Review

Impact of nutrition on the condition of the oral mucosa and periodontium: A narrative review

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Abstract

Diet and eating habits significantly affect health and quality of life. Various diets and food eliminations can lead to nutritional deficiencies and malnutrition. This article discusses the relationship between nutrition, nutritional deficiencies, and the condition of the periodontium and oral mucosa. An analysis of PubMed materials was conducted to assess the impact of nutrition on the condition of the oral mucosa and periodontium. We also considered dietary habits such as vegetarianism, the ketogenic diet, the Paleo diet, the Mediterranean diet, the Western diet, and intermittent fasting. Vitamin deficiencies, both water-soluble and fat-soluble, as well as macro- and microelements, can manifest in the oral cavity, among others, as gingivitis and bleeding, recurrent aphthous stomatitis, enamel hypomineralization, cheilitis, angular cheilitis, halitosis, glossitis, lingual papillae atrophy, and stomatitis. Malnutrition does not cause periodontal disease, but it increases the risk of its occurrence and accelerates disease progression. Inadequate nutrition, combined with other predisposing factors, may contribute to an increased risk of oral cancer and the development of leukoplakia.

Keywords: diet, oral health, nutrition, oral mucosa, periodontal health

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Introduction

Diet and eating habits significantly affect health and quality of life. Various diets and food eliminations can cause nutritional deficiencies and malnutrition. There are many conditions that influence the health of the oral cavity such as the diseases of the teeth's hard tissues, periodontium and mucosa.[1] This article will discuss the relationship between nutrition, nutritional deficiencies, and the condition of the periodontium and oral mucosa. It will take into consideration eating patterns such as vegetarianism, the ketogenic diet, the Paleo diet, the Mediterranean diet, the Western diet, and intermittent fasting. This will enable the reader to better understand the topic of diet and nutrition in the context of oral health.

Malnutrition can significantly affect oral health, and poor oral health, in turn, can result in malnutrition. A diet low in nutrients can lead to the progression of oral disease through altered tissue homeostasis, reduced resistance to microbial biofilm, and a decrease in tissue healing.[2]

The first signs of deficiency of some micronutrients, for example, the B vitamins, are seen in the mouth and include glossitis, cheilitis and angular stomatitis.[1] Vitamins and minerals play an important role in the rapid cell turnover of the oral mucosa. Due to its unique anatomical environment, the oral cavity may manifest early signs of nutritional disorders as well as other systemic diseases.[3]

There is a strong link between some systemic diseases and periodontitis; diet and nutrition can have an impact on a patient's condition.[4] The primary causative agent of periodontal disease is the mixed bacterial colonization in the oral tissue.[5] However, micronutrient and macronutrient deficiencies in the diet modify the course of periodontitis. Higher levels of vitamins A, B and C, calcium, zinc, and polyphenols have been shown to prevent periodontal disease.[6] Furthermore, periodontal disease has been associated with non-alcoholic fatty liver disease (NAFLD) induced by a Western diet.[2] Thus, following different diets and the associated deficiencies of individual nutrients will have an impact on the progression of periodontal disease.

Scientists have noted a significant influence of popular eating patterns on the condition of the oral mucosa. For example, the biggest concerns regarding the vegetarian diet are the iron deficiency of animal origin and the inhibitors found in some plants that can be ingested abundantly. Some oral changes observed in vegetarians may indicate iron deficiency anemia and vitamin B12 deficiency.[1] However, another study suggests that the antioxidants found in fruits and vegetables can have a positive impact on periodontal health because they protect the oral tissues from oxidative damage and modify the inflammation present in periodontal diseases such as periodontitis.[7] Other eating patterns, which are further described in this review, may also have a significant impact on the condition of the oral mucosa. Technological and cultural advances are changing people's lifestyles and eating habits, which can lead to the development of many diseases. Our study provides a comprehensive review of the latest research. This article is noteworthy and important from a public health perspective.

Objectives

This study aimed to illustrate the influence of many aspects of nutrition on the condition of the oral mucosa and periodontium.

The article lists considerations concerning general malnutrition as well as nutritional deficiencies of individual substances. Additionally, it outlines the beneficial effects of different substances on the oral mucosa. Current popular nutritional patterns have been analyzed for their good and bad effects on oral health.

Material and methods

The conducted review focused on the search for material on the impact of broadly understood nutrition on the condition of the oral cavity.

The authors conducted a comprehensive review of the most current research in this field, identified relevant sources and gathered the available knowledge in one place. The inclusion criteria covered the broadly understood diet, eating habits, and nutritional deficiencies and their implications for oral health. The preliminary search allowed for the selection of a set of keywords that seemed to be the most relevant and consistent with the topic of the review: diet, oral health, nutrition, oral mucosa, and periodontal health. English-language articles available in the PubMed database and published in the last 20 years were selected. The PubMed database was considered the most appropriate database due to the possibility of searching many scientific databases. The exclusion criteria were articles that did not take into account the correlation between dietary patterns, nutritional deficiencies and oral health. The studies meeting the inclusion criteria were analyzed in detail, and the main issues and conclusions were presented.

