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LITERATURE REVIEW

Effectivity of Calcium, Phosphate and Vitamin D in Dental Caries Prevention

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ABSTRACT

Background: *Micronutrient elements are vitamins and minerals that are required in small amounts but play important roles in our body. Insufficient micronutrients can affect health including dental health.* ***Objective:*** *Analyzing effectiveness of micronutrients (calcium, phosphorus, and vitamin D) in preventing dental caries.* ***Literature study:*** *This literature study was conducted from Google Scholar, Science Direct, and Pubmed (MEDLINE). The strategy used in literature collection is in the form of writing keywords that are used to find articles to be reviewed with a publication period between 2012 - 2020.* ***Discussion:*** *Dental caries is a demineralization of an inorganic part of the tooth due to a multifactorial etiology and occurs when demineralization exceeds remineralization. The calcium and phosphorus ions level in the saliva could affect the balance between demineralization and remineralization of enamel and its deficiency can strongly influence morphology of the tooth. It has been found that calcium level significantly influences hard dental tissues defense mechanisms. On the other side, vitamin D also plays an important role to form enamel and dentin in the tooth development process because of its receptor in ameloblasts and odontoblasts. Deficiency of vitamin D can cause enamel hypoplasia which is a significant factor for early childhood caries.* ***Conclusions:*** *Calcium, phosphorus, and vitamin D significantly affecting the demineralization and remineralization process. The optimum concentration and level of calcium, phosphorus, and vitamin D in the body effectively increase the tooth defense mechanism and reduce the dental caries.*

Keywords: *Calcium, Phosphorus, Vitamin D, Dental Caries*

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INTRODUCTION

Micronutrient elements are those vitamins and minerals that are required in small amounts in our body which play important roles such as the production of enzymes, hormones, and other substances, that are generally recommended for a dietary allowance (RDA) in mg / day and can enter the body through the respiratory tract, drinking water, and food components.[1] Insufficient intake of micronutrients can affect health, function, and physical and cognitive development throughout the life cycle. Dental caries is a localized and progressive destructive disease of the teeth.[2] Acid produced by bacteria, especially *Streptococcus mutans* and *Lactobacillus* which causes demineralization due to the fermentation process of dietary carbohydrates.[2]

Dental caries is the most common chronic disease among youth aged 6–19 years. The prevalence of total dental caries from National Health and Nutrition Examination Survey (NCHS) in 2015-2016 for primary or permanent teeth among youth aged 2–19 years was 45.8%. Prevalence increased with age, going from 21.4% among youth aged 2–5 to 50.5% among those aged 6–11 to 53.8% among those aged 12–19.[3] Based on the data above, it is necessary to prevent dental caries through the effectiveness of intake of micronutrients, which are vitamins and minerals. In the relationship between dietary mineral intake and oral disease. The mineralization of teeth depends on a large number of micronutrient factors, of which vitamin D, calcium and phosphorus play an important role.[3]

Vitamin D is a steroid hormone with pleiotropic effects on calcium and phosphorus metabolism and the immune system. Calcium deficiency is usually due to vitamin D deficiency, either through dietary deficiency or lack of exposure to sunlight.[4] It can also be due to a diet low in calcium. In this dental caries case, the concentration of calcium (Ca) and phosphorus (P) from dental plaque and levels of Ca and P ions in saliva can affect the balance of demineralization and remineralization of enamel. High levels of Ca in plaque are associated with a lower incidence of caries. Other vitamins than vitamin D may play another important role as suggested vitamin B6 which can play a role in the prevention of dental caries.[5] In addition, Vitamin K is another promising candidate for protection against dental caries.[6] Through this article, the authors want to provide a narrative overview on the effectiveness of calcium, phosphate, and vitamins in dental caries prevention. In order to find the effect of Ca, P and vitamins for preventing caries, and to determine the correlation between optimum concentration and amount of Ca, P, and vitamins to perform maximum effect of dental caries prevention. The main database searched is focused on systematic reviews about micronutrients (minerals and vitamins) and other articles in PubMed and Google Scholar which were published in English, dated from the year 2010 to 2020 were included in this article review.

