprehensively assess confounding factors such as dietary habits, oral hygiene practices, cultural considerations, and genetic predisposition. Additionally, intervention trials testing the effectiveness of combined vitamin D supplementation and oral health programs would provide valuable evidence for policy development. Research should also explore the cost-effectiveness of preventive programs and investigate potential genetic and environmental interactions specific to the Saudi population that might influence the vitamin D-ECC relationship.

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contributed to data interpretation and ensured alignment with public health standards and context. Sarah Gamal, Co-author and scientific contributor; assisted with literature review, referencing, and evidence-based support throughout the manuscript.

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