Influence of diet and nutritional deficiencies on the condition of the oral mucosa and periodontium

Oral and systemic homeostasis is closely related to diet, which means nutrition has both local and systemic effects on the human body. Local impact is understood as the influence of food on the tissues of the oral cavity, taking into account their composition and consistency as well as

frequency of eating.[8] A balanced diet affects the growth and development of the body tissues. Proper nutrition is vital for human growth and development. Nutritional imbalances during the period of active growth may cause severe developmental defects.[9] The bones and soft tissues of the mouth respond quickly to nutritional deficiencies because they are constantly renewed, unlike the teeth, which are primarily affected by nutrition during their formation.[8]

Symptoms of nutritional deficiencies may affect some or all tissues within the oral cavity, including the teeth, periodontium, salivary glands, mucous membranes, and the skin around the mouth.[3]

On the other hand, an excess of certain nutrients, such as carbohydrates or food products with a low pH level, can lead to the appearance of tooth cavities or non-carious tooth defects.[10] Food residues settle on the surface of the teeth, forming plaque. Plaque consists of bacteria that convert carbohydrates supplied by food into acids. A decrease in pH level below 5.5 results in demineralization of enamel hydroxyapatite crystals and proteolytic breakdown of the structure of tooth hard tissues. Therefore, the more sugar we consume, the more substrate we provide to the bacteria present in the unremoved plaque.[11] Studies showed that fermentable carbohydrates, apart from free sugars, have an impact on dental caries, but the consumption of starchy staple foods and fresh fruits is associated with lower levels of dental caries.[12] According to the American Heart Association, the American Academy of Pediatrics and the World Health Organization, free sugar intake should be limited to less than 10% of the total energy intake for adults and children.[13] Another issue that affects the formation of carious cavities is the frequency of sugar consumption and its consistency. Frequent consumption of sticky products that are difficult to rinse out when swallowing saliva or drinking fluids as well as products containing carbohydrates provides the greatest risk for caries.[10,14] Thus, it is very important to eat a certain number of meals per day and at regular intervals. Snacks and products rich in carbohydrates should be minimized in the diet.[15] Moreover, the susceptibility to caries in the presence of carbohydrates may be influenced by genetics and micronutrients, such as vitamin D.[16] Non-carious defects are of a non-bacterial origin, and their effects are irreversible.[12] Their presence can be influenced by the composition of saliva, general diseases, mechanical stress, and nutrition.[17] Regular consumption of acidic foods and beverages, occupational acid exposures, and drugs or diseases that affect saliva flow rate all contribute to an increased risk of erosive dental hard tissue defects.[18] Each type of acid has erosive potential. Solutions that are undersaturated with respect to enamel tissues will dissolve it. For instance, beverages containing calcium-chelating acids, such as citrate, may cause erosion at higher pH levels.[19] Erosion is commonly associated with citrus fruits, juices, pickled cucumbers, vinegar, and energy drinks.[20,21] In the Western diet, soda, wine and citrus-based drinks are often consumed because they are refreshing. In the European culture, the consumption of cheese and wine is a wise solution as cheese buffers the acidity of the wine and provides substrates for remineralization. The erosive potential of a diet depends on the frequency of acidic food consumption, acid strength and the buffering capacity of saliva.

The consistency and hardness of consumed products may lead to the formation of non-carious cavities. The mechanical loss of mineralized tooth tissues can lead to abrasion or attrition. Attrition is associated with occlusal surfaces, while abrasion is associated with buccal or lingual surfaces. Enamel can be worn away as a result of a hard diet. Plant products are rich in phytoliths, which are abrasive[20]; chewing abrasive substances such as tobacco can cause visible abrasion on the occlusal surfaces. It can also be caused by eating vegetables that have not been properly washed and still contain traces of soil. Abrasive changes also occur as a result of shelling sunflower seeds.[21]

The symptoms of nutritional deficiencies are often primarily visible in the oral cavity due to the rapid exchange of mucosal cells and the presence of a bacterial biofilm. A healthy epithelium undergoes cellular renewal every 3–7 days and acts as an effective barrier to toxins. Nutrient deficiency can lead to tissue breakdown, resulting in more frequent infections and the development of oral lesions.[7] For example, vitamin B deficiencies manifest as the inflammation of the tongue, lips and corners of the mouth, and anemia manifests as generalized pallor, atrophic glossitis, angular cheilitis, and recurrent aphthous stomatitis (RAS).[7,22]

Periodontal diseases are pathological conditions of the tissues that support the teeth. If left untreated, they can result in tooth loss, which will adversely affect chewing, food intake and nutritional status. Malnutrition does not cause periodontal disease, but it increases the risk of its occurrence and contributes to faster disease progression. The condition of the periodontium is influenced not only by malnutrition of the body but also by the quantitative and qualitative composition of the diet.[23]

Oxidative stress resulting from the advantage of oxidants over antioxidants is partly involved in the pathogenesis of periodontal diseases. A component of the inflammatory process is the production of reactive oxygen species (ROS) by immune cells stimulated by insufficiently buffered pathogens, causing an oxidative imbalance. Reactive oxygen species contribute to the damage of periodontal cells and tissues at the molecular level, with a particular affinity for lipids.[7,22,24] They damage lipids by initiating a chain of lipid peroxidation.