The Role of Ca in Remineralization and Demineralization

Caries occur when demineralization exceeds remineralization. Remineralization of white-spot lesions may be attainable with presently available agents possessing fluoride, calcium and phosphate, and casein phosphoprotein amorphous calcium phosphate.[7] Calcium, phosphate, and fluoride ions play an important role in the battle between demineralization and remineralization processes and accordingly modify the susceptibility of tooth to caries progression. During demineralization, calcium release precedes phosphate release from enamel, dentin, and cementum. Therefore, using calcium rather than phosphate to suppress the demineralization process would be effective.[8] Study from Adegboye *et al.* stated that higher calcium intake may also enhance enamel remineralisation, reduce demineralization.[9]

Saliva is supersaturated with calcium and phosphate with a pH equal to 7, a level that

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favors remineralization. When acid stimulation is too strong demineralization prevails until the formation of a carious lesion.[11] Studies from Philippe and Lingstrom stated that Vitamin D, calcium, and phosphate play a major role in remineralization.[10] However, remineralization of enamel by saliva is seldom completely achieved, especially when there is an imbalance in duration and extent of demineralization/remineralization phases. Therefore, it is required the use of an external source of Ca^{2+} and PO_4^{3-} ions to increase the Hydroxyapatite supersaturation to efficiently prevent demineralization and boost remineralization.[11]

The calcium concentration of dental plaque strongly influences the balance between demineralization and remineralization of enamel. In an epidemiological study, Gedalia and colleagues, in a controlled clinical trial in children, demonstrated that eating a 5 g piece of hard cheese daily, following breakfast, for a period of 2 years, resulted in the development of significantly less caries. Cheese stimulates salivary secretion and increases plaque calcium concentration.[12]

The Role of Phosphorus in Remineralization and Demineralization

Presence of microbial acid products can reduce hydroxyapatite, marked by formation of porosity on tooth enamel. Porosity on tooth enamel can be fixed by using calcium and phosphate ions.[8] Hydrogen ion binds to phosphate ion on hydroxyapatite and produce HPO_4^{2-}, and this ion cannot be balanced with normal hydroxyapatite bonds and cause some of the enamel hydroxyapatite crystals dissolve and cause the enamel to become brittle. This demineralization process can be inhibited by remineralization, neutralize pH and sufficient calcium and phosphate to restore the minerals that have been broken down.[13]

Remineralization of enamel is known to be performed by phosphate and calcium from saliva.[14] There are two calcium phosphate compounds that can induce remineralization. It is casein phosphopeptide-amorphous calcium phosphate (CPP-ACP) which is formed by casein phosphopeptide (CPP) that aggregates with calcium phosphate and forms an amorphous calcium phosphate (ACP). The aggregation between these two compounds results in remineralization and prevents demineralization.[15]

The Role of Vitamin D in Remineralization and Demineralization

Another micronutrient related to caries prevention is vitamin D. Various studies have shown that vitamin D has an important role in development of bones and teeth. Vitamin D acts as a regulator of calcium levels in craniofacial development and maintenance of good oral health. In the body, calcium and phosphorus can be found in enamel, the most mineralized substance. Calcium and phosphorus are obtained from food with the help of vitamin D as an absorption agent. The absorption of calcium and phosphorus helps improve the strength of the teeth and surrounding bones.[16] Ameloblasts and odontoblasts, which are known to form enamel and dentin, also has vitamin D receptors.[16] Ameloblasts and odontoblasts are the target cells for 1, 25-dihydroxyvitamin D, the active form of vitamin D. If there is a deficiency of vitamin D during the period of tooth development, one of the effects is developmental damage such as enamel hypoplasia. This enamel hypoplasia is a significant risk factor for severe early childhood caries.[17] If metabolism and levels of this vitamin are irregular, "rachitic teeth" can occur too. This condition causes the teeth to be hypomineralized and damaged, making them prone to fractures and decay.[18,19]

In addition, vitamin D is also associated with one of major oral diseases, caries.[17] Vitamin D can help reduce the risk of dental caries by playing an important role in the mineralization of bones and teeth. As a mineralized organ, teeth are surrounded by 3 hard tissues, namely