A diet high in refined carbohydrates and saturated fats is pro-inflammatory, while a diet rich in polyunsaturated fats (e.g., fish oils) and antioxidants present in fruits, vegetables and nuts (e.g., cashews) is anti-inflammatory.

Consuming a pro-inflammatory diet can cause oxidative stress after a meal, which can lead to inflammation. This condition is known as meal-induced inflammation; it is also associated with a postprandial increase in glucose.[7] A 2020 study performed in 240 individuals found a correlation between poor diets and deepening of periodontal pockets in middle-aged adults. Healthy diets included white meat, fish, fruits, vegetables, cereals rich in fiber, such as rye, oats and barley, and those with a higher ratio of unsaturated fatty acids to saturated fatty acids. Negative components included sugar, salt, red meat, and alcohol.[25,26] Research has shown that even the consumption of highly glycemic foods may increase gingivitis and periodontitis.[27] This phenomenon can be counteracted by adding fiber to the diet, which reduces the postprandial glucose spike.[7]

Woelber et al. demonstrated the effect of an anti-inflammatory diet on periodontal disease. The diet was based on eliminating processed carbohydrates (including sugar, honey, white flour, and white rice), reducing starch consumption, supplementing omega-3 fatty acids, and limiting the amount of trans and omega-6 fatty acids. The consumption of industrial animal proteins (dairy products and meat) was also reduced; plant proteins and small amounts of organic meat were favored. A daily supply of vitamin C, vitamin D, antioxidants, fiber, and nitrate-containing plants was provided. The study showed that the anti-inflammatory diet significantly reduced gingivitis to a clinically relevant extent.[28,29]

Antioxidants can help reduce the severity of the disease by scavenging free oxygen radicals and can counteract periodontitis associated with the presence of ROS. The antioxidant micronutrients include vitamins A, C and E, glutathione, melatonin, and lycopene.[7,24]

Melatonin is secreted by various organs in the human body, and is derived from plants and grains. It is not classified as a major nutrient but has been suggested to be more antioxidant than vitamin E. Studies have reported that the topical application of melatonin may complement periodontal treatment. The anti-ROS effect of melatonin reduces periodontitis and bone loss in diabetic animal models and, therefore, has the potential for the treatment of diabetic periodontitis.[24] These reports require further investigation.

Lycopene is a red pigment present in tomatoes, carrots and watermelons. It has antioxidant properties. Some studies suggest that lycopene supplementation may improve periodontal health; however, its mechanism of action on periodontal tissues has not been established and warrants further research.[24]

Malnutrition and poor oral hygiene are important predisposing factors for periodontal disease, including necrotizing gingivitis.[9] Dental plaque is considered the main etiological factor in the development and progression of periodontal diseases, and the increase in its volume is associated with high sucrose consumption. However, the maximum reduction of sugar in the diet does not limit the progression of gingivitis, which proves that periodontal diseases are caused by multiple factors.[23]

Susceptibility to periodontal disease increases as a result of vitamin C, folate and zinc deficiencies, as these nutrients increase the permeability of the gingival fissure barrier. Calcium, phosphates, vitamins A and E, and beta-carotene maintain the integrity of the gums and the proper functioning of the immune system.[8] Therefore, supplying the abovementioned ingredients in the diet has an impact on periodontal health. Protein–energy malnutrition (PEM) in early childhood is associated with the deterioration of the periodontal condition in adolescents; it affects the developing immune system, which reduces the individual's ability to respond to periodontal pathogens.[7,23]

Studies have shown that a diet characterized by the consumption of highly processed foods with low micronutrient value promotes gingivitis and periodontitis. On the other hand, a plant-based diet rich in low-glycemic complex carbohydrates (fruits, vegetables and legumes), omega-3 fatty acids, micronutrients, plant nitrates, and fiber not only is conducive to overall health but also positively affects the health of the periodontium and gums. The inflammatory potential of dietary proteins depends on their origin. Animal proteins are associated with increased levels of insulin-resistant growth factor 1, which plays an important role in carcinogenesis. Plant-based proteins, on the other hand, appear to reduce the risk of cardiovascular disease, type 2 diabetes and kidney disease.[27] This, in turn, may have implications for periodontal health. However, more research is needed to thoroughly investigate this issue.

Certain dietary probiotics are believed to contribute to the maintenance of periodontal health. There are several mechanisms that may explain the effects of probiotics: production of lactic acid that inhibits the proliferation of periodontal bacteria by penetrating the bacterial membrane and acidifying the cytoplasm; production of hydrogen peroxide that inhibits the growth of pathogenic bacteria; modification of proteins at the point of attachment; and the production of vitamins and other substances.[6] Prebiotics, which mostly include undigested fibers produced from complex carbohydrates, have a number of benefits for the body, including the reduction of inflammation and the modulation of appetite. There is no evidence of an effect of prebiotics on periodontal disease. However, 2 prebiotics may be useful in promoting oral health-related bacteria, namely methyl-beta-d-galactoside and N-acetyl-d-mannosamine.

In addition to the described systemic effects of diet on periodontal health, there are several dietary antimicrobials that may cause local effects. Examples of these compounds include unsweetened green tea, cocoa, coffee, wine, ginger, garlic, curry, coriander, cinnamon, and oregano. Studies have shown both negative and positive ef-

fects of some of these foods on periodontal disease.[27] The study by Liu et al. found that 7 bacterial taxa, particularly *Streptococcus* sp., *Ruminococcaceae* sp., *Haemophilus* sp., *Veillonella* spp., *Actinomyces odontolyticus*, and *Gemella haemolysans*, underwent significant changes after oolong tea consumption. These studies suggest that a long-term consumption of oolong tea may have an impact on the oral flora and a negative impact on the condition of the periodontium.[30]

A healthier lifestyle, a proper body mass index (BMI), good oral hygiene, and regular visits to the dentist, as well as a higher consumption of antioxidant micronutrients, contribute to a good condition of the periodontium.[7]

Deficiencies in certain micronutrients can cause oral mucosal diseases. Their identification through early oral symptoms can prevent the development of serious and irreversible systemic and neurological damage. Deficiencies in B vitamins, iron and folate are associated with RAS, glossitis, cheilitis, and angular cheilitis. Recurrent aphthous stomatitis is characterized by recurrent single or multiple painful ulcers confined to the oral mucosa (Table 1) (Fig. 1).[9,23] Glossitis caused by a deficiency of B vitamins may manifest as changes in the color, size and sensitivity of the tongue, as well as changes in the papillae, such as enlargement, flattening and eventual loss if left untreated. The tongue may appear pale or erythematous, ranging from shades of red to purple. Vesicles and ulcers may be visible, first at the apex, then covering the rest of the tongue. Patients may have problems with sensation of taste, burning and pain. Angular cheilitis is primarily associated with deficiencies in riboflavin, niacin, pyridoxine, folic acid, cobalamin, protein, and iron. In the course of the disease, erythema, maceration, fissures, and furrows arranged radially around the corners of the mouth can be observed. Secondary bacterial and yeast infections are also common.[3] All of the abovementioned oral mucosal diseases may cause difficulties in eating, which can aggravate the underlying malnutrition.

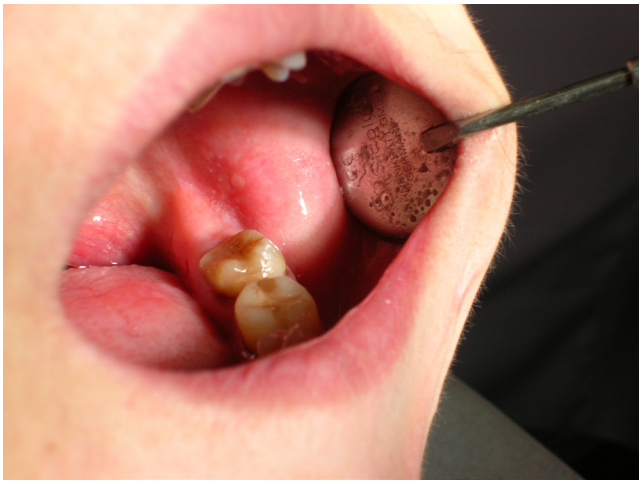

Fig. 1. Erosion of the buccal mucosa within the oral cavity

In the literature, one may encounter conflicting data on the relationship between retinol and beta-carotene and the incidence of oral lichen planus. Researchers have shown lower levels of vitamins E, C, D, and B12, zinc, calcium, and folic acid in patients with oral lichen planus. The presented data suggests that an unhealthy diet may increase the risk of oral lichen planus.[31] Oral lichen planus manifests in different forms affecting the gingival mucosa. Oral lichen planus may present as a desquamative gingivitis or a vulvovaginal gingival lichen planus due to genital involvement.[32] These forms are associated with periodontal problems, while the effects of malnutrition and poor oral hygiene on periodontal status are well documented. Supplementation with folic acid is recommended for patients with folic acid deficiency and lesions in the oral cavity. Attention should also be paid to the relationship between vitamin A, C, B12, and folic acid deficiencies with the occurrence of leukoplakia. Available data confirms that a diet rich in fruits and vegetables, especially tomatoes and tomato products, significantly reduces the risk of leukoplakia.[9]