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cementum, dentin, and enamel. Vitamin D systemically acts as an initiator of signaling pathways via the vitamin D receptor, a transcription factor that controls gene expression via the element vitamin D.[20] Vitamin D will increase vitamin D receptor to induce structural gene products, such as calcium binding proteins and various extracellular matrix proteins (eg, dentine phosphoproteins, dentin sialoglycoproteins, enamel, and amelogenin) to form dentin and enamel.[18] This responsive gene also affects mineral and energy metabolism, bone, skeletal muscle, cell life cycle and migration, immune response, and detoxification. [20, 21,22] The role of vitamin D in tooth mineralization can also be seen since the fetus is in the womb. In the condition of pregnant women, fetal primary teeth can be affected by maternal 25 (OH) D levels because systemic levels of vitamin D in fetal serum will follow maternal concentrations.[23,24] Thus, maternal vitamin D levels can be used as a standard surrogate marker for the fetus. If any condition causes maternal 25 (OH) D levels to be imbalanced, fetal levels can also be directly affected by the health of the baby especially tooth development.[23, 24, 25, 26, 27 27, 28]

Research revealed that a higher maternal vitamin D intake during pregnancy will result in a lower risk of dental caries in children because maternal prenatal 25-hydroxyvitamin D [25OHD] has the potential to have an effect on primary teeth and the development of ECC.[23, 29] Pregnant women with vitamin D supplementation levels below 15 ng / mL were also found to have a 14% higher risk for primary teeth.[27] About 50% of the potential for enamel damage will decrease if vitamin D supplementation is given in sufficiently high doses during pregnancy.[26, 29] Maternal vitamin D deficiency will form a pattern of associated mineralization defects at the particular week of pregnancy when vitamin D deficiency occurs. For example, maternal vitamin D deficiency status could affect the beginning of primary maxillary central incisor calcification if vitamin D deficiency occurs at 13 weeks from conception. It could potentially lead to a hypoplastic/ mineralization defect in the incisal third of the crown. One study also showed defects in the incisal third, middle third and cervical one third because of maternal deficiency of vitamin D at 12-16, 20-32 and 36-40 weeks.[27]

DISCUSSION

Dental caries is a demineralization of the inorganic part of the tooth with the dissolution of the organic substance due to a multifactorial etiology and occurs when the organic acids produced increase the solubility of the calcium hydroxyapatite that is present in the hard tissue of teeth.[31] High concentrations of calcium in plaque or saliva may reduce bacterial adhesion to enamel and inhibit bacterial biofilm formation. Studies done by Glass RL, et al. stated calcium was associated negatively with caries experience.[30] Another study from Scardina and Messina stated that calcium, phosphorus, and casein contained in cow milk inhibit caries.[31]

Increase in calcium level in the remineralization solution may enhance the deposition velocity of minerals in the caries lesion. Study from Sejdini et al., 2018 stated that the Ca concentration before and after saliva stimulation and the quantity of Ca before and after saliva stimulation have shown a high correlation. Calcium level significantly influences hard dental tissues defense mechanism and the increase of caries number, the calcium level decreases. [32] On the other side, deficiency in phosphate is known to induce rickets.[33] In terms of the relationship between dietary mineral intake and oral disease, the calcium (Ca) and phosphorus (P) concentrations of dental plaque and the levels of Ca and P ions in the saliva could affect the balance between demineralization and remineralization of enamel.The normal level of calcium is 1-2 mmol / L. Based on the study conducted by Lisna and Nisak, the results showed that the salivary calcium level in the caries group was 0.98 ±

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0.310 mmol / L and in the caries-free group was mmol / L 1.55 ± 0.312. This study showed that there was a significant difference ($p < 0.05$) between the salivary calcium levels in the caries and caries-free groups.[34] Saliva is a major source of minerals that demineralised enamel rebuilds. The hydroxyapatite (HA) crystals in tooth enamel, consisting of Ca, Mg, and Pi (phosphate) are more susceptible to dissolution by acids. Ca assists this process by providing F with a place to bind with. Minerals in drinking water are the main source of Ca and Mg which are absorbed by the body.[35] The optimum Ca in drinking water that is beneficial for health ranges from 40-80 mg / L. Ca concentration in saliva to help repair early carious lesions ideally should not exceed 90 mg / L. Ca and F together caused 45% decrease in DMF-S index, supporting the role of Ca in teeth remineralisation.[36]