Table 1. Effects of nutrient deficiency on the oral mucosa

Nutrient	Effects of deficiency on the oral mucosa
Vitamin A	gingivitis, gingival hypoplasia, proliferation of crevicular epithelium, alveolar bone resorption[36,37]
Vitamin D	painful erosions, ulcerations and aphthous ulcers in the oral cavity, damage to the secretory salivary glands that leads to xerostomia,[8] periodontitis[37,38]
Vitamin E	none
Vitamin K	submucosal and gingival bleeding, both spontaneously and after trauma, ecchymoses of the buccal mucosa and palate[3]
Vitamin C	gingival edema, friable and erythematous interdental papillae, poorly formed, soft, and often loose teeth, tiny hemorrhages on tips of the interdental papillae, aphthous-like lesions,[3] xerostomia[37]
Vitamin B complex	lower resistance to bacterial insults, RAS, enamel hypomineralization, cheilosis, cheilitis, halitosis, gingivitis, glossitis, atrophy of the lingual papillae, stomatitis, rashes around the nose, dysphagia, pallor, stomatodynia, erosions in the mouth[36,37] angular cheilitis, recurrent ulcerations, oral candidiasis[1,47]
Calcium	increased risk of periodontal diseases and tooth loss, increased severity of periodontitis[3,36,40]
Iron	RAS, atrophic glossitis, angular cheilitis, pallor of mucous membranes,[1,9,23,47] higher gingival index, BOP, probing pocket depth, higher percentage of sites with a CAL ≥ 6 mm[43]

RAS – recurrent aphthous stomatitis; BOP – bleeding on probing; CAL – clinical attachment loss.

Protein–energy malnutrition causes significant changes in the ecology of oral microbes, resulting in the predominance of anaerobic pathogens, an increased tendency of bacteria to bind to the cells of the oral mucosa, weakened responses of acute phase proteins, cytokine system dysfunction, and atrophy of the salivary glands. Therefore, malnutrition may reduce the body's ability to defend against oral infections and, consequently, lead to the development of life-threatening diseases.[7,33] Protein–energy malnutrition is associated with the exfoliation of the mucosa. The gums are often affected by scurvy with hemorrhagic gingivitis, manifested by red swelling of the interdental papillae. Bleeding gums are also a common symptom of vitamin K deficiency.[3]

Oral cancer is caused by a complex interaction between genetic factors and environmental exposures. Poor diet combined with other predisposing factors may contribute to an increased risk of oral cancer. Certain foods, such as areca nuts and complex products containing them (betel and gutka), are significantly associated with the development of oral cancer. Frying or baking protein-containing foods can generate heterocyclic amines, which are carcinogenic. The consumption of charcoal-based products is a significant risk factor. In addition, foods high in fat (pasta and cheese) and dishes cooked at high temperatures or in a microwave oven are significantly correlated with an increased risk of oral cancer. In addition, the temperature of the food consumed is also important. The Diet, Nutrition and the Prevention of Chronic Diseases report[22] concluded that there is convincing evidence linking hot food and drink consumption with the risk of oral cancer. It should also be mentioned that poor diets combined with alcohol consumption and smoking significantly increase the risk of oral cancer.

Some products have been reported to protect against oral cancer. These include green vegetables, carrots and cruciferous vegetables. Daily consumption of fruits and vegetables can reduce the risk of oral cancer by 50%. Importantly, the greatest benefits of these foods were observed when eaten raw. A special role should be assigned to citrus fruits. According to some studies, fruits are more beneficial than vegetables. Inadequate consumption of these products, poor eating habits and an unhealthy lifestyle can cause oxidative damage that induces the process of carcinogenesis by the DNA strand damage mechanism. For prevention, a daily diet should include antioxidants such as vitamins A, C, E, beta-carotene, lycopene, and selenium. In addition, the proper supply of dietary fiber plays an important role in reducing the risk of oral cancer by protecting the body from oxidative stress.[8,9,22] It is also worth to consider the treatment of oral cancer with the natural product – propolis. Propolis consists of flavonoids, phenolic acids, vitamins, and minerals. It is used in many dental specialties due to its antibacterial, antifungal, antiviral, anti-inflammatory, antioxidant, and anticancer properties. What is more, 100% of its natural polymers, such as cellulose, proteins and nucleic acids, are produced by living organisms and can be used in the treatment of periodontitis, oral mucosal diseases and oral cancer therapy, among others.[34,35]

Relationship of vitamin deficiencies and micro- and macroelements with diseases of the mucosa and periodontium

Vitamin A

Vitamin A plays an important role in the maintenance of the epithelium; its deficiency may cause gingivitis, gingival hypoplasia, proliferation of the crevicular epithelium, and alveolar bone resorption (Table 1).[36,37]

Vitamin D

Preclinical and clinical studies confirmed that vitamin D, through its metabolic pathways, may participate in the pathogenesis of periodontitis by influencing the mineral density of the teeth, and is inversely correlated with the severity of periodontal disease. Its main function is to regulate the calcium and phosphorus balance, which promotes the growth of bony tissue.[38] Vitamin D has visible tuning, anti-inflammatory and mineralizing effects on the periodontium, and can reduce the number of viable *Porphyromonas gingivalis* through active autophagy.[37,39] Vitamin D may also affect the periodontal immune response by reducing the expression of interleukin (IL)-8 and IL-6.[37] There is a scientifically confirmed correlation between vitamin D levels and RAS, Behçet's disease, PFAPA (periodic fever, aphthous stomatitis, pharyngitis, and cervical adenitis), Sjögren's syndrome, periodontitis, and oral squamous cell carcinoma (OSCC).[38] Recurrent aphthous stomatitis is characterized by the presence of painful erosions and ulcers in the oral cavity (Table 1). Their size varies from 1 cm to a few centimeters in diameter. There are 3 categories of RAS, depending on their size. Vitamin D has an important role in modifying the course of the disease. Behçet's disease is an immune-mediated condition whose symptoms include oral and genital ulcerations, arthritis, uveitis, retinal vasculitis, neurological disturbances, sporadic deep vein thromboses, erythema nodosum, and gastrointestinal inflammation. Patients with Behçet's disease have lower vitamin D levels than healthy individuals.[38] PFAPA is characterized by the presence of aphthous ulcers in the oral cavity, episodes of fever, pharyngitis, and cervical lymphadenopathy (Table 1). Vitamin D is an important modifier of PFAPA. Studies have shown that the supplementation of vitamin D during the winter season reduced the number and duration of fever episodes in patients with PFAPA.[38] Sjögren's syndrome is an autoimmune condition that can be modified by vitamin D. It is character-

ized by damage to the secretory salivary glands, leading to xerostomia, tear secretion dysfunction, conjunctivitis, and keratitis (Table 1).[38] Clinical studies have shown a significant relationship between the endocrine activity of vitamin D and periodontitis, confirming the role of vitamin D as a modifier of the immune response in the periodontium (Table 1).[37,38] Patients with generalized aggressive periodontitis, an early form of the disease with marked familial aggregation, showed significantly elevated plasma levels of vitamin D binding protein, which suggest an association between D binding protein and specific genotypes of generalized aggressive periodontitis.[37] The experiments have shown the ability of 1,25(OH)-D_2 (active vitamin D metabolite) to inhibit the monocyte production of pro-inflammatory cytokines IL-1B and tumor necrosis factor alpha (TNF-α), both of which play significant roles in the pathogenesis of periodontitis by impairing wound healing and inducing bone resorption. Studies showed a correlation between vitamin D deficiency and the risk of oral candidiasis in human immunodeficiency virus (HIV)-positive patients.[38] This is due to the role of vitamin D in the human immune response.[37–39] Additionally, adequate vitamin D levels are reported as an anticancerogenic factor. Studies showed that low levels of vitamin D serum may increase the incidence of cancer and mortality in men, specifically alimentary system cancers, such as OSCC.[38]

Vitamin E

Vitamin E is a membrane antioxidant. It is essential for the heart's health and cell wall protection. Vitamin E is reported to maintain the gingival health and the integrity of the immune system.[8] It has no oral manifestations of deficiency.[3]

Vitamin K

The typical oral manifestations of vitamin K deficiency are submucosal and gingival bleeding, both spontaneously and after trauma, and ecchymoses of the buccal mucosa and palate (Table 1).[3]

Vitamin C

The relationship between vitamin C and periodontal disease may be due to vitamin C's role in maintaining and repairing healthy connective tissue along with its antioxidant properties. Vitamin C deficiency-related scurvy, manifested in the oral cavity by gingival edema, friable and erythematous interdental papillae, and poorly formed, soft and often loose teeth (Table 1), is strongly associated with periodontitis.[36] Interestingly, these findings are not present in edentulous patients. Periodontal disease is more common in individuals with a low dietary intake of vitamin C. Scorbutic gingivitis, manifested by tiny hemorrhages at the tips of the interdental papillae, may be accompanied by aphthous-like lesions (Table 1).[3] In bone, due to the inability of osteoblasts to form osteoid, there is an increase in oxidative stress and susceptibility to infections caused by the alteration of the oral-periodontal ecosystem. In addition to periodontal changes, vitamin C deficiency can also cause xerostomia (Table 1).[37]

Vitamin B complex

Vitamin B complex deficiency is associated with lower resistance to bacterial insults, RAS, enamel hypomineralization, cheilosis, cheilitis, halitosis, gingivitis, glossitis, atrophy of the lingual papillae, stomatitis, rashes around the nose, dysphagia, and pallor of mucous membranes (Table 1).[36,37] Current research indicates that low levels of folic acid are associated with the periodontal tissue's reduced ability to act against bacterial irritants. Vitamin B12 deficiency can be manifested by stomatodynia, glossitis and erosions in the mouth (Table 1).[36]