The recommended level of phosphate intake for adults and elderly in the United States is 700 mg/day, although studies shown that around 35% of the US adult population consume more than double the amount of phosphate than the recommended amount.[37] In a study that was conducted on 8317 school children (average age :9.99 ± 0.68 years), the occurrence of dental decay was significantly higher among children who consumed a higher amount of phosphate. The study found that after adjusting all the covariates, for every single unit increase in calorie-adjusted sugar intake, the odds of having dental decay increased by 12%, and for 1 unit increase in phosphate, the odds of having any dental decay increased by 33%. In a subgroup analysis, dental decay occurrence increases significantly in children who consumed low sugar and high phosphate compared to children who consumed low sugar and low phosphate, and it implicates that excessive phosphate consumption alone can propagate dental decay, even when sugar consumption is low.[38]

Vitamin D can be obtained through endogenous synthesis, exogenous attainment of diet, and supplementation. Vitamin D intake is important to fulfill because it affects the formation of enamel, dentin, and oral bones.[17] The optimal concentration of vitamin D (≥75 nmol / L) has been shown in several studies to reduce the potential dental caries in children.[17, 39, 40] Studies conducted by Schroth et al. (2013) stated that caries-free children were twice as likely to have optimal vitamin D concentrations (≥75 nmol / L) and those with severe early childhood caries were nearly three times more likely to have deficiency rates (<35 nmol / L). The results of another study indicated that vitamin D supplementation reduced the risk of caries by about 47%, but with low certainty.[3] Although serum vitamin D is unable to change the main structure of teeth, it turns out that vitamin D is able to prevent caries by regulating immunity through eradication of microbes with peptide activity.[41]

To get the overall benefits of vitamin D, the experts committee of National Academies of Sciences, Engineering, and Medicine developed intake recommendations for general vitamin D in the Reference Diet Intakes (DRI). Reference values used in planning and assessing nutritional intake vary according to age and sex for healthy people, such as the Recommended Dietary Allowance (RDA) indicator. RDA indicates the average daily intake level is sufficient to meet the nutritional needs of almost all (97%–98%) healthy individuals.

Table 1. Recommended Dietary Allowances (RDAs) for Vitamin D

Age	Male	Female	Pregnancy	Lactation
0-12 months*	10 mcg (400 IU)	10 mcg (400 IU)		
1–13 years	15 mcg (600 IU)	15 mcg (600 IU)		
14–18 years	15 mcg (600 IU)	15 mcg (600 IU)	15 mcg (600 IU)	15 mcg (600 IU)
19–50 years	15 mcg (600 IU)	15 mcg (600 IU)	15 mcg (600 IU)	15 mcg (600 IU)
51–70 years	15 mcg (600 IU)	15 mcg (600 IU)		
>70 years	20 mcg (800 IU)	20 mcg (800 IU)		

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RDAs are often used to plan a diet that is nutritious enough for an individual. RDAs for vitamin D indicate daily intakes sufficient to maintain normal calcium metabolism and bone health in healthy people. RDAs for vitamin D are written in both international units (IU) and micrograms (mcg) (Table 1), which 1 mcg of vitamin D is equal to 40 IU.[42]

CONCLUSION

Calcium (Ca), phosphorus (P), and Vitamin D are part of micronutrients which has an important role in tooth remineralization and demineralization. Both calcium and phosphorus significantly influence tooth defense mechanisms, while vitamin D influences tooth development. Calcium and phosphorus concentrations could affect the balance between demineralization and remineralization of enamel. Vitamin D helps obtain calcium and phosphorus to improve the strength of the tooth and help to reduce the risk of dental caries by its important role in mineralization. Therefore, calcium, phosphorus, and vitamin D on their optimum intakes, concentration, and level in the body could work effectively in preventing dental caries.

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