Macro- and microelements

Macro- and microelements, such as fluorine, aluminum, molybdenum, cobalt, sodium, potassium, phosphorus, and chlorine significantly affect the incidence of dental caries and have an influence on bone structure, but their impact on the oral mucosa will not be discussed in the following sections.[40–42]

Calcium

Calcium deficiency is associated with an increased risk of periodontal diseases and tooth loss (Table 1). Calcium absorption is dependent on adequate vitamin D levels, and patients with low calcium levels may have the same oral signs of enamel pitting and hypoplasia as those with vitamin D deficiency.[36] There is an inverse relationship between calcium intake and the severity of periodontitis. Unfortunately, increasing calcium intake does not lead to an increase in salivary calcium levels, which are beneficial in preventing dental caries and periodontitis.[40]

Iron

Iron deficiency anemia is the most prevalent nutritional deficiency in the world. It is associated with an increase in oxidative stress resulting from hypoxia in the body's tissues. Studies show that patients with chronic periodontal disease and accompanying iron deficiency anemia exhibited higher levels of gingival index, bleeding on probing (BOP), probing pocket depth, and a higher percentage of sites with a clinical attachment loss (CAL) ≥6 mm than patients with chronic periodontal disease without iron deficiency anemia.[43]

A summary of the effects of nutrient deficiencies on the oral mucosa and periodontal diseases is presented in Table 1.

Nutrition and systemic diseases involving the oral cavity

Oral health is closely related to diet, including nutritional influences on craniofacial development, oral infectious diseases and oral cancer. However, the most significant effect of nutrition on the teeth is caused by its local action, resulting in the development of dental caries and enamel erosion. The problem of dental erosion is increasing and is associated with dietary acids, a major source of which is soft drinks.[33] Dental erosion, tooth hypersensitivity, dental caries, and oral mucosa alterations can be the oral manifestations of eating disorders, such as anorexia nervosa and bulimia nervosa.

The associations between oral health conditions, nutritional status, dietary practices, and general health status are complex and involve many interrelated factors.[23] Dental diseases have a considerable impact on self-esteem and the quality of patients' lives.[33] High-protein and high-carbohydrate diets have a big influence on oral halitosis. Oral halitosis is a common condition that causes persistent bad breath and affects approx. 25–30% of the global population.[44] Lichen planus is a chronic inflammatory skin disease involving the mucous membranes of the oral cavity. A study conducted by Di Stasio et al. showed that patients suffering from oral lichen planus presented with symptoms of depression, anxiety and distress.[45] The relationship between mental disorders and eating habits is well known. Diet, the consumption of high-calorie and processed foods, and changes in people's lifestyles are considered risk factors for the development of many diseases, including psychiatric disorders. Compounds such as vitamin D, vitamin B complex (including folic acid), zinc, and magnesium, have a positive effect on mental health.[46]

The influence of popular eating patterns on the condition of the mucosa

Ketogenic diet

The ketogenic diet involves a high intake of fat, a moderate intake of protein, and a low intake of carbohydrates. The maximum carbohydrate intake is 50 g per day, which puts the body in a state of physiological ketosis.[7,47,48] The ingested fats break down into ketones, which are used as an energy source. By burning ketones, ketone bodies are formed, which are excreted through exhalation and urine. This leads to xerostomia and a characteristic breath with a fruity or acetone odor. The breakdown of proteins, which produces ammonia, also leads to bad breath.[47,49] Large amounts of consumed carbohydrates contribute not only to the formation of dental caries but also to periodontitis due to the stimulation of the accumulated dental plaque. The use of the ketogenic diet reduces the severity of these conditions. A significant reduction in BOP was observed in the individuals who adhered to the ketogenic diet, even in the absence of oral hygiene for 4 weeks.[49] The implementation of a ketogenic diet largely eliminates the formation of carious lesions, which is particularly important in patients receiving radiotherapy or immunotherapy, as they often suffer from xerostomia. The ketogenic diet causes a decrease in the BMI index, which is important because being overweight promotes the development of periodontal diseases.[22,47–49]

Paleo diet

The Paleo diet involves eating substantial amounts of nutrient-rich foods such as vegetables, fruits, lean meats, and seafood, and eliminating inflammatory foods such as grains, dairy, refined sugars, refined oils, and processed foods.[4,22,47] Due to the small amount of carbohydrates consumed, the severity of the appearance of carious lesions is reduced. Fruits and vegetables are the main sources of carbohydrates in this diet.[6,23] Eating starchy vegetables that are rich in vitamin A helps to keep the lining of the mouth healthy, and the vitamin C present in fruits and vegetables helps heal wounds and prevent infections.[39] Folic acid, which supports the growth and repair of cells, is also present in fruits and vegetables. Since this diet is rich in fruits and vegetables, it contains a lot of antioxidants that reduce the risk of mouth and throat cancer.[23,47]

Vegetarian diet

A diet that excludes meat and meat products and is mainly based on foods of plant origin is called a vegetarian diet. There are several types of vegetarian diets: vegan, raw vegan, pesco-vegetarian, ovo-vegetarian, flexitarian, lacto-vegetarian, and lacto-ovo-vegetarian diets. A vegetarian diet can contribute to a lack of various nutrients, such as protein, which can negatively affect the health of the body and mouth. Therefore, a vegetarian diet should be rich in whole grains, seeds, nuts, and soy, which are high in protein.[1,47,50,51]

According to the Academy of General Dentistry, patients on a vegetarian diet may suffer from vitamin and element deficiencies. These deficiencies manifest in the oral cavity in the form of glossitis, angular cheilitis, taste alterations, and glossodynia. Vitamin B12 deficiency manifests itself as glossitis, angular cheilitis, recurrent ulcerations, and oral candidiasis. Iron deficiency can cause atrophic glossitis, pallor of mucous membranes, and angular cheilitis (Table 1). The effects of a zinc deficiency in the oral cavity include an increased number of flattened filamentous cells and warts, ulcers, and xerostomia.[1,47]

Studies indicate that the saliva of individuals following the vegetarian diet is less able to form a barrier to free radicals and pollutants than that of non-vegetarians. A plant-based diet is rich in antioxidants and has a positive effect on the condition of the periodontium. It protects the teeth from oxidative damage and alters the inflammatory response in periodontitis.[47] Studies show that vegetarians have good overall oral health.[50]

Intermittent fasting

Intermittent fasting involves eating only during a certain period of the day. It consists of abstaining from eating for a certain number of hours. For example, fasting at 16:8 means a 16-hour fasting period and an 8-hour eating period during which food can be consumed. There are no restrictions regarding food choices and carbohydrate intake.[47]

Fasting increases gluconeogenesis and levels of hormones such as human growth hormone and ghrelin. Limiting the eating period to 8 h a day contributes to the shortening of the bowel, in which the saliva pH drops to an acidic level. The reduction in chewing time may result in decreased salivation, a greater risk of xerostomia and caries, and gingivitis. Intermittent fasting inhibits inflammation and reduces the production of free radicals, which is beneficial in combating periodontitis.[52] Thus, patient education should include hygiene instructions and xerostomia prevention.[47]

Western diet

Diet, physical inactivity, sedentary lifestyle, and obesity (a consequence of an unhealthy lifestyle) are, after smoking, the main risk factors for the onset of cancer. It is estimated that changes in alimentary habits can decrease the likelihood of cancer onset by 30–50%.[48,53] Generally, oral cancer is a growing global problem, and it is not unified.[54] The incidence of head and neck cancers – oral cavity tumors, pharyngeal cancers – registered a global incidence of 5.2% in 2018. The 5-year survival rate is 40–50%.[55] Alcohol consumption and papillomavirus infections also play a crucial role in carcinogenesis. Epidemiological studies underline a protective effect of a high intake of fruits and vegetables, especially in the case of oral cavity cancer.[56] The prevalence of the fast food culture in developed countries and its effects on the Western diet, which is low in fiber and rich in sugar and processed foods, are tightly linked to a loss of microbial diversity and dysbiosis. The Western diet is also closely associated with a high risk of obesity and cardiovascular disease.[48]

Mediterranean diet

The traditional Mediterranean diet is characterized by a high intake of vegetables, legumes, fresh fruits, non-refined cereals, nuts, and olive oil, obtained through mechanical pressing and having an acidity rate lower than 0.8%. It involves a moderate consumption of fish and dairy, a low consumption of red meat, and a moderate use of ethanol (mainly red wine), consumed during the main meals. The Mediterranean diet is considered an effective and manageable method to fight cancer occurrence owing to its protective effects in reducing oxidative and inflammatory processes in cells and avoiding DNA damage, cell proliferation, inflammations, angiogenesis, and metastasis.[57] Regular consumption of olive oil may have a protective effect against periodontitis, although the temporal association needs to be further examined.[58] Many studies have demonstrated a strong and antagonist relationship between some chronic diseases and a high adherence to the Mediterranean diet.[57]

Conclusions

Nutrition has a significant impact on the human health and well-being, including oral health. Nutritional deficiencies may affect not only the teeth but also the periodontium and oral mucosa. It is essential for dentists and dental hygienists to have knowledge of symptoms associated with a particular nutrient deficiency as they are often the first to diagnose them. We hope that this article will help dental professionals detect nutritional deficiencies earlier and more efficiently. This may lead to prompt and effective treatment as well as may help in preventing long-term deficiencies and their complications. This article is a source of knowledge not only for medical professionals but also for non-medical people. It is very important for individuals to have practical knowledge about their health and the importance of the chosen diet. The included information can help medical professionals take care of their own and their patients' well-being as well as look more consciously at their own diet and notice possible dietary mistakes that can result in unpleasant consequences, for example, those that appear in the oral cavity. The described effects of deficiencies on the oral cavity may be the first sign of nutritional deficiencies that require immediate treatment.

Ethics approval and consent to participate

Not applicable.

Data availability

Not applicable.

Consent for publication

Not applicable.

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